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Energy for Sustainable Development

Experience with PV Lighting Systems and the adoption of Incorporated Society Model in Tonga

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Abstract

PV lighting systems can make an important contribution to improving the sustainability of energy service delivery for communities in developing countries that do not have access to the electricity grid. However this may not be the case unless a holistic approach is taken to considering economic, environmental, social and technical sustainability. This paper reviews experiences with PV lighting systems in the remote Tongan islands and 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. It makes recommendations based on the most successful adopted rural electrification model known as "Incorporated Society Model" applicable to Tonga and other developing nations. The model was designed to facilitate the PV lighting project funded by France and Australia in 2001 through SPC, Noumea and being locally modified and used widely in the Kingdom's rural electrification programme.

1 INTRODUCTION

Stand-alone photovoltaic lighting systems have been used to provide electricity in remote locations in Tonga since 1987. PV lighting systems power many 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 described in this paper 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 in the Kingdom of Tonga. It employed household surveys and data extracted from interviews with key PV stakeholders to examine problems influencing the sustainability of remote Tongan PV lighting systems, identifying matters related to their environmental, economic, technical and institutional sustainability. The further reviewing of the same type of project funded by France and Australia through SPC provided findings to guide the long-term sustainability of PV lighting technology in the rural and remote locations of Tonga

Environmental problems are increasing in the remote islands with the island subsistence economies continuing to exploit fossil fuel and fuel wood resources. These environmental problems are exacerbated by the lack of proper recycling methods for discarded equipment (including failed components of PV systems such as batteries and lights), increasing the amount of solid waste materials disposed into the local environment. The current financing arrangements are also unsatisfactory with users reluctant to pay monthly fees, compounding problems with maintenance and access to spare parts. In addition, system design and project planning have generally ignored social and cultural priorities and concerns with users commonly experiencing unmet needs, poor system performance and in some cases inoperative systems. The By-Laws, implemented to administer the PV lighting systems, have never been effectively enforced further undermining community involvement in and satisfaction with project implementation.

This experience with PV lighting systems in Tonga parallels that of other remote developing country projects. Significant problems identified in other projects have included: system designs poorly matched to user needs; poor installation practices; inadequate or unworkable maintenance arrangements; and poor or inadequate supporting institutional infrastructure (Bygrave, 1998; Cabraal et al., 1998; Dipal et al, 2001; Mrohs, 1998; Liebenthal et al, 1994; Stone et al, 1998). However, while the evidence indicates that these matters are crucial to the success of

remote area solar solutions, work on them has been limited with minimal attention paid to the interrelationships between them.

The work described in this paper took the view that project sustainability can only be ensured by a comprehensive and integrated approach to the development of solutions. It was found that the sustainability of remote Tongan PV systems could be significantly enhanced by the utilization of mature PV technologies under appropriate technological and institutional frameworks that reduce environmental problems and meet the socio-economic needs of target communities. Analysis of the problems encountered in Tonga led to the development of proposals to achieve that goal.

2 SPECIFIC TONGAN SUSTAINABILITY ISSUES

2.1 Environmental Sustainability

The introduction of PV lighting on the remote islands of Vava'u has reduced kerosene consumption for lighting by about 70 percent. Provided the PV systems operate for a sufficient period, climate change emissions will be reduced in addition to other environmental and economic benefits. 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 proper facilities for handling solid wastes. PV battery recharging stations would help reduce the battery waste problem and improve the sustainability of PV technology in the islands.

Kerosene is mainly used for cooking on the islands, and use of solar cookers could displace some of this kerosene use. Increasing the use of LPG stoves could also conserve fuel wood, as would the introduction of efficient woodstoves and solar ovens.

A lack of government environmental policy and legislation contributes to these problems with financial constraints 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 only been implemented in the main islands and urban areas. The sustainability of environmental activities 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.

2.2 Economic Sustainability

The economic sustainability of island PV systems has yet to be achieved. "Approaches have tended to view technology as hardware or equipment to be installed rather than equipment and information on how to develop, adapt, utilise, manage and maintain PV equipment" (Bygrave 1998, p.280). As a result, the island people have limited knowledge about the technology and are unable to contribute to its correct operation and maintenance. Bygrave further notes, "Because of this, key institutional, social and cultural issues relating to NRSE technology transfer have been ignored, undermining the technology transfer process" (Bygrave 1998, p.280). Here, hardware refers to the purchase, shipping and installation of PV systems while 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.

The initial EU project budget devoted 98% to the project hardware and 2% to the project software. Such a project budget structure is common in developing countries. For example training of PV users in Thailand has tended to average around 5% of the project cost (Hiranvarodom et al., 1999). However, it has been recognised that the higher the training budget of a PV project the higher the rate of success of the project. Training costs for specific PV projects may be as high as 24% of total cost (Hiranvarodom et al., 1999) and it is now generally recognised that the success of PV systems in developing countries depends on the ability to transfer both hardware and software. Donors need therefore 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 the government policy of deducting a 5% annual commission from the revolving account. The majority of the islanders were also unhappy with the current 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). The financial sustainability of the project depends on the willingness of users to pay the monthly fees and this would be assisted by making the fee depend on the number of lights installed and removing the government commission on the revolving account.

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 currently PV lighting systems support only handicrafts, and then only by extending potential working hours.

An alternative economic model could involve the use of donor funds for the initial investment with user down payments and monthly payments used to support system expansion. Users would be given ownership of their systems once their payment schedule had been completed (which would need to be shorter than the anticipated working life of the system). Looking at PV installations under Incorporated Society Model, the following new policies and development are put in place to improve the sustainability of the projects

- Every PV household had already been installed with equal number of lights regardless of the different sizes of houses.
- In view of income generated design, the level of donor funding is always the controlling factor for designing feature, but the new design ensures the longer hours of operation during the night in order to assist the income generated productions from weaving and handicrafts.
- The employment of technician in each PV Island is essential not only to ensure the day-to-day maintenance activities, but also to collect the monthly fees from households. The rate of monthly fee collections reached 100% at end of the year.
- The establishment of regional Solar Incorporated Society (SIS) in each district in the Kingdom provided avenues for the establishment of
    - SIS Financial management guidelines and policies
    - SIS Business Plan and Bank Accounts rules and regulations
    - SIS Budget allocations and financial executing policies
    - SIS Socio-Economic Analysis Scenarios and Forecast

2.3 Technological Sustainability

Technical problems are common in Tongan PV lighting projects. Maintenance is sometimes ignored, and the supply of spare parts is poor due to funding constraints and poor communication and transportation. The lack of funding and the inability of donors and government to meet these requirements hinder public awareness and the training of users. Improving the efficiency of solar utilisation requires the cultivation of public awareness at the individual and community level (Khatib 1993). Proper examination and testing of PV equipment is impeded by a lack of Tongan testing facilities and expertise and by a lack of codes and

standards for installation and maintenance. Effective PV 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 pivotal to the technical reliability of the systems. Improved public awareness and training programs are also essential for the long-term success of PV in remote locations.

The technical sustainability of PV systems on the remote Tongan islands faces a myriad of difficulties that are reinforced by the way project design was dominated by economic and technical perspectives, to the detriment of social and cultural considerations. This is confirmed by user dissatisfaction over differences in the number of lights installed per household and over the way that some were given outside lights while others were not.

The empirical research identified a high level of technical problems in the systems, resulting from a lack of maintenance, poor installation or user intervention. Some technical problems, such as solar panel EVA melting, were caused by low quality PV equipment. Excessive discharging of batteries might also have caused damage to batteries. The research confirmed that users like the illumination provided by the PV lighting systems. However, it was confirmed at one of the community meetings that the Solar Committee had authorised some users to remove lights and batteries from houses, in order to add new lights to other houses for funerals and cultural occasions. It was also confirmed that some PV houses had been unoccupied due to migration to the main islands. This indicates that facilitating flexibility in use should be an important design criterion.

Data on system performance could be collected by distributing data loggers to the 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 monitoring the economic performance of the equipment and maintenance activities. Involving users in installation, maintenance, and data logging activities would not only improve knowledge but also increase users interest at a cost below that of formal training.

Both PV system and overall project design is central to any consideration of the technical and economic aspects of a PV project. A critical problem is that the donor focus on hardware results in little support for the software elements of projects (Bygrave 1998). For example, in Tonga, systems are designed to suit the donor’s budget and PV equipment is selected on the basis of designer perceptions rather than the end-use requirements of the users. So project design requires a greater emphasis on software while system design must cater to the social and cultural requirements of users and facilitate flexibility in use.

Under the new model of SIS, the following technical improvements have been put in place to respond to abovementioned technical problems

- Before the implementation of the project, a PV installation and Maintenance training course was conducted to train the local technical personnel especially the electricians from private electrical companies
- After implementation, the User's Awareness Training being conducted at community level in order to reveal basic skills and preventative tips to remote citizens
- Every Community had been given a hired installed system in order to avoid the removal of systems from households for funeral, wedding or other cultural occasions
- It is part of the responsibilities of the local technicians to collect, measure and record technical daily performance data on individual PV systems as part of monthly reports
- Technical designing of PV system must incorporate the level of insolation, thus designing the system based on level of current drawn by each appliance and the worst case level of insolation in May, June and July

2.4. Institutional Sustainability

The Tongan government dominates current policy formulation and decision-making and user and private sector participation is minimal. Bygrave (1998) notes that approaches are bound to fail if they do not consider institutional mechanisms, involve all stakeholders, and meet users needs. The Tongan legal framework for PV development is provided by By-laws. These By-Laws have never been enforced, which is another factor in user reluctance to pay monthly fees. The National Energy Committee (the premier Tongan energy decision-making body) sometimes doesn't function and the Tongan Energy Planning Unit carries out PV project management with minimal collaboration from other PV stakeholders. All island Solar Committees should conduct monthly meetings but these sometimes don't take place, and minutes and user proposals are not submitted to the government. Solar Committees also sometimes do not enforce the collection of monthly fees and some committees have invested part of the collected fees in a Community Bank Account without government authorisation. Local technicians are sometimes unavailable, some have moved to the main island for better employment, and this lack of trained personnel is an important constraint on PV investment (Jochem 2000). An appropriate institutional infrastructure would include training schemes, hardware standards, sales and service networks, financing mechanisms and the provision of information (Mrohs 1998).

Donors support increasing the level of 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 the small size of the PV market.

It can be concluded that PV adoption in the remote islands of Vava'u faces serious institutional barriers. The equipment was not adequately tested, design and installation caused social problems, maintenance has been very poor, and the availability of spare parts is constrained by remoteness and a lack of funds. Significant opportunities exist 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.
Having faced problems as a result of specific institutional requirements, the SIS developed the following new arrangements to improve the structure

- Each Solar Incorporated Society in the main districts of Tonga (5 districts) has been established with effective Constitutions and management guidelines under the umbrella of the Tonga Incorporated Society Act, 1984. It then means that rules of Law is effectively under controlled in the overall management and decision makings
- The Governor of the district is the automatic chairperson of the Society, while other members are selected representatives from government departments and of course the Town Officers from the remote islands
- A new branch of Energy Office is also established in each district to manage the solar projects, after placement of qualified Energy Technician or Energy Officer to head the branch office. The new Energy Office branch is responsible for ordering spare parts and provide up date directions to local energy technicians in the sites
- Electricity disconnection and reconnection decisions are effectively done to ensure the up to date payment of monthly fees, and sometimes a court case is imposed for unpaid households.
- It is realised that the new model is quite effective, since households have managed to collect enough fees to meet the daily operational cost and still have enough money to meet the replacement of spare parts at the long run.

3 CONCLUDING REMARKS

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

Sufficient investment, reliable technology, and a proper institutional framework operating under a suitable legal and policy framework, are all required. Sufficient investment should cover both the hardware and software aspects of PV technology. PV investment must be framed by an appropriate business model and directly support the socio-economic activities of the recipient community. The users' financial contribution to PV operation and development depends on the ability to collect sufficient fees and will be determined by the removal of all barriers to fee collection. Adoption of a reliable PV technology will depend on access to proper testing facilities, good system design that meets user needs, the application of PV codes and standards for installation and maintenance, consideration of social and cultural impacts, and the promotion of public awareness and understanding. The sustainability of the institutional framework will be determined by the effectiveness of the processes of governance indicating that these must involve stakeholder participation in policy formulation and decision-making.

The adoption of Incorporated Society Model specifically in rural electrification sector is essential for achieving sustainability especially in small remote communities. The successful features of the model are summarised as

- Appropriate Technology Transfer since both the local government and communities received both hardware and software parts of the technology
- The utility concept of ownership is adopted in the model since part of the PV system is owned by the Society and the other part is owned by user
- The adoption of Good Business Plan ensures the appropriate set up of monthly payment by household, which is determined by NPV economic analysis of income and expenditures processes.
- The ability to relate the designing of PV system to Socio-Economic context of the local communities.
- The presence of legal framework is central to the success of management and operational processes.
- The capability to collect and reserve enough fund to replace the lifetime part of equipment pave foundation for long term sustainability.

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