HYBRID MINI-GRIDS FOR RURAL ELECTRIFICATION: LESSONS LEARNED

EXECUTIVE SUMMARY

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Executive Summary

Currently around 1.5 billion people worldwide live without access to electricity, and without a concerted effort, this number is not likely to drop. Grid extension is often highly costly and not feasible in isolated rural areas, or is unlikely to be accomplished within the medium term in many areas. In such situations, electricity mini-grids can power household use and local businesses. They provide centralized electricity generation at the local level using a village distribution network and, when fed with renewable or hybrid systems, increase access to electricity without undermining the fight against climate change.

Members of the Alliance for Rural Electrification (ARE) have been involved in the implementation of hundreds of mini-grid projects around the world. The lessons learned from these projects, which are summarized in this report, provide insights on the key issues that must be considered to devise sustainable, replicable models for the scale-up of hybrid mini-grids. Implementing sustainable hybrid mini-grids involves complex technical, financial and organizational issues which must address the end-users and their needs, capacity building and training, tariff and subsidy setting, and institutional strength.

I. Technical Issues

The combination of generation sources and components selected for a hybrid system will have a real influence on the life time of the system and its affordability to end-users. Despite the fact that the economic situation of rural areas pushes for technology choices made on a short term least-cost basis, quality has a dramatic influence on the system's lifetime and no compromises should be made on the quality of system components to reach the real long term lowest generation costs.

To increase efficiency gains and cost savings, priority should be given to sizing the system appropriately and to energy efficiency. In fact, regardless of the choices, energy efficiency is very important since it can influence dramatically the energy load, and therefore the amount of power generation required. This will impact investment costs and the financial viability of the project. In fact, for most countries supply and demand side management should constitute the first energy policy. In many rural communities, there is a tendency to focus on the reduction of short-term investment costs, which will necessitate on-going awareness raising and efforts to vbolster local availability of energy-efficient appliances.

The decision on the energy sources to use is of course central. Diesel is an expensive resource often difficult to distribute in rural areas. Consequently, 100% diesel-fuelled mini-grids likely will be more expensive on a lifetime basis than hybrid ones, and they are also less autonomous as fuel availability cannot be assured. Hybrid mini-grids, in contrast, utilize local renewable resources, making it less likely that power will not be available.

Several types of renewable energy technologies can be utilized in mini-grids:

- Small or micro-hydro is the cheapest technology, but also the most site dependent, as it requires a river with specific flow rate and volume conditions. Small hydro is a mature technology which has been installed all over the world over the past 30 years.
- Solar photovoltaic (PV) is suitable for almost any location around the world and is also comparatively easy to install, maintain and scale up. However, initial investment costs are higher than those of other technologies.
- Small wind power technology is very site specific, since wind conditions vary dramatically from place to place therefore, wind resources must be carefully studied before a system is installed. However, on

Batteries and diesel gensets are other important components of hybrid systems. The battery is a central element for the cost of electricity over the lifetime of the system. Appropriate energy management should maximize the lifetime of the batteries as replacement costs represent an important part of the overall project costs. The genset will play an important role in ensuring the battery is charged. The use of diesel generators should be minimized as fuel is costly; however, the genset is important to ensure quality of service when the other technologies are low or when the demand is especially high. There should be always some kind of automatic management measures built into the system to protect critical components from severe damage, such as total depletion of the battery charge. Training of local operators and users is essential to ensure that the components are used correctly and will last throughout the whole projected lifetime.

Bus bars and local distribution network are the last key elements within a hybrid mini-grid. The choice of AC or DC current in particular has an impact on the system, its capacities and its price, as well as on the devices that can be powered. However, the choice of AC or DC mostly depends on the technologies to be coupled in the system as well as whether batteries will be used in the system. Single-phase distribution grids are cheaper than three-phase ones, but the later allow greater opportunity for commercial enterprises to obtain power and the possibility of future inter-connection to the national grid.

Field studies and exhaustive demand analysis are a basic pre-requisite for any mini-grid project, regardless of the technology selected. Over-sizing some components, such as wiring and the converters, can be a good idea to anticipate a future demand growth and facilitate the mini-grid's expansion.

II. Financial/Sustainability Issues

Financial and operation issues are critical to the long-term sustainability of mini-grids. Questions such as operations and maintenance, role of the private sector, tariffs and subsidies, and capacity building and training are essential to consider when developing rural electrification programs. This is particularly true with the use of hybrid mini-grids. Key issues to consider follow.

1) Sustainable financial and technical solutions for operations, maintenance and management (O&M&M) are key to overall system success. A well maintained and managed system can run over 25 years and this should be the target of every new system implemented worldwide. Therefore O&M&M have to be carefully integrated in the project business planning right from the inception in order to foresee a cash flow sufficient to cover these costs. The ownership rights and the role of each partner also must be clarified, to determine who is going to be responsible for what and for which investment.

If long-term O&M&M is the key indicator of a successful project/program, many external factors will also play a role. Availability (of products, trainings, reliable actors willing to assume responsibility for O&M, spare parts) for instance is of the biggest importance as is access to finance at all project levels. Therefore, successful rural electrification programs have to rely on functioning networks of local companies and financial intermediaries, which should be looked at and supported in parallel with or as part of the program. This can be addressed in different ways: for example, through technology transfer and company agreements, well-designed call for tenders, technical and business trainings and support to business organizations. The financial sector especially is central and its absence is often critical in rural areas. Therefore, targeted capacity building actions as well as financial instruments such as guarantees and financial risk mitigation instruments are very important.

2) In general, access to information and to training is fundamental to ensure long-term program success. Many stakeholders involved in the rural electrification project chain do not know how to deal with renewable energies, or may not be used to obtaining and paying for electricity. Hence, education, trainings and information about the benefits of access to energy and of renewables are necessary prior to any project. Strong and targeted publicity campaigns explaining rural electrification programs will also increase positive impacts.

3) The private sector must in the future play a bigger role in investing, implementing and operating hybrid systems all over the world if investment is to be scaled up and the challenges to system sustainability are to be overcome. Several factors can be influenced to attract companies and investors over the long term:

- The first option to increase the economic attractiveness of rural electrification is to act on the size of the market. To become more interesting economically, projects should be built ideally around existing business applications or public institutions in order to increase their critical mass, potential profits, and local involvement (i.e., interest in maintaining a system).

- Another option is to support directly income generating activities as part of the rural electrification project itself to increase the positive impacts on the community and generate the needed revenues to cover O&M&M and profits.

- Concentrating energy loads or bundling projects in attractive packages is another means of increasing market size and the attractiveness of rural electrification projects. Territorial concessions are a known and good strategy but they need to be simplified to diminish the costs and the time involved in the process.

4) Setting appropriate tariffs and subsidies (i.e., obtaining the right energy price) is probably the most important factor to ensure project sustainability. A sustainable rural electrification tariff must at least cover the system's running and replacement costs (break-even tariff), even though the opportunity for profit is key to attract private operators (financially viable tariffs). Tariffs must also maintain the balance between commercial viability and consumers' ability and willingness to pay.

Along with good tariff structures, smart combinations of subsidies are key to attract operators and ensure project sustainability. They can support the investment, the connection, the operation, and/or the output. Investment subsidies are a good solution if they go along with a good tariff structure, whereas Output Based Aid (OBA) schemes, if adequately planned, are powerful instruments to leverage private investments and ensure O&M. Other forms of support should be offered in parallel to project developers: tax credits; low import duties; site surveys; market studies; and capacity-building.

Regulations, policies and the legal framework are another incentive or barrier to the development of economic activities. This is particularly true for rural electrification with mini-grids, which offer a long-term service requiring stability and suitable instruments. Regulation has to be an instrument favouring new projects, not a burden. It needs to be light and flexible for small power producers in terms of standards and tariffs, and at the same time, it has to protect rural consumers. Power purchase agreements (PPAs) are an especially important feature, since these contracts are regulating the relations between the different parties involved in a long- term rural electrification project with a mini-grid. PPAs frame these relations and must give enough confidence to the private and banking sectors to invest in a project. PPAs must be fair, binding, ban unilateral changes and protect every actor equally. PPAs should also be as standardized as possible to decrease administrative costs, increase efficiency, simplify procedures, and most of all to enhance market transparency and attract operators and lenders.

III. Organizational Issues

The development of sustainable mini-grid projects can follow several business models according to local social and economic conditions.

- The community-based model has been tried out extensively around the world with varying success, depending mostly on the involvement of the people and the pricing policy. The community has to be involved as soon and as much as possible through financial or in-kind participation and through the constitution of a social structure supervising the implementation and the O&M&M of the project. Even community-based organisations need structured legal rules and binding contracts should be signed to secure payments with clear penalties in case of contract breaches.

- Tariffs have to be determined in advance, but flat-fees with categories adapted to different users are usually a good option since consumption is generally low. Tariffs always have to be high enough to cover O&M as well as replacement costs. Some community-run mini-grids have proved to be successful and this type of organization can have many positive impacts on the community itself in terms of self governance and local buy-in into the electrification system. However, this approach also needs a long preparation period and much technical and social capacity building to compensate for the lack of skills and the potential for social conflicts. Therefore, the introduction of another partner – either private or public – to take over some aspects of system management is preferable.

- Another business approach for mini-grid rural electrification is based on a private operator, whose participation is only realistic if a project is profitable and therefore attractive. Output–based aid and long-term concession, when well designed, can be attractive schemes to increase private sector participation; and a certain level of standardization is advised to reach a certain degree of replication and economies of

scale. Strong and targeted marketing around the call for tenders and the program are key to attract private sector participation. However, operators should be the main designer of their system based on costs and quality, but including consumer health and the environment as criteria. Private providers present the advantages of having some investment capacity and should have technical capacity, so that they can handle all operational issues. However, to be developed extensively in rural areas this model requires significant training, both on technical and business issues. Also, this approach requires community involvement and a proactive private sector development component to build demand for electricity services.

- The utility-based model is another option which has been widely used around the world. Utilities generally have more experience, financial resources, and technical capabilities to carry out rural electrification projects. They can realize economies of scale and use their central position to take advantage of financing options, but many of them are also inefficient and lack commitment at the local level. If this model is to be successful, it has to follow a business-oriented approach. Because of their capacities and experience, utilities should have a role to play in the future; however, partnering with private sector and community-based organizations will allow them to avoid the barriers linked with their centralized management structure and size. This type of hybrid, public-private model is probably the most interesting structure, but is also the hardest to define because it can encompass many different approaches. Hybrid business models tend to be very site specific and thus can be quite diverse with changing ownership structures, O&M contracts, and other variables.

Continuing and adapted capacity building and training on technical, business, financing, and institutional aspects of project and program development is necessary at every point of the project chain and must include every stakeholder. Lack of financial, institutional, and technical capacity is still one of the main reasons for unattractive programs and misunderstandings between the public and the private sector, including the financial sector. General training on rural electrification should therefore be provided to all stakeholders. At the local level, detailed technical training for end-users (i.e., customers) must cover both electricity uses (energy efficiency, load management) and technical limitations of the mini-grid. The personnel responsible for O&M should also be trained right from project implementation, with follow-up training over the long term.

For the sake of project sustainability the involvement of all the local stakeholders of the project is fundamental: Local authorities should be involved from the inception regardless of the business model chosen for the project. They can help assess electricity needs, conduct good project monitoring, help organize the community, enforce the rules, help develop local productive enterprises or added-value activities, etc. The participation of the local community can take different forms: participation in the initial investment, connection fee, monthly payment etc. It is also fundamental that the disconnection policy be clear and enforced. Finally, the involvement of the local personnel responsible for the O&M can be increased by tying salaries with system performance.

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Alliance for Rural Electrification

Shining a Light for Progress

The Alliance for Rural Electrification (ARE) is the international business organisation for the renewable energy off-grid sector.

Our members are companies, research institutes, renewable energy agencies and associations. ARE members stand for high quality, experience and sustainability.

Together we develop the renewable energy markets of the future!

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