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Who shall inherit the mini grids? Examining ownership and business models for PV Hybrid Mini grids

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ABSTRACT

In the next 20 years a large proportion of new energy access is expected to come from distributed mini-grids, many of which will be powered using renewable energy. PV-Diesel hybrid systems are an increasingly popular solution to reduce fuel costs while maintaining a firm, dispatch-able energy supply. One frequently cited barrier to the large scale adoption of such systems has been the lack of business models that are both effective and sustainable for long term service provision. This paper summarises the different ownership and business models demonstrated in the published literature – specifically Utility, Private Sector led, Community run and Hybrid combinations. The advantages and disadvantages are discussed and examples of application from case studies are described. The paper concludes by discussing why ownership and business models present a barrier for this technology and what can be done to address this issue.

1. INTRODUCTION

It is a common observation that successful implementation of renewable energy projects depend not only on technical design, quality and construction of projects but also the owners capacity to sustainably finance, operate and maintain the projects (Wimmer 2008; ARE 2011). Without this, projects cannot see out the lifespans for which they have been planned, costed and hence approved. Photovoltaic hybrid mini-grid systems[1] (PVHMS) are no exception. PVHMS combine Photovoltaic (PV) generation with traditional fossil fuel technologies, most commonly diesel generators, to provide electrical services to multiple users interconnected via a mini-grid.

PVHMS are often cited as the most cost effective way to deliver reliable electricity to remote communities who are waiting for, or may never see connection from a centralised grid (see for example (Bakkabulindi et al. 2010; Jacquin et al. 2011; Bullis 2012)). The potential market for such systems is enormous, with decentralised mini-grids able to deliver over 40% of global new energy access between 2010 and 2030 (OECD/IEA 2010). Add to this falling price of PV and the rising cost of fossil fuels, PVHMS are expected to make large contributions to this growth and case studies have already been identified in at least 42 countries (Breyer et al. 2010; Werner & Breyer 2012).

Technically the systems are more complex then single source systems, and design difficulty varies greatly with PV penetration (see Arribas and Meike (2012) for a broad classification and associated challenges along with Werner and Breyer (2012) review of actual case study configurations). Much of the literature has previously discussed project modelling and technical design, and it is often observed that the most critical issues with the implementation of PVHMS is no longer of a technical nature, but instead are organisational and regulatory challenges (Jacquin et al. 2011).

The lack of adequate and replicable business models for PV mini-grids has long been identified in the literature and remains a challenge in 2013 (Gül 2004; Turcotte & Sheriff 2001; Leeuwen 2013; ARE 2011; Mauch 2012; Lilienthal 2013). There is little available literature that takes an independent look at business models for PVHMS. This paper aims to explore the reasons why ownership and business models continue to act as a barrier to PVHMS deployment, and what can be learnt from the literature to address this. It will describe the different business models that are used in these inherently unique and locally tailored systems and discuss why such a barrier still exists, and what can be done to help reduce it. The lessons garnered through the paper make comment on the ownership responsibility for PVHMS as well as who is set to inherit the profit or problems of thousands of new systems forecasted for development.

2. PHOTOVOLTAIC HYBRID MINIGRIDS: A SPECIFIC CASE FOR IMPLEMENTATION

As a hybrid system, PVHMS can be seen to inherent both strengths and weaknesses of its parent technologies. On the upside, the diesel and storage components are largely dis-patchable and work to level out periods where the solar resource is insufficient to meet the user needs. The PV component significantly reduces runtime and loading on diesel generators and therefore dependence on the fuel source, an expensive component of operation particularly in remote areas. Together the system operates with a degree of redundancy, where failure of one generation source or lack of fuel may not mean the service is interrupted completely.

On the downside, as systems incorporate a large amount of renewable energy, the capital costs at the outset are large, so there is a greater amount of risk. Projects need to be sustained for a long period to realise the lower Levelised Cost of Electricity, no doubt cited in the business case. Also, PVHMS rely on some - albeit reduced - diesel supply. Considering some case studies,

[1] While the majority of hybrid systems being discussed are PV-Diesel, the authors have decided for this discussion the topic will suit the broader application for hybrids generally. Other terms used in the Literature include Solar minigrid and Multi-user Solar hybrid Grid (MSG).

systems may only become cost effective over 10 or more years (e.g. Malaysia Department of Education case study (Mahmud 2012)), therefore fuel supply risk will be a burden of ownership. Furthermore, PVHMS are a relatively complex technology, which typically requires customised design in each application. This means systems do not have the advantage of modularity and simple installation as seen with Solar Home Systems (SHS), inhibiting PVHMS from achieving comparable adoption rates.

Figure 1 below builds on work from Lilienthal and Mauch, and incorporates additional information on SHS research (IEA-PVPS T9:02 2003) to get a better perspective of where mini-grids fit relative to other rural electrification choices. Small systems between <1kW include lanterns, small DC home systems, and some cases AC systems as well. These systems have lower financing costs can be user owned or leased with reasonable payback periods. Lanterns require little to no maintenance and so have been considered, a product typically sold through the cash sale, but less commonly through a programmatic approach for those with very low income.

A PVHMS 'product' as such would be a difficult proposition due to the high degree of customisation required to best fit a community and its existing assets. Therefore programs or financeable projects this may not rigidly provides for the majority of system implementation and this is obvious from the models discussed later. Importantly there also exists a crossover of ownership options, namely the utility, the private sector or even be community based. These ownership types, along with hybrid approaches which contain elements of each, will be discussed in detail in the next section.

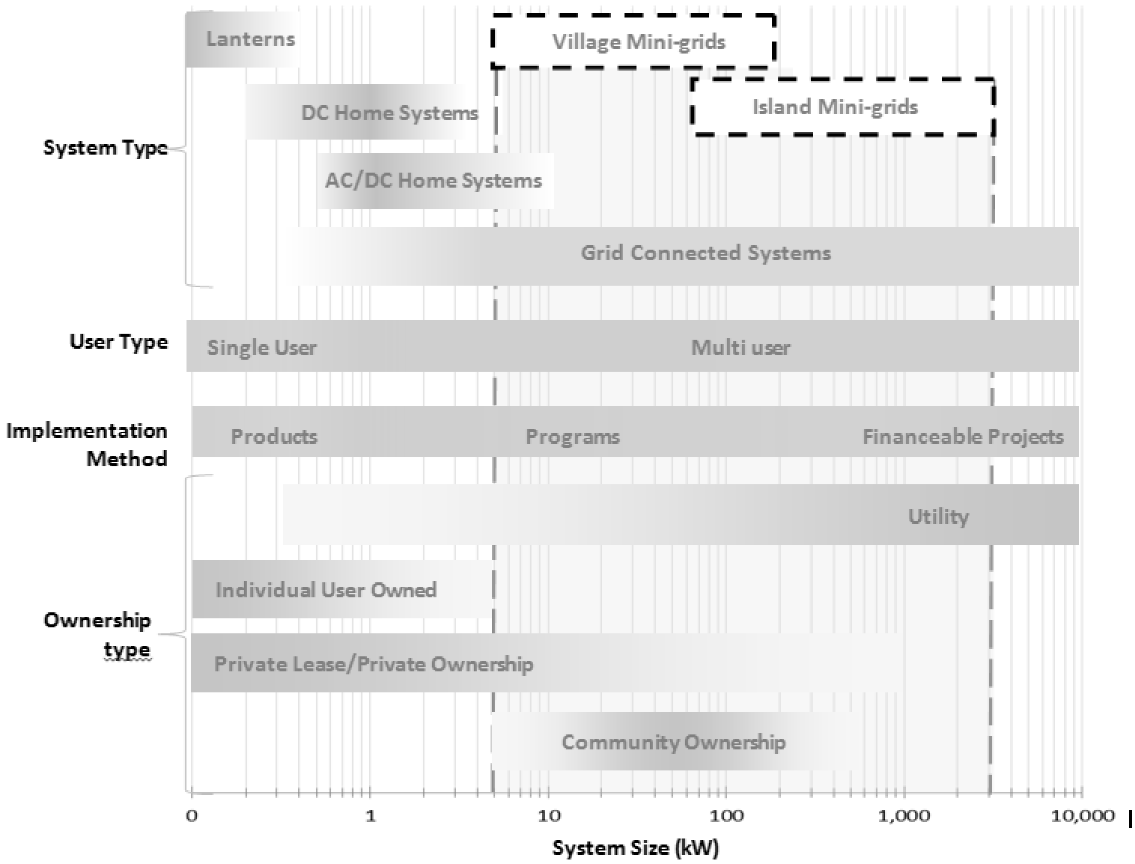
3. TYPES OF OWNERSHIP AND BUSINESS MODELS FOR PV HYBRID PROJECTS

A review of PVHMS literature uncovered two reports which discuss business models in detail. Namely these are the Alliance for Rural Electrification's Lessons Learnt report (ARE 2011) and the IEA's Task 11's Social Economic and Organisational Framework paper (Jacquin et al. 2011). In this section, the different models identified in section 3 are summarised using these reports and, where noted, they are expanded with other case studies found in the literature.

3.1. Utility based Model

A utility model is viewed as the traditional approach to drive electrification projects. Utilities are generally an experienced party with the financial resources and technical skills to implement and manage large projects. They also operate from a centralised position with large stocks of spare parts. Accordingly to the ARE report, there are several examples of well-run utility based electrification programs in Thailand, Tunisia and Morocco – however, the success of these programs typically rely on innovative business approaches adopted by the utilities, rather than on the traditional public orientated programs. The utility model has much scepticism due to their effectiveness over the years, and problems with end user acceptance (see China for instance (Shyu 2010)). A lot of the problems stem from

Figure 1 Applications and Categorisations based on System Size
(building upon (Lilienthal 2013; Mauch 2009)**)**



the liberalisation of energy markets in many developing countries, which in turn forced utilities to market driven priorities, so running low revenue mini-grids in rural areas is not a priority. They are also considered relatively inefficient, sometimes even bankrupt, and O&M costs are much higher than other project developers. Some further detailed case studies include Malaysia (Department of Rural Development (Mahmud 2012)) and Northern Territory, Australia – Ti Tree, Kalkarindji and Lake Nash projects owned and jointly operated by Power Water Corporation (NT Green Energy Task Force 2010), although to date there is little published information available on the latter.

3.2. Private Sector-based Model

Effective private ownership business cases can be made either with or without direct government support and those without are seen as the key to up scaling PVHMS to their full potential (Leeuwen 2013). This is because an effective and sustained rural electrification program must follow an economic logic and be able to attract private customers. A private sector model may take different forms depending on the eventual ownership of the system (as it could be transferred after implementation to another actor), the types of contracts (with end users or utilities) and the type of subsidy (now more commonly available (ARE 2011)). It's argued that the major advantage of a private sector based model is that it provides electricity more efficiently than any other model; revenue streams mean companies are incentivised to provide long term operations and maintenance, and typically have a high degree technical ability.

The private sector also may have investment capacity that is much needed in rural areas, and inaccessible to a community run project (also not tied to any political interference as say, a utility might be). However, due to the financial capacity of most rural areas in developing countries, the private sector may not be able to get involved in these markets without some form of public financial support.

One study in Chad compiled surveys of government, industry and end-users and noted that the Private companies were viewed as successful in running the corresponding mini-grids (because prices better reflected of what it costs to generate and maintain the supply) (Lecoufle & Kuhn 2012). ESMAP in 2008 cited 700 electricity generation plants in Cambodia that have been financed, constructed and operated by independent power producers who were under direct contract to village governments (Reiche & Tenenbaum 2006), although these may not necessarily have been PVHMS.

3.3. Community Based Model

If an electrification project cannot get interest from utilities and the private sector itself, the community which hosts the project can act as both the owner and the operator of the system. This is a common business model as often it is the only option for rural electrification (see examples of Latin America (Reiche & Tenenbaum 2006)). There are a number of advantages in such an approach; firstly the owners and operators are also the consumers, so they have the direct interest in quality of service and longevity of the system. Community based organisations increase self-governance and are often cited to be more efficient than utilities (less bureaucratic and better placed to determine needs). The programs also facilitate rural capacity building, training and jobs for the community.

There are however also significant challenges in that local communities typically lack the technical skills to design install and maintain the systems themselves, but also may not possess the business skills to effectively run the project sustainably. They will also face additional challenges in access to finance. It's further noted that sometimes communities lack the cohesion to share and schedule electricity (Vallve 2012).

3.4. Hybrid Business Model

An alternative is a hybridized model comprising a combination, typically in some form of Public Private Partnership (PPP). This could entail different O&M responsibilities, or split ownership agreements between grid infrastructure and generation capacity to take full advantage of the respective strength of each participating group. For instance a utility or a private company might implements and own the PVHMS, a community based organization manages the daily operation and a private company offers technical back up and management advice. Such an arrangement would benefit from the experience and scale of utilities infrastructure work, the local involvement and participation of the community organization and the technical expertise and efficiency of a private service company. On the downside there is a complication such a complex model as it involves so many stakeholders and establishes long term interdependence and obligations.

Again while there are no documented examples of PVHMS, ARE cites one Sunlabob micro-hydro project in Laos which operated under a PPP arrangement. Firstly public partners funded the fixed assets, the community was transferred ownership while Sunlabob financed the movable assets (generation equipment) and commits to a 25 year Power Purchasing Agreement (PPA). While this model without the need for ongoing public support, the electricity remains quite expensive for the end users and small loads mean limited revenue and payback time for Sunlabob. Other examples of hybridized ownership approaches come from micro hydro projects in Southern Africa, such as the aptly titled Build Operate and Transfer (BOT) projects, have been described by Mabutubuki-Makuyana (Chandirekera Sarah Mutubuki-Makuyana 2010).

4. DISCUSSION

This paper set out to answer a number of questions, beginning with why a lack of replicable business models might exists and how it poses a barrier for PVHMS. Firstly, on a technical level, systems are inherently complex and unlike simpler technologies of SHS require localised design and great expertise in initial commissioning. While a replicable 'cookie cutter' design can be used for SHS, the integration of existing diesel in the design, load variability, larger storage and control requirements mean that such an approach is difficult to manage with PVHMS, but not impossible. It also means that private companies offering complete solution would have to be specialised at not just PV and batteries but installation and ongoing maintenance of diesel systems as well. A further reason is the high capital cost, which sits somewhere of a grey area between being too expensive for the local community and somewhat too small from a utilities perspective, as the associated administrative and operating costs could quickly outstrip the capital cost. Finally, as mentioned in this paper, there are very few publications and documented examples that incorporate information on business models – this makes it difficult to share learning's and success stories.

The question that follows then is what can be done to remove these barriers. One of the most promising approaches to ownership is a hybrid approach. With this strategy the responsibility for different aspects of a project are given to those who are best equipped to manage and understand them. The key to assisting such hybrid business models will be strengthening the institutional capacity to serve such a model, and developing stakeholder support through proper model facilitation. If such an approach is implemented and proves to be successful it will quickly spread, similar to what was witnessed with Grameen Shakti in Solar Home Systems.

The final question posed, the titular "who shall inherit the mini-grids?" – cannot so much be answered now, but was included to stress the long term responsibility of ownership and service. With pay back periods sometimes stretching beyond the 10 year mark developers need to stress that every decision made in the initial stages of the project will have repercussions down the line. Integrating a complex, multi-technology solution could well mean that systems are less reliable and suffer inherent fuel dependence long into the future. It is foreseeable that this will burden the utilities, and inevitably the end users.

Many national governments are seeking to reduce dependence on fossil fuels, increase expansion of rural electricity and reduce greenhouse gas emissions. As a relatively new technology and one that has yet to prove itself to run the course - the stakes are high. It is the author's opinion that PVHMS are an underutilised tool to achieve these measures, but this is unsurprising given the complexity and limited success of early pilot projects.

5. CONCLUSIONS

Photovoltaic Hybrid Mini grid Systems possess a compelling potential to serve rural electrification purposes. With a reduced but continuing fuel dependence in something of a middle step backwards from fossil fuels, and this will make them attractive in a range of contexts. This paper has discussed the 4 main types of ownership model have been demonstrated in the published literature. The Utility based model brings expertise and longevity but at questionable efficiency, as utilities have been better suited to large less innovative projects. The private sector based model brings strong technical ability with efficient, economically driven sustainability but needs stability to see out the project lifetime, along with incentives to invest. Community based models strongly aligned incentives, allow skills and capacity building in the local community but also have a large hurdle in transferring the technical expertise to successfully run projects. The most promising approach discussed in this paper has been the hybridised model, which is essentially a combination of the best aspects of the other models mentioned, adds complexity to operations and needs to be carefully structured. The lack of business models is related to the complexity of the technology, but as presented here hybrid implementation models designed to play towards this complexity hold the most promise.

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