CAPACITY BUILDING TO IMPROVE THE SUSTAINABILITY OF SOLAR HOME SYSTEMS IN THE REMOTE ISLANDS OF TONGA

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ABSTRACT
To be sustainable (WCED 1987), the design of solar home systems (SHS) for communities on the remote islands of Tonga should take into account the following characteristics of those communities: First, there is a tendency for community members to migrate to larger population centers in Tonga or to other countries so that community populations and individual households can be unstable in size and demography. Second, appliances that can operate on low voltage DC supply, such as telephones, DVD players and televisions, may be brought into a remote community, increasing the demand for electricity and changing the daily pattern of electricity use. Third, community functions are commonly held at night, and batteries, lights etc. from a number of SHS's may be brought together and rewired into an unplanned configuration for the occasion. Finally, remote communities often rely on unstable sources of income such as remittances, agriculture, fishing and handicrafts, and may find it difficult to make regular payments for electricity services. This paper reviews outcomes from SHS experience to date in Tonga and other Pacific Island nations, presents outcomes from field research and SHS household surveys conducted in the six remote islands of Ha'apai and proposes ways in which SHS programs might be improved. As a result of our investigations and lessons from prior research, we argue that all project stakeholders should participate in coordinated learning activities to fully understand the context prior to designing and implementing SHS programs.

1. INTRODUCTION

The Kingdom of Tonga is a Small Island Developing State (SIDS) in the South Pacific. With international support, stand-alone solar home systems (SHS) have been installed in the remote islands of Tonga for over two decades, most recently employing a community based model known as the Incorporated Society Model. This paper reviews SHS experience in Tonga to date and presents the outcomes of field research on the six remote islands of Ha'apai, one of Tonga's main island groups, in which 23 households were surveyed out of 220 total households with SHS. It adopts a research hypothesis that more attention should be paid to community engagement and capacity building to better implement roles and policies and to maintain effective relationships between all project stakeholders.

This paper adopts the World Energy Council (WEC) definitions of Accessibility, Availability and Acceptability (3A) for energy services (WEC 2007). The WEC proposes that:

- Accessibility implies that minimum levels of stationary and transport energy services are made available to the two billion people in the world without reliable commercial **energy at prices that are both affordable and sustainable**, reflecting the full marginal costs of energy production, transmission, and distribution.
- Availability relates to **long-term access to supply (security)** as well **as short-term quality of supply (efficiency)**. Energy shortages can disrupt economic development, so a well-diversified portfolio of domestic energy options open is the key.
- Acceptability addresses **public attitudes and environmental impacts**, including issues such as deforestation, land degradation soil acidification, indoor pollution; greenhouse gas emissions, nuclear security, safety, waste management, and proliferation; and the possible negative impact of the technologies and their transfer to developing countries is key.

2. REVIEW OF EXPERIENCE TO DATE

A typical SHS system in Tonga does not have an electricity meter, making it difficult for a household to manage electricity consumption and thus battery life. Households

are also discouraged from using appliances other than lights and radios, although they often do. The installation of batteries and controller in a locked case outside the house precludes a household from making temporary lighting arrangements for cultural, social and religious activities that are important in remote communities. There is also a tendency for community members to migrate to larger population centers in Tonga or to other countries so that community populations and individual households can be unstable in size and demography. This creates an additional challenge for SHS design and funding (Tukunga et al, 2011) and raises a need to consider other supply options such as central community charging stations and rechargeable DC appliances, perhaps managed by the operator of a community shop.

2.1 Donors

The affordability and sustainability of renewable energy projects, including SHS projects in Tonga and other small island developing states, are affected by insufficient capacity at national level in proposal writing for small-scale projects (IUCN 2009a, p.4) as well as by inadequate financial mechanisms, lack of micro-finance programs, loan incentives and availability of credit in rural areas (Wade 2005, p.14; Tukunga et al, 2011).

In fact, donors dominate the design and implementation of most rural and remote SHS projects in Tonga as illustrated in Table 1 for various donor-funded SHS projects in the remote Tongan islands of Ha'apai. More generally, most SHS projects in Tonga and other the South Pacific SIDS have been largely financed by overseas development assistance (ODA) (Fairbairn 1998; Wade 2005; IUCN 2009a; PIF 2010; SPC 2011). Differences in donor preferences can result in inconsistencies in equipment specification and implementation approach.

Table 1: SHS projects remote Tongan islands of Ha'apai
Source: Tonga Department of Energy, 2009

Island	*Year Installed*	*donors*	*Sys.*	*Qty*	*Mod Wp*
Mango	1988	EU	SHS	5	35
Mango I	1991	EU	SHS	21	48
Mango II	2009	IUCN	SHS	15	80
Mo'u	1994	EU	SHS	49	55
Mo'u I	2009	IUCN	SHS	36	80
Fonoi	2002	AUS/France	SHS	24	80
'O'ua	2002	AUS/France	SHS	38	80
Tungua	2002	AUS/France	SHS	33	80
Matuku	2002	AUS/France	SHS	22	80
Kotu	2002	AUS/France	SHS	34	80
Fotuha'a	2002	AUS/France	SHS	18	80

We can assess the acceptability of the donor finance model for SHS projects by considering the public attitude to the resulting SHS project and donor willingness to address the environmental impacts of the SHS project. Donor countries active in the South Pacific evaluated the outcomes of their policies in 2009, resulting in the August 2009 adoption by the Pacific Island Forum of the Cairns Compact[1], which proposed a coordinated development approach based on the following principles:

- a recognition that broad-based, private sector-led growth was essential to achieving faster development progress and that donors should encourage the private sector, including through micro-finance and support for larger-scale private sector projects;
- a recognition that improved governance and service delivery are essential to achieving faster development progress;
- a recognition that greater investment in infrastructure would underpin greater economic development;
- an acknowledgement that country leadership, mutual accountability and mutual responsibility between Forum Island countries and their development partners are fundamental to successful development outcomes;
- the need to draw on international best-practice as expressed in the Paris Declaration on Aid Effectiveness and the Accra Agenda for Action; and
- a revitalized commitment to the achievement of the MDGs in the Pacific.

As a result, most regional and national renewable energy projects under donor financial initiatives are now coordinated, formulated and implemented as partnerships between donors, governments, NGOs, regional institutions and the private sector (IUCN 2009a; IUCN 2009b; IUCN 2010, SPC 2007; SPC 2010a; SPC 2010b; SPC 2011a; SPC 2011b; SPC 2011c; NZMFAT 2011).
Donors and governments have often tried to convince the private sector to invest in remote renewable energy projects in Pacific Island SIDS. Consistent with that strategy, project evaluations have recommended greater involvement of both the private sector and civil society (Akker 2006, p.6) as well as the use of public-private sector partnerships (NZMFAT 2011, p.6). However, participation by the private sector and civil society remains low and is hindered by many barriers. As a result, most donor-funded rural SHS projects in Tonga and other countries assume that a local utility will replace the equipment installed by a project when it reaches the end of its service life (e8 2007, p.34).

[1] www.ausaid.gov.au/publications/pdf/CairnsCompact.pdf

The need for effective aid delivery to avoid duplication and destructive competition has favored the development of linkages and effective collaboration between donor energy programs in the Pacific, e.g. by the World Bank, Asian Development Bank, UNDP, European Union (Akker 2006 p.6; NZMFAT 2011). Donors have also supported the integration of environmental considerations into regional and national energy projects (IUCN 2009b, p.2, e8 2007 p. 34) and promoted renewable energy and efficient energy use (NZMFAT 2011, p.4). However, rural communities often feel they don't have ownership of SHS projects (Sefana et al 2009) and insufficient attention has been paid to recovery and recycling of failed SHS equipment in Tonga and other pacific SIDS (Wade 2005; Akker 2006; Tukunga et al 2011; ADB 2011).

Some older and more recent donor SHS projects in Tonga have had poor outcomes. Key issues relate to accountability and transparency in project formulation. For example, in the final evaluation report for the Pacific Islands Renewable Energy Project (PIREP) funded by the Global Environmental Facility (GEF), executed by United Nation Development Program (UNDP) and implemented by South Pacific Regional Environmental Program (SPREP), Akker (2006) revealed the absence of independent evaluation for PIREP's Project Document Framework (PDF), and recommended to both GEF and UNDP the need for structured evaluation for PDF design in order to learn from project experience. Also, Fairbairn (1998, p.5) argued the need for long term involvement of all stakeholders, as some planners, designers and donor agencies have made poorly founded assumptions in relation to rural electrification projects. In October 2010, the Joint Review of the 5th Pacific Island Leaders Meeting (PALM 5) recommended the adoption of processes that foster mutual accountability (PIF 2010).

Figure 1 is based on a SHS household survey the first author undertook in August 2011 in the 8 remote islands of Ha'apai. It shows that in 39% of the surveyed households, most electricity was consumed in the family room (common room), consistent with 50% of Ha'apai households relying on sales of agriculture, fish products and handicrafts such as weaving for income, as shown in Figure 2.

A SHS designed for restricted hours of operations (5-6 hr/night) may not be adequate in this context. Instead, the SHS should be designed to suit the context, for example allowing for handicrafts and recharging battery appliances (Tukunga et al, 2011).

2.2: Government role in setting policy and establishing institutional arrangements

Prior to 2002, SHS projects were undertaken in Tonga in an absence of relevant energy policy, legislation and institutional arrangements (Wade 2005; Tukunga et al, 2011).

Fig.1: Location of household's high electricity consumption

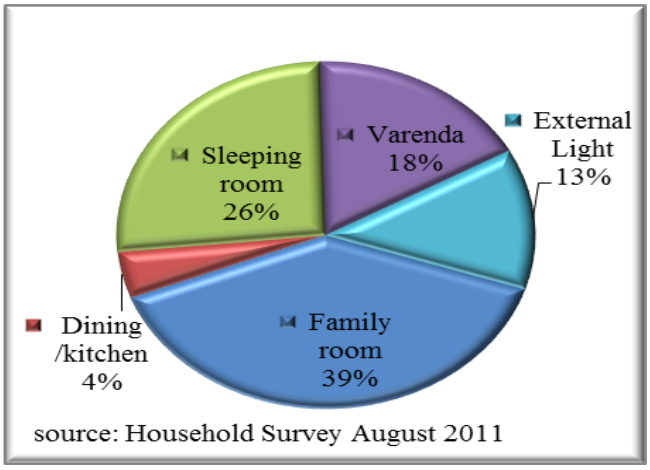
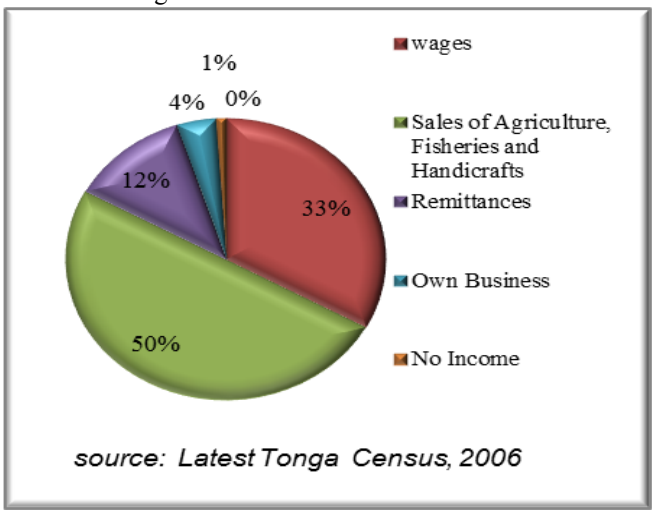


Fig.2: Household sources of income



The adoption of the Tonga Energy Road Map (TERM) in 2009 acknowledged the importance of government, donors and other stakeholders as participants in one team (SPC, 2010a, SPC 2011a, SPC 2011b, SPC 2011c). Furthermore, the Tonga Renewable Energy Policy and Renewable Energy Bill in 2008 reflected the increased priority of energy development for the government of Tonga (Sefana et al 2009, p. 20; SPC 2011b, p.1).

Tonga has adopted the Solar Incorporated Society Model for remote island SHS projects (Sefana et al 2009, p.23). However, the Ha'apai Solar Electricity Incorporated Society (HSEIS) has not always been able to collect sufficient revenue from SHS users to make SHS projects financially viable (Wade 2005; Sefana et al, 2009; Tukunga et al,

2011). In fact, the International Union for Conservation of Nature - Oceania (IUCN) has observed that insufficient revenue collection is a common experience in Pacific SIDS (IUCN 2009a, p.5).

Another key issue is a lack of reliable information and data to guide policy and institutional arrangements in the Pacific SIDS. The Secretariat of Pacific Community (SPC) noted the importance of baseline data and indicators and the fact that energy sector planning and development within Pacific Island countries and the region generally lack current and reliable energy data (SPC 2010, p. 17). One practical problem has been the unmonitored influx of DC appliances into remote communities (Sefana et al, 2009; Tukunga et al, 2011) leading to excessive load on SHS systems (Sefana et al, 2009; Tukunga et al, 2011), premature battery failure and a shortfall in revenue collection.

Another outcome of inadequate project monitoring and evaluation has been that Tonga and other Pacific SIDS have had little choice but to rely on the advice of external consultants for project design and implementation (Sefana et al 2009, p.11; Fairbairn 1998, p. 10). Consequential problems include lack of integration of rural renewable energy development with rural economic development (Wade 2005, p.14), lack of commitment by local technicians to projects (Sefana et al 2009, p.11) and insufficient government commitment and financial and technical support (Sefana et al (2009, p.25).

Tonga's Environmental Impact Assessment (EIA) Act of 2003 [EIA Act 2003, Part III Section 6 & 7] stipulates that all major projects require the submission of an EIA report to government for consideration prior to project commencement (Sefana et al 2009, p.26). Sefana et al (2009, p.24) recommended the inclusion of "Solar Electricity Supply" in the agenda of monthly community meetings "*fono*", and that the outcomes of the *fono* deliberations should be relayed to the HSEIS office and the government of Tonga. Sefana et al (2009, p.23) indicated that there was no clear arrangement for the collection of used batteries for export for recycling.

Other practical limitations of SHS policies and institutional arrangements in Tonga have been identified. For example, mandates are unclear as to the roles of the town officers and local technicians in relation to the disconnection of consumers for non-payment of fees (Sefana et al 2009, p.25) and with respect to the connection of additional electrical appliances (Sefana et al 2009, p.36). Some island technicians failed in their reporting responsibilities – in some cases because they were unable to understand the forms provided by the HSEIS office, in other cases the HSEIS office did not request timely submission of monthly reports (Sefana et al 2009, p.36). Some solar technicians and communities failed to carry out simple maintenance work such as cleaning PV panels (Sefana et al 2009, p.22).

Finally, there were also examples of insufficient provision of services, such as adequate spare parts on the islands with the technicians (Sefana et al 2009, p.22), inadequate management of waste fuels (Fairbairn 1998, p.11) and, in a related context, failed batteries (Fang et al 2004, p. 6). More generally, there is a need for political leadership on global warming and the energy security (SPC 2010b, p. 3).

2.3: Education and Training

Education and training is critical to ensuring a long life for SHS projects. However, SHS stakeholders including the recipient communities require appropriate levels of education and training. For example, project managers require coordination and management skills. ADB has warned that there is inadequate coordination of knowledge management activities and information gathering, which is affecting the capability of investors, manufacturers, suppliers, and financiers to implementing solar energy development policy in Asia and the Pacific (ADB 2011; Tukunga et al 2011). There is a tendency for trained staff to migrate from remote islands to population centers, and hence a need for regular training programs to maintain the workforce (Mario 2003, p. 14).

Sefana et al (2009, p.29) recommended SHS awareness training for remote island communities of Ha'apai, Tonga while (Mario 2003, p. 13-14) argued that the lack of SHS understanding and reporting capacity at local government level in the Pacific Islands justified awareness training, which should include site visits to renewable energy projects, noting that this can be difficult due to funding constraints.

In a similar vein, Sefana et al (2009, p.37) recommended intensive training for remote island technicians, which should cover the technical aspects of solar PV and the technicians' reporting obligations. They note that Tongan experts have conducted assessments of technical services in the two remote islands of Kotu and Mo'unga'one as well as Kotu Is (Sefana et al 2009, p.11) and could deliver training programs.

There is also a need for local educational facilities to provide training in rural marketing strategies and business management with a focus on rural markets (Wade 2005, p.16). SPC (2010a, p.8) conducted a small scale coconut oil processing and marketing training to improve business skills in rural and remote areas.

The acceptability of training can be assessed from its capacity to improve outcomes from SHS projects with respect to the socio-economic lifestyles of local

communities and environmental impacts. For examples, a review of a training program for silk weavers in Cambodia provided under a NZAID silk support sector project found that 603 weavers had received training in technical skills, resulting in a 90% increase in sales volume (NZMFAT 2011, p.6). Similarly, a review of an English training program for Mongolia showed that 800 locals had benefited from the program, assisting them to rise to positions of prominence in government (NZMFAT 2011, p.6).

Experience with SHS projects in Tonga reveals inadequate technical training and poor coordination with manufacturers. For example, amorphous silicon type cells installed on Mango Island failed prematurely and a single PV panel - 2 light SHS proved insufficient (Sefana et al 2009, p.12). This experience also reveals a need for relevant technical standards and certification for both hardware and technicians (Wade 2005, p.15; SPC 2011b, p. 7). Awareness programs should also teach local communities about recycling and re-use (Fairbairn 1998, p.9).

Poor design capacities are reflected in poor estimation of the service required which has frequently led to under designed systems and long-term customer dissatisfaction (Fairbairn 1998, p.7). Contributing factors include inadequate managerial skills in HSEIS office and the lack of a comprehensive computerized accounting and technical system (Sefana et al 2009, p.38), lack of community education (Mario 2003, p.13) and insufficient engagement of women, lack of project monitoring and evaluation (Fairbairn 1998, p.11) including field surveys to provide reliable information and identify capacity building needs (SPC 2010b, p. 6).

In the author's 2011 survey, 35% of surveyed households were not satisfied with local technical and maintenance services, implying a need to improve management, governance and technical skills. In another survey, Sefana et al (2009, p.16) indicated that all surveyed households in the remote islands of Mo'unga'one in Ha'apai, Tonga had connected radios to their SHS and used the SHS batteries to charge mobile phones. The effect of the influx of DC appliances on energy use by remote communities and its impact on SHS performance has yet to be assessed

2.4: Private Sector involvement in the provision of SHS

To date, the private sector has not participated effectively in the provision, operation and maintenance of SHS in Tonga. There are many reasons for this, including past experience that suggested to potential investors that the provision of SHS is risky, implying a need for access to risk abatement methods, extended manufacturer warranties and loan guarantees (Wade 2005, p.15). Fairbairn (1998, p.9) suggested that the introduction of an Energy Services Company (ESCO) model might help. The Sustainable Energy Industries Association of the Pacific Islands (seiapi.org) was launched in 2010 and its involvement in developing design and installation guidelines for PV grid connect systems and off-grid PV systems is now a high priority for the region (SPC 2011b, p.6).

The security and efficiency of private sector participation in renewable energy development and particularly SHS projects would start with allowing private sector participation, such as the desirability of including representatives of the Tonga Communication Corporation and Chinese Importing Companies as members of the HSEIS Management Committee (Sefana et al 2009, p.29). In fact, neglecting the true cost of business operation through imposing government subsidies can lead to wrong investment decisions, and may deter private sector investment (Fairbairn 1998, p. 9). Government and private sector partnerships, such as Marshall Island government partnership with Island Eco as a solar company located in the Marshall Islands (SPC 2010b, p. 5) is another way of attracting private sector investment. Finding ways to improve the country's fiscal and macroeconomic policy, such as NZAID support for the Pacific Financial Technical Centre as part of International Monetary Fund initiative (NZMFAT 2011, p.6), is a vital step for improving security of private investment.

The acceptability of private sector participation requires strengthening business management. New Zealand seeks to strengthen the management of Pacific businesses in both local and international markets (NZMFAT 2011, p.6). The move to standardize the technical design of PV systems in Tonga would be one step forward for both private sector involvement and community support (Sefana et al 2009, p.13). However, private sector investment did not occur even with the adoption of a utility concept for SHS systems, in which the *solar utility* owns the panels, the batteries, the controllers and up to the circuit breaker inside the house, while the consumer owns the switches, lights, radio socket and all the cabling downstream of the circuit breaker (Sefana et al 2009, p.13).

The acceptability of SHS for both private sector and local communities is determined by the presence of incentives and regulatory authority (Tukunga et al, 2011). It has been realized that shops are one of the most effective forms of private business in remote islands, so aligning SHS system design with a shop-based model should enhance private sector participation (Tukunga et al, 2011).

The implementation of SHS projects in the remote islands of Ha'apai, Tonga involved some expectation of private sector engagement, for example in the provision of spare parts especially lights and key SHS components. However, Sefana et al (2009, p.10) noted a lack of spare parts supply in the islands due to lack of private sector interest, which

was partly due to the high cost of obtaining parts from overseas and partly due to doubts about the sustainability of SHS revenue collection. On Kotu Island, 53% of the lights were functioning in 2009 while 47% had failed but spare lights were not available (Sefana et al 2009, p.10).

Experience shows that the regulated tariff of $13/month for SHS in the Ha'apai island group is affordable in some circumstances but not others due to variable and uncertain household income. However, on-going financial viability at all times may be required to attract private sector involvement.

Limited understanding of the remote island market for energy has made it difficult to determine the appropriate marketing approach and has increased the need to demonstrate appropriate RE technologies to provide familiarity with a model that can work (Wade 2005, p.16). A project design that aligns SHS system design with the business shop model has yet to be explored, but the effectiveness of the shop model has already been experienced by private sector due to presence of regulatory framework for pricing and services.

3. CAPACITY BUILDING FRAMEWORK

Table 2 shows some key characteristics of remote islands, which must be considered by stakeholders in designing the institutional, policy and technical aspects of SHS model, if they are to meet their interests and still maintain the long-term sustainability of the project. The key general idea is the need for joint partnership between donors, government, private sector and suppliers/manufacturers, training institutions, and utility thus further develop their good relationship with each other including remote communities and therefore use the existed business model like the retail shop to guide the identification and design of SHS model for the remote islands.

In order to address high migration as well as different levels of stakeholder goals and objectives, a central solar rechargeable station for each island should be made competitive with each other as the retail shops competed with each other on services and prices.
A fee for service as well as the use of rechargeable appliances will address influx of DC appliances, support diversifying cultural energy needs and unstable sources of income experienced by remote communities.

4. CONCLUSIONS

There is still much to learn about how to improve the sustainability of solar home systems in the remote islands of Tonga. However, it is clear that all project stakeholders should participate in coordinated learning activities to fully understand the context prior to designing and implementing SHS programs. Table 2 sets out some preliminary ideas about desirable features of such a capacity building program.

Table 2: Capacity Building Programs

	High migration	Influx DC appl.	Cultural values	Sources income
Donors	Sustainable finance	Low enviro. impacts	SHS & culture	Unstable income SHS
Government.	Affordable tariffs	SHS to cope with influx appliance	Culture supports SHS	SHS meets income
Training Institution.	SHS for high social mobility	Safe services and operation	Cultural training SHS	Fee for service appliances
Private Sector	Matured business model	Profit returns	Profit cultural practices	Retail Shop model
Capacity Building	Competed recharge solar station/ appliances	Fee for service SHS	SHS supports diversify energy needs	Retail shop SHS model

5. ACKNOWLEDGEMENTS

The authors wish to acknowledge valuable discussions with Associate Professor Iain MacGill of the University of New South Wales and the Australian Government for Tevita Tukunga's Australian Leadership Award PhD scholarship.

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