Experience with off-grid photovoltaic systems in Tonga and Indonesia

Hugh Outhred[1], Stephen Healy[1], Maria Retnanestri[1], Tevita Tukunga[2]

[1]University of New South Wales, Sydney NSW 2052 Australia
[2]Ministry of Energy, Tonga
Phone: +61-2-93854035 Fax: +61 2 93855993 Email: h.outhred@unsw.edu.au

ABSTRACT

Off-grid PV systems can make a positive contribution to the sustainability of communities in developing countries that do not have access to a regional electricity grid. However, this cannot be taken for granted. Reviews of experience with PV systems in developing countries have identified problems such as system designs poorly matched to user needs; poor installation practices; inadequate or unworkable maintenance arrangements; and poor or inadequate supporting institutional infrastructure. Successful project design, installation and operation should consider the economic, environmental, institutional and technical aspects of project sustainability.

This paper reviews experience with PV solar lighting systems in the outer islands of Tonga and discusses a current project to investigate off-grid PV applications in Indonesia, paying attention to the economic, environmental, institutional and technical issues discussed above. In the case of Tonga, the paper identifies weaknesses in the way in which the systems were designed, installed and managed, and in the institutional framework within which the project was undertaken. In the case of Indonesia, the paper suggests issues that should be considered in evaluating existing projects and in planning future projects. The paper makes recommendations that we believe have wider relevance to developing countries.

1. Experience with off-grid PV in developing countries

The review by Nieuwenhout et al [1] of experience with solar home systems in developing countries published in 2000, noted, *"more and more doubts have arisen about the effectiveness and suitability of small PV systems for rural development. Many organizational, financial and technical problems appear difficult to tackle"*. The review concluded that not enough information is available about the field performance of such systems, *"slowing down further development and successful dissemination"*. Important success factors were identified as:

- adequate service infrastructure,
- flexibility in system sizing,
- appropriate modes of deployment and pricing
- good design, including measures to enhance the life of batteries and other system components, and
- user empowerment, including education about appropriate use and maintenance practices.

These conclusions are consistent with the United Nations Development Program's concept of Sustainable Human Development (SHD): *"SHD means empowering people and creating an enabling environment for their initiatives in all spheres of life. Along with recognizing that people themselves have to make the decisions about their lives, developing their capacities to make informed decisions and to implement their decisions is central to empowerment."* [2].

Green [3] has recently analyzed fifteen years' experience with solar battery charging programs in northern Thailand, concluding that about 60% of systems are no longer operational. *"Many of the technical failures observed are attributed to social factors, as well as flawed implementation strategies"* [3]. Like Nieuwenhout et al, Green deplores the lack of follow-up on field performance to guide future program design. *"Considering the amount of financial resources already allocated ... by major funders over the last decade, this lack of direction is extremely worrying"* [3].

Thus the above analysis of field experience with off-grid PV systems in developing countries identified difficulties of many kinds – technical, cultural, institutional and economic. Balance of system components (particularly batteries) are less robust than PV modules, and the social context of PV applications requires much more attention than it appears to have received to date.

This bears out the previous experience of a large number of earlier studies reviewed in [4]: *"Significant problems identified... have included: system designs poorly matched to user needs; poor installation practices; inadequate or unworkable maintenance arrangements; and poor or inadequate supporting institutional infrastructure"*.

This experience is also corroborated by the results of a survey of renewable energy applications in remote Australian communities. *"Education and training were perceived to be vital to the success of RE systems in remote areas. However, good on-the-ground examples of successful* *training packages were not apparent. Existing warranties for RE systems were not found to be consistently honoured. Demonstration systems were generally not thought to be the best way of transferring technology, and people resented being used as guinea pigs by having technology, that was in the process of development, lumped on them."* [5].

2. Sustainability of PV systems

Based on our own experience and that reported in the literature, we believe that a holistic approach to project design and implementation of off-grid PV systems can contribute to sustainable human development. However, this must consider economic, environmental, institutional and technical dimensions of sustainability. In the remainder of this paper we report on investigations of the sustainability of off-grid PV systems in Tonga and Indonesia.

3. Experience with solar lighting systems in Tonga [4]

Stand-alone PV lighting systems have been used to provide electricity in remote locations in Tonga since 1987. They power remote households and community halls improving both lifestyles and living standards. However, while donors have spent many millions of dollars to fund the purchase and installation of these systems this initiative has yet to prove its sustainability.

The research reported in [4] involved an analysis of an EU funded PV lighting project installed in 1996 on ten remote islands in the region of the main island of Vava'u. The research used household surveys and data from interviews with key PV stakeholders to examine problems influencing the sustainability of remote PV lighting systems, identifying matters related to their environmental, economic, technical and institutional sustainability.

Environmental sustainability of solar lighting in Tonga

Environmental problems are increasing in the remote islands with the island subsistence economies continuing to exploit fossil fuel and fuel wood resources. Fuel wood and kerosene are mainly used for cooking on the islands, and the use of efficient stoves and solar ovens could reduce the use of wood and kerosene. The introduction of PV lighting on the remote islands of Vava'u has reduced kerosene consumption for lighting by about 70 percent. However, PV equipment has also had negative impacts on the environment by increasing solid waste materials in the islands.

Lead acid batteries, PV panels, controllers, lights and switches all become solid wastes at the end of their working lives. The islanders already discard dry cell batteries into the island environment because there are no suitable recycling facilities. PV battery recharging stations could displace dry cell use, reducing the battery waste problem and improving the sustainability of PV technology in the islands.

Improved environmental sustainability on the remote islands will require a community-based approach, in which community members are trained and given the authority to maintain their environment under government guidance. However, this is hampered by a lack of government environmental policy and legislation, with financial constraints being one significant reason for the delay in government action. Donors are the major source of finance for environmental development in Tonga and to date activities have focused on urban areas on the main islands.

Economic sustainability of solar lighting in Tonga

98% of the initial EU project budget was devoted to the project hardware and only 2% to the project software, where software refers to the knowledge and skills relevant to the installation, use and maintenance of PV technology as well as appropriate institutional support and service delivery infrastructure. Such a budget structure is common in projects offered to developing countries. However, it is now recognised that the higher the training budget of a PV project the higher its chances of success. Thus, donors need to allocate greater resources to the software elements of projects than has been customary if they are to be sustainable.

Only 35% of the total system user fees expected by the government were collected and only a few households had up to date monthly payments when surveyed. Moreover, a significant number of households preferred to pay into a community bank account rather than the currently mandated government revolving account. This was because of government policy to deduct a 5% annual commission from the revolving account.

The majority of the islanders were also unhappy with a uniform rate of monthly fees because they believed it is not justified for households with 2 lights to pay the same as households with 3 or 4 lights as is currently the case (this may be partly due to a lack of understanding of the energy-constrained nature of PV systems but may also indicate that communities place a high value on the added usage flexibility provided by additional lights).

Despite a growing reliance on remittances and employment, the most important long-term income sources on the islands remain fishing, agriculture and handcrafts. In order to achieve a more stable level of income on the islands PV systems should be designed to support income-generating activities. However these PV lighting systems support only handicrafts, and then only by extending potential working hours.

Technical sustainability of solar lighting in Tonga

Technical problems are common in the Tongan PV lighting project. Maintenance is sometimes ignored, and the supply of spare parts is poor due to funding constraints and poor communication and transportation. Some technical problems, such as solar panel EVA melting, were caused by low quality PV equipment. Lack of protection against excessive discharging might also have damaged batteries.

Effective installation and maintenance requires adequate user training, field research and the incorporation of the social and cultural needs of the host communities, with adequate access to spare parts. Although pivotal to the technical reliability of the PV systems, insufficient attention has been paid to these issues. Also, proper examination and testing of PV equipment is impeded by a lack of Tongan testing facilities and expertise and there are no Tongan codes and standards for installation and maintenance.

Data on system performance could be collected by distributing data loggers to users, and by equipment testing and measurement under the supervision of local technicians. Such data could be analysed to identify problems related to installation, maintenance, poor quality equipment or inappropriate use, as well as to assess the economic performance of the equipment and maintenance activities. Involving users in installation, maintenance and data collection would not only improve knowledge but also increase users interest at a cost below that of formal training.

Institutional sustainability of solar lighting in Tonga

The Tongan legal framework for PV development is provided by By-laws. However, these By-laws are not enforced, which is an important factor in user reluctance to pay monthly fees. The National Energy Committee (the premier Tongan energy decision-making body) doesn't always meet and the Tongan Energy Planning Unit carries out PV project management with minimal collaboration from other PV stakeholders.

Island Solar Committees don't always conduct monthly meetings or submit their minutes and user proposals to the government. Solar Committees do not always enforce the collection of monthly fees and some committees have invested part of the collected fees in Community Bank Accounts without government authorisation. Local technicians are not always available, some have moved to the main island for better employment, and this lack of trained personnel is an important constraint on effective installment and operation of PV systems.

Donors support increasing the involvement of PV stakeholders in project governance, indicating an interest in establishing a more sustainable institutional framework. Donors also support private sector involvement, but evidence suggests that a private sector model would not work well in the remote islands of South Pacific Countries because of the small size of the PV market. However, there are still significant opportunities to improve the current institutional framework by: (i) restructuring government services and ensuring they are adequately delivered; (ii) introducing field research and data recording; (iii) recruiting full time local technicians; (iv) improving the availability of spare parts; and (v) improving training for local technicians.

4. Off-grid PV systems in Indonesia

The fragmented geography of the Indonesian archipelago and an uneven population distribution create problems extending the nation's power grid, and about 110 million Indonesians do not have access to grid supply [6]. These rural inhabitants are generally farmers, artisans, craftsmen, fishermen or small-scale traders.

Since the 1980s, approximately 5 MWp of PV has been installed in various applications including home lighting, water pumping, communication, community health care and ice making. The technical potential for off-grid PV in Indonesia has been estimated as 900 MW [6].

As an example, in 1988, 102 PV lighting systems were installed in the village of Sukatani in West Java as a pilot PV village program. The project at Sukatani was monitored and periodic site audits of the technical and social aspects were conducted. Studies of Sukatani including its financial management were well documented. The villagers still express a positive response towards the systems fifteen years after their installation, and they kept their PV systems for back up power after grid electricity arrived at Sukatani in 2001.

When comparing a model PV village like Sukatani with others, a question arises as to how similar the outcomes will be elsewhere in Indonesia particularly in regard to project management, monitoring and the impact that PV has had on the sustainability of the local community. We are presently undertaking a study to investigate that question.

Findings from our preliminary fieldwork suggest that in at least some instances, villagers have responded positively to the introduction of off-grid PV systems [6]:

- PV systems have been used for economic activities, a measure of the acceptance of PV into rural life;
- PV systems have been kept as back up power after grid connection, a measure of user satisfaction with PV reliability;
- PV users are willing to invest in bigger capacity systems, a measure of user enthusiasm for PV;
- Some revolving funds have been generated from past projects, a measure of economic sustainability.

In some cases, where the arrival of grid electricity has made the PV systems redundant, PV modules have been sold in a second hand market. This raises an interesting question as to whether there is local innovation in PV use.

However, it is not clear that the good outcomes achieved by some of the early projects will be replicated more generally.

For example, the experimental project at Sukatani demonstrated good financial management and bookkeeping practices but that has not always been the case. An anecdotal report for another project mentioned that a new management board encountered difficulties continuing PV system service and management when taking over the role from the previous board because of inadequate transfer of knowledge. This resulted in a lack of trained technicians and spare parts, which eventually led to non-payment by some users. Non-payment became contagious when other users observed that there were no consequences.

A preliminary observation of another (solar lighting) project indicated that many users found that the PV lamp was too bright for sleeping and that it could also attract the unwanted attention of thieves to their homes. Consequently they used traditional kerosene lamps after 10 pm, effectively eliminating the energy saving of the PV system and raising their energy expenditure as they then paid for both fossil fuel and PV lighting. One user who installed motorcycle bulbs to reduce the illumination was surprised to find that energy consumption increased, exhausting the stored PV energy very quickly.

This case indicates that a cultural gap still exists between PV and the users. A PV system with smaller wattage lamps might solve this particular problem. More importantly, adequate information concerning system features and performance should be provided to potential users prior to a transaction to avoid disappointment.

For PV to be socially and economically sustainable, it is imperative that it contributes to the local socio-economic culture. Motorcycles have brought economic opportunities such as taxi and courier services as well as derivative businesses such as spare parts and service workshops, fuel retail outlets and tire repairs. Thus the motorcycle illustrates how a new technology can create local jobs and strengthen a local economy.

5. Conclusions

The sustainability of PV systems in Tonga would be enhanced by the utilization of mature PV technologies under appropriate economic, technical and institutional frameworks that reduced environmental problems and met the socio-economic needs of target communities. This would require a new direction for energy investment and changed institutional arrangements.

The authors believe that for PV systems to be sustainable in off-grid applications in Indonesia, it is imperative that they are delivered to rural Indonesians in a sustainable institutional framework that addresses the interests of key stakeholders.

PV must be an enabling technology that strengthens the rural socio-economic culture and allows rural societies to care for the environment from which they earn their livelihood. For PV systems to be socially and economically sustainable, it is imperative that they are incorporated into the local socio-economic culture of remote societies. For PV systems to be technologically sustainable, it is imperative that they deliver to the villagers more than a technocratic solution which is inherently either centralistic or corporatist, and departs from local culture.

We believe that these recommendations have relevance to other developing countries. In line with the United Nation Development Program's concept of Sustainable Human Development, the objective should be to empower people to make and implement informed decisions about how PV systems can assist them in all spheres of life. For this reason, education should be given a central role in all projects.

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