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Solar Energy for Clean Water Access in Fiji

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Abstract

Access to clean water is a perennial challenge around the world and approximately 2 billion people depend on contaminated water for their survival. Unsafe water accounts for about 842,000 deaths annually. Fiji, one the Pacific Island Countries (PICs) had about 220,000 people depending on surface water or rainwater for their needs in 2015. Groundwater sources have the potential to provide access to clean water to population in many areas around Fiji. However, unelectrified communities who depend on diesel-based water pumping systems have a lot of associated costs and maintenance issues with water delivery. At many instances, these systems are abandoned and communities' resort to unsafe water sources.

With abundance of solar providing access to resource in the Pacific, Solar Water Pumping Systems (SWPS) can play a major role in providing safe water to many remote, unelectrified communities. This paper describes a case study dealing with SWPS application in a school community in one of the remote locations in Fiji Islands, A techno-economic analysis shows that SWPS is an environment friendly cost-effective solution.

1. Introduction

Availability of fresh water is the primary medium through which the effects of climate change are felt in many parts of the world (UN, 2017). Access to clean drinking water with adequate sanitation is crucial for overall well-being of communities and is one of the key sustainable development goals (SDGs). According to the World Health Organization (WHO), approximately 2 billion people consume water that is contaminated with faecal matter (WHO, 2018). Use of unsafe drinking water leads to many deaths due to water related diseases. Diahorrea itself accounts for the deaths of 842,000 individuals globally and 252,000 children, of age below 5 years, every year (WHO, 2017). In the Pacific Island Countries (PICs), 50% of the population did not have access to improved water supplies for consumption by end of year 2015 (WHO, 2016). These figures include 79% rural dwellers, with lack of improved water facilities for consumption in the PICs.

The main source of fresh water in the PICs include rainwater collection, surface water and ground water tables (White & Falkland, 2010). In Fiji itself, more than 220,000 rural dwellers depended on creeks and rainwater harvesting as their source of water in 2015 (Cava, 2016). The use of surface water such as rivers, lakes and ponds as the primary source of drinking-water brings about huge health risks to people with this type of access, especially children. Moreover, drought conditions impact the surface water sources within a short time, while it takes much longer to impact the ground water aquifers. Many communities in Fiji have borewells to cater for their water needs, which are powered by costly diesel generators in areas without grid connection or in smaller off – grid islands. Several diesel generator-based water pumping projects have come to a halt due to fuel bills and water has to be carted to these areas at exorbitant costs.

With abundant solar resource in PICs, solar water pumping systems seem to be a promising solution to cater for clean drinking water needs of remote communities in a cost effective and sustainable manner. Several solar powered water pumping systems have been installed around the globe which provide sustainable water access (Hamidat, Benyoucef, & Hartani, 2003; Hammad, 1999; Raturi, 2011; Short & Oldach, 2002; Short & Thompson, 2003; Yahya & Sambo, 1995). The principle of operation of solar water pumping systems are well explained by (Short & Oldach, 2002) and are quite simple, whereby irradiation from the sun is converted to electrical energy and electrical energy drives the pump, pumping the water.

Western side of Fiji usually has 4 to 5 sun hours, which is sufficient enough for water pumping systems. Also, the primary advantage of using Solar Water Pumping Systems (SWPS) is that the peak usage time coincides with the time at which solar energy is available for pumping (Shrestha, 1996). This work provides a case study of solar water pumping systems in Fiji to provide clean drinking water in remote schools.

2. Methodology

Questionnaire based survey, personal communication and observations were carried out to gauge the community needs and situation analysis. The information on the initial water systems in the subject village was carried out through discussions with the local primary school committee members. In order to simulate the system, PVSyst version 6.7.5 was used and economic calculations were done using the excel spreadsheet.

3. Context of the Study

Fiji is a tropical country, which is located between 12° to 22°S latitude, 177°E to 178°W longitude. The annual rainfall in dry sides of Fiji averages to 2000 mm while the wet sides get an average of 3000 mm to 6000 mm of rain ("The climate of Fiji," 2006). Namau, Ba, is located on high lands in the western side of Fiji, about 30 kilometers from the Ba town. The total population of this area is 150 approximately in 2018. The total school population for the primary school situated in Namau village is 39 students and 5 teachers. A nursing station is also situated in the village. The village is still not electrified but there are plans to electrify this area in the near future.

3.1. Background of the studied area

Initially, the village had a lot of problems with water. River water and rain water harvesting were the major sources for water needs of the community and the school. The community benefitted with an NGO project, whereby a dam was built and proper reticulation was done to supply the village with water. There were problems associated with this system as it used to dry up in drought conditions and water was unsafe for drinking. During rainy days, the water from the source would be muddy. Eventually, the residents of the community were back to using unsafe river water for daily needs. After assessing the needs of the health center and the school, the Ministry of Health (MoH) had drilled a borehole at the school compound to cater for the water needs of the school and the health center and was powered by a diesel generator. The water quality tests had been carried out by the Mineral Resources Department of Fiji (MRD) and results confirmed that the water met WHO drinking water standards.

According to the head teacher, the school had to pay at least $25 per week pumping water to the storage tanks, just to cater for needs of the school and the nursing station (Charan, 2018). Due to the costly nature of pumping water, the project came to a halt within a year and the borewell was abandoned. Also, there had been ongoing maintenance issues with the operation of the diesel generator. Once again, water had to be either fetched by the villagers from the river via use of the drums or carted from the town, at a cost of about $220 for 10,000 liters of water. Outbreaks of diarrhoea were frequent in the settlement which led the students to be absent from school on frequent basis. There had been many instances, whereby the school had to be closed due shortage of water on the school premises ("Development of rural school solar water pumping project," 2015).

4. Solar System Provides Sustainable Water Access

With the support of a ROC (Taiwan) government grant, the University of the South Pacific had installed a solar PV water pumping system in an attempt to revive the existing borewell in 2015. Since the existing reticulation system had been intact; solar panels, control system and solar pump had to be installed in the vicinity of the school. Figure 1.0 shows the installed system at Namau Public School.

Figure 1. Solar panels and control system for the solar water pumping system with onlooking students and teachers of Namau Public School.

5. Water needs of the Community

Water needs of the community has been investigated thorough discussion with the head teacher and the community members. Table 1.0 outlines the water needs of the Namau community. On average, the school uses 5 m^3 of water on week days, while water is rationed to the community. On weekends, bulk of water is supplied to the community.

Table 1.0: Water needs of the community

	Water needs	
	Week Days (liters/day)	Week Ends (liters/day)
School	5000	0
Nursing Station	500	500
Community	2000	7000
Total	**7500**	**7500**

5.1. Simulation Parameters

The most important parameter that determines the overall feasibility of any solar system is the available solar resource. For simulation studies, the NASA- SSE monthly average solar irradiation data was used for the grid -17.61° and 177.79° East. Figure 2.0 shows the average solar irradiation data measured via satellites. The annual average solar insolation in Namau Ba approximates to 2000 kWh/m2, which is excellent for solar energy development.

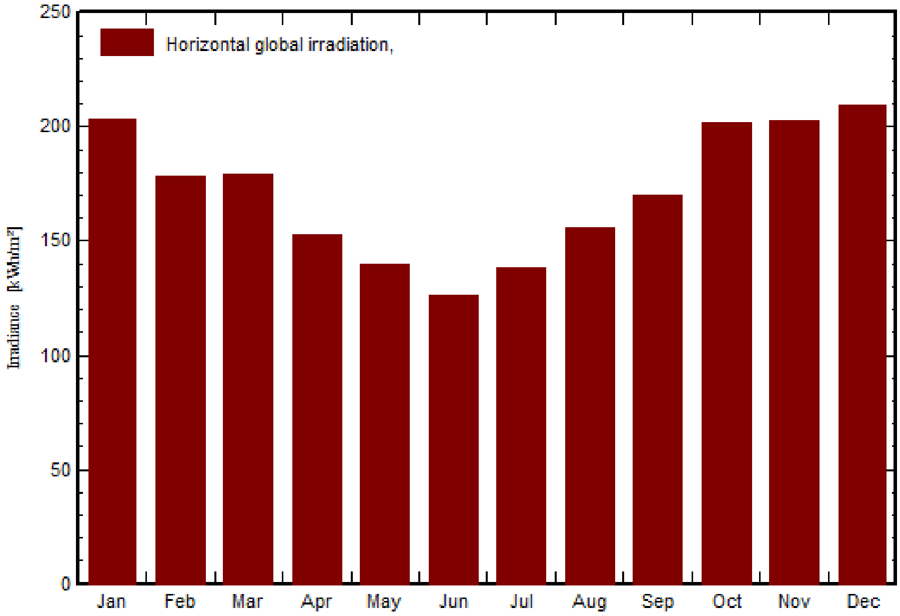

Figure 2. Average solar irradiation in Namau area (17.61° South and 177.79° East)

5.2. System Design

The main system design parameters are outlined in table 2.0. The pump used for system simulation is different from the one actually installed, however the characteristics are almost the same. Shading analysis were not required while calculations were done on yearly basis.

Table 2.0: Main system design parameters

Plane Tilt	23°
Azimuth	0° (True North)
Optimized respect to	Yearly Irradiation Yield
Water Needs	7500 liters per day
Feeding altitude	4.00 m
Pipe Length	25.00 m
Number of Elbows	4
Borewell diameter	15 cm

Solar Panels	Trina Solar, 235 Wp, Si Poly, Model: TSM-235-PO5
Controller	MPPT-DC-Converter
Pump Type	570 W, Range: 10-100 m, Type: Progressive Cavity

5.3. Simulation Results

The results obtained for the above simulated system are outlined in table 3.0. The system has been oversized in order to cater for sudden fluctuations in in water demand.

Table 3.0: Results table

Nominal PV power	0.94 kW
Nominal Pump power	0.57 kW
Water pumped per year	2741 m^3
Pump efficiency	28.5%
System efficiency (excluding solar panel efficiency)	41.4%
Electrical energy at pump	695 kWh / year
Unused fraction of the energy	48%
Loss of Load	0%

As seen from the results, unused fraction of the energy is quite high, of about 48%, however, the system is oversized to cater for the uncertain load surges in times of village functions and functions on schools as well. The extra electricity can also be used by the school for other purposes. Figure 3 and 4 show that most of the time, the tanks full and the energy is unused. Figure 5.0 shows the average effective energy and water pumped per month over the year.

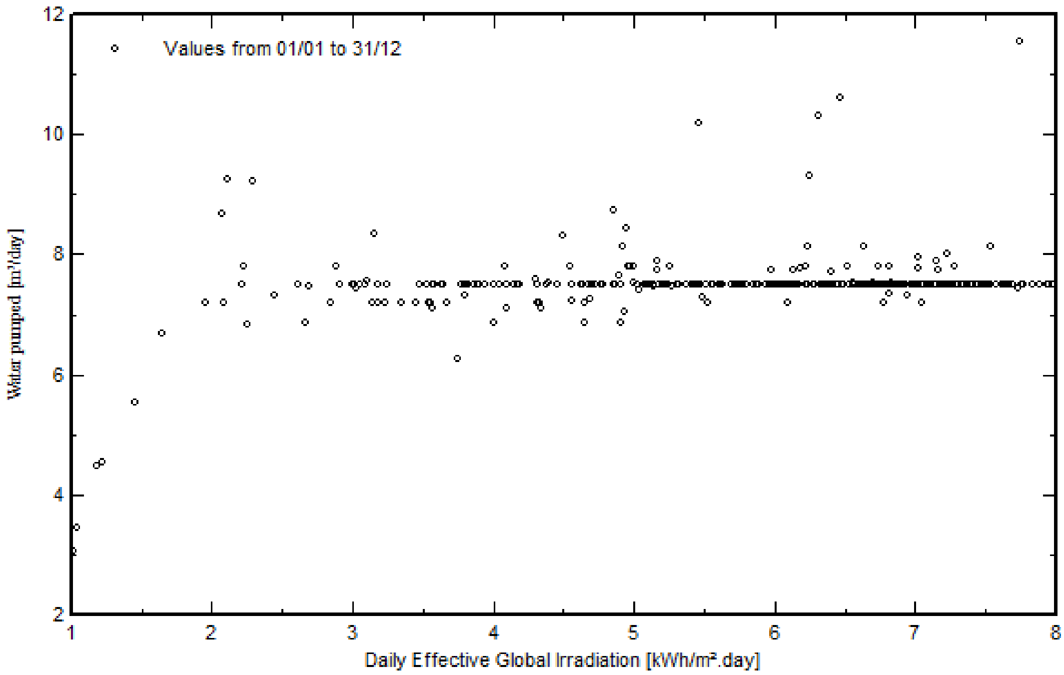

Figure 3: Daily water production as a function of irradiation.

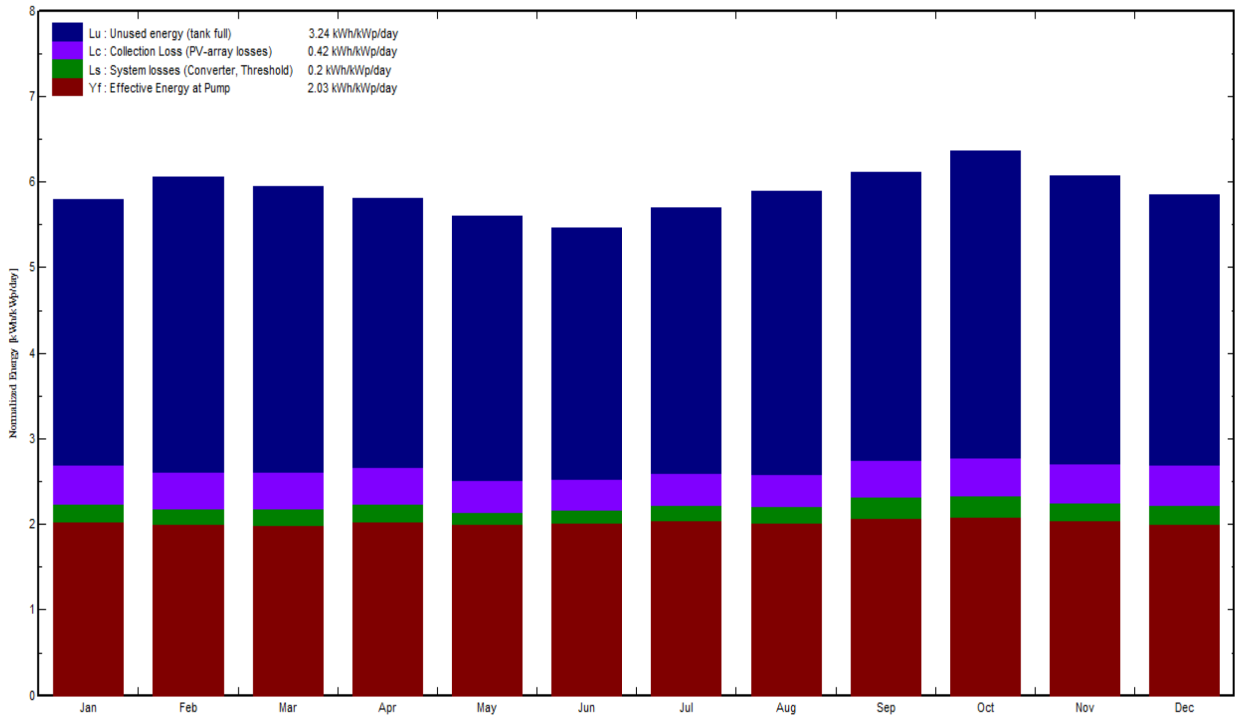

Figure 4. Normalized productions per installed kWp.

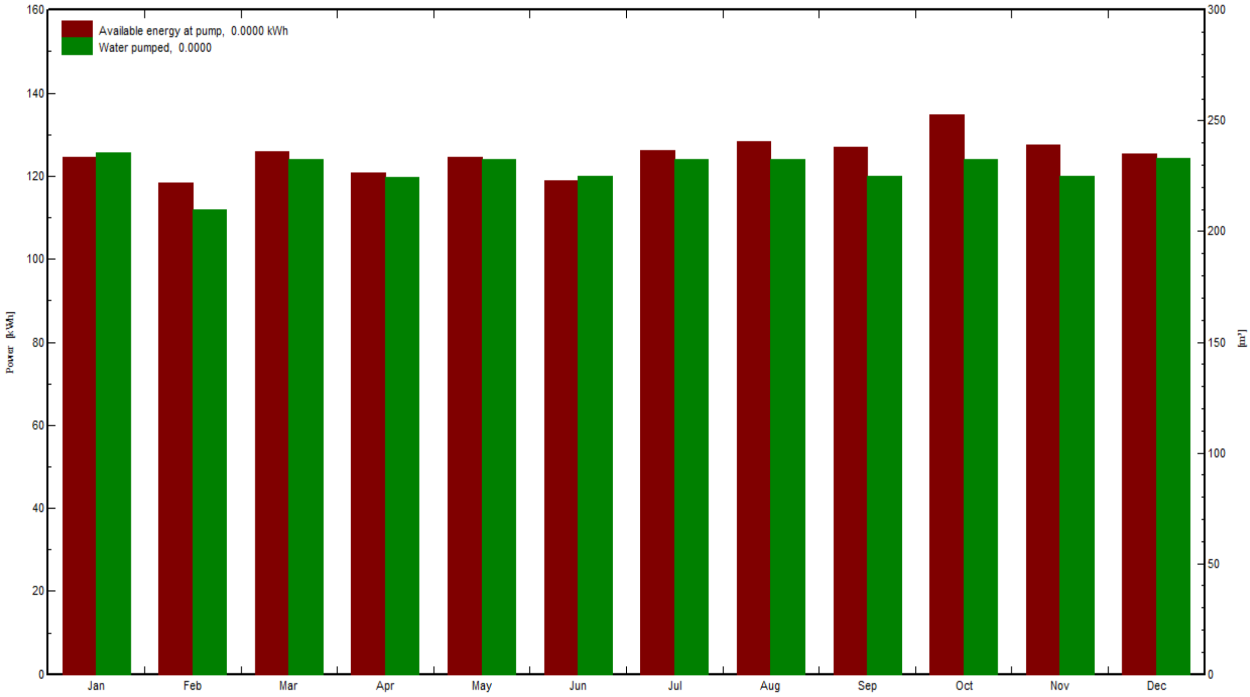

Figure 5 : Available energy at the pump versus water pumped over the year

6. Economic Analysis

Economic analysis plays a major role in determining the feasibility of any installed system. The end users mainly opt for choices for systems, which costs them less, regardless of other issues such as environmental impacts, and other social issues.

SWPS usually have high upfront costs but are much cheaper compared to diesel-based systems in the long run (Zieroth, 2005). This is because solar PV systems do not have any moving parties, hence minimal maintenance is required. On the other hand, diesel generators require a lot of maintenance, consume costly fuels and have environmental impacts as well. Studies reveal that cost of electricity in remote off-grid areas is usually more than twice compared to grid-based systems (Jensen, 2000; Weisser, 2004).

Table 4.0 compares the costs of using the three conventional types of water sources for the Namau settlement.

Table 4.0: Economics of using conventional sources of water

	SWPS	Diesel based pumping	Water carting + community project
Initial Costs ($)	**12,000** Solar system + controller + Pump	**1,600** Diesel Genset + Pump	**0**
Running Cost - life time) ($)	**1,000**	**36,250** Fuel + O&M + Pump	**715,000** Assuming water is

	Pump replacement	replacement	carted during 6-month period and the community project relied upon for needs
Discount Rate (%)	**5**	Assumed **constant**, however fuel prices are vulnerable	Assumed **constant**, however rates are forecasted to increase subject to increase in fuel prices.
Total Yearly Cost ($)	**968**	**1514**	**28600**
Cost of water ($/m^3)	**0.35**	**0.55**	**20.86**

The cost of water through SWPS turn out to be $ 0.35 per m^3 and cheaper than the two other methods of obtaining water for daily water needs. The diesel-based pumping costs about $0.55 per m3, which was uneconomical. Moreover, the cost of fuel is definitely going to increase in the future and the fuel needs to be transported from the nearest market place which add to the overall costs. Maintenance and operation of diesel-based systems require a technically qualified person to be looking after the system, while SWPS only requires maintenance once in a while. Water carting, through which the government is helping the communities is a very expensive exercise. Substantial amount of time for the villagers and the children are saved, in terms of getting water to the school. According to the head teacher, absenteeism of students from the school due to water related diseases has decreased.

7. Discussions and Conclusion

This work provides a case study of solar water pumping systems in a rural school community in Fiji. Cost of water obtained through SWPS turns out to be $ 0.35 per m^3 and cheaper than the diesel-based systems. The installed system proves an average of 7500 litres of water on daily basis and expected to run for 25 years. Moreover, the main advantage of using SWPS is that it provides clean water without any environmental impacts. An additional advantage of using the ground water sources in this area is that there is no risk of contamination through induced sea level rise. Access to clean drinking water allows the nation to achieve the targets for sustainable development goal (SDG number 6, which is central to many other SDGs including goals 2,3 4, 12, 13 and 14). Similar SWPS have been installed in 4 other schools in Fiji as a part of the USP/ROC project.

8. References

Cava, L. (2016, 17 September). Most rural dwellers use creeks and rivers: Usamate, *The Fiji Times*.

Charan, A. (2018, 05 October). [Solar Water Pumping Project].

The climate of Fiji. (2006). Fiji.

. Development of rural school solar water pumping project. (2015). Suva.

Hamidat, A., Benyoucef, B., & Hartani, T. (2003). Small-scale irrigation with photovoltaic water pumping system in Sahara regions. *Renewable Energy, 28*(7), 1081-1096. doi: http://doi.org/10.1016/S0960-1481(02)00058-7

Hammad, M. (1999). Characteristics of solar water pumping in Jordan. *Energy, 24*(2), 85-92. doi: http://doi.org/10.1016/S0360-5442(98)00078-4

Jensen, T. L. (2000). Renewable energy on small islands. *Forum for Energy and Development (FED)* (second ed., pp. vi).

Raturi, A. (2011). Feasibility study of a solar water pumping system. *Applied Solar Energy, 47*(1), 11-13.

Short, T., & Oldach, R. (2002). *Solar powered water pumps: the past, the present—and the future?* Paper presented at the ASME Solar 2002: International Solar Energy Conference.

Short, T., & Thompson, P. (2003). Breaking the mould: solar water pumping—the challenges and the reality. *Solar energy, 75*(1), 1-9. doi: http://doi.org/10.1016/S0038-092X(03)00233-0

Shrestha, J. N. (1996). *Solar PV water pumping system for rural development in Nepal: problems and prospects.* Paper presented at the Energy Conversion Engineering Conference, 1996. IECEC 96., Proceedings of the 31st Intersociety.

UN. (2017). Water and climate change. *UN Water.* Retrieved 03 October, 2018, from http://www.unwater.org/water-facts/climate-change/

Weisser, D. (2004). On the economics of electricity consumption in small island developing states: a role for renewable energy technologies? *Energy Policy, 32*(1), 127-140. doi: http://dx.doi.org/10.1016/S0301-4215(03)00047-8

White, I., & Falkland, T. (2010). Management of freshwater lenses on small Pacific islands. *Hydrogeology Journal, 18*(1), 227-246. doi: http://doi.org/10.1007/s10040-009-0525-0

WHO. (2016). *Sanitation, drinking-water and health in Pacific island countries : 2015 update and future outlook*. Manila, Philippines: WHO Regional Office for the Western Pacific.

WHO. (2017). Diarrhoeal disease. Retrieved 03 October, 2018, from http://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease

WHO. (2018). Drinking water - key facts. Retrieved 03 October, 2018, from http://www.who.int/news-room/fact-sheets/detail/drinking-water

Yahya, H., & Sambo, A. (1995). Design and installation of solar photovoltaic powered water pumping system at Usmanu Danfodiyo University, Sokoto. *Renewable Energy, 6*(3), 311-312. doi: http://doi.org/10.1016/0960-1481(95)00029-J

Zieroth, G. (2005). Feasibility of solar pumps for Mauke water supply. *Ministry of Foreign Affairs, Denmark*.