Socio-economic impacts of solar powered freezers in rural fishing communities: Fiji case study

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Abstract

Pacific Island Countries and Territories (PICTs) present significant challenges associated with energy poverty and lack of access to electricity, resulting in limited social mobility and economic development. While providing access to energy services, conventional fossil fuels are very costly and difficult to deliver to remote Pacific communities. Renewable energy sources can provide a cheaper and more reliable solution for these communities if integrated with aspects such as food and water security, health, education, and income-generating activities. This study explores the range of socio-economic impacts that energy access projects of this type can have in remote Pacific communities via a case study approach. Namely, this work presents a solar freezer project installed in 2015 in the small fishing village of Wainika in Fiji. Results show that the project has substantially contributed to food security, wider income opportunities, community infrastructure development, household support, improved education and healthcare, gender equality, and social mobility.

Keywords: Pacific Islands, Energy Poverty, Renewable Energy, PV Systems, Socio-economic Impacts, Remote Communities

1. Introduction

Energy poverty and lack of energy access are particularly acute in many Pacific Island Countries and Territories (PICTs), where geographic isolation and limited resources make it difficult to establish and maintain energy infrastructure. Approximately 70% of the population in the Pacific region lacks access to electricity on average, with countries like Vanuatu, Solomon Islands, and Papua New Guinea having the lowest levels of access (SPREP, 2018; Dornan, 2014). This poses significant obstacles to economic development, education, healthcare, and social mobility (Kanagawa and Nakata, 2007). The majority of the population which lacks access to energy is located in rural and remote locations. Conventional energy sources, such as fossil fuels, can be costly and challenging to transport to these areas, further exacerbating energy poverty and hindering development (Wolf et al., 2016).

Renewable energy sources, such as solar photovoltaic (PV) systems, have the potential to provide reliable and affordable energy services to off-grid communities, where fuel costs and transport logistics to operate traditional generators are problematic and often prohibitive (Weir, 2018; Urmee et al., 2019). Solar PV systems in particular have become a technology of choice for off-grid energy projects in the remote and outer islands of PICTs due to their flexibility and abundant primary resource, easing electrification efforts in challenging resource-constrained contexts and providing a range of socio-economic advantages such as accessing novel income opportunities, strengthening of rural markets, creating new employment opportunities through technical capacity building, improving education through enabling technologies, and accessing improved energy-based essential services such as communication services and lighting (Aklin et al., 2017). In fact, access to energy services and technologies should meet community priorities and have linkages to food, water, health, education, and income-generating applications to be effective and enhance community resilience (To et al., 2021).

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Amongst the various services and technologies that off-grid PV systems can enable, refrigeration has been identified as a key service to improve the livelihood of communities (Soboyejo, 2015). In particular, freezers can assist in the storage of perishable and essential items such as food, medicine, and vaccines – with profound implications on food security and safety, income generation through fishing, and healthcare. Because of these crucial linkages, solar powered freezers have been extensively deployed across PICTs (with some systems shown in Figure 1). For example, UNOPS and the India-UN fund delivered and installed 120 chest freezers for household use in the Marshall Islands to improve food security (UNOPS, 2022). As part of a collaboration between WorldFish and the West Are'are Rokotanikeni Association (WARA), 9 solar powered freezers were delivered to various communities in the Solomon Islands to specifically support income generation for women (Eriksson et al., 2019). UNICEF and the government of Japan equipped 234 health clinics in Fiji, Samoa, Solomon Islands, and Vanuatu with cold chain equipment such as chest freezers and portable freezers for vaccine storage and delivery to remote communities (Sharma, 2023).

Fig. 1: Solar powered freezer for vaccines in health clinic (Left) and for fish in community hall (Right), Fiji

Building upon the known benefits of solar powered refrigeration, this study aims to further demonstrate the linkages between energy access and socio-economic outcomes for remote fishing communities in the Pacific. Using a case study approach, this study explores the long-term socio-economic ramifications of a solar freezer project that was designed and installed in a remote fishing community in Fiji in 2015. Through this investigation, a holistic view of the direct and indirect impacts such initiatives can have on rural livelihoods, economic growth, and overall community development will be demonstrated.

2. Context: Wainika Village

Wainika is a small village settlement in Fiji with 23 households and a population of roughly 115 residents. It falls in the province of Cakaudrove near Udu Point and is about 66 km from Labasa, the main urban center in Vanua Levu. Despite being a part of the main island, the settlement is still not connected to the main centres through roads due to the mountainous topography of the area. As shown in Figure 2 (Left), the only means of accessing the village is through sea only via small outboard motor boats due to the lack of proper jetty facilities to accommodate for the anchorage of larger inter-island vessels. Generally, the village can be viewed as an island set due to its isolated nature and maritime character. The livelihood of villagers is heavily dependent on fishing both for subsistence and as a source of income. In fact, the location of the village is not favourable for sufficient levels small-scale subsistence farming, with very few areas of flat land which are still subject to sea water intrusions during high tides, stormy weather, and cyclones. Nonetheless, some locals still choose to farm some cash crops such as *dalo* (taro) and coconut used for local copra production. Women mostly carry out domestic duties and perform various forms of crafts (for instance, pandanus mat weaving), although they are also involved in fishing by collecting *kai* (river mussels) and setting up small fish traps during high tides.

To assess the village's key community aspirations and development priorities, a *Talanoa* (informal discussion session with the whole community) was conducted in 2014 as a culturally-appropriate consultation mechanism (see Figure 2, Right). During this consultation, the villagers mainly expressed their concerns regarding food security and the difficulties of long-term storage for fish and other food items – concluding that supporting fishing is a central priority to improve their livelihood. As such, a solar-powered freezer to store fish was agreed to be an effective solution to respond to these challenges and aspirations. This would enable long-term storage of fish and better means of selling the fish to buyers outside Wainika.

Fig. 2: Travel from Labasa to Wainika (Left) and community consultation in the village's community hall in 2014 (Right)

3. Solar Freezer Project Overview

An initial assessment was carried out to determine the on-site availability of the solar resource using a SunEye Tool. Figure 3 shows the annual sun paths drawn on top of the captured skyline in proximity of the village's community hall – the building selected by the community for installation of the system. The clear path or open sky is shown in yellow and the detected obstructions causing potential shading issues in green – indicating very minimal obstructions caused by the hills surrounding the village, with solar access ranging between 94 and 100%. Average insolation in Wainika is roughly 4.55 kWh/m^2/day.

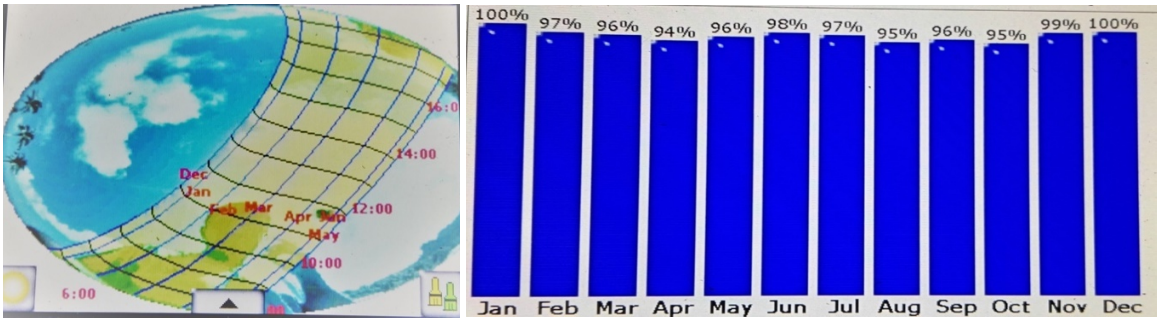

Fig. 3: Sun path diagram (Left) and monthly solar access (Right) at Wainika community hall

A 1.44 kW PV system was installed by the University of the South Pacific (USP) in November 2015, with three 200L freezers added in December 2015, and was funded by the French embassy. An overview of system components can be seen in Figure 4 and Figure 5, while a system wiring diagram of the installation can be seen in Figure 6. Table 1 summarises the system costs and equipment. The installation includes a backup generator (only used twice – once after cyclone Yasa and once during system maintenance in 2018), a battery bank, a data logger, and an inverter to accommodate for AC loads like the freezer. The system was slightly oversized to ensure high levels of availability through periods of bad weather and heavy energy usage. A user manual with simple instructions regarding maintenance and operation of the system was also provided to the village Headman. The village Headman organised a committee to oversee the sale of fish to external middlemen from Labasa, Wainigadru, or Savusavu at a fair price. Individuals in the village were only allowed to access the freezers in the presence of a member of the committee to oversee the intake and dispatch of perishable goods. This arrangement was established to ensure correct system usage and prevent the unnecessary opening of the freezers to save energy. The committee also oversaw the approval of additional system loads.

Fig. 4: Solar panels on community hall roof (Left) and freezers (Right)

Fig. 5: Electrical components (Left) and uncovered battery bank (Right)

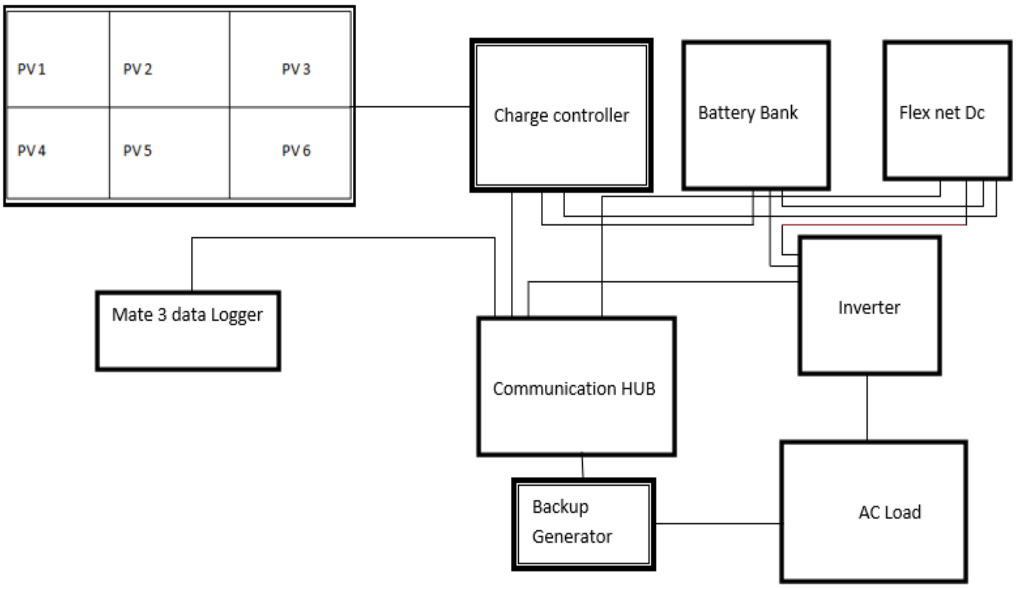

Fig. 6: System wiring diagram

Tab. 1: System costs and equipment (in FJD)

Item	qty	Cost
240W Trina Solar Panel	6	$3,780
3kW 24V Outback Inverter/Charger (24 VDC, 230 VAC @50Hz)	1	$5,902
Outback MPPT charge controller and monitoring system	1	$2,670
600Ah 24V Lead Acid Battery Bank (Deep Cycle)	12	$6,660
2.5kVA Generator (backup)	1	$3,521
Mounting frame for solar panels	/	$420
Wiring and protection materials (solar only)	/	$1,682
Modyl 200L Chest Freezers	3	$2,607
Installation, training, and commissioning	/	$1,080
Transportation, freight, and meals	/	$2,390
TOTAL		$30,712

4. System Performance

PV system performance was monitored using an Outback Flexnet DC coupled with a MATE3 over the course of 9 months (November 2015 – May 2016), requiring minimal community intervention and oversight. Monitoring of the energy into and out of the system battery bank was also implemented to study the energy usage and performance of the freezers under varying load and temperature conditions. Before the installation of the freezers on the 8th of December 2015, the system was only used to power six lights in the community hall and some mobile phone charging. Figures 7-9 respectively show the average daily energy supplied to the battery bank from the solar panels, average daily freezer energy consumption, and the battery bank state of charge (SOC). The average daily energy supplied to the battery bank is 4.62 kWh, with a maximum of 9 kWh. On average, a minimum SOC of 89.53 % was recorded for the battery bank. Throughout the month of December, activities in relation to fishing greatly increased due to community members returning to the village for holidays, although the community was able to effectively coordinate the quick sale of fish to external parties to avoid overloading the freezers. On most occasions, fishermen returned their catch for freezing in the morning, with plentiful hours of sunshine remaining in the day. This practice has greatly helped in maximising energy usage throughout the day.

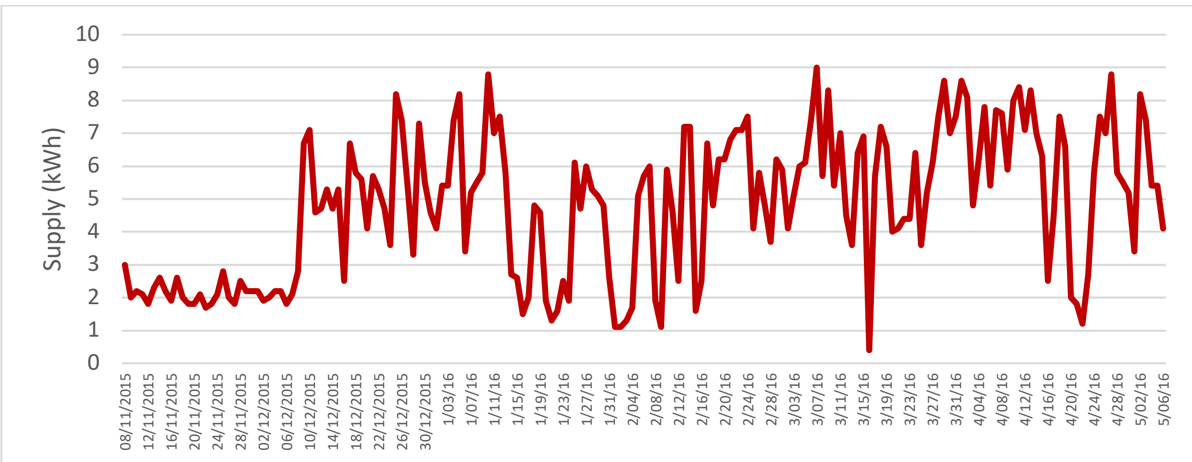

Fig. 7: Average daily energy supplied to battery bank

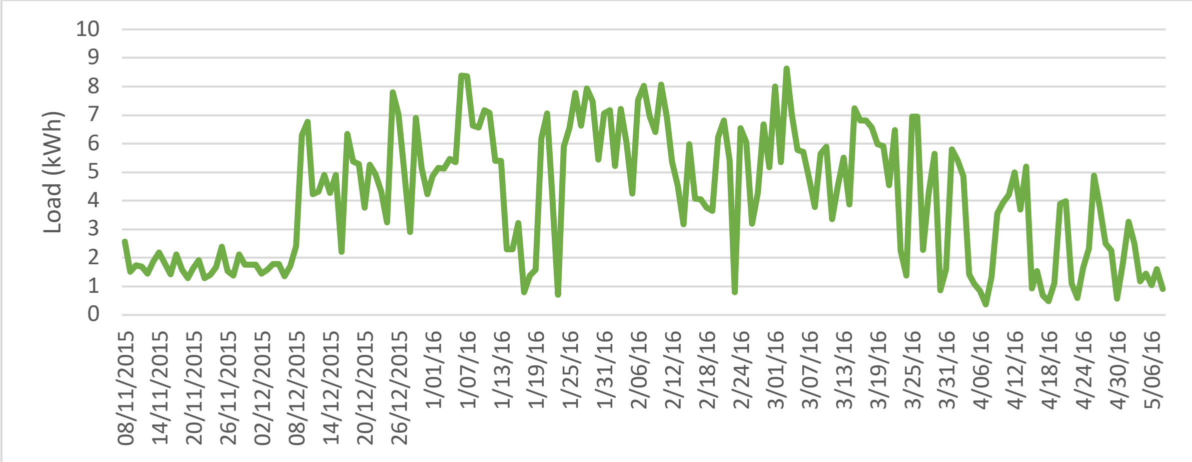

Fig. 8: Average daily energy supplied to the freezers

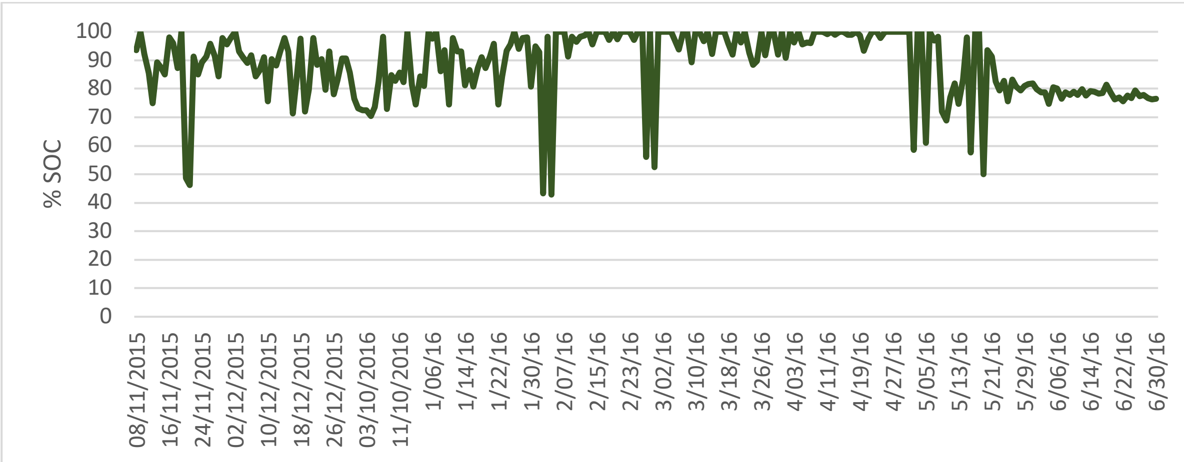

Fig. 9: Battery bank state of charge

5. Socio-economic Impact Assessment

A sample of 20 questionnaires were issued to various community members to assess the social impacts and the economic benefits of the project 6 months after the installation of the freezers, and various consultations were carried out through the years following the installation. Community members that participated in the questionnaire and the ongoing consultations included the village chief, the Headman, fishermen, housewives, farmers, and students. On average, the system generated a profit of roughly $1,300 per month. Given a total system cost of $31,000, this project would have had a payback period of roughly 2 years had the system not been donated to the village. The chief also stated that there are roughly $10,000 saved in a dedicated Village Home Finance Company (HFC) account to cover ongoing maintenance and replacement costs.

Table 2 summarises the socio-economic impacts of the project according to the villagers' questionnaire responses. When asked which impacts have been most beneficial, 30% of the interviewees mentioned income generation, 20% food security, 30% both, and 20% other impacts – demonstrating the strong linkage between energy access, food security, and improved income opportunities. Almost all questionnaire respondents also mentioned that the project itself had contributed to their increased awareness of the benefits of energy for the community's livelihood. Compared to a survey conducted prior to the installation of the system, it was found that many members of the community had shifted towards fishing as their primary role, as shown in Figure 10. Respondents highlighted that they considered fishing to be a more reliable form of income since cold storage had been made available. In particular, many women traditionally busied with domestic duties also started fishing as their primary means of income, suggesting that this type of project has gender equity outcomes as well.

Tab. 2: Socio-economic impacts

Impact	Details
Food Security	Storage for fresh fish and other perishable items over a longer period. Removed need to smoke fish for storage.
Income Opportunities	Income generation through sale of frozen fish to buyers outside Wainika, including a stable buyer from Suva. Buy and resale of fish from other neighbouring villages. Capacity for more community members to engage in fishing as a reliable full-time job. Women enabled to work in crafts.
Infrastructure Development	Refurbishment of community hall including painting, tiling, louvers, ceiling, and roof. Refurbished community church. Construction of health facility and crafts building.
Equipment Upgrade & Safety	Purchase of a fibreglass boat for fishing. Purchase of fishing lines, rods, and life jackets.
Household Support	Ability to purchase more groceries and other essential household items. Reduced household expenses associated with buying ice from Labasa, Wainikoro, and Savusavu to store perishables.
Education	Purchase of exercise books, shoes, and bags for children in preparation of returning to school.
Healthcare	Providing storage space for vaccines and insulin for highly diabetic individuals, removing need to travel to Wainikoro or Labasa for this purpose on regular intervals.
Gender Equality	Purchase of a sewing machine. Additional supply of cotton materials, thread, and needles for sewing and stitching purposes. Working space for women in the crafts building to generate income via sewing. Women involved in fishing.
Social Mobility	Organisation of committee to ensure fish reaches the market at a fair price without residents having to travel themselves to Labasa. Assistance in funding for community gatherings and transportation. Support for church gatherings to perform *Lotu* (prayer).

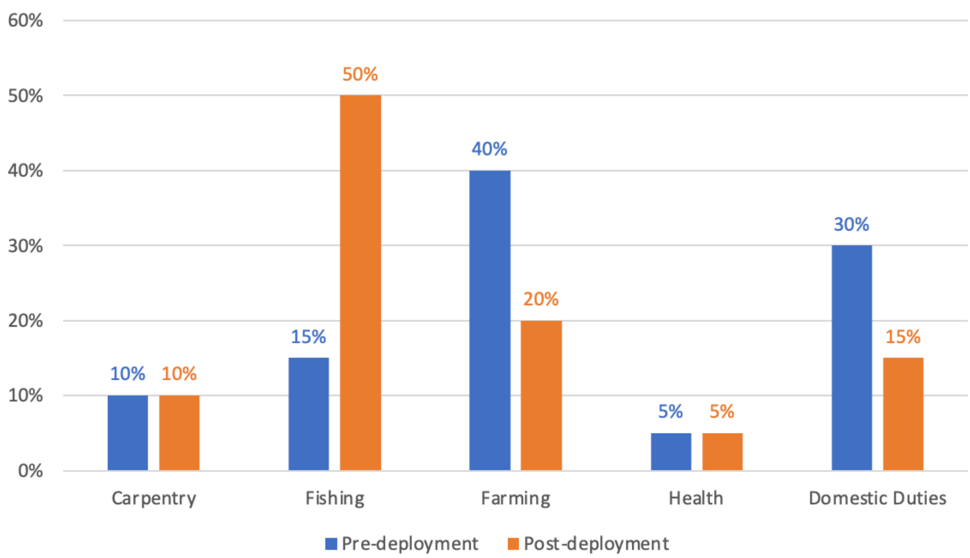

Fig. 10: Comparative analysis of community roles in Wainika

Another community interview conducted by IRENA in October 2019 also confirmed the success of this project in terms of ensuring food security and providing a range of social and economic benefits, with the village chief stating that the project had significantly raised the standard of living for the whole community (IRENA, 2019). The project has also been discussed at regional workshops and is a key example of a successful energy access project in the Pacific (Ravasua, 2019). A more recent visit to the system in September 2023 revealed that the batteries had to be replaced (a process now underway) and that no additional appliances have been run off the system – suggesting the village committee has been very conservative in trying to avoid system misuse or overuse, perhaps missing out on capturing additional benefits but most certainly preserving the system to the fullest extent possible.

6. Conclusions

This solar freezer system has become a primary factor towards improving the general livelihood of individuals in the remote community of Wainika. A suitable technical design and sense of ownership of the project by the village chief and other residents have been major reasons for the success of this project, as it continues to perform effectively in its 8^{th} year of commissioning. This project showcases that energy access projects that meet community priorities and enhance resilience can result in substantial socio-economic benefits. Proper record keeping, village-wide cooperation, and enforcing strict operational guidelines through a village committee have also been identified by the community as some of the key factors for the success of this project. Furthermore, the backup generator for the system has only been used twice since the installation of the project, highlighting the quality of the solar resource and the value of oversizing the system to ensure its availability. With proper maintenance and operation, oversized systems such as this one are very robust and may limit fuel costs only to emergency situations, greatly reducing the financial toll these take on communities. Recommendations for future work include the installation of a larger PV system to enable the implementation of more freezers.

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