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ABSTRACT

Energy poverty describes the lack of access to household electricity and non-polluting fuel for cooking. This lack of access can be a serious impediment to economic and social development. We present an urban and rural snapshot of the state of energy poverty in two Pacific Island states. Pacific Island states have embarked on ambitious programmes to provide renewable energy and improve energy efficiency to alleviate imported fossil fuel dependence. We present two case studies of renewable (solar photovoltaic) based energy and solar refrigeration introduced at the community level in Vanuatu and the Marshall Islands that have reduced energy poverty and had a positive impact on economic and social development. A third case study on the outcomes of an urban energy efficiency project in the Marshall Islands is presented, which aims to lessen energy poverty by decreasing the cost of electricity bills for households. The results of these case studies suggest a need within the energy efficiency and renewable energy sectors to: (i) provide technical trainings and public awareness campaigns for end-users in the Pacific; (ii) give ownership to end-users in order to enable them to control their own development solutions and to prevent declining interest over time; (iii) use market forces to promote both energy efficiency and renewable energy solutions; (iv) prevent poor quality equipment and appliance use through certifications and standards; and (v) trial and create incentives for measures that are already considered to be potentially cost-effective (such as LED lights, energy displays, insulation for houses, and grid-connected renewable energy through distributed power generation). Any renewable energy or energy efficiency solution that is already cost-effective is in the interest of all stakeholders, including government, consumers, and society, as it will result in energy being more affordable, thereby decreasing rates of energy poverty in the Pacific Islands.
INTRODUCTION

Access to modern energy services is crucial to human well-being and to a country’s economic development. Energy poverty describes the lack of access to household electricity and non-polluting fuel for cooking, and is prevalent in both urban and rural areas of developing countries (IEA, 2012). Energy poverty can prevent access to clean water, sanitation and healthcare, as well as reliable and efficient lighting, heating, cooking, mechanical power, transport and telecommunications services.

Reducing energy poverty in Pacific Island Countries (PICs) is necessary for development, as 70% of the 10 million people living in PICs do not have access to electricity (SPREP, 2010). While a substantial portion of this non-electrified population lives in rural, isolated islands, where grid establishment is unfeasible, energy poverty can also be found in urban areas where access to grid power is unaffordable.

Fossil fuel and electricity prices in both urban and rural areas in PICs are significantly higher than those of nearby developed countries (see Table 1.1), and development levels are significantly lower, with an average per capita income of $2,300 regionally (Browne, 2006). Growing populations, coupled with changes in development levels and lifestyle requirements, have exponentially increased consumer power consumption across the region, despite rapidly increasing fuel costs (UNICEF, 2009). The result has caused many to face energy poverty, unreliable electricity, unpaid power bills, and disconnection of grid-tied electric supply. The rural regions are especially susceptible to energy poverty, as fossil fuels’ prices in such areas can be nearly double that of the already expensive urban prices. However, regional published data on average household energy expenditures is not available, and thus one can only estimate the percentage that energy poverty affects.

Table 1.1: The Republic of the Marshall Islands’ and Vanuatu’s retail fuel and electricity prices and those of nearby developed countries: the United States and Australia (Ungaro, 2012).

<table>
<thead>
<tr>
<th>Country</th>
<th>Petrol (USD/litre)</th>
<th>Diesel (USD/litre)</th>
<th>Kerosene (USD/litre)</th>
<th>Residential electricity (USD/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMI</td>
<td>$1.32 urban, $1.98 rural</td>
<td>$1.27 urban, $1.72 rural</td>
<td>$1.32 urban, $1.72 rural</td>
<td>$0.41-0.50 urban</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>$1.93 urban, $2.72-3.26 rural</td>
<td>$1.89 urban, $2.72-4.07 rural</td>
<td>$3.24</td>
<td>$0.44-0.70 urban</td>
</tr>
<tr>
<td>US</td>
<td>$0.89-1.01</td>
<td>$1.00-1.03</td>
<td>Not sold regularly in small quantities</td>
<td>$0.11-0.12</td>
</tr>
<tr>
<td>Australia</td>
<td>$1.35-1.47</td>
<td>$1.38-1.50</td>
<td></td>
<td>$0.12-0.25</td>
</tr>
</tbody>
</table>
REGIONAL INCENTIVES FOR DECREASING ENERGY POVERTY

PICs are vulnerable to the projected effects of climate change and climate variability, with increasing threats from sea-level rise and severe weather events, such as cyclones, floods, and droughts. Such changes threaten PICs’ economies and societies, and are likely to result in increased poverty (IPCC, 2007). However, in contrast to their vulnerability, PICs do not have a significant carbon footprint (0.6% of global CO2 emitted), due to their small population (0.1% of the global total) and nominal infrastructure (Lewis, 2014). Therefore, reducing PICs’ reliance on fossil fuels through uptake of renewable energy and energy efficiency will not directly prevent the effects of climate change; however, it may increase PICs’ resilience in response to such effects.

Furthermore, electricity costs, combined with rising food, fuel, and transportation costs, have the potential to contribute to economic hardship across PICs if not confronted. Virtual monopolies of fuel supply leave PICs vulnerable to market changes. This is especially true as PICs’ transport and electricity sectors rely on nearly 100% fossil fuels, and imports as a percentage of GDP are increasing rapidly (GEF Council, 2005). For example, fuel imports in Vanuatu increased from 3 to 8% of GDP between 2002 and 2008 (Roper, 2009). Projected shortages in global fossil fuel supply are expected to further raise global oil prices, as it is estimated that a 40 - 60 year supply of proven oil and gas reserves remain (BP, 2009). Accordingly, energy security and autonomy, in addition to development and resiliency benefits, are significant driving factors for reducing fossil fuel consumption through energy-efficiency measures, and increasing the uptake of renewable energy power generation in PICs.

ENERGY EFFICIENCY TO REDUCE ENERGY POVERTY

Energy efficiency (EE) is the effectiveness of an energy source in providing the energy required for products and services. Thus, the goal of EE improvements is to reduce the amount of energy it takes to provide required services to the consumer through behaviour change, improved technologies, and changes that conserve the energy produced. Many EE improvements pay for themselves in the long term, in that the energy savings are greater than the cost of the improvements. Educating consumers on EE can make electricity more affordable, as consumers are aware of: how much electricity they are using; how they can effectively decrease their consumption, especially during peak power times; which appliances and electronics are efficient; and how to avoid wasted energy (such as insulation improvements). The most important EE improvements are those that offer cost-effectiveness, high-energy savings, and a significant decrease in negative externalities (such as poor air quality and a large carbon footprint), although any energy saving results in less power required to be produced (Karmmen & Pacca, 2004).

RENEWABLE ENERGY TO REDUCE ENERGY POVERTY

Per capita energy consumption is closely linked to per capita GDP of PICs, resulting in differing
energy needs. Currently, many rural communities are reliant upon kerosene lanterns for lighting and diesel generators for electricity, both of which are associated with negative health effects due to air pollution (Holdren & Smith, 2000). Furthermore, kerosene lanterns offer low efficacy (lumens/watt) and poor quality light, as they give off up to 100 times less light than electric lights (REN21, 2011).

Demand for renewable energy (RE) in PICs is also driven by the underlying goal to meet the basic needs of those in poverty, and therefore, rural electrification strategies must be considered in terms of the positive effects on marginalised groups. In the World Summit on Sustainable Development (WSSD), where the Millennium Development Goals (MDGs) were decided upon, energy services were identified as essential in poverty eradication, with RE being the most sustainable method of electrification. Rural electrification especially affects women’s quality of life, as they are the primary users of electrical appliances (i.e. lights, tea kettle, refrigerator, radio, TV, charging mobile phones), as much of their responsibilities are within the home. Electrification has been shown to reduce poverty through improved economic activity, literacy, education, healthcare, gender equality, and social benefits; however, these changes are often unpredictable and depend upon favourable conditions (Cabraal et al., 2005; Chakrabarti, 2002; Martinot et al., 2002).

STRATEGIES RESEARCHED FOR REDUCING ENERGY POVERTY THROUGH ENERGY EFFICIENCY

One approach to improving EE focuses on demand-side management (DSM), which aims to reduce the amount of electricity required by energy consumers, through reducing their daily electricity demand. DSM measures include financial incentives, consumer education, and knowledge of personal energy consumption, with technologies such as smart meters, energy displays, prepayment meters, and devices that allow remote control of energy use.

While DSM technologies may appear not to be mainstream, one-third of American households now use electric smart meters, many of which have been installed by the local utility company (DeFreitas, 2012). Such meters have been shown to reduce peak power demand, by communicating to consumers what time of the day peak power occurs, and reminding them of the additional costs they are accruing. Smart meters can also educate residents on how much electricity they are using in total, and allow household owners to reduce their power consumption by identifying the areas where they use the most electricity. Utilities in the U.S. have found smart meters to be effective; for example, Oklahoma Gas & Electric’s installation of smart meters has replaced the need for them to construct an additional power plant this decade (Marks, 2012).

Demand-side measures have been proven in the literature to be effective in reducing energy consumption in many developing nations around the world; however, there is a lack of data on their effectiveness in PICs (Roth & Brodrick, 2008). The exception is prepayment meters, which have been trialled in Tonga, Fiji, Vanuatu, Nauru, and the Marshall Islands. These meters allow consumers to pay for their electricity as they go, much like a prepaid mobile phone. However, such efforts have generally been met with limited success due to technological breakdowns.
and a lack of expertise to repair the devices. As electric utilities increase their know-how and experience with prepayment meters, there is anecdotal evidence that these measures are proving to be effective in reducing energy consumption. An important differentiator between prepayment meters and measures discussed here is that utilities own and install prepayment meters for the purpose of avoiding the potential failure to receive payment, rather than as a measure intended to reduce energy consumption.

STRATEGIES RESEARCHED FOR REDUCING ENERGY POVERTY THROUGH RENEWABLE ENERGY

RE technologies have the potential to provide rural electrification while at the same time acting as a cleaner, more reliable, and cost-effective energy service. In the past two decades, solar photovoltaic (PV) systems have become the most widely adopted RE technology for rural electrification in PICs, due to the widespread availability of solar energy and the flexibility in scale of the systems. In fact, literature indicates that solar PV home systems (SHSs) represent the most cost-effective technological option for remote communities in PICs and globally, where demand for electricity is low, the population is small, and fuel costs are high (Chaurey & Kandpal, 2009; Nguyen, 2007; Woodruff, 2007). Furthermore, the price of solar modules has declined significantly over the past decade, with prices having dropped by 20% for each doubling in cumulative production (Jol et al., 2008).

Additionally, SHSs have become a more appropriate technology for rural electrification, with a large portion of the industry now designing systems with rural end-users in mind. For example, ‘pre-wired,’ ‘plug-and-play,’ or ‘turn-key’ systems are offered by numerous companies, ranging from small-scale lighting and mobile charging devices, to battery charging stations, to stand-alone micro-grids. Many companies are also now offering equipment specifically designed for harsh tropical and oceanic conditions, such as sealed inverters, anti-rust mounting frames, marine grade lights and wires, and maintenance-free batteries, resulting in more reliable solar equipment for PICs. With appropriate equipment, installation, and maintenance, solar PV systems can be expected to last 25-30 years, with the batteries requiring replacement approximately every 7-10 years (Lewis, 2007). Thus, given solar PV’s flexibility in scale and carbon offsetting qualities, as well as recent improvements in affordability, reliability, and user-friendliness, its usage has the potential to effectively contribute toward 100% electrification of PICs.

CASE STUDY: ENERGY EFFICIENCY IN URBANISED MAJURO, MARSHALL ISLANDS

BACKGROUND

This research examines the potential for energy-saving programmes in Majuro, the urbanised capital of the Republic of the Marshall Islands (RMI). There, grid-supply electricity is generated by diesel power plants using imported fuel, and the grid is currently overburdened, due to high demand and expiring equipment, resulting in recurrent blackouts. As a result, residential electricity prices have risen steeply in the last decade, making DSM measures attractive on many fronts. In addition, the RMI faces energy issues related to their isolation, making energy security
and autonomy important driving factors for EE improvements, as fuel importation is costly and challenging.

Rapid population growth, urbanisation, development changes, and lifestyle alterations have resulted in exponentially increasing energy demand in the RMI despite increasing fuel costs (UNICEF, 2009). This has caused many households in the RMI to face high electricity prices, unpaid bills, disconnections, illegal connections, fuel poverty, population growth, and urban migration. Thus, DSM measures can benefit households directly by reducing such negative effects.

This case study analyses the effectiveness of energy displays as DSM measures for improving energy efficiency in houses in the RMI and other PICs. This research is in line with both regional and national policies aimed at improving energy availability and decreasing carbon emissions. Specifically, the RMI’s National Energy Policy (2009) states a target of improved energy efficiency in 50% of households by 2020.

**METHODOLOGY**

Household energy displays can help to reduce activity levels by allowing users to know exactly how much electricity they are using and its cost at any given time through displays of real-time usage. Consumers can then check their energy usage at any time, thus allowing them to be informed and involved in their energy cost and usage. This research has tested the success of two types of energy displays, TED Energy, Inc. 5000-C meters and Belkin F7C005 Conserve Insight Energy Cost meters, sourced from the USA. The TED meters showed total household energy use, and collected real-time data, with downloadable energy reports on the usage over time. The Belkin meters are connected to only one appliance and showed how much power that appliance is using, as well as the cost of using that appliance, and the energy used by it over one month.

The households were selected as they were located in the central urbanised area of Delap in Majuro, RMI, and were either dealing with energy poverty, defined as expending more than 10% of combined household income on electricity costs (NEA, 2008) and/or were connected to the grid but had failed in at least two electricity payments within the past year due to inability to pay. Thus, households facing fuel poverty were targeted. The targeted households expressed willingness to participate in the study and allowed researchers access to the equipment used in this research. Thirty households were selected as targets for this study. Resources limited the number of energy meters that could be installed; thus meters were installed at 15 houses in one batch for a duration of 6 months. Subsequently, the installation was repeated at a second batch of houses.

Baseline energy data was gathered and compared to data collected each week from the energy displays for a 6-month period. Quantitative questionnaires were also conducted at the end of the 6 months, and included questions on behaviour change and satisfaction with the energy meters.
RESULTS

The results from the energy data collected and the quantitative questionnaires indicate that:

- Energy meters displaying the energy consumption for the entire household are more effective than those that show energy usage for only one appliance.

- 72% of participants were satisfied with their energy meters displaying the energy consumption for the entire household, and 81% felt that it was worth owning one.

- The Belkin meters did not have a significant effect on energy behaviour, whereas 33% of the households using TED meters did reduce their energy consumption, with an average reduction in those households of $50 per month (around 125 kWh of electricity). With this savings, the cost of the energy meters is paid back over 4 months.

- The most effective behavioural change was that participants reduced the amount of air conditioning used, followed by changes in cooking methods.

A limitation of the meters was that they showed the cost of power per hour and per day, rather than the monthly cumulative cost leading up to a household’s power bill, and thus the amount shown did not seem significant to some households. Also, participants paid more attention to their energy meters in the week before their power bill was due, as compared to the week after, indicating the electricity bill was a main driver for reducing their power consumption. A major barrier to consumer behaviour change is that the households generally have had high energy-consuming lifestyles and are unfamiliar with the need for improved EE. This behavioural characteristic is a major barrier to reducing energy consumption and energy poverty.

This study focused only upon a specific DSM measure. However, the use of energy efficient appliances and LED bulbs is another DSM measure that contributes to energy efficiency. During 2012-2014, such measures were introduced in Majuro. A regional programme supported by Australian Agency for International Development (AusAID) and managed by the Secretariat of the Pacific Community (SPC) provided the impetus towards introducing energy efficient standards for appliances. Such appliances and LED bulbs are imported duty-free and are gaining acceptance in the market. An important difference between these measures and the DSM meters is that the consumer has to spend a notable amount of money to reduce the household’s consumption of electricity as compared to changing user behaviour.

CASE STUDY: RENEWABLE ENERGY FOR LIGHTING AND REFRIGERATION IN RURAL RMI AND VANUATU

BACKGROUND

Solar PV home systems (SHSs) are essential to reducing energy poverty in the rural areas of the Pacific Islands, given their scale, simplicity, lack of moving parts, and affordability. Well-designed, simple and lasting solar PV systems are imperative for providing reliable electricity to
However, since the 1980s, many solar electrification projects in PICs have had minimal impact and a high rate of failure. A large percentage of these previous projects were not designed sufficiently to produce enduring outcomes (i.e., donor-funded equipment-based demonstrations or lack of planned involvement after installation) and are now non-operational (Akker, 2006). Despite many lessons learned and technological improvements over the years, even well-funded and large-impact RE electrification projects implemented today continue to face durability issues. Therefore, in order to successfully reduce energy poverty for the long-term, research on essential practices and appropriate electrification strategies for household solar electrification projects was carried out.

Historically, rural electrification was considered the responsibility of the government in developing countries; however, this has been changing over the past few decades with the involvement of private companies, NGOs, and financing institutions (Vleuten et al., 2007). Consequently, multiple rural PV electrification strategies have been established in order to attempt to reduce the failure rate of energy projects, with two broad supply-side strategies commonly used with SHS projects in PICs (See Figure 1.1).

**Figure 1.1:** The common features of the RESCO and user-owned electrification models (Ungaro, 2012).

The general aim of the RESCO strategy is to remove the high initial costs associated with solar PV systems and to make spare parts and technicians readily available (Beck & Martinot, 2004). Thus, this policy is useful in that costs are dispersed over time, yet such programmes have not
always been beneficial in PICs, as a tendency of failure to make payments and to misuse SHSs has often hindered success (UNESCAP, 2001). In part, this is due to inadequacies on the supply-side, where availability of support, spare parts, and timely maintenance has been an issue, due to inadequate infrastructure, poor planning, and lack of resources (Dornan, 2011).

The use of this model avoids the need for extensive user education, as end-users are not responsible for maintaining or repairing the system. In fact, this strategy often aims to make the SHS inaccessible to end-users in order to prevent mistreatment, with only the utility’s technician having access to the PV equipment; yet alterations and abuse still frequently occur. Consequently, RESCOs hinder user participation and ownership of the SHS, in that end-users are not able to design or expand their systems with changing energy demands, nor are they able to maintain and repair the systems as required (Mala et al., 2008).

In contrast, the user-owned strategies include varying degrees of owner participation; yet generally users are consulted in the design process and some form of training takes place. Thus, through this model, end-users are given ownership over their SHS, and they are often able to expand, repair, and maintain their system as required. In fact, private ownership has been shown to “reduce maintenance costs, overcome tampering, reduce overuse of the system, and maximise the benefits” (Urmee & Harries, 2009).

Many user-owned systems implemented in PICs over previous decades had a high failure rate due to:

- Lack of a long-term operations and maintenance plan
- Maintenance costs being left unaddressed
- Lack of access to spare parts
- Training being inadequate or overlooked
- Project implementers being overly optimistic about the skills and reliability needed for system longevity
- Project objectives not being clearly defined in terms of social benefits and productive users

(Akker, 2006; Jafar, 2000; Urmee et al., 2009)

Many of these inadequacies were attributed to the electrification strategy, and resulted in the assumption that users were not able to successfully own and maintain a SHS (Jafar, 2000; Liebenthal et al., 1994). Yet, factors involved in implementing successful user-owned SHSs have changed over time, including:

- Local technological knowledge and familiarity with solar PV have significantly increased
- Solar training resources have been improved (including in local languages)
• Solar PV technicians and organisations now have extensive regional experience
• Government and donor support for RE has increased due to external factors
• PV equipment has improved in quality, affordability, and user-friendliness
• Spare parts are more consistently available due to larger markets (Ungaro, 2012).

Thus, user-owned SHSs have been predominantly overlooked in recent PIC electrification projects, despite continual recommendations in the literature for increased participation, training, and projects centred on community energy needs (Beck & Martinot, 2004; Urmee & Harris, 2009; Mucadam, 2013). Rather, the primary electrification strategy in PICs continues to be RESCO projects.

**METHODOLOGY**

The research on the two selected renewable energy case studies was carried out in the rural villages of Namdrik Atoll in the RMI and Akhamb Island in Vanuatu. These communities were chosen because of their unique history with solar PV, their remote locations and small populations (under 800 inhabitants in each) and their display of the user-owned electrification model.

Namdrik Atoll is a small atoll in the Ralik Chain of the RMI, consisting of two islands with its total land area being only 2.8 square kilometres, and its lagoon encompassing an area of 8.4 square kilometres. In 2010, a private solar company, Island Economic and Environmental Co. (Island Eco) installed thirty-three 320W SHSs with refrigeration units on Namdrik Atoll, with 75% of the funding being provided by the United States Department of Agriculture Rural Utility Service (USDA-RUS) and 25% by local community members. The Namdrik Atoll Local Government was involved in implementation, and through interest-free loans aided the beneficiaries in financing their portion of the project, as well as paying for some logistical costs. Many of the household members, including women, were involved in the installation, and a training book, the Marshallese Language Solar Power Manual ‘Ta in solar power? (What is solar power?)’ was provided to project participants. The SHSs were owned by the solar company for the first two years after installation, in order to further train end-users, encourage the involvement of the users in the maintenance, and ensure that the systems are working properly, after which the systems were handed over to the users, following a user-owned electrification model.

The second case study was located on Akhamb Island, which is one square kilometre in size and is located approximately 1.8 kilometres off the south coast of Malekula, the second largest island in Vanuatu. The community on Akhamb had very little experience with solar until 2007, when collaboration between two private solar companies based in Port Vila (the capital of Vanuatu) and a U.S. Peace Corps worker, supplied equipment and trained interested families to install their own SHS. Community trainings were also held on solar equipment, wiring, and maintenance, with diagrams and information supplied in the local language. Multiple follow-up trainings were provided to locals with SHSs on how to maintain and improve their systems and consequently, the number of SHSs on Akhamb Island and the neighbouring villages increased from 4 to 43
Quantitative questionnaires were utilised in order to analyse the needs and preferences of the SHS end-users in the two case studies, with the questions being analogous. The surveys aimed to generate insights into the level of success of the electrification model, as well as to give insights into essential practices for project durability. All of the households with solar systems were surveyed on each island, with 18 out of 33 surveys being completed on Namdrik Atoll, and 39 out of 43 on Akhamb Island. At the time of survey in Namdrik, several households lacked the presence of a suitable respondent to complete the questionnaire.

RESULTS

The following results are based on answers to questionnaires from 18 respondents from Namdrik Atoll, RMI, and 39 respondents from Akhamb Island, Vanuatu. The results are divided into 12 indicators, which were developed through a review of the literature on rural electrification, with the addition of socio-cultural aspects (Ungaro, 2012). The indicators are focused on rural end-users in the Pacific Islands, and therefore are relevant for reducing fuel poverty through rural electrification. Each indicator is designed to address the factors which may potentially lead to technology disruptions and collapses.

APPROPRIATE EQUIPMENT USE:

Ninety-two percent of the 43 SHSs installed between 2005 and 2011 on Akhamb Island were working properly at the time of research. Only 26% of end-users on Akhamb were using a deep-cycle battery (designed for solar PV); the others were using vehicle batteries, due to their cheaper cost. AusAid (2011) suggested that a possible solution to encourage the use of deep-cycle batteries would be to subsidise their price. Problems with equipment demonstrate the need for more appropriate PV equipment use, through the creation of certifications and standards for equipment and vendors.

All of the surveyed SHSs installed by Island Eco (IE) in collaboration with Namdrik Atoll Local Government were working at the time of research. These systems used higher quality parts as compared to those on Akhamb. The systems installed by IE-Namdrik were 320W, powering 2 lights and a DC freezer and were well-designed to power the appliances intended; however, during the six months after installation many end-users were found to be using additional appliances, thus leading to system overuse, i.e. a deficit of power. Thus, the quality of equipment did not help to overcome maintenance issues faced from system overuse. Further educational interventions with the users led to a change in this behaviour, in that most of the systems were no longer overused.

EFFECTIVENESS IN MEETING USERS’ NEEDS:

One hundred percent of respondents from both communities reported that they preferred to be able to design and alter their systems, with all of the respondents on Akhamb Island having
designed their own SHS. Although this was not the case with the end-users of the IE-Namdrik systems, the project did conduct a survey of user-preferences, and based their system design upon users’ stated preferences for refrigeration and lighting. One hundred percent of respondents in both case studies indicated that having a SHS was very important to their family, and that they trusted solar PV as a reliable power source. Therefore, SHSs appear to be a satisfactory and trusted technology to meet end-users’ electricity needs.

Overall, lighting and television were the most desired result of electrification in the case studies, followed by refrigeration and other appliances, depending on end-users’ occupations and interests. SHSs need to incorporate these preferences, as otherwise they risk dissatisfying end-users, and users will alter and overuse their systems to meet their needs.

ABILITY TO SATISFY EXPANDING ENERGY DEMANDS:

The IE-Namdrik project was not designed to accommodate expanding energy demands. However, the aim of the systems was to provide refrigeration and limited lighting to households that desired it, rather than to provide electrification, and thus systems were of adequate size to meet this need without expansion.

This was not the case on Akhamb, as systems ranged from 60W to 240W and were initially designed by users to power the appliance of their choice, based on their ability to pay. Some systems were even designed with expanding needs in mind.

COST-EFFECTIVENESS:

With the IE-Namdrik project, users were paying $1750 for the initial cost, equal to 25% of the total installed price of the systems. The Namdrik Local Government provided financing to end-users, by allowing households to reimburse them for the initial cost over time, in order to increase affordability. The cost of maintenance has been minimal since the systems were installed in 2010. However, in 2014 a few users reported that the state of the batteries was showing gradual deterioration.

On Akhamb, 67% of end-users were paying only $0-100 per year to maintain their systems, most of which was spent directly on spare parts. Owners who were unsure how to fix their systems might seek advice from a local technician; however, this cost was minimal ($2-5 per visit). The other 33% included those who had purchased poor quality parts or had more than one part break within a year.

Given the current costs for users, both systems may be considered to be cost-effective to the users in their own right, as one provides refrigeration with minimal maintenance costs for at least 4 years, and one allows users to spend their money directly on components as required. If the subsidy provided by the donor on the Namdrik project was removed (the SHSs on Akhamb were not subsidised), the self-initiated systems appear to be more cost-effective. Yet it is difficult to compare the cost-effectiveness of the two systems using this data set and other quantitative metrics such as rate of return, etc. For example, another indicator would be the savings in
expenses on fuel used for a generator to provide the various services provided by the SHSs in each case study.

In comparison to these two user-owned examples, the RESCO user fee collection model had not been successful at earlier installations of SHSs on Namdrik atoll (Empower, 2005). On Namdrik and other atolls of the RMI, SHSs that provide lighting only were installed in 2013-14 by the EU-North REP project using the RESCO model. The installed cost was approximately $18/watt, as compared to the IE-solar refrigeration SHS costs of approximately $21.75 including installation costs. Thus, the initial cost of the RESCO and user-owned SHSs on Namdrik were comparable.

EFFECTIVENESS IN CHANGING COMMUNITY LIVELIHOODS:

Lighting was used for a variety of activities on both Akhamb and Namdrik. The most regular use was for ‘studying,’ followed by ‘reading,’ ‘eating,’ and ‘cooking,’ with 80% or more of respondents in both communities employing their lights for these reasons (see Table 2.1). Over 80% of users on Akhamb and nearly 60% on Namdrik were ‘making something to sell,’ which commonly referred to women weaving handicrafts at night. ‘Selling something at night’ and undertaking ‘business-related work’ also occurred regularly in both communities. All of these responses indicate that SHS lights are already being used for productive purposes in both communities, and have undoubtedly contributed to improving community livelihoods.

The freezers installed on Namdrik were also being used for productive purposes, as 89% of respondents indicated that they were ‘storing something to sell locally,’ and 83% indicated that they were ‘storing something to export to Majuro’. This reflects the primary sources of income on Namdrik, which are farming and fishing. Thus, crops, meat, and fish can be frozen until they are purchased locally or until transport is available to export them to Majuro. Similar uses could apply to Akhamb Island with refrigeration, as they had similar primary income sources.

Table 2.1: Uses for Solar Powered Lights for SHS owners (Ungaro, 2012).
AVAILABILITY OF RESOURCES AND SUPPORT:

Eighty-two percent of SHS owners on Akhamb felt confident that someone in their community would be able to fix their system if they could not. This was notable as none of the local technicians on Akhamb had participated in a certified solar PV course; rather they had only been trained locally. Overall, on Akhamb, 87% of respondents stated that their system was maintained ‘very well,’ and 90% stated that their lights had been working ‘very well’: an indication that the SHSs have been properly functioning. Thus, self-organised technical support appears to be working well for the community.

In Namdrik, there were lower levels of confidence in technical support, both locally and nationally. With the IE-Namdrik provided SHSs, this was possibly due to the system’s complexity and a lack of spare parts available locally.

AVAILABILITY OF SYSTEM COMPONENTS:

On Akhamb Island, one technician was acting as a local solar vendor, by reselling SHSs and components that are shipped from a dealer in the capital on a credit basis. This has greatly increased the availability of spare parts on the island, and at the same time has resulted in a new local business.

On Namdrik, for equipment that is covered by the project, end-users must rely on technicians’ visits to supply the components and repair the systems. Consequently, SHS components appear to be more readily available on Akhamb Island as compared to Namdrik.

CAPACITY BUILDING:

On Akhamb Island, 59% of respondents had attended a training session in 2009 on the equipment, installation, and maintenance of an 80 Watt SHS. In this training, a system was assembled from scratch and the importance of maintenance and basic troubleshooting was explained. In addition, many end-users had been given technical advice both at the time of installation of their own SHS and from a visiting solar technician in 2010, who had installed a community solar system.

On Namdrik Atoll, only 11% of respondents indicated that they had attended a training session. However, 77% had participated in the installation of their new SHS installed by IE-Namdrik, which was encouraged and served as training for end-users.

Additionally, 95% of SHS users in Akhamb and 94% in Namdrik indicated that it was very important for them to be able to repair and maintain their own system. Therefore, although some training efforts have been made, more capacity building is desired by end-users and is required for users to feel confident repairing and maintaining their SHSs.

GENDER INCLUSIVENESS:

On Akhamb Island, the percentage of women that felt confident in being able to repair a SHS
was much lower than that of men (2 women versus 27 men). On Namdrik, a higher percentage of women compared to men (6 women versus 16 men) expressed confidence in being able to repair a SHS than on Akhamb.

Also, of the most desired appliances to be powered by a SHS, only the washing machine, which was mentioned by 5 respondents on Namdrik, and the freezer, which was mentioned by 8 respondents on Akhamb, would significantly lessen women’s workload. The IE-Namdrik project did incorporate both male and female opinions into the goal of providing refrigeration, and has contributed to lessening women’s workloads. Overall, these results show that women are less involved in solar electrification and are less confident overall in handling their SHSs than men, although the IE-Namdrik systems were more gender-inclusive.

AFFORDABILITY:

The average biweekly income was approximately $110 on Namdrik, or $454 per capita per year, and approximately $150 biweekly on Akhamb, or $831 per capita per year. With higher incomes on Akhamb, approximately one-third of households have already been able to purchase a SHS at the retail cost without financing, with new systems being installed monthly. Access to financing would likely increase this rate and make systems more affordable at the outset.

However, the initial cost of a SHS may be affordable on Namdrik as well, as the RMI receives a high amount of Official Development Assistance (ODA) per capita ($1,525 versus $460 in Vanuatu in 2010), in addition to U.S. nuclear compensation funds (OECD, 2008). Furthermore, in both communities, income can often be generated when needed; however, at the same time, cash can be very limited and slow to be received. It follows that many respondents on Akhamb commented that they preferred to pay for their electricity all at once, through purchasing a SHS, rather than on a weekly basis as they had done previously with kerosene, or as is done with RESCO models. Interestingly, almost all of the respondents felt that having a SHS was cheaper than their previous energy source.

PARTICIPATION AND OWNERSHIP:

IE and Namdrik Atoll Local Government were responsible for maintaining the installed systems, through a project-initiated user-owned model. However, with this project, ownership is to be transferred to the end-users following the completion of the two-year trial and training period, after which the owners will be fully responsible for their systems. This enables users to gain experience handling their systems with full technical support for two years. With this project, it would have been impractical to provide a large variety of systems, as large order quantities of equipment and spare parts were procured. However, having a few system options may have better served users’ needs, and increased participation in the system design.

On Akhamb Island, systems were self-initiated and user-owned, with maintenance being divided between the owner, a community member, and a solar company, often depending on the knowledge required. All of the SHS owners reported that they were involved in the system design and were allowed to alter their system as desired.
Interestingly, all of the respondents in both communities reported that it was ‘very important’ for them to own their solar system and be responsible for it. Therefore, it appears that a high level of participation and ownership is desired by most end-users.

WILLINGNESS TO PAY:

The most common reason to purchase a SHS on Akhamb was that end-users thought SHSs would be a cheaper energy source than they had previously used, indicating that affordability was important. As most respondents reported solar to be less expensive than their previous energy source, it can be assumed that many end-users were satisfied with this aspect, and therefore willing to pay for maintenance.

On Namdrik, the most common reason to purchase the SHS was to improve the user’s income. As most end-users were benefiting from the productive uses of their solar-powered freezer, it can also be assumed that there was satisfaction regarding this aspect of the IE-Namdrik systems. Both the IE-Namdrik project and the systems installed on Akhamb appear to be fulfilling end-users’ motivations to purchase a SHS, indicating a willingness to pay for future repairs and systems.

TECHNOLOGY AND POLICY RECOMMENDATIONS FOR ENERGY EFFICIENCY

This research proposes that energy displays that show energy usage for the entire household and that are culturally appropriate in that they show the cumulative amount spent per month on the meter, in addition to real-time energy usage, are likely to result in improvements in energy efficiency in urban areas of the RMI and other PICs. Air-conditioning usage is the most likely behaviour to be changed.

At the same time, this research indicates unfamiliarity with the long-term benefits of energy efficiency among residential electricity consumers. As consumer behaviour change is a major factor in reducing energy consumption, an extensive public awareness campaign for urban areas is recommended, and could be funded by national governments or electric companies.

Furthermore, Pacific energy companies should consider implementing appropriate energy meters in a larger number of households as a trial project. If successful, large-scale rollout could result in slowing increasing energy demands, and prevent energy companies from needing to expand their energy supply. Such an EE programme would not be costly, and has the potential to even pay for itself (as has occurred in the U.S.). In addition, energy displays should be coupled with incentives for household scale renewable energy power production, thus allowing for distributed power generation, which is cost-effective compared to expanding centralised electricity generation. Such measures are in the interest of all stakeholders, including governments, energy companies, consumers, and society.

TECHNOLOGY AND POLICY RECOMMENDATIONS FOR RENEWABLE ENERGY

The research carried out in the two case studies has analysed the essential criteria for rural electrification using solar PV home systems (SHSs) in the Marshall Islands and Vanuatu. The
results showed that the most important success criteria for end-users include:

- **Technical:** Low-maintenance technologies; equipment standards and certifications; conservative system-sizing; and various size availability.

- **Economic:** Projects cash-flow positive; end-users involved in maintenance; and services linked to productive uses.

- **Institutional:** Reliable technical support; communication between users and suppliers; support and parts available locally; and training for end-users.

- **Socio-cultural:** End-user control; services include women’s and local needs; and financing available.

This research proposes that despite the prevalence of Renewable Energy Service Company (RESCO) managed projects in PICs, self-initiated user-owned SHSs are more likely to result in enduring benefits for end-users (and therefore more cost-effective investments in household solar PV), as they:

1. Provide an economic incentive for end-users to take care of their systems
2. Allow for customised systems to address end-users’ needs and productive uses
3. Incorporate end-users’ desires for participation and ownership
4. Empower end-users to create and be responsible for their own development solutions.

Self-initiated electrification enables end-users to be independent from aid from developed countries, through a transfer of power to beneficiaries, which allows them to control their own development solutions.

While such benefits are beginning to be acknowledged by the global literature and by respondents, the literature, project documents, and many on-going projects from PICs generally view rented SHSs as the preferred electrification model. This preference is derived from two concerns: 1. End-users will not be able to afford initial and replacement components without costs being dispersed over time, and 2. End-users in PICs are unable to properly operate and maintain their own SHSs.

The results of this research do not support the view that rented SHSs are the most effective or efficient approach to rural electrification. On the contrary, this research has shown that self-initiated, user-owned approaches have a greater chance of enduring project success if they are well designed. Here, the costs of self-initiated systems can be dispersed over time through providing users with access to financing. Such practices have been successful in many developing countries in other regions and this research did not find any reason why such an approach would not be successful in PICs. In addition, self-initiated systems have the potential to be more cost-effective, through avoiding the need for complex institutional structures, thus increasing affordability.

This research addressed the issue of end-users being unable to properly operate and maintain
their own SHS through two case studies, while at the same time expanding the current knowledge of the potential of user-owned SHSs in PICs. The results demonstrated rural end-users’ ability and desire to learn how to manage a SHS with limited access to resources and support. The end-users in Vanuatu have successfully installed and maintained SHSs themselves with no external initiative, with limited training, and self-organised technical support.

In conclusion, market solutions are the best way forward for future PIC electrification, in that they provide the most cost and time efficient way of maintaining a balance between social and technical needs, because they minimise the need for over-investment in institutional structures. The funding that would otherwise be spent on building bureaucracy in RESCO models can be more efficiently allocated to the social dimensions of a user-initiated and user-owned market approach. Such solutions will increase the rate of enduring SHSs being implemented in PICs, thus reducing fuel poverty.

CONCLUSION

Three conclusions are offered from the case studies in order to significantly reduce energy poverty through renewable energy (RE) and energy efficiency (EE) solutions in the Pacific Islands.

Firstly, there is a need to build capacity among end-users in order to increase the uptake of RE and EE. The EE case study indicated a general unfamiliarity with the long-term benefits of energy efficiency among residential electricity consumers. The two RE case studies suggested that training for rural end-users was extremely effective, yet additional training was needed. In the Pacific, technical trainings and public awareness campaigns have often overlooked targeting end-users, especially in rural communities. Technical support should be for the long-term, with follow-up trainings and continual access to support.

Participation and ownership over technologies are essential for long-term uptake, and participants should be included in all phases of projects, from design to evaluation. A review of the rural electrification literature showed that without ownership over technologies, support from end-users often drops off, thus decreasing the effectiveness of the solutions. The two RE case studies demonstrated the effectiveness of transferring ownership to the end-users so that they can control their own development solutions.

Secondly, the case studies indicated the cost-effectiveness of energy meters and of user-owned solar systems for rural electrification. It is recommended that measures that are already considered to be potentially cost-effective yet are still relatively new to the Pacific, including energy displays and distributed power generation using household-scale solar and wind power, should be trialled by the government or power producers. Regionally accepted technologies such as LED lights, insulation for houses and solar PV for rural electrification should rely on market approaches to promote uptake of such RE and EE solutions. These approaches may include incentives, subsidies, and feed-in-tariffs to increase uptake of the technologies.

Thirdly, certification and standards for equipment and vendors should be enforced, in order to encourage more appropriate equipment use in both EE and RE, as poor quality solar PV parts and household appliances were found in all three case studies. The private sector should be included
in these efforts, yet policies need to be initiated by governments. Such measures may be able to prevent the need to continue to expand centralised electricity generation, thus decreasing reliance on fossil fuels.

REFERENCES


