Why So Many Remote Renewable Energy Projects Fail:

A Literature Review[1]

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About the CERG

Technical issues revolve around finding the appropriate choice of renewable technology, based on resource availability, scale, and the size of the community. Perhaps the most important issue is that of energy storage- by their nature **wind and solar sources are intermittent**. **Batteries for storage are expensive and limited in their capacity**. Technical issues are also related to finance issues, particularly the high **capital costs and ongoing requirements for maintenance**. Off grid communities tend to be impoverished, thus increasing the financial constraints. This takes us to the political challenges- the use of resources and marshalling of renewable energy will mostly likely require cooperation. For example, it may be more economically feasible to create a micro-grid than individual renewable energy generation; this requires developing a set of institutions around the governance, including financing of such resources.

As Schmidt et al (2013) point out, despite the fact that the market for bringing electricity to the rural poor is estimated at $4-5 b. per year, and heavy promotion by development agencies working with states, large-scale diffusion has been very slow. Moreover**, the private sector has not yet found ways to develop a profitable business model around such markets**. While the rapid and ubiquitous adoption of mobile phones across the world demonstrates that if costs are cheap enough, poor households will readily adopt modern technology. Renewable energy systems are, unfortunately, still too costly for many individuals to afford. Many governments in the South have not extended their electricity grids to remote rural areas, thus creating pockets of serious poverty. Geographic barriers are likely a cause as well as a symptom of energy poverty. In addition, a weak or non the private sector has

Financial, including access to financing, incentives (i.e. lack of them for externalities such as emissions and conservation); and cost
Institutional- particularly fragmentation of policy efforts
Community- the need for a project champion and qualified personnel

examine the technical possibilities. These include a survey of existing renewable energies, the severe weather incidents, and avoidance of cascading outages (Hirsch et al 2018). Microgrids can allow for higher levels of service, avoiding the limitations described above in regard to individual systems (Williams et al 2015). The could allow for better technologies with higher scales, such as wind turbines that are simply not possible on the individual level.

Microgrids are often conceptualized as an integrated solution for combining cooling, heat, and power (trigeneration or CCHP), and has been tested out on college campuses, at jails, and at military installations in the US, the dominant location with some 40% of global microgrids. A major challenge is how to incorporate and regulate distributed energy resources into the main grid in a way that allows grid utility operators to follow a sound business model and ensure capacity and reliability (Hirsch et al 2018). In Europe, community-owned utilities are more common, reducing integration friction.

One major question begged by the microgrid concept is how a large network of distributed grids can be coordinated to ensure reliability? Asmus (2010) describes the spectrum

operator. The VPP relies on software systems to automatically dispatch and optimize generation coming from disparate sources, using web-connection systems that monitor each producer and consumer. In the latter sense, utilities may take on the role of system integrators on top of their traditional functions.

Graber et al, in a study of microgrids in India, where they are multiplying, find that they are often used as a backup as grid power is unreliable and frequent blackouts occur. Microgrids allow consumers to band together to share power in a limited locale, and consumers generally rather their experience with microgrids more positively than with grid power. Thus, as alluded to in the introduction, microgrids, as with standalone systems, are as likely to be complementary, rather than substitute, goods to grid access.

Williams et al (2015, 1272) describe a series of potential policy interventions that could be used to support microgrids, but are applicable to remote renewable energy more generally:

Subsidies, including capital, operating, output/performance-based (if the project meets specified targets), or direct tariff

Tax incentives, including customs and import duties, income tax, and sales tax/VAT exemptions

Financing support, including loan guarantees, partial risk guarantees, and preferential lending

Concessions (eg exclusive rights to provide services in a specified area)

They provide an equally useful set of revenue models (1276) which they divide into collection and tariff models. Collection models include pre-paid, post-paid and sale to a third party retailer. Tariff models include fee for service, fixed charge, consumption-based tariff, and hybrid models

customers, such as base mobile phone stations, public offices, and mining or agricultural businesses that can help to stabilize base revenues for capital recovery.

The main challenge in conceptualizing microgrids is the governance aspects. The ability to create microgrids successfully depends upon a collective governance apparatus to build, maintain, and prepare cost recovery tools and thus has to be weighed against the potentially more feasible alternative of household power.

A Review of Existing Formal Modeling Tools

Modeling Different Renewable Energy Sources

Formal modeling can provide a good starting framework **for comparing different types of renewable energy solutions in regards to technical and economic and financial factors**. There are several emerging approaches to more formally choosing an appropriate energy sources for decentralized systems, as reviewed by Bhattacharyya (2012). One of the most prominent is HOMER (Hybrid Optimization Model for Electric Renewables) set up by NREL (National Renewable Energy Laboratory), a branch of the US government. The model is design to optimized small scale power systems using combination of renewable and conventional power technologies. It can evaluate the available power technologies (individually or combined) based on the resource availability of the specific site, to identify the least-cost energy solution for the area. HOMER is designed to optimize the design of a systems involving PV generators, batteries, wind turbines, fuel cells, hydrogen tanks, hydro turbines, diesel generators, and AC/DC convertors (Bernal-Agustín and Dufo-Lopez 2009; Lilienthal, et al 1995, and Lillientahl 2005). HOMER seems to be the most widely-used decision-making tool.

Another is HYBRID_2 by the Renewable Energy Research Laboratory. The model is intended to predict the performance and cost of hybrid power system as well as comparison of different design and combination of renewable and non-renewable power technologies and sources. HYBRID2 is the combination of a time-series and statistical approaches that can run techno-economic simulation and detailed long-term performance analysis within the time step interval of 10 min-1 hrs. HYBRID2 has a graphical user and result interfaces that provides a user-friendly environment (Manwell et al 2006 and Sinha and Chandel 2014).

A third is HOGA (Hybrid Optimisation by Genetic Algorithms), developed by the U. of Zaragoza in Spain. These decision-making tools use both technical and financial inputs to model different tradeoffs. It is an optimization tool using genetic algorithms and sensitivity analysis.

A fourth option is RETScreen, a feasibility analysis tool, developed by Ministry of Natural Resources, Canada in 1998. The model can be used to evaluate the energy production, financial life-cycle costs analysis, and environmental costs and benefits (e.g. greenhouse gases reductions) of different renewable energy projects. The software is available in 36 languages and the online application of the software in viewer mode is available to use **free of charge**. RETScreen can model both project feasibility and performance analysis of existing projects. The model library is connected to a series of global databases including more than 6000 climate ground stations, hydrology data, technological product information, as well as NASA climate database (Sinha and Chandel 2014; Leng 2000; Markovic et al 2011).

Bhattacharyya (2012) also discusses multi-criteria decision making models as applied to energy decision

Scalable size and Modularity (**modularity and scalability**)
Shorter pre-development preparation, including less time required for weather and environmental assessments, and generally less social opposition (eg vs. hydro or wind)
Relatively simple construction
Low operation and maintenance costs

The downside is that **batteries for energy storage are expensive**, thus solar does not provide the same level of comfort as fossil fuels (during times when the sun is not shining). Crossland et al (2015), in a study of off grid sites in Rwanda, find that solar systems were problematic. The grid was under-sized compared to needs, and batteries tended to run dun down in 2 years, with high replacement costs. This is related to the fact that loads were high during the evening, putting additional strain on battery capacity. Since the solar systems were donated, users were not aware of such limitations and had the initial belief that solar would be cost free.

Pode (2015) describes a World Bank program to promote solar home systems in Southeast Asia as a failure. This stemmed from **high up front costs**, and of a battery sufficient to cover 2-3 cloudy days. In addition, there were multiple issues with reliability and quality, and no service network to manage such issues. Chaianong and Pharino (2015) point to a series of obstacles to promoting solar rooftop energy in Thailand. These include **lack of installation and maintenance personnel; poor manufacturing; problems of stability** of voltage and harmonics of electricity generation, leading to rapid wearing down of the battery; intermittency due to a variety of factors beyond cloudiness and night, such as the angle of the PV panel and humidity; and high up front costs.

In studying Western China, where mini-grid solar systems were set up, Shyu (2013) finds that the government did not adequately survey the needs of the population before designing the systems. Based on survey data, the author found widespread dissatisfaction with the **amount and reliability of electricity supply**. The author concludes that some guidelines on customer usage, including time for peak usage, to control/limit load usage, as well as installing diesel backup generators might alleviate such issues.

Micro-Hydro Systems

Run of river technologies allow for electricity generation that is **not subject to cloudy or windless days**. However, **river flows will vary based on temporal weather conditions**. Murni et al (2012) describe the case of 2 remote micro-hydro systems in Borneo. Key issues included poor assessments of energy demand, leading to overloading; inadequate provisions for operations, maintenance, and safety; and volatility in supply based on rainfall and other hydrological factors. These issues, in turn, reflect inadequate consultation with the community during the design and implementation of the project. Nonetheless, they find overall satisfaction and increased in income by the beneficiaries; the lower cost of electricity than from diesel outweighed the inconveniences of intermittent amounts of supply.

-hydro still requires transmission and distribution wires, and thus could be expensive as well as requiring a community institution for managing the resource. **Environmental concerns include water**

generators can be a backup source of energy. Hybrid systems can come in various sizes from many megawatts power system for an off-grid island to as small as one kilowatt for an individual household and thus have the advantage of scalability. Redundancy across wind and solar can also counteract intermittency in each source. The challenge for such efforts is evidently the **higher capital costs and knowledge requirements of redundant systems**. The hybrid systems literature is dominated by articles finding the right combinations of diesel and renewables for particular locations (e.g. Ahadi et al; Hrayshat 2009). We could see in such systems that diesel could, in theory, be replaced by batteries.

In fact, many hybrid systems use lead-acid batteries. The disadvantages of hybrid energy systems are **complicated controlling process, struggles with short battery life, high installation costs, and high maintenance costs and retirements** as they consist of more components (Bernal-Agustín and Dufo-Lopez 2009). As Pode (2015) points out, is that battery technology is still expensive and short-lived. She describes attempts in Southeast Asia to utilize new models, such as leasing batteries and using battery charging stations, which could be diesel- or solar-based. There are additional ideas about energy storage emerging that need further testing, such as pumped hydro and compressed air (via wind systems), or concentrated solar power (Kapsali et al, 2012; Ibrahim, et al 2011).

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development agency, providing 5-6 hours of electricity per night. Tariffs were set up with an initial payment and monthly payment based on whether the users wanted a 3 point plug (limiting them to using up to 3 lights) or a 5 point plug, which gave them 2 additional connection points. Both charges had an effect of limiting the number of households who could participate, particularly the relatively high up front charge. The monthly charge was comparable to the costs of kerosene, however, households tended to supplement their electricity usage with kerosene. More problematic still is the fact that the kerosene is subsidized.

Mini Case Examples of the Interplay of Technical, Financial, and Governance Challenges

The conclusion of our review is that a successful project needs to consider the interaction of the three (technical, economic/financial and governance) different factors in

The authors close by noting that a key problem for RE is that the lack of a large enough market impedes the subcontractors and service providers needed to spread and sustain it.

The World Bank assessment report (2018) offers some very interesting observations

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