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LESSONS LEARNED FROM THE NREL VILLAGE POWER PROGRAM

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ABSTRACT: Renewable energy solutions for village power applications can be economical, functional, and sustainable. Pilot projects are an appropriate step in the development of a commercially viable market for rural renewable energy solutions. Moreover, there are a significant number of rural electrification projects under way that employ various technologies, delivery mechanisms, and financing arrangements. These projects, if properly evaluated, communicated, and their lessons incorporated in future projects and programs, can lead the way to a future that includes a robust opportunity for cost-effective, renewable-based village power systems. This paper summarizes some of NREL's recent experiences and lessons learned.

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1. BACKGROUND

Following the Earth Summit in June 1992, held in Rio de Janeiro, Brazil, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) became seriously engaged in assisting with the introduction and integration of renewable technologies in developing countries. In 1993, a workshop was convened at NREL with 33 representatives from the private sector, government agencies, development organizations, nongovernment organizations, and research institutions to discuss the issues of applying renewable energy in a sustainable manner to international rural development. A summary recommen-dation was that NREL could assist in renewable energy-based rural electrification (RERE) by developing and supporting six related activities: resource assessment, comparative analysis and modeling, performance monitoring and analysis, pilot project development, Internet-based project data communications, and training. Thus was born the NREL Village Power Program consisting of activities that cut across several renewable technologies and have grown to include a wide range of technical, economic, and social disciplines.

Currently, NREL is active in 20 countries, and is supporting pilot projects in 12 of those countries. Technologies presently include photovoltics, wind, biomass, and hybrids; increasing emphasis on small geothermal and small hydro are on the horizon. The remote rural applications include home, communications, water pumping, school and health clinic, battery charging, ecotourism, and village minigrid hybrid power systems.

While considerable effort has been devoted to developing new computer models for economic analysis, training and working with in-country partners, and gathering and documenting not only NREL experiences, but also experiences of others, it is the facilitation of pilot projects that counts most. Pilot projects are more than mere technical demonstrations—they are central to renewable energy-based village power development. By and large, it has been shown that renewable technologies work. The most important aspects of pilot projects are their inherent ability to engage in-country partners in hands-on experience that can lead to not only technical, but economic and institutional sustainability as well.

It is important to note that many of the pilot projects from which NREL's experience has been gained were funded, and in many cases developed, by other organizations and agencies. NREL has provided a variety of services including technical, economic, regulatory, and project management assistance to a wide range of projects.

The purpose of this paper is to describe the lessons NREL staff have gleaned from their participation in the various pilot projects. We hope that these lessons will help the RERE community to implement increasingly more-sustainable projects that lead to widespread replication.

2. APPROACH

The approach used to document the lessons was to poll eight key NREL Village Power team members who have been involved in the development, implementation, and evaluation of renewable-based pilot projects. Consolidating this information, an attempt has been made to look for common themes, while maintaining the variety of experiences. The following four categories were chosen as a way to capture our experiences: institutional aspects, pilot project characteristics, implementation processes, and technology development needs.

3. LESSONS LEARNED

3.1 Institutional Aspects

Reliable, well-designed, and integrated technology is important, but it is the institutional aspects of a project that make or break long term sustainability.

Partnering. Establishing an effective working relationship with a capable, credible in-country champion is critical to project success. In-country partners understand the local legal, political and social context. However, recognize that partner capabilities and interests may change over time. State-owned electric utilities that are sold to private sector, for profit institutions can undergo a dramatic swing in interest and support.

Maintenance. Nothing is maintenance-free, therefore, a maintenance support infrastructure needs to be established and nurtured. This issue must be addressed from the very conception of a project. It need not be complex, but it does need to be functional and appropriate for the size, complexity, and sophistication of the systems deployed. A training program with documentation that is matched to the local capabilities, regular refreshers, personnel turnover, a spare parts' inventory and supply information, and funds for preventive and problem maintenance must all be addressed.

Tariff design (grid systems). Developing world rural tariffs for grid-connected systems are often heavily subsidized and send the wrong price signals. While rural subsidies may be appropriate in some cases, the tariff design needs to reflect both the actual cost and quality of service. Multilevel or stepped tariff designs are particularly important in cases where 24 hour, ac service with renewable hybrids is subsidized due to the large swings in short-run marginal cost. The technical (metering) and institutional (meter reading and billing) costs of grid connected line extension or minigrids need to be evaluated when considering the tradeoffs between grid power and small stand-alone systems.

Tariff design (stand-alone systems). In small stand-alone systems for homes, schools, health clinics, water pumping, and other applications, strong efforts need to be made to decouple the concepts of electricity sales measured in ¢/kWh from fee-for-service monthly payments. Many rural customers are already paying US$5-15/month for basic energy services that can be better met with stand-alone renewable energy systems (and without subsidies). It is often difficult to convince electric utilities and other local officials to think about an energy-services approach.

Development coordination. Most countries have significant rural development programs including education, health, communications, economic development, agriculture, water, and electricity. The links among these programs and the supporting agencies are potentially substantial, and currently underutilized. Rural electrification, does not, in and of itself, create rural economic development. Linking programs is important for overall success.

Planning tools. Rural electrification planning methodologies and policies generally do not integrate and evaluate renewable energy solutions fairly, if they are recognized at all. While pilot projects seldom need to be formally evaluated, up front, by the planning agencies, pilot projects can provide important input to these agencies to further enhance their adoption of renewables as a viable option. There needs to be a conscious effort to work with planning agencies to modify their evaluation methods to fairly accommodate renewable energy solutions.

Economics. Because rural electrification generally consists of line extension or diesel minigrids based on an annual budget for installations, the concept of life-cycle cost analysis, which fairly compares capital intensive and operating-expense intensive technologies, is uncommon. The concept of life-cycle costing needs to be integrated into the training of planning officials.

Language. Many expectations have not been met because of misunderstanding resulting from language and culture differences rather than nonperformance. It is particularly important in pilot projects to emphasize open and complete communications.

3.2 Pilot Project Characteristics

Pilot projects are more than just technical demonstrations. The most successful pilot projects seek to create an environment that can lead to future replication.

Performance. First and foremost, the project must perform well technically. To this end, extra care and expense should be devoted to the design, construction, commissioning, robustness, and reliability of the pilot system. In pilot projects, robustness and reliability are more important than energy-conversion efficiency. Resist the temptation to field the "latest and greatest" until it has been thoroughly tested under controlled conditions. Repairing equipment in remote locations is difficult and expensive.

Energy efficiency. Energy-efficient end-use applications/appliances are critical to economically sized renewable energy systems. Investments in energy efficiency have much more economic value than adding generation capacity to meet the demand of inefficient appliances. It is important that a complete systems engineering approach be maintained, attempting to deliver the best end-use service for the least overall system cost. Retrofitting expensive hybrid power systems in a village without first addressing end-use appliances is a mistake.

Quality of service. Along with the issue of energy efficiency comes the issue of quality of service. Examples include: electric lighting provides better light than from kerosene wick lamps; 24-hour service is preferred to 4-6 hour service; reliable, available electricity is more valued than an unreliable supply. These differences in quality of service should be reflected in comparing alternative solutions.

Replication mind-set. Pilot projects need to be designed technically and conceptually, with the commercial replication path in mind. Pilot projects that cannot be replicated in the region commercially serve only as technology demonstrations with far less value to the existing electrification program than those designed to feed into a national rural electrification plan. It is important to ask the question: "If the pilot project is successful, what is the likelihood that a commercial solution will follow?" If the answer is "none," rethink the rational for the project.

One-of-a-kind demonstrations. Single projects in remote locations are not sustainable. While it is tempting from a budgetary perspective to do single projects, they quickly become operation and maintenance (O&M) nightmares. Multiple systems in a region are required to develop and sustain the necessary support infrastructure. Single-unit technical demonstrations do have their place. Make sure they are in a place that they can be maintained, or removed, when the demonstration is over.

Loads. Estimating electric loads for newly electrified villages is difficult, often resulting in overdesign, wasted energy, and poor economics. Estimating load growth in villages receiving ac power for the first time is equally difficult. Integrating deferrable and discretionary loads helps system economics, but is difficult in practice. Designing modular systems that can be incrementally grown as village loads increase needs more attention. Incorporating these issues into planning models is equally challenging.

Diesel retrofits. It is often more economical (from a life-cycle cost perspective) to install a new, appropriately sized diesel than to use the existing, oversized, poorly maintained one. However, local authorities and renewable energy equipment suppliers resist scrapping the existing diesel because the new diesel reduces the capital available for the nonconventional equipment.

Performance monitoring. Pilot projects, unlike commercial projects, are explicitly intended, based on their performance, to lead to larger scale replication. To this end, they need to be instrumented to confirm energy and operational performance. They also need to be evaluated for institutional response and effectiveness. The results of these evaluations need to be communicated to both the local and international development communities so that technical and nontechnical lessons can be adapted in the replication process.

Buy-down. Because pilots generally introduce new technical solutions to regional authorities, it is often necessary to cost-share the initial project. However, it is important to require significant cost-sharing by the implementing/operating organization to assure partner commitment and capture management attention.

3.3 Implementation Process

Pilot projects help country programs obtain firsthand experience that may lead to widespread adoption of renewable energy technology in the rural electrification process.

Political will. The most important factor for successful implementation is a supportive, positive attitude by the rural electrification officials. The existence of a champion for renewables for rural services who is in a position of authority keeps up the momentum during the extended process of resource assessment, site selection, project design implementation, evaluation, and replication. There is no substitute to a dedicated, influential, local champion.

Duration. The time from initial interest in renewables to commercial replication takes 4-6 years, in a positive climate. The pilot phase usually takes 2-3 years from site selection through initial evaluation. Pilot projects are part of a long-term process of change. Initial commitments should be coupled with the realization that long-term collaborations are a key to successful programs.

Commercial replication. The transition from the pilot phase to commercial replication can be difficult. The transition is greatly aided by a well-funded pilot phase that includes multiple, regional projects; local capacity building; strong engagement and commitment by a commercial partner; and substantial technical assistance. The transition usually means a change from primarily sponsor-driven activities to business-driven activities. The more the pilot project can be set up to look and act like a business, the easier the transition.

Needs-driven approach. Renewable energy solutions to rural electrification should be resource- and need-driven, rather than based on a specific technology/application. The available renewable resources, the village electrical demand and applications, villager willingness and ability to pay for electrical service, and the economics of alternatives should determine the appropriate solutions. It is important to be objective and neutral in evaluating and presenting options. It is important to let the locals participate, and select, appropriate solutions.

Administration. In order to sustain a newly implemented rural electricity system, an administrative system needs to be developed and sustained. Many rural villages have formed cooperatives for fishing, agriculture, and other economic development activities. The specific electricity administrative solution will be regional or village dependent or both. While a number of models have been successful, care is needed in matching the administrative system to the village social dynamics.

3.4 Technology and Development Needs

While it is essential to deploy only commercial technology in pilot projects, it is fair to say that there are opportunities for technological improvement in components, systems, ancillary equipment, and supporting processes.

Hybrid systems. While wind, PV, and micro-hydro have been commercial technologies for a number of years, their hybridization with fossil fuel generators for rural applications are an emerging technology. Renewable energy-fossil hybrids have their roots in telecommunications applications in remote sites; however, the extremely high-value electricity for telecommunications applications has resulted in expensive, extreme reliability designs that are inappropriate for rural electricity service. While there are tens of thousands of isolated diesel generators deployed throughout the world, village hybrid system sales are infinitesimal at this stage because the design, manufacturing, integration, implementation, and distribution segments of the industry are very sparse and immature. This results in high prices, costly implementation and support, and rapidly evolving designs. Hybrid systems are a potentially significant solution to rural ac electricity needs, but further technology development and industry expansion will be required.

Controls. Electronic controls and converters are the least robust component in the reliability/robustness chain. While there have been significant improvements in the quality and functionality of these components over the last 5-years, they remain the chief cause of system problems. Complicating the issue is the lack of maintenance support capacity for these components in rural areas. Robustness and modular electronics need to be the focus of controls development; in addition, spare parts and development of electronic service capacity need to be part of any pilot project.

Lightning/corrosion. Many developing countries' rural applications are exposed to severe corrosion and electrical storm conditions. While much is known about lightning and corrosion protection of electrical components, in many cases conventional solutions for high-value electrical systems are neither cost-effective nor appropriate for rural systems. Cost-effective application engineering is required for corrosive and electrical storm-sensitive environments.

Meters. Metering and billing are often a problem. Prepayment meters may greatly increase the sustainability of mini-grid systems. While several prepayment meter designs are commercial, they need to be less expensive in order to receive serious international attention.

Resource data. Wind resource data for rural areas are either nonexistent or of marginal quality, yet are critically important for comparing wind-based systems to other options. Wind mapping, using various existing meteorological and geographic databases and customized computer models, has enhanced the ability to evaluate wind as an option. Existing solar databases are sufficient for estimating PV as an option. There is an increasing use of GIS-based census and demographic data in the developing world for grid extension planning. There is an opportunity to combine resource mapping and GIS-based rural planning models for determining the opportunity and the best locations for renewable village electrification.

Integrators/packaged systems. Because the market for rural renewables is just emerging, the role of system integration is underdeveloped. There are a number of component and system suppliers, but the function of system integration (comparing and packaging alternative architectures and solutions, along with due attention to load efficiency and demand-side options) is very limited, especially as an in-country capability. While integrated, packaged systems have certain commercial and functional benefits, they (and their supply) are premature; therefore, the market will need to develop further to attract/enhance the integration function.

4. SUMMARY

Renewable energy solutions for village power applications can be economical, functional, and sustainable. Pilot projects are an appropriate step in the development of a commercially viable market for renewable rural solutions. Moreover, there are a significant number of rural electrification projects under way that employ various technologies, delivery mechanisms, and financing arrangements. These projects, if properly evaluated, communicated, and their lessons incorporated in future projects and programs, can lead the way to a future that includes a robust opportunity for cost-effective, renewables-based village power systems.

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