Module 11

Distributed generation: options and approaches

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

CONTENTS

1. MODULE OBJECTIVES

1.1. Module overview

The main themes described in this module are as follows:

- Outline and brief description of the different scenarios for power supply to rural areas.
- Overview of the technologies for renewable energy based mini-grid systems, including wind, hydro and PV, biomass systems and hybrid systems.
- Information on requirements for successful implementation of renewable energy mini-grid systems.
- Discussion regarding institutional and framework issues which are required to support the implementation of mini-grid systems.

1.2. Module aims

This module aims to:

- Explain the options for power supply to rural areas, with a basic comparative analysis.
- Enable understanding of the principles of mini-grid systems.
- Present the different technological options for use in mini-grid systems.
- Outline the expected costs for different options.
- Provide an overview of the issues involved in the successful implementation of mini-grid systems, technical and non-technical.
- Review the institutional and framework issues affecting the effective deployment of mini-grid systems.

1.3. Module learning outcomes

This module attempts to achieve the following learning outcomes:

- To be able to define the different scenarios for power supply to rural areas.
- To understand the potential technologies used in mini-grid systems.

- To have a broad appreciation of outline costs for the different technologies.
- To appreciate the key issues to be considered when considering a mini-grid project.
- To gain an appreciation of the policy and other institutional issues and frameworks that will provide support to mini-grid projects.

2. INTRODUCTION

This module provides an outline and description of distributed generation; otherwise known as distributed-grid or mini-grid systems. It considers the options and technologies used in distributed-grid systems.

The module also reviews the requirements for planning such systems and the issues to consider. Finally it reviews the mechanisms required on the policy, fiscal and infrastructure level to support effective implementation of distributed grid systems.

The information contained in this module is intended to explain the basic operation of such systems, to understand their strengths and weaknesses and hence to have a better grasp of the benefits and the barriers faced by them.

3. ELECTRICITY SUPPLY SCENARIOS

About a third of the world's population, over 1.6 billion people,[1] do not have access to electricity and rely almost exclusively on wood, agricultural residues and animal dung to meet their energy needs.

These people basically have three options or scenarios for the provision of electricity:

- Utility network grid-connection (via grid extension);
- Stand-alone systems;
- Distributed-grid systems (often known as mini-grid systems).

3.1. Utility network grid-connection

Established electricity systems tend to rely on centralized generation from large plants which are often some distance from the point of use. Much of this generation is supplied by fossil fuel plants, and the power transported over transmission lines to "passive" distribution networks which deliver the power to the end-user.

In many developing countries a national or regional utility company or companies are charged with the provision of access to electricity. Often these companies struggle to keep up with growing electricity demand within the areas already forming part of the grid network, usually urban, with the consequence that extension of the grid to rural and even peri-urban, populations, which have high service costs per customer and a low ability to meet cost-recovery tariffs, do not get connected.

Early electricity systems in developed countries did use distributed generation – power plants were located within a mile or so of their load on low voltage lines. The development of transformers and the adoption of high voltage transmission lines using alternating current allowed lines to transmit power over longer distances. Coupled with this, rapid improvements in generating technologies, in particular steam turbines, meant that larger plants could be built allowing economies of scale in generation. Universal supply became possible, and politically and economically desirable.

[1] World Energy Outlook 2002, International Energy Agency, Paris, France, 2002, www.iea.org

Developing countries have tended to follow this model. However, these characteristics are not the inevitable result of wanting to supply electricity, but rather are the product of political, economic and technical forces.

3.2. Stand-alone systems

The most common type of small-scale stand-alone system involves the use of renewable energy power source (i.e. a wind generator or PV array), to maintain an adequate level of charge in an electrical storage battery. The battery in turn can provide electricity on demand for electrical applications such as lights, radios, refrigeration, telecommunications, etc., irrespective of whether or not the wind is blowing or the sun shining. A controller is also used to ensure that the batteries are not damaged by overcharging (when surplus energy is dissipated through a dump load) or excessive discharge, usually by sensing low voltage. Load connected to the battery can either be DC or AC (via an inverter).

Small stand-alone charging systems are suitable for remote households in developing countries. Larger stand-alone systems (and potentially more than one renewable energy power source and correspondingly larger battery banks – at an increased cost) are also available, and may include a diesel generator to ensure that the batteries are always charged and that power availability is high.

Less common is the stand-alone system which does not incorporate a battery. This involves the use of a wind turbine with, at least, a diesel generator, which will automatically supply power when required. This has the advantage of not requiring a battery bank but control the systems are complex.

3.3. Distributed-grid (mini-grid) systems

Distributed-grid or mini-grid systems are decentralized power plants, effectively larger stand-alone systems, which supply power to isolated groups of householders, communities or even larger groupings. They involve a local grid-network for the supply of power.

Connecting the utility grid to remote regions usually requires electricity transportation over long distances to a dispersed population. For this reason mini-grid systems can provide more cost-effective electrification than grid-extension for such areas. Mini-grid systems can not only provide access to household electricity in rural areas, but also contribute to income generation, i.e. small-scale industry, and social needs, i.e. clinics. They can be used for the generation of motive power, heat, and other energy requirements. They may also contribute to changes that benefit the local economics and the environment.

A typical village mini-grid system would provide a village with energy for various applications:

- Electricity for lighting and appliances (radio, TV, computer, etc), in homes and public buildings such as schools and clinics;
- Electrical power (or mechanical power common from hydro-powered systems) for local industries;
- Electrical power (or mechanical power common from hydro-powered systems) for agricultural value-adding industries and labour saving activities;
- Electricity for lighting and general uses in public spaces, i.e. health centres, and for collective events.

3.4. Summary

These are clearly three very different approaches and comparisons are difficult to make with such diverse systems. However, table 1 below does aim to review the main issues.

Table 1. Providing electricity to rural communities: issues in relation to the different scenarios

Issues	Grid-connection	Stand-alone	Mini-grid
Power availability	May be power outages	Usually readily available	Readily available
Transmission and distribution costs	High	Nil	Low
Infrastructure	Significant for fuel supplies & electricity distribution	None	Small and more straight forward
Site selection/new plant development	Large plant – selection and procurement challenging although well understood	Usually based on location of need but may also be site specific	Based on location of need but may also be site specific, less complicated than plant for grid-connection
Environmental impact	High although newer generation systems offer improvements	Low	Usually low depending on the power source

Review questions

1. What are the three scenarios available for the supply of electricity to rural communities?

2. What are the advantages and disadvantages of each approach?

4. OPTIONS FOR MINI-GRID SYSTEMS

4.1. General considerations

Options for mini-grid systems can of course be non-renewable, i.e. diesel-based mini-grids. However, diesel generators can be expensive to operate and environmentally damaging. Renewable energy mini-grid systems may use only renewable energy technologies, especially hydro-power in suitable locations, although they are frequently combined with a diesel generator called into action only when essential.

This hybrid arrangement offers all the benefits of renewable energy in respect of low operation and maintenance costs, but additionally ensures a more secure supply: any system incorporating renewable energy usually has high investment but low operating costs, and is environmentally benign. However, two advantages of most renewable energy systems, i.e. simplicity and reliability, may be negated by the addition of rotating machinery or over-complicated hybrid system control.

There is now sufficient experience in a number of developing countries, particularly in Asia, providing successful examples of a wide-range of renewable energy based mini-grid systems. It is recognized, however, that mini-grid systems are generally more difficult to implement than grid extension or stand-alone systems. Reasons include: lack of understanding and limited knowledge of regulatory frameworks. There are also very site specific aspects requiring considerable preparation and development in order to match local requirements with the technologies. Technical assistance may be required for system design and for training for operation.

Box 1. **Township electrification programme**

To provide a solution for the lack of electricity access within China, especially in rural areas, the China's State Development and Planning Commission (renamed in 2003 to the National Development and Reform Commission (NDRC)) launched a renewable energy-based rural electrification programme called Song Dian Dao Xiang – "Sending Electricity to Townships". This programme included the installation of 20 MW from PV system, 840 MW from wind and 200 MW from hydropower. In just 20 months, electricity to more than 1000 townships in nine western China provinces – Xinjian, Qinghai, Gansu, Inner Mongolia, Shaanxi, Sichuan, Hunan, Yunnan and Tibet was realized – supplying power to nearly one million people and providing the base for rural economic development. The government have subsidised the capital costs of equipment by providing US$ 240 million.

Source: Renewable Energy in China: Township Electrification Program, NERL (National Renewable Energy Laboratory), www.nerl.gov, 2004

Box 2. **Solar energy for village electrification in China**

To provide a solution to the energy problem in Qinghai Shenge village, a PV mini-grid energy system was installed. All houses in the village were electrified by a single PV system that has an inverter, hence AC electricity is consumed. The houses are also connected in a mini-grid system through power lines that are strung through the village. The PV system, which has a total capacity of 7.5 kWp, produces power for local government offices and the basic needs of the village at all times. The electricity is used first to charge batteries, where the energy is stored for later use. This is usually in the evenings when the villagers return home. During the summer time when the young men travel long distances with the animals they raise, the total energy consumption is noticeably lower. The system loads include lighting, televisions and radios, as well as washing machines and other community equipment such as communication devices and a ground satellite receiver. Although the system provides electricity for normal everyday consumption, there are some restrictions. For example, the use of the washing machine is limited to two hours a week. Overall the technical performance of the system has been very good with only a limited number of initial problems. Now the system is running well.

Source: Deployment of Photovoltaic Technologies: Co-operation with Developing Countries – 16 Case Studies on the Deployment of Photovoltaic Technologies in Developing Countries, IEA-PVPS, 2003.

Box 3. **China brightness rural electrification programme**

China has been playing an active role in the Brightness Programme (designed to bring electricity to rural areas) since it was established in 1996 during the World Solar Peak Conference in Zimbabwe. China's Brightness Project Implementation Planning was established in 1998 to provide electricity for the remote areas of Gansu, Qinghai, Inner Mongolia, Tibet and Xinjiang using both household and village systems.

The programme aims to provide electricity for 23 million people by 2010 using renewable energy technologies like wind and solar PV generation, with a goal of providing 100 watts of capacity per person.

This programme has been progressing in stages, and in its first stage it has already achieved the following results: *(a)* 1,780,000 household systems, 2000 village systems and 200 station systems installed; *(b)* established national and local government offices financing approaches and practical financing mechanisms; *(c)* established industrialized production enterprises which can fulfil market demands; *(d)* set up a distribution and service network and marketing mechanisms; and *(e)* installed technical training systems with different levels of training for local technicians and engineers.

Source: Renewable Energy in China: Brightness Rural Electrification Program, NERL (National Renewable Energy Laboratory), www.nrel.gov, 2004

4.2. Mini-hydro powered systems

Hydropower based mini-grid systems usually use small hydropower plants, often the run-of-river type, usually without a dam. Therefore, they usually avoid the adverse effects on the local environment large-scale dams are often associated with.

Such schemes usually comprise three core elements:

- Civil works: to divert the water, channels and piping to take water to the power generation equipment (penstock), the power house building and the water exit channel;
- Power generation equipment: turbine and drive system (turbine, generator and/or mechanical devices), generator, controller, inverter and electrical switchgear;
- Power distribution system: to distribute the electricity, usually by a main distribution line to a central point, then by sub-distribution lines and consumer service connections to consumption points. Small village systems may use a battery bank for energy storage, voltage stability and services to remote customers.

In order to assess the viability of a hydro-powered system, information must be gathered on the resource, usually obtained locally through agencies such as the local forest and water resources groups. Several years of information should be gathered and calculations based on average data. Water resources can vary very significantly depending on the season and even year by year. An international database of small hydropower resources has been developed and maintained by the IEA (see Internet resources). The website provides data for potential and developed sites, GIS searching capabilities, country profiles, international contacts for small hydro and a world small-hydro resource atlas.

According to the World Bank's Renewable Energy Toolkit (REToolkit),[2] the costs of mini-hydro power systems vary considerably as the result of many site-specific design and performance related factors. One survey found the average capital cost (in constant $US 1998) of the sample investigated to be $US 965 per kW for plants used for mechanical power and $US 3,085 per kW for plants generating electricity, including the costs of transmission, which can clearly vary.

[2]web.worldbank.org

4.3. Hybrid powered systems

Hybrid powered systems are formed from a combination of wind, PV, hydro and diesel power, e.g. PV/diesel, wind/diesel or PV/wind. These systems were originally developed for telecommunications applications in remote sites. However, telecommunication applications require extreme reliability, which results in expensive systems unsuited to rural electrification.

The basis for hybrid systems is the need to have a more reliable supply of energy. Although a stand-alone renewable energy system will generally have some means of storing energy to accommodate a pre-defined period of insufficient sunshine or wind (for PV and wind powered systems respectively), unfortunately there may still be exceptional periods of poor weather when an alternative source is required to guarantee power production. Hybrid systems combine a renewable energy generator with another power source – typically a diesel generator – although occasionally another renewable supply such as a wind turbine is applied.

The options for hybrid-powered systems are most commonly:

- PV-diesel hybrids
- Wind-PV-diesel hybrids
- Wind-diesel hybrids

These systems can be developed as retrofits of existing diesel mini-grid systems or as new integrated designs. In general, well-designed hybrid systems will substantially reduce diesel fuel consumption while increasing system reliability. This can be of particular importance to existing diesel mini-grid system where the fuel is subsidised to support these systems, creating a burden on the Government resources.

In addition to the diesel generator and the renewable energy generator, hybrid systems consist of a battery bank for energy storage, a control system and particular system architecture that allows optimal use of all components. Hybrid systems have been shown to:

- Provide electricity more cheaply than grid extension;
- Be as or even more reliable than grid power;
- Operate more effectively than diesel-only systems;
- Be modular and relatively easily assembled from standardized packages.

In order to assess the viability of a wind or solar (PV) powered systems, information must be gathered on the resource, usually obtained locally. General solar resource data exist for hundreds of locations worldwide, and can be interpolated to a particular project location as an estimate. However, wind and other renewable resource data remain very site specific.

Hybrid systems are potentially very cost-effective solutions to rural AC electricity needs. For low load applications (<10 kWh/day), wind/PV hybrid systems are very attractive. For larger applications, wind/diesel hybrids are very attractive as long as a reasonable wind resource is available. Bilateral and multilateral finance and market stimulation programmes should be based on best service at least cost.[3]

The cost of hybrid systems is currently high compared to conventional diesel mini-grid systems. However, as is typical for emerging technologies and markets, systems design and industry structure will continue to evolve in concert with the growth in demand, technology development funding, and costs which can be expected to decrease significantly[4]. Renewable energy systems, and specifically wind and PV, have complementary characteristics for mini-grid systems when compared with diesel powered systems, as shown in table 2 below.

Table 2. Relevant characteristics of wind/solar vs. diesel for mini-grid systems

Characteristic	Wind/solar	Diesel
Capital cost	High	Low
Operating cost	Low	High
Logistics burden	Low	High
Maintenance requirements	Low	High
Available on-demand	No	Yes

4.4. Biomass powered systems

Biomass powered mini-grid systems are usually based on either combustion or gasification technologies. Direct combustion systems may use steam turbines and if so, are generally used for only the larger applications. Biomass gasification systems produce a synthesis gas, which can be burned in a gas or diesel engine to provide electricity or motive power or burned in a boiler or furnace to provide heat. These systems can be used in a variety of sizes, ranging from kilowatts to megawatts.

[3]World Bank REToolkit

[4]Prospects for Distributed Electricity Generation, Congressional Budget Office, www.cbo.gov

Box 4. **Power wind/diesel hybrid pilot project in Xiao Qing Dao village**

To provide electricity to the Village of Xiao Qing Dao, the US department of Energy (DOE), the National Renewable Energy Laboratory (NREL) and the State Power Corporation of China (SPCC) developed and installed a pilot wind/diesel/battery hybrid system. The system consisted of four 10 kW wind turbines connected with a 30 kW diesel generator to a 40 kW inverter and a battery bank. Xiao Qind Dao, also called "Little Green Island" is a small island with approximately 370 people where most residents earn their livelihood from fishing and fish farming.

Prior to the project implementation the village residents depended on a 13 kW diesel engine-run generator, which provided 3–4 hours of intermittent electricity during the night only used to power low-wattage lighting and satellite TVs. The hybrid system, installed in November 2000, provided electricity for 24 hours which powers street lighting, good quality indoor lighting, refrigerators, cable TVs, washing machines as well as other electronic equipment. Despite the increase in quality of life, the current electricity is provided at a lower cost. With the hybrid system, island residents pay between one and two Yuan (US$ 0.13 and 0.26)/kWh (depending if the system relying only on wind power or if the diesel generator is used). The village used to pay three Yuan (US$ 0.39)/kWh by the previous system.

In a post-installation assessment the residents of Xiao Qing Dao village reported a high level of satisfaction and the hybrid system showed good performance. With the application of this project, residents have been able to raise their incomes through the use of refrigerators for preserving fish for sale. Also, since the system was installed eleven children have gone to college and have even continued to graduate. The children's success was attributed to the high-quality lighting, which increased daily study time.

Source: Renewable Energy in China: Xiao Qing Dao Village Power Wind/Diesel Hybrid Pilot Project, NERL (National Renewable Energy Laboratory), www.nrel.gov, 2006.

The first consideration must be to review the feedstock available and hence to tailor the technology and system design to this. Feedstock characteristics that are likely to affect the design and technology selection include energy content, particle size distribution, moisture content, organic and non-organic (ash) content and chemical composition. The feedstock may need preparation (i.e. drying). In larger systems, feedstock preparation may be partly or fully automated. Systems in developing countries usually implement manual or mechanized feedstock handling, but they are not generally automated.

The assessment of biomass resources obviously requires a very local input. National and even regional level assessments do exist and may be useful to determine the likely feedstock for a particular area. However, the biomass supply chain must be investigated in detail at local level as part of the project development process. The biomass feedstock may be forest residues, agricultural residues, mill wastes or energy crops. Long-term project viability requires the development of supply agreements with specific suppliers for amounts, prices and set time-frames. The significant costs for collection and transportation, storage and handling also need careful consideration.

Biomass combustion

Combustion systems burn biomass fuel in a boiler or engine, the former producing steam that is expanded in a turbine to produce power, the latter using shaft

Box 5. **Case Study: Village power using biofuel in India as a replacement for diesel**

In the remote village of Chalpadi in the Indian State of Andhra Pradesh, oil extracted from the seeds of the local *pongamia pinnata* tree is being used as biofuel to run an off-the-shelf diesel engine that provides power to a community run village electrification mini-grid. The town originally received the diesel engine from the Indian government, as part of its rural electrification programme, but when the cost of diesel became prohibitive, the town turned to the idea of extracting oil from pongamia seeds as a source of fuel to power the generator instead of diesel.

Villagers now "pay" for the operation of the generator and their electricity by collecting the seeds needed to make the biofuel. A women's self-help group responsible for the operation and maintenance of the engine, levies a weekly tariff of seven kilograms of pangamia seed per family. In April 2003, the town sold 900 tonnes of carbon-dioxide equivalent verified emission reductions (CERs) to Germany. The sale fetched the community $4,164.00, equal to a year's worth of income for every family in the village.

The state government has plans to replicate the project in some 100 villages. In addition, the federal government of India is actively encouraging biofuel production sources from pongamia and other oilseed-bearing tree species. The next phase of the Indian project is to form women's associations that will produce the seed, process the biofuel, and use the fuel to power irrigation pumps. The woman's associations will then sell water to local farmers as a woman-owned business enterprise.

Source: Increasing Energy Access in Developing Countries: The Role of Distributed Generation, the Business Council for Sustainable Energy and the US Agency for International Development, May 2004 power via a generator (for electricity production) directly. Much of current biomass power generation is based on direct combustion in small, biomass-only plants with relatively low electric efficiency (in the order of 20 per cent).

Where heat is needed, either in northern climates for winter heating or for small industry use, combined heat and power (CHP) applications can be cost-effective. Total system efficiencies for CHP can approach 90 per cent.

Biomass gasification

Gasification is the process by which a synthesis gas (syngas) is produced from biomass material. This gas can then be burnt in an engine to provide power. Products for modular systems are now emerging onto the commercial market. System sizes range from 3kW to 5MW. There are numerous applications in India alone, including village power, industrial process heat and electricity, and even grid electricity supply.

Review questions

1. What are the key system layouts for renewable energy based mini-grid systems?

2. Why are hybrid-powered systems attractive?

5. PLANNING THE APPROACH

5.1. Technical issues

When choosing a power supply system for a rural community there are several technical factors, in addition to the available resource, that have to be considered.

Distance from the utility grid

If the community to be connected is relatively close to the existing grid, then the cost of extending the grid will need to be compared to the likely cost of a mini-grid system. There is often a cut-off distance at which grid extension is not viable, or difficulties on the terrain between the grid and the community, such as mountains or marshes, can make line extension very difficult.

System power losses

Grid extension may also require improvement of the transmission system to reduce losses; this is a recognized problem in some areas where the grid has been extended to rural areas, especially using lower voltage transmission lines, 11kVA or 33kVA, over very long distances. This may limit the line extension and hence prompt the decision to install a mini-grid system. In some rural and even urban areas electricity theft is also a problem.

This results in:

- Poor service to rural communities due to frequent load shedding;
- High cost electricity;
- Instability in the power supply, with fluctuating voltage and frequency.

Load characteristics

The density of the load is the quantity of power demanded in a specified area. A high electricity demand in a small area may justify grid extension. Rural communities may however be dispersed and require or be able to afford, only limited amounts of electricity. A very dispersed grouping may indicate that small individual stand-alone systems, such as solar (PV) home systems, may be more appropriate. Another alternative would be a central battery charging station.

Demand-side management and base/peak load issues

The level of power supplied to the utility grid network is often not sufficient to meet demand. Even in cases where the base load needs are fully met there may be problems supplying the peak loads. In these situations, priority is invariably given to the larger cities. Any supply to rural areas is therefore frequently of an inferior quality, with frequent load shedding at peak hours. Distributed generation will ensure that this does not become an issue. Grid extension without due consideration of this issue will exacerbate this problem.

Many rural communities use electricity almost exclusively for lighting in the evening. This means that the revenue collected by the power companies from the rural community will be very low. Using the available power for income-generating activities as well as lighting makes grid extension more financially viable; however, one advantage of community-owned mini-grid systems is that the development of productive end uses for the power can be better planned into the development of the system.

5.2. Non-technical issues

Economics and billing

The decision to extend the grid and connect rural customers will ultimately be based on the cost to the utility. Rural electrification is often subsidized, either by the other customers or by the government. Utilities often have a cut-off point for the distance that the grid line can be viably extended for a given number of consumers, which will be based mainly on the cost of the line extension.

Mini-grid systems, especially those incorporating renewable energy technologies, often have high capital costs for equipment and initial set-up of the distribution system. For community systems this can be covered, at least in part, by a low interest loan or grant. The financing available will affect the end product.

All systems need to have a payment strategy developed before implementation, whether they are financed by the government, donor projects or by the local community. This is important because billing and tariff collection have been found to be a particular problem in rural areas. Utilities have problems because the cost of reading meters and collecting tariffs can be higher than the revenue collected from the rural communities who use electricity for lighting only. This is often the case when the revenue collector has to travel from a central office in town. Revenue collection costs can be reduced by households with metered connection supplying electricity to nearby households, either legally or illegally. However, this can lead to exploitation of the sub-connected, usually the poorer households, by the metered consumer charging excessive amounts for the electricity supplied.

There are a number of solutions that can specifically help low-income households to obtain electricity connection and help utilities to meet their required return on investment, these may use tariff systems that do not involve meter readings, but on the capacity of power supplied to individual houses. This is usually regulated by:

- Circuit-breakers;
- Load limiters;
- Prefabricated wiring systems;
- Community involvement tariff reforms, for instance, payment at a local shop.

Ownership and management

Experience has shown that, if there is consultation with the local community before any system is installed, and responsibility for its operation and

Table 3. Pros and cons of centralized and decentralized ownership and management of rural power supply[5]

For	Against
Centralized management of grid	
Financial risk on utility	No stake in power supply, so lack of interest in maintaining it.
Management capacity already exists	Operation and maintenance staff often brought in from outside community.
Technical capacity already exists	Bureaucratic management. Repairs take longer because they must be approved by central management. Tariff collection expensive. No load management. Disputes between utility & community possible.
Decentralized management (community-owned stand-alone scheme)	
Interests in continual operation of scheme Load management possible Flexible tariffs possible Repairs made quickly Less bureaucracy Local person employed as operator Local people provide labour, reducing initial capital required for scheme.	Financial risk placed on community. Technical training required. Management training required. Outside assistance required for major repairs (costly). Local disputes possible if management breaks down.

[5] *Rural Energy Services: A handbook for sustainable energy development*, Teressa Anderson, Alison Doig, Dai Rees & Smail Khennas, IT Publications, 1999. ISBN 1 85339 462 9

maintenance given to the community, then the system will be more likely to work well and there will be less chance of vandalism. Contributions in kind (e.g. providing labour for installation) can also be important for community ownership.

The other option for a mini-grid system is private ownership and operation. The pros and cons of each approach are summarized in table 3.

Discussion question

Consider the pros and cons of centralized and decentralized ownership and management of rural power supply. How might the difficulties be mitigated?

6. INSTITUTIONAL ISSUES

Institutional issues are important for rural energy development in general and mini-grid systems in particular. Four of the main issues are discussed here but this selection is not exhaustive.

6.1. Government policy

Government policies to support the development of rural electricity supply are crucial to successful implementation.

6.2. Effective implementing agencies

An effective implementing agency dedicated to and dealing with issues related to rural electrification has been shown to be critical to successful rural electrification. The exact institutional structure, however, does not appear to be critical, as a variety of approaches have been successful. Generally agencies will be responsible for managing any rural electrification fund, conducting rural electrification planning, providing technical services, and promoting rural electrification.

The most successful model has been for those agencies which have a high degree of independence when operating and whose primary role is to pursue rural electrification, to create standards and to evaluate proposals for investment. Such institutions are often also responsible for defining the roles of grid extension vs. off-grid systems, and contributing to separate regulatory frameworks including tariff structures and subsidy schemes for grid extension and off-grid options.

With autonomy, responsibility is also required, meaning that a rural electrification agency having its own budget and control over access to materials and labour, should also be strictly accountable for meeting defined targets.

The exact institutional structure does not appear to be critical, as a variety of approaches have been successful. They include a separate rural electrification authority (Bangladesh); setting up rural electric cooperatives (Costa Rica); allocating rural electrification to a department of the national distribution company (Thailand); or delegating it to the regional offices of the utility (Tunisia).[6]

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[6] Rural Electrification in the developing world: A summary of lessons from successful programs, ESMAP, 2004

The issue of an integrated collaboration mechanism between the rural electrification agency, the energy regulator and grid operators is explained into some more detail in module 10 “Increasing access to energy services in rural areas”.

6.3. Attracting investment/reducing risk

It is important that utility companies and/or private-sector rural energy service companies at the community or regional-level are involved in rural electrification, including mini-grid systems. The high costs and potentially low returns are often unattractive and therefore, policy, institutional and monetary support is required to make involvement attractive. This support will usually include some form of risk mitigation.

Practical measures may include market assessments (ensuring that the potential market is more clearly understood), grants (hence reducing the initial investment required) concessions (exclusive right to provide electricity services to the customers in its service territory) and risk guarantees (this may only be partial to reduce long-term financial risk).

6.4. Local institutional structures

Community-based ownership models, i.e. cooperatives, often offer a good solution to meet local needs, especially for mini-grid systems. However, training and guidance is often required for all aspects of the project, from setting-up the organisation to installing the system, developing a workable tariff structure and training for maintenance.

Review question

1. What are four of the main institutional issues that are important for rural energy development in general and mini-grid systems in particular?

Box 6. Policies for sustainable energy solutions – geothermal power development in the Eastern Caribbean

The Eastern Caribbean Geothermal Development Project (Geo-Caraïbes Project) was launched to overcome the barriers to development of geothermal energy in the Eastern Caribbean. The Geo-Caraïbes Project Countries – Dominica, Saint Kitts & Nevis, and Saint Lucia – possess world-class geothermal resources. Each country faces critical electricity supply challenges, with prices among the highest in the world (approaching US$ 0.30/kWh). Despite the would-be obvious project potential, no geothermal power development has succeeded in these countries. Among the barriers to such development is the lack of appropriate policies and regulations that establish the prerequisite conditions to attract competent commercial developers.

The objectives of the Geo-Caraïbes Project are to overcome the barriers to the development of geothermal power, and to implement a regional strategy that will create the conditions for successful development of one or more commercially viable geothermal power plants.

In addressing these matters, the project has developed partnerships among energy stakeholders – including the government, electricity utilities, energy consumers and commercial associations – to prepare legislative measures that will provide for the equitable treatment of project developers, ensuring that their investments are protected and that they are provided reliable and fair compensation for their risks. Likewise the measures will ensure the protection of the environment, preservation of the geothermal natural resources, and the appropriate compensation for host governments. It is expected that such policies and regulations will be adopted in each of the project dountries, by the time the resource assessment and financing tools are established, such that the sustainable development of locally sourced geothermal power will result.

Draft policies have been prepared for each participating country. Implementation of the comprehensive resource evaluation, establishment of the drilling risk fund, and adoption of policies and regulations is pending.

7. FRAMEWORKS

7.1. Regulation

Regulation considerations for mini-grid systems need to be approached differently from grid connection/extension. Key approaches are detailed below, and are largely based on the detailed ESMAP report on off-grid regulatory issues,[7] the ESMAP Best Practice Manual on the promotion of decentralized electrification investment[8] and the ESMAP report of promoting electrification.[9]

- Adopt light handed and simplified regulation – particularly procedures and processes for mini-grid systems/other off-grid electrification. Establish an enabling regulatory framework that has clear separation of responsibilities. A clear separation of responsibilities requires that separate departments have distinct responsibilities for *(a)* planning, monitoring, policy setting, licensing and permits, *(b)* establishing/promulgating regulations, *(c)* compliance ("regulator"), and *(d)* conflict resolution, arbitration, and adjudication in cases where an involved party wishes to appeal a finding of the regulator.
- The national or regional regulator should be allowed (or required) to temporarily or permanently "contract out" or delegate regulatory tasks to other government and non-government entities. One scenario would see a national or provincial regulator delegating regulatory tasks to a rural electrification agency/fund that inevitably is the de-facto regulator because they are often more knowledgeable about the operations of electrification providers and are better able to weigh the costs and benefits of imposing regulatory requirements.
- The regulator should be allowed to vary the nature of its regulation (i.e. concessions vs. licences vs. permits) depending on the entity that is being regulated (small vs. large, grid vs. off-grid, private vs. community based).
- Quality of service standards must be realistic, affordable, easily monitored and enforced. It is counterproductive to try to impose quality of service standards that cannot be met, although this does not imply that quality of service should be ignored. Unfortunately, although everyone talks about improving quality of service, in practice quality of service often gets very little attention.

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[7]Reducing the Cost of Grid Extension for Rural Electrification. (2000b) ESMAP Report 227/00. Energy Sector Management Assistance Program (ESMAP), Washington, DC: World Bank. 2000

[8]Best Practice Manual: Promoting Decentralized Electrification Investment, Joint UNDP/World Bank ESMAP, October 2001.

[9]Promoting Electrification: Regulatory Principles and a Model Law. Reiche, Kilian, Bernard Tenenbaum, and Clemencia Torres, Joint Publication of ESMAP and the Energy and Mining Sector Board. World Bank: Washington, D.C., Paper n.º18, July 2006

- Legal rights and a level playing field for private sector participation: government regulations should permit private sector participants to entry the market for supply of electricity and ensure fair competition for all suppliers with respect to the traditional utility in competing for new customers.

7.2. Tariffs and subsidies

The key costs for any system are the capital and installation costs and the running costs, often designated as operation and maintenance costs (O&M). Particularly for mini-grid systems, which may require considerable control and management, the extra cost consideration of management costs is included in the running costs, to yield O&M&M costs

In practice the cost of providing electricity in any rural situation is high and the recovery of all costs through tariffs may not be viable, especially given the limited resources of the community. However, tariffs should be designed to cover O&M&M costs as a minimum, and preferably some of the initial investment costs. There is, in general, a practice to provide subsidies for rural electrification, but this is best applied to connection/access costs, not to ongoing consumption costs.

It is not uncommon for projects to set an acceptable tariff level, based on these principles and the ability to pay of the community, and then to define the level of subsidy required. Although for renewable energy mini-grid, with high investment costs and low operating costs, tariffs set in this way may be more attractive than those, for instance, for diesel systems, and hence it may be possible to add a tariff component towards the recovery of (or least part of) the investment. The balance must be between ensuring that the system is commercially viable and that the consumers can pay for the energy provided.

To summarize, for renewable energy mini-grids, an adequate tariff structure should:

- Recover at least O&M&M costs;
- Reflect, ideally, the configuration of the real cost of the system – a fixed charge (usually higher than typical tariff structures applied in large grid systems) to reflect fixed O&M&M costs, a variable charge to reflect fuel costs, and a levelized capital cost charge partially reflect capital investment costs;
- Remain below consumers' ability to pay;
- In addition, community involvement is critical for renewable energy mini-grids. Communities sometimes can pay up to 10–20 per cent of the capital investment of renewable energy mini-grid systems upfront in the form of labour, material, and cash contributions.

For these reasons a tariff may be replaced by a fixed monthly fee. There are other pricing/payment schemes such as pre-payment systems as well as new solutions for intelligent metering. Such tariffs can be differentiated by customer segment and ability to pay. Collection of any tariff also needs careful consideration.

Box 7. **Mexico encourages renewables**

Based on findings that remote self-supply projects offer good possibilities for renewable energy development, the government has created a new contract template for self-supply projects. The new contract offers energy banking, favourable wheeling charges and capacity recognition of self-supply projects with intermittent generation from renewable sources.

Mexico's current electricity law presents barriers for renewable energy development. The National Utility CFE does not apply a least-cost approach for acquiring energy from third parties and a number of benefits derived from the use of renewables (social, economical, and environmental) are not taken into account by the current legislation. In December 2005 the Mexican House of Representatives passed a Law for the Use of Renewable Energy Sources (known by its Spanish acronym LAFRE). The measure has now been sent to the Mexican Senate for its review and approval. The bill seeks to support a wide array of energy stakeholders such as public and private electrical utilities, companies, municipalities, and individuals. The new legislation contemplates the use of photovoltaic, hydro, tidal, geothermal, and biomass, biofuel or organic wastes as renewable sources of energy.

The new law authorizes the creation of incentives to promote the use of renewables. It creates a national Trust Fund (fideicomiso), funded by a mix of federal and international resources to support several targeted funds. The trust fund will provide an incentive to foreign direct investment, augment national government borrowing power, contribute in keeping interest rates stable, and improve the availability of credit for clean energy investments and for consumers looking to purchase clean energy products. The Secretariat of Energy (Secretaría de Energía – SENER) will be in charge of establishing further incentives, thus allowing the legislation to keep up with new opportunities for the advancement of renewables. SENER will also coordinate with the Ministry of Economy on a package of incentives to encourage manufacturing of renewable energy equipment in Mexico.

Some incentives only will be given to Mexican utilities, such as CFE and Luz y Fuerza del Centro (LFC), and to Mexican electricity generators (defined as Mexican individuals or entities organized under Mexican law and domiciled in Mexico). The bill recognizes the significance of renewables and the benefits it brings to the country's electrification.

Any subsidies and proposed tariff structures must be clear to allow potential investors/operators to make decisions. For instance a government will usually decide on subsidies, but a regulator can nullify government granted subsidies with low tariffs.

Discussion question

What institutional and framework support is offered to rural electrification, and specifically to mini-grid systems in your country? Are there other support mechanisms not covered here? What measures might be added to provide further support?

8. CONCLUSION

There are basically three options or scenarios for the provision of electricity to rural areas: utility network grid-connection via grid extension, stand-alone systems and distributed-grid systems (often known as mini-grid systems).

Distributed-grid or mini-grid systems are decentralized power plants, effectively larger stand-alone systems, supplying power to isolated groups of households, communities or even larger groupings. They involve a local grid-network for the supply of power.

There is now sufficient experience in a number of developing countries, particularly in Asia, providing successful examples of a wide range of renewable energy-based mini-grid systems. Energy systems usually incorporated into mini-grid systems are: hydro, wind, PV, biomass and diesel systems. Diesel engines are frequently combined with wind turbines and/or PV to form a hybrid system.

When choosing a power supply system for a rural community there are several technical and non-technical factors that have to be considered including: distance from the utility grid, system power losses, load characteristics, demand-side management, base/peak load issues, economics and billing and ownership and management. Other considerations are institutional and framework issues.

LEARNING RESOURCES

Key points covered

This module covers the following key points:

- Outline and brief description of the different scenarios for power supply to rural areas.
- Basic overview of the technologies for renewable energy based mini-grid systems, including wind, hydro and PV, biomass systems and hybrid systems.
- Information on requirements for successful implementation of renewable energy mini-grid systems.
- Discussion regarding institutional and framework issues which are required to support the implementation of mini-grid systems.

Answers to review questions

Question: What are the three scenarios available for the supply of electricity to rural communities?

Answer: Grid-connection/extension, stand-alone systems and distributed or mini-grid systems

Question: What are the advantages and disadvantages of each approach?

Answer: See table 1 for the issues and considerations.

Question: What are the key system layouts for renewable energy based mini-grid systems?

Answer: Hydro powered, hybrid (incorporating a combination of wind and/or PV and/or diesel) powered and biomass powered systems.

Question: Why are hybrid-powered systems attractive?

Answer: Hybrid systems have been shown to: provide electricity more cheaply than grid extension, be as or even more reliable than grid power, operate more effectively than diesel-only systems, be modular and relatively easily assembled from standardised packages. Renewable energy systems, and specifically wind and PV, have complementary characteristics for mini-grid systems when compared with diesel powered mini-grid systems, especially concerning operating costs, logistics burden and maintenance requirements see table 2.

Question: What are the four main institutional issues that are important for rural energy development in general and mini-grid systems in particular?

Answer: Government policy, effective implementing agencies, attracting investment/reducing risk and local institutional structures.

Presentation/suggested discussion topics

Presentation:

RENEWABLE ENERGY – Module 11: Distributed generation – Options and approaches

Suggested discussion topic:

1. Consider the pros and cons of centralised and decentralised ownership and management of rural power supply. How might the difficulties be mitigated?

2. What institutional and framework support is offered to rural electrification, and specifically mini-grid systems in your country? Are their other support mechanisms not covered here? What measures might be added to provide further support?

Relevant case studies

1. Policies for Sustainable Energy Solutions – Geothermal Power Development in the Eastern Caribbean

2. Mexico Encourages Renewables

3. Huarci, Barkol, Xinjiang, China: A Wind Power Village System Project developed by Harnessing a Poverty Alleviation Loan

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Financing Renewable Energy Projects: A guide for development workers, Jenniy Gregory, Semida Sileira, Anthony Derrick, Paul Cowley, Catherine Allinson & Oliver Paish, IT Publications, 1997. ISBN 1 85339 387 8.

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*China Village Power Project Development Guidebook – Getting Power to the People Who Need it Most, A Practical Guidebook for the Development of Renewable Energy Systems for Village Power Project*s, SETC/UNDP/GEF, Project CPR/97/G31 Capacity Building for Rapid Commercialization of Renewable Energy in China, 2004

Rural Electrification in the developing world: A summary of lessons from successful programs, Douglas Barnes and Gerald Foley, Energy Sector Management Assistance Program (ESMAP), Washington, DC: World Bank, 2004

Prospects for Distributed Electricity Generation, www.cbo.gov

INTERNET RESOURCES

World Bank Group Energy Program: worldbank.org/energy

World Bank site specifically providing information on and links to Mini-grid design tools: web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTENERGY/EXTRETOOLKIT/0,,contentMDK:20758111~menuPK:2069968~pagePK:64168445~piPK:64168309~theSitePK:1040428,00.html

International Energy Agency: www.iea.org

IEA International database of small hydropower resources: www.small-hydro.com/index.cfm?fuseaction=welcome.home

NREL (National Renewable Energy Laboratory) DOE, USA site providing examples (database), resource information and analytical models: www.nrel.gov/villagepower/

GLOSSARY/DEFINITION OF KEY CONCEPTS

Biogas	Gaseous fuel produced from animal and crop residues. A mixture of methane, carbon dioxide and water vapour.
Biomass	Solid fuels from a wide range of sources.
Capital cost	Price for initial purchase.
Developing countries	Countries which fall within a given range of GNP per capita, as defined by the World Bank.
Distributed generation	Decentralized power plant, effectively larger stand-alone systems, that supply power to isolated groups of householders, communities or even larger groupings. They involve a local grid-network for the supply of power. Otherwise known as distributed-grid or mini-grid system.
Distributed-grid system	See distributed generation.
Distribution losses	Electricity lost in the process of distribution of electricity to consumers including losses due to pilferage.
Distribution network	The network (wiring system) allowing electricity to be distributed from the site at which it is produced to the customers.
Electricity grid	The distribution network providing electricity, unless otherwise specified this is usually on a national or regional basis, from central generating plant.
Energy services	The end use ultimately provided by energy.
Energy sources	Any substance or natural phenomenon that can be consumed or transformed to supply heat or power.
Geothermal energy	Natural heat from within the earth, captured for production of electric power, space heating or industrial steam.
Geothermal plant	A plant in which the prime mover is a steam turbine that is driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the Earth. The fluids are extracted by drilling and/or pumping.

Grid extension	Lengthening of the distribution network of the electricity grid, usually to connect more consumers, probably further afield.
Grid-connection	Link to the electricity network
Hybrid	A power plant, having two kinds of components that produce the same or similar results.
Independent power producers (IPPs)	Privately owned power companies that produce electricity and sell it for a profit to the national grid or to a distribution utility.
Legal and regulatory framework (LRF)	Combination of the laws, institutions, rules and regulations governing the operations of the electricity industry.
Levelized costs	The levelized cost approach is a commonly used index of long-run costs and is defined as the net present value of all direct costs (for capital, fuel, and O&M) over the expected lifetime of the system, divided by the system's total lifetime output of electricity. This approach is often used to compare distributed generation technologies with one another and with utility costs and residential prices.
Mini-grid system	See distributed generation
Operating cost	Price for running a system
Small hydro	Small-scale power generating systems that harness the power of falling water (<10MW).
Solar photovoltaic (PV) technologies	Devices that convert the sun's energy into electricity for use in lighting, refrigeration, telecommunications, etc.
Stand-alone systems	A system not connected to the electricity grid, usually of small capacity.
System losses	The power that is lost during generation, transmission and distribution of electricity.
Transmission lines	The wiring system that makes up the distribution network.
Transmission losses	The electricity lost in the process of transmission.
Utility company	An entity partially or wholly involved in electricity generation, transmission, and/or distribution.

Utility network	The distribution network of a specific utility (company).
Wind turbines	Devices used to generate electricity using kinetic energy from wind.

Case study 1.

POLICIES FOR SUSTAINABLE ENERGY SOLUTIONS – GEOTHERMAL POWER DEVELOPMENT IN THE EASTERN CARIBBEAN

CONTENTS

1. BACKGROUND

A multi-year initiative – the Eastern Caribbean Geothermal Development Project (Geo-Caraïbes) – was recently launched to overcome the barriers to development of geothermal energy in the Eastern Caribbean. The Geo-Caraïbes Project Countries – Dominica, Saint Kitts and Nevis, and Saint Lucia – possess world-class geothermal resources. Each country also faces critical electricity supply challenges, with prices among the highest in the world (approaching US$0.30/kWh). Despite the would-be obvious project potential, no geothermal power development has succeeded in these countries. Among the barriers to such development, is the lack of appropriate policies and regulations that establish the prerequisite conditions to attract competent commercial developers.

The Project is primarily funded by the Global Environment Facility (GEF), and is implemented by the United Nations Environment Programme (UNEP), and is executed jointly by the Organization of American States (OAS) and the Agence Française de Développement (AfD).

2. THE PROJECT

2.1. Challenge

The lack of development of indigenous energy resources is a primary constraint on the economies of many small island-developing states (SIDS), including those of the Eastern Caribbean. In many of the islands, imported fossil fuel for electrical generation and transportation accounts for a startling one-third of GDP. Despite the abundance of renewable natural resources – including geothermal – the Eastern Caribbean island states have to date been unsuccessful in transforming these resources into commercial power sources

2.2. Solution

The objectives of the Geo-Caraïbes Project are to overcome the barriers to the development of geothermal power, and to implement a regional strategy that will create the conditions for successful development of one or more commercially viable geothermal power plants in the Eastern Caribbean. The resulting electricity from this generation will supply the country(ies) where the project(s) is/are located, and will offer the opportunity to supply power to the neighbouring French islands – Guadeloupe and Martinique – via submarine cables. The critical barriers to geothermal development in the participating countries addressed by the Project include:

- Lack of capacity/knowledge regarding Geothermal;
- Geological resource risk;
- Economies of scale;
- Need for private capital;
- Inadequate policy and regulatory frameworks.

3. POLICIES AND ACTIONS

Among the most significant barriers to the commercial development of geothermal energy has been the lack of transparent and enforceable policies and regulations. Such policies and regulations must address key issues including:

- Governance of the geothermal resource;
- Access to land;
- Rights for independent power producers in an otherwise monopolistic utility structure;
- Arrangements for long-term power purchase agreements (PPAs);
- Rights and responsibilities with regard to the environment, safety and labour.

In addressing these matters, the Project has developed partnerships among energy stakeholders – including the government, electric utilities, energy consumers and commercial associations – to prepare legislative measures that will provide for the equitable treatment of project developers, ensuring that their investments are protected and that they are provided reliable and fair compensation for their risks. Likewise, the measures will ensure the protection of the environment, preservation of the geothermal natural resources, and the appropriate compensation for host governments. It is expected that such policies and regulations will be adopted in each of the Project countries, by the time the resource assessment and financing tools are established, such that the sustainable development of locally sourced geothermal power will result.

4. PROJECT DATA

Where and When: Dominica, Saint Kitts and Nevis, Saint Lucia. 2003 to 2010.

Initiated by: Participating governments, United Nations Environment Programme (UNEP), and the Organization of American States (OAS)

Effectiveness: Draft policies have been prepared for each participating country. Implementation of the comprehensive resource evaluation, establishment of the Drilling Risk Fund, and adoption of policies and regulations is pending (GEF Full Project Phase).

More Information: www.thegef.org

Contact to learn more: mlambrides@oas.org

Case study 2.

MEXICO ENCOURAGES RENEWABLES

CONTENTS

1. BACKGROUND

Besides policies hostile to clean energy implementation, Latin American countries face a host of major macroeconomic barriers to clean energy development. These include unstable currencies, current account deficits, tight access to private credit and high inflation. Mexico is among the first countries of the region seeking to establish a more favorable energy and macroeconomic marketplace for clean energy by taking several steps toward providing incentives to use renewable energy. A comprehensive analysis of Mexico's long-term renewable energy planning is to be published by the Government in mid-2006.

Based on the Government's findings that remote self-supply projects offer good possibilities for renewable energy development, the Government has created a new contract template for self-supply projects. The new contract offers energy banking, favorable wheeling charges and capacity recognition of self-supply projects with intermittent generation from renewable sources. Projects with a combined capacity of no less than 1300MW have already been granted permits.

With the support of bilateral and multilateral donors, the Government is developing a renewable energy risk reduction valuation technique and a method to assess the contribution of intermittent sources to grid capacity. Instruments to enable small-scale self-supply are being developed and transmission models that incorporate wind power into the electricity sector are being designed.

2. PROJECTS DEVELOPING IN MEXICO

With support from the Global Environment Facility (GEF), the Government developed the Large-Scale Renewable Energy Development Project and the Action Plan for Removing Barriers to the Full-Scale Implementation of Wind Power. The Mexican utility Comisión Federal de Electricidad (CFE) is also implementing several wind and geothermal projects.

All these new measures are part of an overall scheme to diversify Mexico's energy matrix and augment the share of renewables in electricity generation. Furthermore, they are a necessary step toward meeting the country's growing energy demand, improving the people's quality of life, and responding to Mexico's international commitments regarding the reduction of greenhouse gas emissions.

3. LARGE-SCALE RENEWABLE ENERGY DEVELOPMENT PROJECT

With support form the GEF, the Mexican Government initiated the Large-Scale Renewable Energy Development Project. Through the implementation of this initiative, Mexico expects to stimulate the commercialization of renewable energy applications and markets, particularly at the grid-connected level, in order to reduce greenhouse gas (GHG) and other emissions while responding to increasing energy demand and energy diversification imperatives necessary for sustained economic growth. The project proposes a two-phase, single project approach to address key policy and tariff issues currently hindering renewable energy development, and facilitate initial investments with use of GEF support in a competitive financial mechanism to overcome initial investment barriers.

The project aims to reduce global carbon dioxide emissions by 4 million tonnes (Mt) per year by promoting the development of a commercial wind energy market in Mexico. The project will reduce identified barriers to wind energy development. As a result, institutional, legal and regulatory frameworks of the electricity sector are being revised so that they provide a more level playing field for wind energy.

4. LAW FOR THE USE OF RENEWABLE ENERGY SOURCES

Mexico's current electricity law presents barriers for renewable energy development. The national utility CFE, does not apply a least-cost approach for acquiring energy from third parties and a number of benefits derived from the use of renewables (social, economical, and environmental) are not taken into account by the current legislation. In December 2005 the Mexican House of Representatives passed a Law for the Use of Renewable Energy Sources[1] (known by its Spanish acronym LAFRE). The measure has now been sent to the Mexican Senate for its review and approval. The proposed legislation would lead to the removal of renewable energy barriers. The bill seeks to support a wide array of energy stakeholders such as public and private electrical utilities, companies, municipalities and individuals. The new legislation contemplates the use of photovoltaic, hydro, tidal, geothermal, and biomass, biofuel or organic wastes as renewable sources of energy.

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[1] Ley para el Aprovechamiento de Fuentes Renovables de Energía (LAFRE)

The new law authorizes the creation of incentives to promote the use of renewables. It creates a national Trust Fund (Fideicomiso), funded by a mix of federal and international resources to support several targeted funds. The trust fund will provide an incentive to foreign direct investment, augment national government borrowing power, contribute in keeping interest rates stable, and improve the availability of credit for clean energy investments and for consumers looking to purchase clean energy products. The Secretariat of Energy (Secretaría de Energía – SENER) will be in charge of establishing further incentives, thus allowing the legislation to keep up with new opportunities for advancement of renewables. SENER will also coordinate with the Ministry of Economy on a package of incentives to encourage manufacturing of renewable energy equipment in Mexico.

Some incentives will only be given to Mexican utilities, such as CFE and *Luz y Fuerza del Centro* (LFC), and to Mexican electricity generators (defined as Mexican individuals or entities organized under Mexican law and domiciled in Mexico). The bill recognizes the significance of renewables and the benefits it brings to the country's electrification system both in the short and the long term. It complements the current legal framework and is consistent with the Public Electric Utilities Law.[2]

5. CONCLUSION

By passing this bill, the Mexican Government expects to increase the quality and reduce the costs of renewable energy technologies (components, systems, and services) by expanding markets for the Mexican renewable energy industry; increase the use of clean energy sources to combat global climate change and protect the natural environment by limiting pollution; and increase the economic, social and health standards in rural, off-grid households and communities by utilizing renewable energy systems for productive applications.

[2]Ley del Servicio Público de Energía Eléctrica (LSPEE)

Case study 3.

HUARCI, BARKOL, XINJIANG, CHINA: A WIND POWER VILLAGE SYSTEM PROJECT DEVELOPED BY HARNESSING A POVERTY ALLEVIATION LOAN

CONTENTS

1. BACKGROUND

Huaerci is a village located at an altitude of 1600 m in Barkol County, which has 90 households with 360 Kasac inhabitants. In this village, husbandry is the main economic activity and the monthly average income is below the national poverty line (circa of 400Yuans (approx. US$ 50) per capita in 2000). This village had no electricity and utilizes candles to provide light at night. The nearest electricity grid is situated 110 km away, and the distance and topographic conditions make it impossible for the grid to be extended in order to supply electricity to Huaerci village.

However, the annual wind speed of 8.3m/s and average insulation of 3100 hours per year present an opportunity for renewable energy resources to be utilized to solve the lack of electricity problem of the village.

2. SYSTEM CONFIGURATION

In 2000, a single wind power system (WPS) of 10kW with 55kWh battery bank and 7.5kW DC-AC inverter was installed in the village to supply electricity. This system provides power to the 90 households 24 hours a day. With electricity availability, ten colour TVs, more than 30 black/white TVs and one CD player have been purchased by the village residents. The total residential load is about 5kW, and monthly power consumption is about 300kWh, with 45kWh consumed additionally by the institutional loads.

3. FINANCING AND MANAGEMENT

A government-subsidized loan for the people, with a 3 per cent interest rate and five-year loan term, was arranged for the project by the county Poverty Alleviation Office (PAO).

Within this system a 1.2Yuans/kWh (US$ 0.16/kWh) tariff is charged to all consumers, and most of this revenue is used for maintenance costs. Also a village power management committee made up of village government officials, representatives of villagers and the deputy director of the border control station has been formed.

4. IMPACTS OF THE PROJECT AND POLICY AND LEGAL CONTEXT

To the complete satisfaction of the government and the village residents, the system has run very well. Furthermore, it has greatly improved the quality of life of village residents and allows children to study in the evenings. However due to the limited system capacity, no productive loads are served to date and education should be provided to the residents in order to make full use of their system, especially for productive uses.

As already mentioned, Huaerci is a neighborhood of Barkol County. Once RE systems have been seen as a way to achieve combined poverty alleviation actions with rural electrification programmes, the Barkol government became interested in developing stand-alone RE systems for other remote communities. Thus since 1999, six villages have been powered by WPS systems and another two villages are planned to be electrified, each with 30kW WPS.

5. LESSONS LEARNED

- Prediction and load analysis is important. A critical factor for cost recovery is proper system configuration to match the system load.
- The six village REVPSs provide a great opportunity to develop a multiple project management entity and to introduce a commercialized management model so as to ensure system sustainability.
- To place the system on a more commercial footing, productive load potential is needed.

6. SUSTAINABILITY AND REPLICABILITY

The initial investment costs of WPS systems are beyond local residents and local governments financing capacity and, sustainable operation is only possible if the system can be considered as a part of a utility extension programme, or financing is made available from upper levels of government or outside donors.

This type of system can be replicable elsewhere if:

- A good wind resource is available;
- The village is of reasonable size and preferably with opportunities for harnessing productive loads (the unit cost per installed capacity is indirectly proportional to the village size)
- The tariff structure is considered in order to maximize the system revenue;
- The technical operator not only runs the system but also provides some services to end-users and encourages wise electricity use.

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Renewable Energy

Module 11:
DISTRIBUTED GENERATION: OPTIONS AND APPROACHES

Module 11

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Module overview

- Outline and brief description of scenarios for power supply
- Overview of the technologies for renewable energy-based mini-grid systems
- Requirements for successful implementation
- Institutional and framework issues

Module 11

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Module aims

- Explain options for power supply
- Enable understanding of the principle of distributed/mini-grid systems
- Present the different technological options
- Outline the expected costs
- Provide an overview of issues involved in the successful implementation
- Review the institutional and framework issues

Module 11

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Module learning outcomes

- To be able to define scenarios for power supply
- To understand the potential technologies
- To have a broad appreciation of outline costs
- To be knowledgeable about the key issues to be considered
- To gain an appreciation of the policy and other institutional issues and frameworks

Module 11

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Electricity Supply Scenarios

- **Utility network grid connection—**centralized generation from large plants some distance from the point of use
- **Stand-alone systems—**A system not connected to the electricity grid, usually of small capacity
- **Distributed grid (mini-grid) systems—**decentralized power plant supplying power to isolated groups involving a local grid network

Module 11

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Electricity Supply Scenarios (2)

Issues	Grid connection	Stand-alone	Mini-grid
Power availability	Maybe power outages	Usually readily available	Readily available
Transmission and distribution costs	High	Nil	Low
Infrastructure	Significant for fuel supplies and electricity distribution	None	Small and more straightforward
Site selection/ new plant development	Large plant—selection and procurement challenging although well understood	Usually based on location of need but may also be site specific	Based on location of need but may also be site specific, less complicated than plant for grid connection
Environmental impact	High although newer generation systems offer improvements	Low	Usually low depending on the power source

Module 11

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Options for Mini-Grid Systems

- Non-renewable, i.e. diesel-based
- Hydro power
- Wind power
- PV power
- Biomass power
- Hybrid systems (e.g. PV-Wind)

Module 11

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Barriers and Issues

- Technical issues
  – Distance from the utility grid
  – System power losses
  – Load characteristics
  – Demand-side management and base/peak load issues
- Non-technical issues
  – Economics and billing
  – Ownership and management

Module 11

SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Institutional Issues

- Government policy
- Effective implementing agencies
- Attracting investment/reducing risk
- Local institutional structures

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Frameworks

- Regulatory issues
  - Adopt light-handed and simplified regulation
  - “Contracting out” of regulatory tasks
  - Variation of regulation depending on the entity that is being regulated
  - Quality of service standards must be realistic, affordable, easily monitored and enforced
  - Legal right and level playing field for private sector participation

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SUSTAINABLE ENERGY REGULATION AND POLICYMAKING FOR AFRICA

Frameworks (2)

- Tariffs
  - Recover at least O&M&M costs
  - Reflect the system cost configuration
  - Remain below consumers' ability to pay
- Other payment options
  - Fixed monthly fee
  - Pre-payment systems
  - Intelligent metering

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CONCLUSIONS

- Three options:
  - Utility network grid connection, via grid extension
  - Stand-alone systems or
  - Distributed grid systems (often known as mini-grid systems)
- Energy systems usually incorporated into mini-grid systems are: hydro, wind, PV, biomass and diesel
- Both technical and non-technical factors have to be considered
- Other considerations are institutional and framework issues

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