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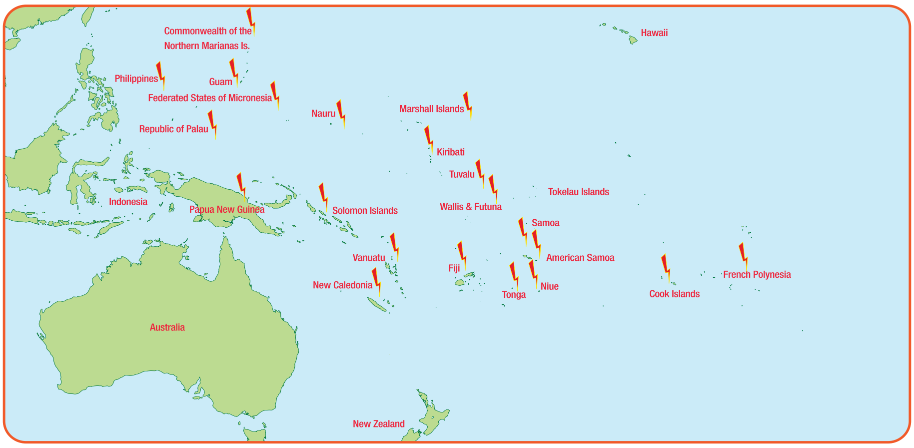

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Editor's Note

Gordon Chang
Executive Director

The articles in this issue of our magazine reflect some of the areas of focus in our utilities. The increasing focus on renewable energy as a source of sustainable energy production for the outer islands in addition to remote areas on our main islands is a recognition by the utilities of the issues of climate and the delicate environment in which the small islands exist. When it is recognized that the Pacific Islands are providing a greater focus on sustainable energy than the much larger developed countries, particularly in view of our small energy usage and economic situation, it could provide an example for these larger countries to follow.

Notwithstanding this, there remains the ongoing need to reform and to continually improve the performance of our utilities.

It is now "full steam ahead" for our fast approaching 31st Annual PPA Conference to be held in Tonga. All indications are that the hosts, Tonga Power Limited have all their preparations almost completed. This will certainly be a Conference conducted in true Pacific Island style.

Our Association has been honored to have the Senior Energy Specialist, World Bank, Ximing Peng to provide the keynote address at our formal opening. It is not too late for those members that have not registered to make their bookings for this important Conference, which has as its theme "Cost of Transition to Renewables"

I look forward to working with you all at our Conference in Nuku'alofa, Tonga and wish you all safe travel to the Friendly Islands of Tonga.

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Typhoon-Safe containerized Solar Power Stations for Islands: Ecosun Innovations Solar Project in Borneo

Florent Duthoit
Asia Pacific Sales Manager - Ecosun Innovations

Introduction

Ecosun Innovations, a French company specializing in designing and manufacturing containerised solar power stations, has recently launched an ambitious project in the Island of Borneo, Indonesia.

This project aims to provide solar energy hybrid system solutions to a mining site, reducing dependence on fossil fuels, improving energy efficiency and protecting the solar installation against typhoons.

Figure 1: two deployed Mobil-Grid® 72 kWp solar containers in Indonesia

Figure 2: 20' container Solarfold® 130kWp – 110

Context and Project description

Borneo, an island region rich in biodiversity, faces major energy challenges. The dependence on diesel generators for energy is not only costly in terms of price but also complex in terms of logistics. Transporting and managing diesel requires specific infrastructure and high operational costs. Additionally, installing renewable energy in these regions is particularly complex due to geographical isolation and challenging weather conditions.

Islands are often subject to storms, heavy rains, and other climatic phenomena that complicate the installation and maintenance of energy infrastructure. Besides these logistical and economic challenges, diesel generators present significant environmental issues, including greenhouse gas emissions and air pollution. Ecosun Innovations identified an opportunity to transform this situation with advanced solar solutions.

The project in Borneo includes the installation of 4 containerised solar power station Mobil-Grid® of 72 kWp each (292 kWp in total) and a Battery Energy Storage System (BESS) Solar Hybrid Box® of 30 kVA – 60 kWh. These containers, which are easily interconnectable and stowable, allow for the production and storage of solar energy in complement to an existing 1000 kVA diesel grid, significantly reducing fuel consumption (35%). The deployment of these containers was completed in a record time of 2 days.

Figure 3: Stored "Solar Wings" inside a solar containers Mobil-Grid® 72 kWp

Figure 4: "Solar Wings" Deployment from a solar containers Mobil-Grid® 72 kWp

Figure 5 and 6: Deployed "Solar Wings" field from solar containers Mobil-Grid® in Indonesia

Store a solar installation in a container in less than 30 minutes to protect it from typhoons

To date, the project has been successfully deployed and continues to operate optimally. Ecosun Innovations plans to extend this model to other sites in Asia and the Pacific, aiming to promote the use of renewable energy on a large scale.

In addition to the Mobil-Grid® and Solar Hybrid Box®, Ecosun Innovations offers other innovative solutions like the solar container Solarfold® of 130 kWp.

Installed on rails and operated by a motor, the 196 solar panels can be deployed in rows in less than 30 minutes. Once installed, in the event of a typhoon warning which generally arrives 24 to 48 hours in advance, users can store the panels and redeploy them once the typhoon has passed.

This solution serves as an emergency response to electricity shortages on islands following a disaster, providing immediate energy for critical needs, such as powering health services or emergency operations. Throughout the rest of the year, it can also be used to generate sustainable energy.

When combined with a diesel generator, the SolarFold® significantly reduces diesel consumption and, with the addition of battery energy storage, can even replace the generator entirely. SolarFold® is the ideal solution for isolated locations, like islands, to address energy dependence issues.

Figure 7 & 8 : 20' container Solarfold® 130kWp – 110 kVA

Switching Diesel for Containerised Solar Energy: Impact and benefits

Switching from diesel to containerised solar energy presents significant advantages in terms of wind safety, costs efficiency, environmental and social impact.

- **Wind Safety**: In the event of strong winds such as the Pacific Islands can experience, containerized solutions can be folded back in a few minutes to weather the storms.
- **Environmental**: In Indonesia, the project avoids the use of 166,000 liters of diesel per year, reducing CO2 emissions by 500 tons annually.
- **Economic**: Still in Indonesia, Annual diesel savings are estimated at over 200,000 USD, with a return on investment (ROI) expected in less than 6 years. One of the keys to the project's success is the use of Plug-&-Play technology, which has reduced installation costs and accelerated the commissioning of solar systems. This modular and flexible approach also eliminates the need for land acquisition, simplifying deployment in remote areas.
- **Social**: Improved working and living conditions of end users with a cleaner and more reliable energy source.

Conclusion

Ecosun Innovations' project in Borneo is an inspiring example of how solar technologies can transform industries and communities. Containerized solar solutions allow island areas to protect their solar installations from recurring typhoons and reduce or even eliminate their dependence on diesel. By providing clean, reliable, and economical energy, Ecosun Innovations paves the way for a sustainable and prosperous energy future for Borneo and beyond.

Ecosun Innovations will have a booth at the Pacific Power Association Annual Conference from September 30th to October 3rd, 2024.

If you would like to know more about the company and its product, you may visit the company's website or contact its representative based in Asia:

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A Case Study: Fiji – Nukubati Great Sea Reef Resort

Germany New Zealand Chamber of Commerce

As part of this environmental analysis, the techno-economic feasibility study considers hydrogen as a storage technology. Economic factors such as the levelized cost of electricity, capital costs, and the payback of the investment (break-even point) are also considered. Other relevant metrics include the shares of renewable energy sources, surplus electricity produced, and CO2 emissions.

The scenarios and analyses of the case studies created by using a Multi-Vector Simulation software (MVS) show that energy systems based entirely on renewable, as well as hydrogen and fuel cell technologies, promise substantial cost reductions and emission savings in most cases. The information on the respective conditions and the results of this study, collected by the German Chamber of Commerce and analysed by the Reiner Lemoine Institute, demonstrate the possibilities and economic benefits of integrating green hydrogen and fuel cell technology into the decentralized energy supply of island nations. The project was funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV).

The Nukubati Great Sea Reef Resort is a four-star resort located on the island of the same name, Nukubati, near the island of Vanua Levu. The small island of Nukubati is not connected to the electrical grid, so the resort is self-sufficient, powered by a solar array, a battery storage system, and a diesel generator. Recently, smart meters were installed to facilitate the further development of the energy system's design. The resort has its own seawater desalination plant, which is currently rarely in operation because the primary water source is collected rainwater. Since the water cycle of a decentralized energy supply system, consisting of an electrolyser (splitting water into hydrogen and oxygen using electricity) and a fuel cell (combining hydrogen with filtered atmospheric oxygen to produce water while releasing electricity), is closed, there are very minimal water needs. Should hydrogen be extracted from the cycle (e.g., for refuelling vehicles), covering the additional water demands through onsite seawater desalination could be considered. The operators of the resort are very interested in sustainable power supply and aim to increase the share of renewable energies in the system long term.

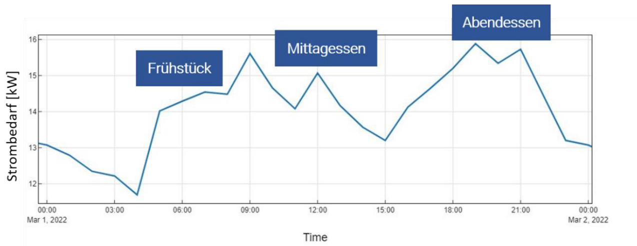
Subsequently, all the important input parameters for this case study will be presented. Then, a brief overview of the key results of the energy system modelling for the Nukubati Great Sea Reef Resort will be given.

1. Electricity Consumption
1.1. Nukubati Great Sea Reef Resort

The load estimation for the Nukubati Great Sea Reef Resort is based on manual readings of electricity demand over a 24-hour period by resort staff. The daily demand follows a consistent pattern, strongly linked to meal preparation and kitchen activities. Illustration 1 shows an example of such a progression.

Below is a breakdown of the main events in the load profile:
- 5:30 AM: The kitchen begins operation.
- 7:00 - 10:00 AM: Breakfast service.
- 12:00 PM: Start of lunch preparation.
- 12:30 PM - 1:30 PM: Lunch.
- 5:00 PM: Start of dinner preparations.
- 7:30 PM - 10:00 PM: Dinner.

Illustration 1 Daily Load Profile of Nukubati Great Sea Reef Resort



The blue markings in Illustration 1highlight the load peaks corresponding to these events.

The data presented represents a typical daily consumption pattern for the resort, assuming full occupancy. According to discussions with the operators, slight variations may occur depending on the level of occupancy, although these are minimal. According to the resort's statements, there are no noticeable differences between weekdays and weekends to consider. The daily profile is used as the basis for creating an annual profile due to the lack of availability of long-term measurements or electricity bills (no grid connection). The key demand characteristics are listed in the table below.

Illustration 2 Load Requirements of Nukubati Great Sea Reef Resort

Parametre	Unit	Value
Peak Load	kW	15,9
Average Load	kW	14,1
Annual Consumption	kWh	123,506

2. Solar Potential

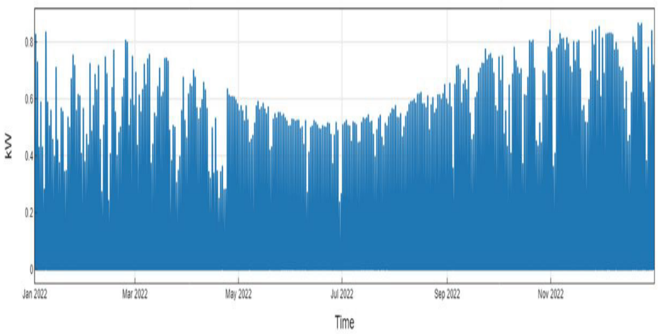
The online tool "Renewables.ninja" was used to calculate the potential hourly electricity generation from PV systems at the location of the Nukubati Great Sea Reef Resort. The tool considers weather information and data, particularly solar irradiation, and converts these into electricity generation using the GSEE model (Global Solar Energy Estimator) (see Pfenninger and Staffell, 2016). The chosen coordinates correspond to the location of the resort, and the optimal tilt and azimuth angles were calculated based on these coordinates. They are listed in the table below.

Illustration 3 Solar Potential of Nukubati Great Sea Reef Resort

Coordinates (Lat., Long.)	-16.463846, 179.020674
Tilt angle	18,3 °
Azimut angle	0 ° (Geographic north)

The following illustration demonstrates the specific PV potential over the course of a year. The annual potential amounts to 1,521 kWh/kWp, with peak production occurring in the winter months and reaching up to 0.87 kW/kWp.

Illustration 4 Annual Solar Potential for Nukubati Great Sea Reef Resort



2.2. Site-Specific Input Parameters

Since the Nukubati Great Sea Reef Resort operates off-grid, there is already a mini-grid powered by a solar system and a diesel generator for supplying the hotel complex. The already installed energy system components were considered in the simulation and are listed in the following table. The data is based on information provided by the resort. The diesel price was also transmitted by the resort operators. For financial calculations, the MVS also requires the weighted average cost of capital (WACC), which is based on an analysis by the Asian Development Bank for Fiji.

Illustration 5 Input Parameters for Nukubati Great Sea Reef Resort

Parametre	Unit	Value	Source
Weighted average cost of capital (WACC)	%	6,04	Alpha Spread, verifiziert von Resort1
Diesel price	EUR/l	1,46	Resort
Installed Diesel Generator	kW	62,5	Resort
Installed PV	kWp	86	Resort
Installed Battery Storage	kWh	110	Resort
Installed Inverter	kW	35	Resort

3. Summary of Results

The Nukubati Great Sea Reef Resort would benefit from the addition of hydrogen technology as a long-term or seasonal storage solution. The cost of electricity generation could be reduced by 42% compared to the status quo. The break-even point would be reached after about 7 years. The cost-minimizing system involves a combination of PV and diesel power generation, with solar power production being dominant. The battery storage in combination with the hydrogen storage is central to balancing short-term and long-term fluctuations and ensuring energy security.

The results for three calculated scenarios are summarized below. The following table lists the energy system components and the capacities required for each scenario. The total capacities required for each scenario can be found as the first value in the respective cells, while the second value (in the case of existing infrastructure) represents the additional capacity calculated as optimal by the MVS for the respective scenario.

Illustration 6 Evaluation Nukubati Great Sea Reef Resort

Component (Unit)/Scenario	Dieselgenera-tor (kW)	PV (kWp)	Battery Storage (kWh)	Electrolyzer (kW)	Fuel Cell (kW)	Hydrogen Storage (kg H2
Status quo	62,5/-	86/-	110/-	-	-	-
Cost Minimi-zation	- /4*	138/52	201/91	31	6	13
100 % RE (PV, H2)	- /-	228/142	110/-	97	16	62
100 % RE (PV, Bat,H2)	-/-	151/65	278/168	26	5	46

**Note: This is not the additional diesel generator capacity required, but the remaining necessary capacity for the scenario*

In addition to design parameters, economic indicators such as the cost of electricity generation, total investment costs, and initial investment costs at project start are important and must be considered in the analysis of the various scenarios, as well as the resulting renewable energy shares, surplus electricity, and CO2 emissions. Another important indicator is the break-even point, which compares the status quo with the investment costs including the operation and maintenance costs of the other scenarios, indicating how many years of operation of the energy system it takes for the initial investments to pay off. These parameters are summarized in the following table and Illustration 7 visualizes the calculation of the break-even point.

Illustration 7 Scenario Parameters for Nukubati Great Sea Reef Resort

Component (Unit)/Scenario	LCOE (€/kWh)	RE-Share (%)	Net Present Value (NPV) (€)	Initial Investment Costs (€)	Operation/ Maintenance Costs (€/year)	Break Even Point (years)	Surplus Electricity (MWh/year)	CO2 Emissions (kgCO2eq/year)
Status quo	0,25	46	356.953	0	26.781	-	48,3	43.366
Cost Minimization	0,15	93	206.258	117.777	7.063	7	25,1	4.441
100 % RE (PV, H2)	0,21	100	294.396	250.853	5.817	13	80,0	0
100 % RE (PV, Bat,H2)	0,19	100	264.846	192.406	5.500	10	43,5	4.854

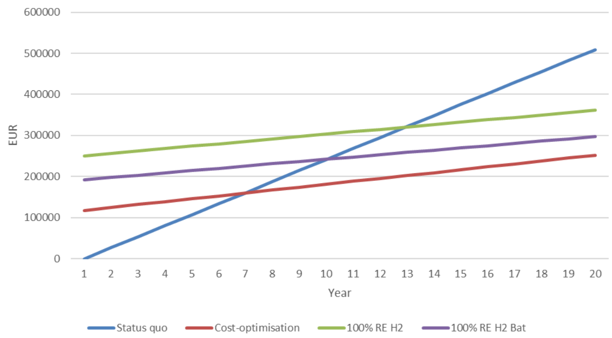
Compared to other off-grid projects, the electricity generation costs are very low, ranging from 0.15 to 0.25 EUR/kWh, as the Nukubati Resort already has a solar system, battery storage, inverters, and a diesel generator, which keep the initial investment costs and hence the electricity generation costs low.

Compared to the status quo, the cost of electricity generation can be significantly reduced in the cost minimization scenario. The initial investment costs for installing additional PV modules, enhancing battery storage, and adding hydrogen components in the cost-minimized scenario amount to 118,000 EUR, with the break-even point being reached after seven years. In the 100% Renewable Energy scenario (PV and hydrogen technology), the break-even point is reached after 13 years.

In each scenario, there is a significant reduction in CO2 emissions, despite the already high share of renewable energies in the system (at 92%, well above the national average). However, the surplus electricity generated in this case study cannot be fed into the grid, as the resort is in an off-grid area. However, this could be used to operate the (already installed but seldom used) seawater desalination plant, which could produce both water for hydrogen production and drinking water for the resort and sale.

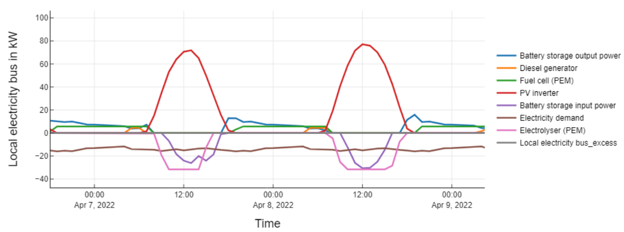
In each scenario, ideally, it involves a closed hydrogen cycle; assuming a 'worst case' scenario with a water demand of 9 litres per kilogram of hydrogen produced, this would result in a water quantity of about 13,266 litres per year (approximately 36 litres per day) in the cost-minimized scenario. Analogously, for the 100% renewable scenario (PV, battery storage, and hydrogen technology), 11,376 litres per year (approximately 31 litres per day) would be needed, and for the 100% Renewable scenario without battery storage, 35,541 litres per year (approximately 97 litres per day) would be needed.

Illustration 8 Visualization of the Break-Even Point Calculation



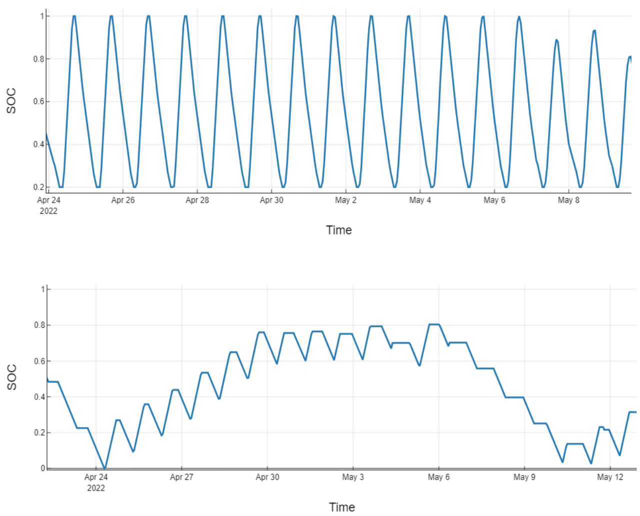
The following illustrations are excerpts from the MVS result page and provide insights into the functioning of the optimized energy systems. First, the energy flow of the system, including all components, is shown over three days for the cost-minimizing scenario in Illustration 9. During the day, the electricity demand (see the brown line, Electricity demand) is mostly covered by the solar plant (see the red line, PV inverter), with the demand at night initially covered by the battery (blue line, battery storage output), then the fuel cell (green line) adds to the supply just before sunrise, followed by the diesel generator (orange line). With lower solar irradiation, the use of the diesel generator and fuel cell generally increases. Besides serving the electricity demand, the solar plant charges the batteries during the day and allows the electrolyser to produce hydrogen.

Illustration 9 Visualization of the Break-Even Point Calculation



To analyse and compare the different operating characteristics and functions of the two storage technologies (battery and hydrogen) more closely, the respective storage levels over a period of one week are shown below. While the battery storage (first image) follows about the same pattern every day (charging during the day, discharging at night), the fluctuations in the hydrogen storage (lower image) are less pronounced. Especially on May 7 and the following days, the functional distinction between the two storage technologies can be observed. While the battery storage compensates for strong day/night fluctuations in the short term, the hydrogen storage comes into play when solar irradiation is lower over entire days, thus reaching a critical charge state of the battery storage. Now, the hydrogen storage steps in, and the stored hydrogen is re-electrified through the fuel cell. Therefore, hydrogen technology can be beneficial for this application example as a long-term and seasonal storage for the system.

Illustration 10 State of Charge (SOC) of the Battery Storage (top) and the Hydrogen Storage (bottom) Over a Week



4. Sensitivity Analysis

4.1. Diesel Price

First, the influence of the diesel fuel price on the simulation results was examined. With a diesel price of 1.46 EUR/L for this case study in Fiji, the following changes in the diesel price occur for the various sensitivity cases (25% and 50% higher and lower diesel prices):

- +50% => 2.19 EUR/L
- +25% => 1.83 EUR/L Status Quo = 1.46 EUR/L
- -25% => 1.01 EUR/L -50% => 0.73 EUR/L

Simulated in the MVS for the cost-minimizing scenario, the results visualized in the following graphic emerge. Displayed are the capacities of the respective system components to be installed in addition to the existing system. The reference scenario (cost minimization) is shown in green (in the centre) for comparison.

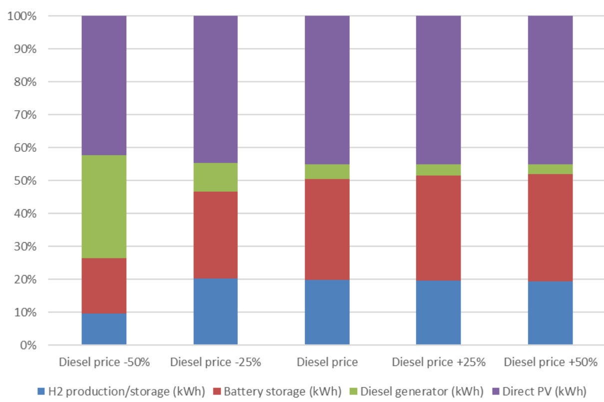
Illustration 11 Optimized Additional Capacities of Individual Technologies at Diesel Price Fluctuations

The construction of new local hydrogen and electrolyser technology is recommended for cost minimization in all cases according to the sensitivity analysis. Except for the (unlikely) case of very sharp declines in fuel prices, the installed capacity remains at a relatively constant level. Aside from the -50% sensitivity case, a strong expansion of the existing battery capacities is also recommended. These increase—in line with the diesel price—up to a doubling of the currently available capacities (110 kWh) in the most expensive price regime. Significant savings potential exists according to the model also through an addition of solar capacity. This is thus recommended for cost optimization already from a diesel price 25% below today's level. Overall, the composition of the energy system fluctuates less with price increases than with price reductions.

That the sizing of hydrogen technology remains largely unaffected by fluctuations in diesel fuel prices is due to the function of hydrogen technology as long-term storage. In contrast, the battery storage, which compensates for short-term fluctuations, is more strongly influenced using the diesel generator.

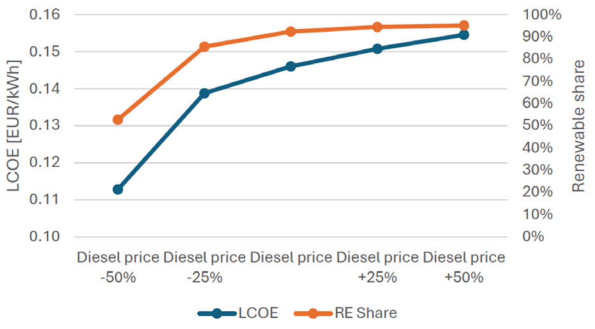
The following illustration graphically represents the percentage share of individual system components in covering the electricity demand. "Direct PV" refers to the PV electricity that is fed directly into the system without being directed to the battery storage or the electrolyser for hydrogen production.

Illustration 12 Share of Electricity Demand Coverage at Diesel Price Fluctuations



Here too, it is clear that the hydrogen components, as well as the direct PV electrification and battery storage feeding, remain largely unaffected by diesel price fluctuations. With a 50% reduction in the diesel price, the use of diesel for electricity generation increases significantly, while both storage technologies accordingly contribute less to the power supply. As the last illustration of this sensitivity analysis, the development of electricity generation costs and the share of renewable energy in the system is visualized.

Illustration 13 Development of Electricity Generation Costs and Renewable Energy Share at Diesel Price Fluctuations



The electricity generation costs (LCOE) fluctuate between 0.11 - 0.15 EUR/kWh. In the case of permanently low fuel prices, the attractiveness of the existing generator infrastructure increases, and the LCOE moves at a relatively low level. As a result of moderate price increases (from -50 to -25%), the LCOE and the cost-minimizing shares of renewable energy carriers increase significantly, highlighting the vulnerability of a diesel-based energy system to external shocks (higher oil prices). The share of renewable energy in the system ranges from 53% to 95% (the higher the diesel costs, the higher the renewable energy share).

Investment Costs for Hydrogen Technology

For calculating sensitivities regarding fluctuations in investment costs in hydrogen technology, price increases and decreases of 25% and 50% were also assumed. This results in the following changes in CAPEX costs:

Hydrogen storage (original price at 350 EUR/kg):

- +50% => 525 EUR/kg
- +25% => 438 EUR/kg
- -25% => 263 EUR/kg
- -50% => 175 EUR/kg

Electrolyser (original price at 610 EUR/kW):

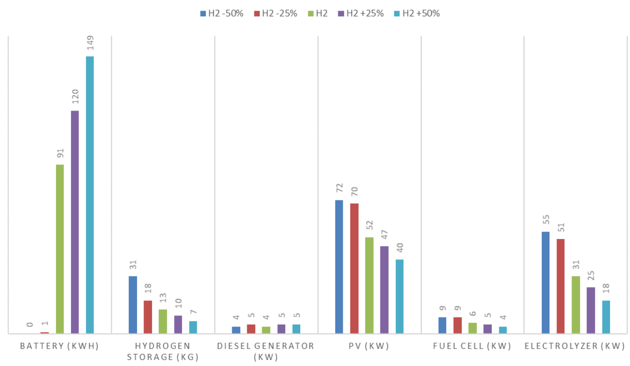
- +50% => 915 EUR/kW
- +25% => 763 EUR/kW
- -25% => 458 EUR/kW
- -50% => 305 EUR/kW

Fuel Cell (original price at 870 EUR/kW):

- +50% => 1.305 EUR/kW
- +25% => 1.088 EUR/kW
- -25% => 653 EUR/kW
- -50% => 435 EUR/kW

Analogous to the sensitivity analysis of diesel prices, the development of the capacities of individual system components at price fluctuations of the investment costs of hydrogen components is illustrated. Here too, the reference scenario (cost minimization) is shown in green.

Illustration 14 Optimized Additional Capacities of Individual Technologies at Fluctuations in Hydrogen Investment Costs



When prices for hydrogen components decrease by 25% or more, the additionally to be installed battery storage capacities become insignificant. If the investment costs increase, the additionally to be installed PV capacity decreases and the battery storage becomes larger. If the prices for hydrogen components rise compared to the current price, a larger battery storage and a larger diesel generator capacity are required.

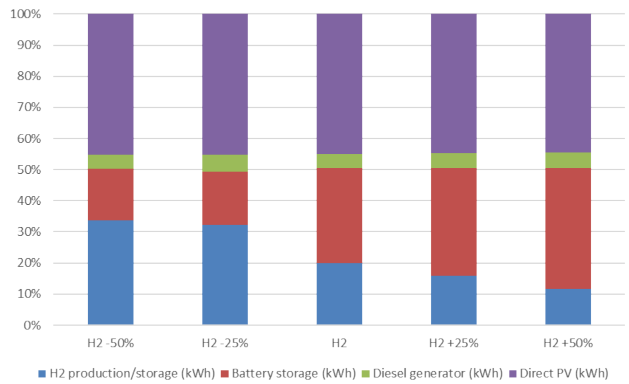
With rising hydrogen technology costs, the additionally to be installed capacity of the PV system decreases, while the battery storage and diesel generator need to be sized larger.

This is the case because the hydrogen storage is significantly reduced, and thus fluctuations in the system must be compensated more through the battery storage and the use of the diesel generator. The hydrogen storage is primarily filled by surplus electricity from the solar plant, which is why it can also be sized smaller with rising hydrogen technology costs.

Overall, it can be said that especially the interplay of battery storage and hydrogen technology is influenced by price fluctuations in hydrogen technology and corresponds accordingly. The cheaper the hydrogen technology, the greater its role in balancing load and power production fluctuations, and this is reflected in the capacities to be installed.

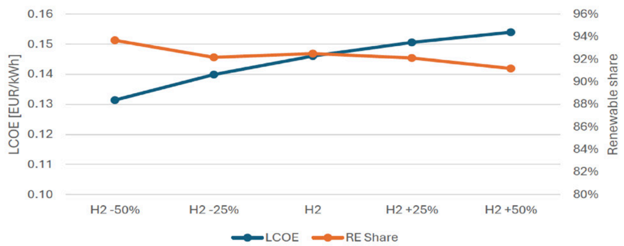
This is also clear from the following illustration: The share of direct electrification (from the PV system and the diesel generator, without intermediate storage) remains largely constant at varying investment costs of hydrogen components, while the share of power supply from the hydrogen storage is gradually replaced by the battery storage at rising investment costs or increases at decreasing costs.

Illustration 15 Share of Electricity Demand Coverage at Fluctuations in Hydrogen Investment Costs



Fluctuations in hydrogen technology prices initially have a minor impact on the resulting electricity generation costs and the share of renewable energy in the system. This can be explained in this case study by the currently relatively small size of the hydrogen system compared to the solar plant and the battery storage. The fluctuations in electricity generation costs are between 0.13 - 0.15 EUR/kWh, and the renewable energy share is between 91% - 94%.

Illustration 16 Development of Electricity Generation Costs and Renewable Energy Share at Fluctuations in Hydrogen Investment Costs



Conclusion

The Nukubati Great Sea Reef Resort would benefit from the addition of hydrogen technology as long-term or seasonal storage, as well as additional PV and battery storages in its mini grid. The optimized system of PV, battery storage, hydrogen technology, and diesel generator would reduce electricity costs by 42%. Both 100% Renewable Energy scenarios include the application of hydrogen technology and promise a cost reduction compared to the status quo. Diesel price fluctuations have only a minor impact on the energy system design; only at a diesel price reduction of -50% does the design change significantly.

This is related to the already high share of renewable energies in the cost-minimized system: When there is little diesel in the system, price fluctuations have a lesser impact on the system sizes. In all sensitivity cases, hydrogen technology plays a role, but the optimized size decreases significantly when diesel prices fall by 25% or more. The battery storage capacity is most strongly influenced by varying CAPEX for hydrogen technology and increases with rising prices. A combination of battery storage and hydrogen technology is chosen, where the share of battery storage correlates with the CAPEX for hydrogen technology.

To be continued in the next issue:

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Powering the Pacific : The Cost Implications of Renewable Energy

Laure Darcy - SOE Reform / PPP Team Leader, Pacific Private Sector Development Initiative (PSDI
David Ling - SOE Reform / PPP Analyst, PSDI
Denzel Hankinson - CEO, DH Infrastructure

Pacific island countries are increasingly investing in renewable energy to improve their energy security, increase sustainability, and reduce energy production costs. In some cases, they have set ambitious targets of 100% renewable energy generation, requiring a wholesale transformation of generation infrastructure. As policymakers consider options for making these investments, their impact on the overall cost of generation is a key concern.

This paper outlines how transitioning from fossil fuels to renewable energy sources can impact the cost of power generation and resulting tariffs for consumers. This policy brief focuses on energy utilities in six of the 14 Pacific developing member countries (DMCs) of the Asian Development Bank (Box 1).[1] It addresses the question of whether and how the increasing use of renewable energy can help governments bring down the cost of electricity to consumers while noting the distinction between the cost of supply and the tariffs charged to consumers, as tariffs can be impacted by regulatory compliance, subsidy arrangements, or other government directives.[2]

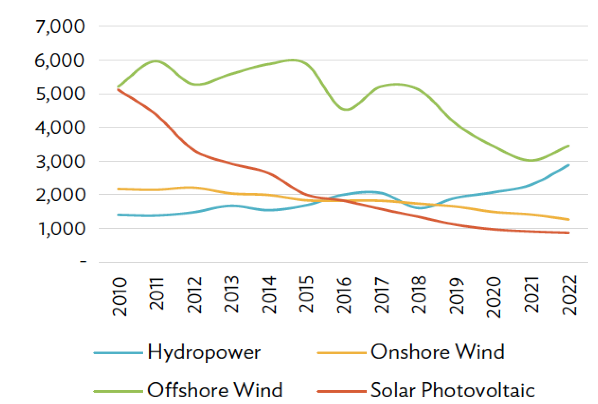
Globally, renewable energy generation infrastructure costs have decreased, particularly solar photovoltaic (PV), whose installed costs have dropped more than fivefold since 2010 (Figure 1). Given that the fuel costs of renewable energy plants are effectively zero, the global levelized cost of renewable energy has also come down during this period, and by 2022, solar photovoltaic and onshore wind had lower levelized costs than energy generated by fossil fuels (Figure 2).[3]

Box 1: Pacific Utilities Reviewed

Fiji: Energy Fiji Limited (EFL)
Palau: Palau Public Utilities Corporation (PPUC)
Papua New Guinea: PNG Power Limited (PPL)
Samoa: Electrical Power Corporation (EPC)
Solomon Islands: Solomon Power (SP)
Tonga: Tonga Power Limited (TPL)

Source: Pacific Private Sector Development Initiative.

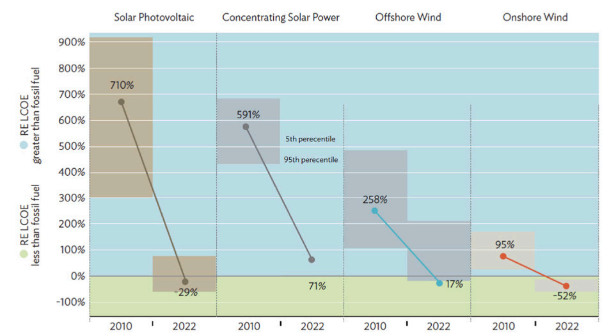
Figure 1: Total Installed Cost of Renewable Power Generation ($/kW)



Source: International Renewable Energy Agency. 2023. *Renewable power generation costs in 2022.* https://www.irena.org/Publications/2023/Aug/Renewable-power-generation-costs-in-2022.

Falling costs globally are reflected in the Pacific, where the total installed cost of solar PV systems fell from about $12,000/kilowatt (kW) in 2008 to $3,000/kW in 2018.[4] Key factors affecting installed costs include scale, location, and footing type (rooftop, concrete, or piled), as well as the need for fencing, civil works, and any requirements to bring in soil and repair and/or upgrade infrastructure. Installed costs for solar PV systems with battery storage systems (BESS) also fell to $5,000–$8,000/kW in 2018.

Figure 2: Change in Competitiveness of Solar and Wind Compared to Fossil Fuel 2010–2022



LCOE = levelized cost of energy, RE = renewable energy
Notes: Figures based on global weighted average levelized cost of energy.
Source: International Renewable Energy Agency. 2023. *Renewable power generation costs in 2022.* https://www.irena.org/Publications/2023/Aug/Renewable-power-generation-costs-in-2022

It follows that Pacific policymakers expect generation costs to come down as utilities replace diesel and heavy fuel oil generators with solar, wind, biomass, and hydro. A moderating factor in this dynamic is the increasing need for BESS as the

1 The 14 Pacific developing member countries of the Asian Development Bank are Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Republic of the Marshall Islands, Nauru, Niue, Palau, Papua New Guinea (PNG), Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu.
2 All of the utilities reviewed for this policy brief are majority state-owned, which in practice has facilitated non-commercial practices, including tariff setting.
3 Levelized cost of energy is measured as the average cost per unit of energy generated across the lifetime of a new power plant.
4 Pacific Regional Infrastructure Facility. 2019. Renewable Energy Costs in the Pacific. Collation of renewable energy infrastructure project cost data in the Pacific. March. p.1.

percentage of renewable energy in a country's total energy mix increases. These batteries are required to smooth the intermittent nature of solar, wind, and some hydro and can also be used to power the grid for periods of time. Battery costs have historically added 100% or more to the total cost of renewable energy installations globally but have started to decrease, a trend that is expected to accelerate.[5]

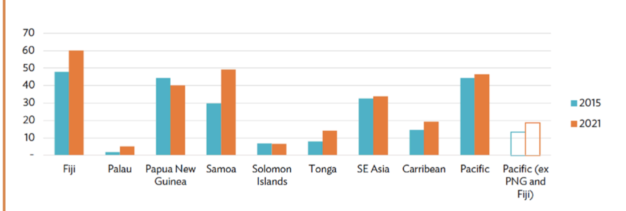
This paper is organized into five sections. Section 1 provides an overview of the current energy generation mix and renewable energy targets of six Pacific countries: Fiji, Palau, Papua New Guinea (PNG), Samoa, Solomon Islands, and Tonga. Section 2 outlines the structure of electricity service costs in the six countries, to illustrate the contribution of generation costs. Section 3 looks at the relationship between electricity service costs and tariffs in the six countries, to explain why they may differ. Section 4 outlines what Pacific countries can do to further reduce their levelized cost of electricity, and Section 5 looks at the role that generation planning can play in this strategy.

SECTION ONE: PACIFIC ENERGY GENERATION MIX

Most countries in the Pacific remain heavily reliant on imported fossil fuels to generate electricity. Of the 14 developing economies in the region, only three had 40% or more of their total electricity produced by renewables in 2021.[6] Those with the largest share of renewable energy generation—Fiji and Papua New Guinea (PNG)— are also the largest generators of electricity in the region, accounting for approximately 83% of the electricity produced across the region in 2021. Their hydroelectric plants—commissioned before 2012—accounted for up to 88% of their renewable energy output in 2015 and 2021.[7] In the remaining 12 countries, diesel accounted for 81% of the electricity generated in 2021. This is roughly comparable to the Caribbean but is higher than Southeast Asia, which generated 66% of its electricity from fossil fuels in 2021 (Figure 3).

The Pacific region has been slower in making renewable energy investments than other parts of the world. While 10 of the 14 ADB developing member countries of the Pacific have increased their renewable share of electricity generation since 2015, the pace of this uptake has been much slower than in Southeast Asia or the Caribbean (Figure 4). From 2013 to 2021, Southeast Asia increased its total renewable energy generation by 68% and the Caribbean region by 71%, slightly outpacing demand growth. The Pacific region increased its total renewable energy generation by only 1%. Recent solar investments in Palau and Tonga will increase the contribution of renewables in these countries; however, the Pacific region continues to lag behind the rest of the world in terms of the pace of its energy transition. The lag can be attributed to a combination of factors, including remoteness, high transition costs, weak regulatory frameworks, and limited availability of land.

Figure 3: Renewable Energy Share of Electricity Generation (2015–2021) (%)

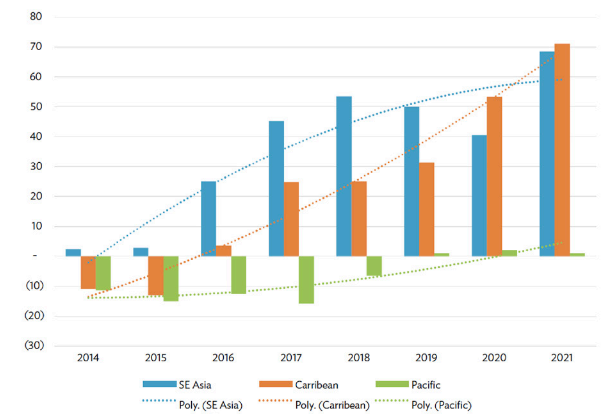


PNG =Papua New Guinea, SE = Southeast

Note: The increase in renewable energy share in the Pacific over the period is largely accounted for by Fiji, which saw a rise of 12% of its renewable energy share and 34% of total renewable energy generation in the region. This 12% increase in Fiji is due to the unusually low contribution of hydroelectric generation in 2015 (48%) due to drought, where it historically averaged 60%. The increase is not due to new investment in renewable energy capacity over the period.

Source: International Renewable Energy Agency. 2023. *Renewable Energy Statistics 2023*. https://www.irena.org/Publications/2023/Jul/Renewable-energy-statistics-2023.

Figure 4: Comparison of Renewable Energy Generation versus 2013 Baseline (%)



Poly = polynomial trend, SE = Southeast, vs = versus

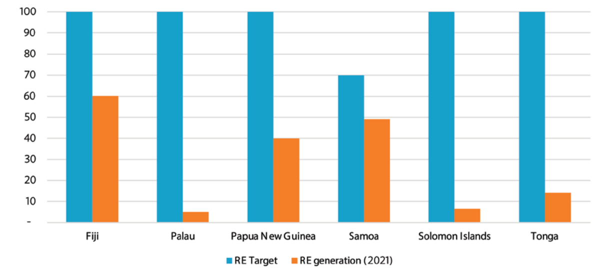
Source: International Renewable Energy Agency. 2023. *Renewable Energy Statistics 2023*. https://www.irena.org/Publications/2023/Jul/Renewable-energy-statistics-2023.

The low penetration of renewable energy in most countries of the Pacific has meant that electricity costs remain highly sensitive to movements in oil prices. To accelerate the transition, governments in the Pacific have set renewable energy generation targets, provided financial support mechanisms, and, in some cases, passed laws that require compliance action (Figure 5). Five of the six countries reviewed in this paper have set renewable energy targets of 100%, which they are now working to meet, subject to the availability of land, financing, and the continued reduction in BESS costs[8].

This paper focuses on how this transition can impact the total cost of electricity service provision. The following section outlines the structure of electricity service costs, particularly the relative weighting of each fuel in the mix, which is the primary source of cash savings when transitioning to renewable energy.

5 According to the United States National Renewable Energy Laboratory, capital costs for 2- to 6-hour battery systems will fall about 40% by 2030, with much of the decline in 2024–2027
6 Fiji, PNG, and Samoa.
7 International Renewable Energy Agency. 2023. Renewable Energy Statistics 2023 and International Renewable Energy Agency. 2023. Energy Profile: Papua New Guinea.
8 The need for a battery storage system (BESS) increases as the percentage of renewable energy in the total generation mix increases. In 2023, the need for BESS made the average levelized cost of energy (LCOE) of renewable energy globally about equal to non-renewable. Tonga is an exception to this global average, as solar + BESS had a lower LCOE than diesel in 2023.

Figure 5: 2021 Renewable Energy Generation versus Targets (%)



RE = renewable energy

Sources: Global Green Growth Institute. 2022. Tonga Adopts Policies to Achieve NDC Targets and Renewable Energy Goals. News release.23 September;

Government of Fiji. 2020. Fiji's Updated Nationally Determined Contribution. https://unfccc.int/sites/default/files/NDC/2022-06/Republic%20of%20Fiji%27s%20Updated%20NDC%2020201.pdf

Government of Samoa. 2023. *Energy Sector Plan Fiscal Years 2023/24 to 2027/28.* https://www.mof.gov.ws/wp-content/uploads/2023/12/Energy-Sector-Plan-2023-2028-English-Version-1.pdf;

Government of Solomon Islands. 2022. Solomon Islands Renewable Energy Roadmap Launched. News release.22 July. https://solomons.gov.sb/solomon-islands-renewable-energy-roadmap-launched.

International Renewable Energy Agency. 2022. *Republic of Palau: Renewable Energy Roadmap, 2022–2050.* https://www.irena.org/publications/2022/Jun/Republic-of-Palau-Renewable-Energy-Roadmap; and

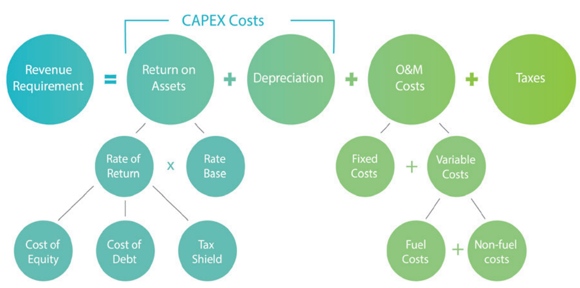
United Nations Development Programme. 2020. Promoting Renewable Energy in Papua New Guinea. News release14 July. https://www.undp.org/papua-new-guinea/press-releases/promoting-renewable-energy-papua-new-guinea.

SECTION TWO: STRUCTURE OF ELECTRICITY SERVICE COSTS

The costs of electricity service are driven by the activities required to produce and deliver it to customers. These include the costs of generation, transmission and distribution, administrative activities associated with customer billing and communications, and regulatory compliance. The costs include capital expenditure (CAPEX), operation and maintenance (O&M), financing (the cost of borrowing or raising equity capital), depreciation, and taxes.

Utilities seek to recover their service costs through the tariffs they charge customers. Tariffs are informed by a utility's "revenue requirement," the revenue it needs to cover its costs. Figure 6 shows the principal building blocks used to estimate a utility's cost of service. Utilities and utility regulators worldwide may use slightly different methodologies to calculate each block, but the overall approach is the same.[9]

Figure 6: The Building Blocks of Utility Costs



CAPEX = capital expenditure, O&M = operations and maintenance
Source: Authors.

2.1 Cost Components of Electricity Service

The remainder of this section describes each cost component of electricity service. Data from six Pacific utilities illustrate the magnitude and structure of each component, and the potential role of renewable energy generation in reducing those costs.

Table 1: Comparison of US Generation Capital Expenditure Costs 2022

Technology	Capital Expenditure ($/kilowatt)	
	Minimum	Maximum
Land-Based Wind	1,027	1,700
Offshore Wind	3,285	5,908
Utility Photovoltaic	1,000	1,333
Battery Storage System for Solar Photovoltaic[a]	1,160	1,294
Hydropower	2,574	16,238
Diesel	1,000	1,300
Coal	3,075	5,505
Natural Gas	922	2,324

[a] Battery storage system (BESS) cost assumes four hours of lithium-ion storage capacity.

Sources: Diesel costs are based on a literature review of various industry sources.

Wind costs are based on R. Davidson. 2023. US Unsubsidised Onshore Wind LCoE Jumps by Nearly 40%. Windpower Monthly. 26 May. https://www.windpowermonthly.com/article/ 1824371/us-unsubsidised-onshore-wind-lcoe-jumps-nearly- 40.

Utility photovoltaic plus BESS costs are based on forecast values for 2022 from W. Cole, A. W. Frazier, and C. Augustine. 2021. Cost Projections for Utility-Scale Battery Storage: *2021* Update.Renewable Energy Laboratory. https://www.nrel.gov/docs/fyosti/2179236.pdf.

All other costs are from the National Renewable Energy Laboratory. 2022. *2022* Annual Technology Baselinehttps://atb.nrel.gov/

2.1.1. Capital Expenditure Costs

A utility's CAPEX costs include generating plants, transmission lines, transformers, and distribution lines and poles. CAPEX costs are driven by the number of customers served, the geographical scope of the utility's service area, the topographical and climate conditions in the service area, and the type of fuels available for electricity generation. Table 1 compares generation CAPEX costs for different technologies in the US in 2022.

Total CAPEX costs for Pacific utilities are lower than in many other parts of the world, but unit costs (e.g., $/kW of generation or $/kilometer of distribution) are typically higher. The utilities' relatively smaller distribution networks, fewer customers, and—in some countries—the absence of a need for high voltage transmission—as distances between generation and consumption are relatively short—result in lower total costs. Unit costs, however, are often higher because of the need to climate-proof or disaster-proof certain investments and build distributed generation or isolated grids to serve customers in remote islands in some countries, such as Palau, PNG, Solomon Islands, and Tonga. The remoteness of many Pacific countries also means higher shipping costs, which will be rolled into the overall cost of any investment.

Most utilities in the Pacific finance CAPEX through debt or from tariff revenue. Much of the debt is on-lent by governments through their ministries of finance (or equivalent) and sourced from international development partners at concessional rates. Some utilities—such as Energy Fiji Limited—are partially

9 This approach is often referred to as the "building block" approach in Oceania (Australia, New Zealand, and the island countries of the Pacific Ocean) or the "rate-of-return" approach in North America. Some jurisdictions—especially those where the utility relies 100% on debt financing—favor a "cash-needs" approach which substitutes principal and interest payments on debt for depreciation and return on assets.

10 Pacific Power Association. 2022. Benchmarking Report: 2021 Fiscal Year. https://www.ppa.org.fj/wp-content/uploads/2023/10/2021-Benchmarking- Report-for-Pacific-Island-Countries-and-Territories-Power-Utilities-FINAL.pdf Data were not reported for PNG Power Ltd, but calculating the debt-to-equity ratio from their balance sheet indicates a ratio of 72%.

owned by private companies and thus have investors who have contributed equity. Publicly-owned utilities also receive some equity from their government owners. Capital structure is an indication of how a utility finances CAPEX. The debt-to-equity ratios of five of the six utilities in this study range from 16% (Solomon Power) to 165% (Tonga Power Ltd [TPL]), with an average of 69.2% across four utilities.[10] These numbers indicate that companies like Solomon Power fund more of their CAPEX from tariff revenue, while TPL relies much more on debt financing. Many Pacific utilities also benefit from grants provided by international development partners.

The total value of a utility's fixed assets at any point in time is referred to as the "rate base." The rate base is a key determinant of utility tariffs. The value of the rate base is driven by the cost of assets and the age of those assets. The asset's age matters because assets deteriorate over time, and with that deterioration, they lose their ability to function. This physical deterioration is known as depreciation and must accordingly be reflected as an accounting cost through an annual depreciation charge and a decline in the utility's rate base.

Investors in a utility—whether they are lenders or equity investors—expect to earn a return of their original investment and a return on that investment. Depreciation is a return of the cost of the original investment over time; financing costs are the return on that investment over time. These components are discussed in sections 2.1.2 and 2.1.3 below.

2.1.2. Depreciation

Depreciation is used to allocate CAPEX costs over an investment's useful life; it is the accounting treatment needed to reflect the physical deterioration of assets. Annual depreciation costs are included in a utility's revenue requirement, while the same amount reduces the value of the rate base. The value of the rate base in any given year is the sum of the original CAPEX value of all assets, less the cumulative depreciation on those assets over time. The impact of depreciation on the revenue requirement depends on the age of the asset and which depreciation method is used.[11]

Many utility assets in the Pacific are near or beyond their estimated useful lives, yet they are still operating. This leaves open the question of what the depreciation charge should be assigned, if any. In such cases, the depreciation charge may be set at zero, and the asset may be excluded from the rate base, or it may make sense to have the assets revalued based on some other principle than the original accounting value or "book value."[12]

2.1.3. Financing Costs

Utilities often borrow from banks or raise funding from equity investors to pay for CAPEX. This allows them to spread the costs of the investments out over time; in exchange, the utilities agree to pay their lenders and equity investors a return additional to the value of the CAPEX. These are the utility's financing costs.

Cost of Debt

A utility's cost of debt is the rate of interest its lenders require to be paid in addition to repayment of the loan principal. The cost of debt in this sample of six utilities varies substantially, from 2% (Electric Power Corporation (Samoa) [EPC]) to 12% (PNG Power Limited [PPL]), with most in the range of 2%–4%.

Cost of Equity

A utility's cost of equity reflects the return investors can expect in the form of dividend payments and/ or changes in the value of shares held. For privately held utilities, equity investors' expected minimum returns on equity will reflect their opportunity costs and the perceived risk of that investment. For stateowned utilities, government shareholders often agree on a target return in the utility's corporate plan but tolerate deviations from this target in practice. In 2021, the returns on equity of the six utilities in this study ranged from −11.3% (Palau Public Utilities Corporation [PPUC]) to 7.0% (Energy Fiji Limited [EFL]), with an average of 0.6%.

A utility's cost of finance impacts the revenue requirement, and hence tariffs, through the "rate of return" on the rate base. The return on rate base is a weighted average of the cost of debt and cost of equity (the so-called Weighted Average Cost of Capital or WACC); it depends on the mix of debt and equity used to finance the assets and the returns expected on debt and equity. The utility rate baseis multiplied by the rate of return to determine the utility's overall financing costs.

2.1.4. Operation and Maintenance Costs

O&M costs in the electricity sector can be categorized as variable or fixed, depending on what factors cause the utility to incur them. Variable O&M costs correlate highly with electricity demand. The largest is typically fuel or electricity purchased from independent power producers (IPPs).13 Other variable costs (non-fuel O&M costs) typically include consumables such as lubricants, coolants, cleaning agents, and spare parts. Fixed O&M costs remain relatively constant, regardless of slight changes in electricity demand. Staff costs are one such example.

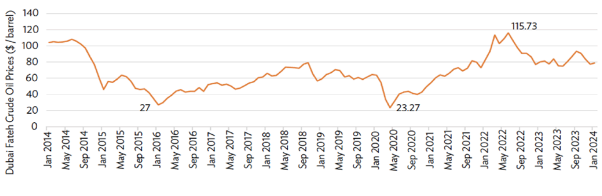
Fuel and fixed costs account for most O&M costs in the six power utilities surveyed. Fuel costs range from \$0.02 to \$0.21 per total kilowatt-hour (kWh) generated across the network, whereas fixed costs range from \$0.03 to \$0.24 per total kWh generated. IPP and renewable energy costs range from \$0.01 to \$0.04 per total kWh generated across the network.[14]

11 Straight-line depreciation is common, in which the asset depreciates the same amount every year during its useful service life. For example, a 20-year asset would depreciate at a rate of 5% per year. Some jurisdictions allow accelerated depreciation, or other depreciation schedules, primarily for tax purposes (because depreciation can be written off as a non-taxable expense).

12 Asset revaluation studies can, however, be time consuming and expensive, usually requiring substantial support from specialized consultants.

Most O&M costs are cash (i.e., costs requiring cash payments to vendors or suppliers), but some are not. Non-cash costs found on a profit and loss statement (P&L) include depreciation and "provisions," which are anticipated costs but for which the exact amount may not be known until some future date. An important provision for many utilities is a provision for bad debt, which is some amount the utility anticipates writing off because they know they will be unable to collect all of the amounts they bill customers.[15]

Figure 7: Volatility in Global Oil Prices (Nominal) 2014–2024



Source: Index Mundi. Crude Oil (petroleum); Dubai Fateh Monthly Price - US Dollars per Barrel. https://www.indexmundi.com/commodities/?commodity=crude-oil-dubai&months=120 (accessed 19 June 2024).

2.1.5. Fuel Costs

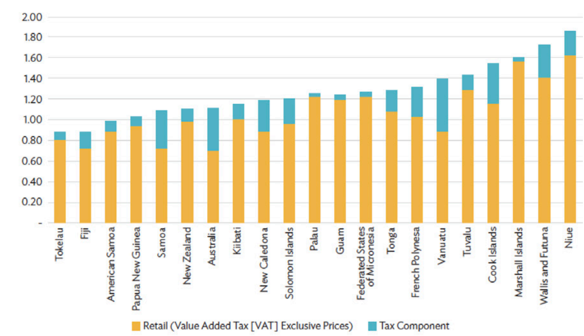
Fuel costs differ substantially by fuel type and generation technology used. Thermal power plants have much higher fuel costs than most renewable energy plants (except biomass) and much more unpredictable costs because the cost of hydrocarbon fuels varies with global and regional market fluctuations. Given the continued dependence on diesel generation in most Pacific countries, fuel costs remain the single largest cost component in electricity generation and the largest source of savings when diesel is replaced with solar, hydro, or wind.

Petroleum fuel imports are a substantial part of Pacific island economies. Fuel costs accounted for an average of 17.7% of imports in 2019/2016 and 7.5% of gross domestic product.17 Given that most Pacific countries (except PNG) do not have production or refining capabilities, the availability and affordability of oil imports are fundamental for energy security.

The global oil price is highly correlated to the price of industrial diesel oil and heavy fuel oil from Singapore. Shipping, distribution, taxes, and retail margins must be added to the base price to obtain each country's enduser price. Since the first oil crisis, global oil prices have fluctuated more wildly and unpredictably than before the 1970s. The last 10 years have been no exception, with 2024 prices reaching levels closer to those seen in 2014 (Figure 7).

Every oil-importing Pacific country shares the same base price, but import prices differ substantially because of transport costs. The base price consists of the Singapore price— reported by the Mean of Platts Singapore—for each defined product grade, a premium or discount to reflect any difference in the quality of the product purchased versus the quoted grade, and a trading premium reflecting a margin for the trader making the purchase.[18] The remoteness of Pacific countries from major production and refining means that fuel transport costs differ substantially from global commodity prices. Fiji is relatively well positioned in transport, receiving medium-range tankers at two ports, which then dispatch fuel to neighboring countries (including Tonga) via local coastal tankers. Samoa and Solomon Islands also receive medium-range tankers directly from Asia. PNG has refineries but also receives some medium-range tanker imports.[19] Figure 8 compares the retail prices for diesel in the Pacific in 2018 and shows that the more remote countries typically have higher diesel costs.

Figure 8: Average Annual Retail Prices for Diesel in the Pacific (2018) ($/liter)



Source: Pacific Community Pacific Regional Data Repository. 2018. *Pacific Fuel Price Monitor.* https://prdrse4all.spc.int/sites/default/files/pfpm_2018_final.pdf

Table 2: Main Categories of Non-Fuel Operation and Maintenance Costs

Categories of Operation and Maintenance Expenses	Examples of Common Sub-categories
Raw Materials and Services	Spare parts and supplies, power purchase costs, etc.
Staff	Wages and salaries, benefits, tax contributions, etc.
Repair and Maintenance	Routine maintenance, unscheduled maintenance
Other Operating Expenses	Cost of rent, advertising, insurance premiums, research, transportation services, etc.
Financing Expenses	Foreign exchange losses, bank fees

Source: Pacific Private Sector Development Initiative.

2.1.6. Non-Fuel Operation and Maintenance Costs

Non-fuel O&M costs are the ongoing costs of maintaining and operating utility equipment to deliver electricity. Table 2 shows the major categories of O&M costs.

The total non-fuel variable, IPP, and renewable energy costs are substantially lower than fuel and fixed costs in most of the six utilities surveyed. This is because renewable energy still makes up a very small proportion of energy generation in most Pacific countries. PNG Power Limited (PPL) is an exception to this trend, with non-fuel variable costs and IPP costs amounting to about $0.04 per kWh, while fuel costs represent only $0.02 per kWh. This is attributable to an abundanceof hydropower generation (roughly 40% of total electricity generated in 2021) and the comparatively lower fuel costs in PNG.

13 Whereas electricity purchases are typically regarded as variable costs, the nature of utility payments to independent power producers (IPPs) depend on how the power purchase agreements are structured. Most investors will not agree to develop an IPP without a "take or pay" or "minimum energy" arrangement. This means the utility pays a fixed cost per month for some agreed quantity of electricity, whether it ends up using the electricity or not.

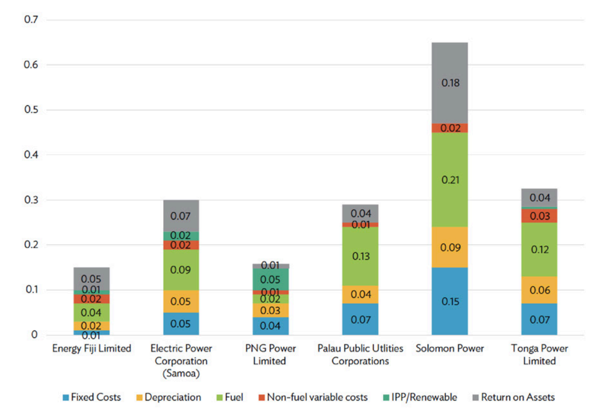
14 Offtake prices under power purchase agreements are higher than these figures as their denominator is only the kWh produced by each IPP, rather than the total kWh produced across the network

The cost benefits of renewable energy generation are evident in this sample of six utilities. For example, Samoa's EPC generated nearly 50% of its electricity from renewable sources in 2021, while Solomon Power had only 2% renewable energy generation. In 2021, EPC spent $0.09 per kWh on fuel, whereas Solomon Power spent $0.21 per kWh—approximately 136% more than EPC. Similarly, in terms of fuel costs per customer, EPC spent $381 per customer, while Solomon Power spent $863 per customer—127% more.

2.2 Summary of Cost Components and Indicative Impact of Renewable Energy

The six utilities in this sample have different cost structures, reflecting the composition and age of their power grid assets, relative efficiency, and sources of finance. Figure 9 shows the magnitude of each cost component within each utility's revenue requirement.[20]

Figure 9: Utility Cost Components 2021 ($/kWh)



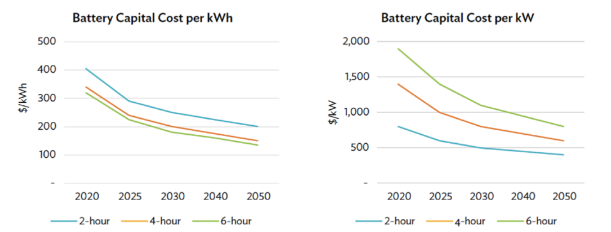
Note: Excludes taxes on profit.
Source: Pacific Private Sector Development Initiative.

O&M costs, including fuel, are the largest components of the utilities' total costs. Fuel represented between 16% (PPL) and 46% (PPUC) of the total costs of electricity service delivery in 2021 and fluctuated with the price of diesel. The utilities with the highest mix of renewable energy generation (EFL, EPC, and PPL) had the lowest fuel costs per kWh generated, and all had far lower costs than Solomon Power. Non-fuel O&M costs represented 25% (PPUC) to 56% (PPL) of total costs, with staffing being the largest contributor.

Solomon Power's overall costs per kWh generated were two to four times higher than the five other utilities surveyed in 2021. There are several contributing factors, one of which is the value of assets relative to the energy Solomon Power generates. Solomon Power needs approximately $2.09 in assets to produce one kWh of electricity. This is nearly twice what EPC needs (the next highest ratio) and five times PPL needs (the lowest). The higher the value of the asset base, the higher the depreciation value and the rate of return. The lower the number of kWh produced, the higher the unit costs shown in Figure 9.

As Pacific countries look to replace some diesel generation with renewable technologies, diesel fuel consumption will decrease. All other factors being equal, if the fuel savings exceed the CAPEX costs of the replacement renewable energy systems—including storage—then the total cost of electricity service delivery should decrease, and the levelized cost of energy (LCOE) of the renewable energy investment will be lower than that of the diesel generation that it replaces.

Figure 10: Projection of Battery Storage System Capital Costs



kW = kilowatt, kWh = kilowatt-hour
Source: National Renewable Energy Laboratory. 2021. *Cost Projections for Utility-Scale Battery Storage: 2021 Update.*

For most utilities in the sample group, renewable energy investments have been too small in recent years to have had a material impact on costs. Generation from renewables is still relatively minor in most countries, meaning that—even though solar, wind, or hydropower have lower operating costs—there is not enough generation from these sources to substantially reduce the overall cost of generation, most of which is still predominantly diesel-based. Section 3 describes other factors that may prevent or delay Pacific utilities from realizing the potential savings from renewable energy generation in the short term.

In PNG and Tonga, indicative cost impacts are available for at least two renewable energy investments. In PNG, the commissioning of the concessional-financed 10-megawatt Warangoi hydro plant reduced the consumption of fuel on the Gazelle grid by an estimated 3 million liters in the first quarter (Q1) of 2023, saving PNG Power an estimated 9 million kina (K) ($2.6 million) and allowing it to break even on the Gazelle grid for the first time in many years. In Tonga, a competitively tendered 6-megawatt solar IPP commissioned in Q4 2023 replaced approximately 433,000 liters of diesel consumption in Q1 2024.21 Projected out to a full year, it is expected that the 10,000 megawatt-hours generated by the solar IPP will reduce diesel consumption by 2.5 million liters, saving TPL an estimated 5.9 million pa'anga (T$) ($2.5 million) per year at 2024 diesel prices. Subtracting out the IPP cost of T$2.6 million results in a net savings of T$3.75 million ($1.75 million) per year, or 6.5% of its total cost of sales. The associated BESS were grant funded, so they have not added to the overall cost of the solar systems.

15 Provisions for bad debt are seen less frequently in some developing economy utilities either because they (i) use pre-paid meters, which collect payments before the electricity can be used; or (ii) do not follow proper accounting standards, anticipating that, at some point in time, delinquent customers will pay. Not following proper accounting standards inflates the value of the utility's assets with accounts receivable that will never lead to cash inflows.

16 Calculated with data from the Observatory of Economic Complexity for the countries of Cook Islands, Fiji, Kiribati, Federated States of Micronesia, Nauru, New Caledonia, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and Vanuatu for the yearof 2020.

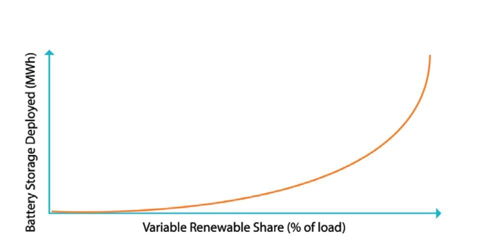
17 Calculated with data from the Pacific Data Hub for the countries of Cook Islands, Fiji, Kiribati, Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu.

per year, or 6.5% of its total cost of sales.The associated BESS were grant funded, so they have not added to the overall cost of the solar systems.

As the percentage of renewable energy added to each grid increases, so does the requirement to add battery storage capacity. Storage capacity is needed to "firm" or smooth the intermittent nature of solar, wind, and some hydro and power the grid for periods when renewable sources are unavailable. While battery system costs are decreasing and projected to decrease further (Figure 10), they do add exponentially to the marginal cost of renewable energy as the share of renewables nears 100% due to the substantial capital investments required to store more and more energy (Figure 11 and Figure 12). Therefore, utilities must carefully assess the marginal costs of reaching their 100% renewable energy goals to understand their potential impact on costs and resulting tariffs.

At a diesel cost of $1.00 per liter, the average marginal cost of dieselgenerated electricity is far higher than the marginal cost of renewable energy (Figure 12). However, as more renewable energy is installed—and with it more storage—the cost of implementing renewable energy increases. At very high renewable energy penetration levels, the marginal cost of renewable energy can exceed diesel generator marginal costs.

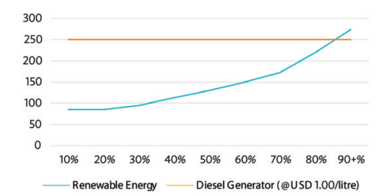
Figure 11: Phases of Battery Storage Systems Deployment on Island Power Systems



MWh = megawatt-hour

Source: Delphos. 2023. Developing Renewable Energy Storage Systems for the Pacific Island Countries.

Figure 12: Indicative Marginal Cost of Renewable Energy versus Diesel Generation for Varying Levels of Renewable Energy Penetration ($/MWh)



MWh = megawatt-hour

Note: Assumptions include $1.00 per liter of diesel, a blend of both solar and wind renewable energy sources, and increasing levels of BESS and/or overcapacity of renewable sources as penetration levels increase.

Source: Pacific Private Sector Development Initiative calculations based on actual and projected renewable energy generation cost data in Tonga and the Pacific more generally.

To be continued in the next issue:

18 Hale & Twomey. 2019. Fuel Use and Supply Security in Pacific Island Countries. Government of New Zealand, Ministry of Foreign Affairs and Trade. pp. 13–14.

19 Hale & Twomey. 2019. Fuel Use and Supply Security in Pacific Island Countries. Government of New Zealand, Ministry of Foreign Affairs andTrade. pp. 10–11.

20 All components of the revenue requirement were taken from utility financial accounts and/or annual reports for 2021. The exception is the allowed return on equity which was assumed to be 10% for all utilities.

21 Problems with inverters reduced the capacity factor of the plants down to approximately 12.7% in Q1 2024, so the kilowatt hours generated and diesel savings were approximately 65% of what was expected.

HDF Energy Inaugurates The World's First High-Power Hydrogen Fuel Cell Factory In Blanquefort, France

Ildo Agnetti
Business & Project Developer LVP Oceania Director Fiji - HDF Energy

Bordeaux, May 31th, 2024 – HDF Energy (Hydrogène de France) is proud to announce the inauguration of the world's first plant to manufacture 1MW+ fuel cells. This industrial site is dedicated to the decarbonization of heavy maritime and rail mobility, as well as the production of electricity for public power grids. With 80% of its production destined for export, the factory is also stimulating the local economy by creating jobs, thereby contributing to the reindustrialization and industrial sovereignty of Europe.

The plant was inaugurated on Thursday 30th May 2024 in Blanquefort (near Bordeaux, France) by Damien Havard, CEO and founder of HDF Energy, and Hanane El Hamraoui, Deputy CEO and VP Industry, in the presence of local public authorities.

International deployment of new uses for hydrogen

HDF Energy is a leading global player in the hydrogen industry, dedicated to developing large-scale hydrogen infrastructures and manufacturing high-power fuel cells. Following its IPO in 2021, the company has expanded internationally to some thirty countries.

With the strength of its 150 experts and its industrial site, HDF Energy is now able to deploy the new uses of hydrogen throughout the world: heavy maritime mobility, heavy rail mobility and the production of electricity for public electricity grids. 80% of the fuel cells manufactured at the plant will be exported.

Technology that meets the needs of global markets

HDF Energy's industrial site will produce fuel cells using PEM (proton exchange membrane) technology, which is already used in light mobility (cars and buses) worldwide: this technology is recognized for its efficiency, durability and technological maturity. PEM fuel cells are powerful, compact and emission-free, making them ideally suited to heavy mobility and electricity generation.

Towards zero-emission heavy mobility and the production of non-intermittent renewable electricity

HDF Energy's fuel cells are paving the way for a new era of environmentally friendly transport by replacing diesel engines in freight and shunting locomotives with a hydrogen propulsion system. They also offer an innovative solution for auxiliary power and ship propulsion, as well as supplying clean electricity to ships at berth.

What's more, the fuel cell is the most strategic component of the Renewstable® hydrogen power plants developed worldwide by HDF Energy. The fuel cells in these plants produce non-intermittent renewable electricity, day and night, thanks to massive storage of photovoltaic or wind energy in the form of hydrogen.

An ambitious industrial project, driving reindustrialization

HDF Energy has set up its 7,000 m² plant on the site of Ford's former gearbox manufacturing plant in Blanquefort, near Bordeaux (France).

HDF Energy's factory is part of the 'HDF Industry' project, a wide-ranging investment plan over several years aimed at developing and industrializing multi-megawatt fuel cells. To meet efficiency, durability and cost requirements, HDF Energy plans to launch successive R&D and industrialization programs for several product ranges from 1 to 10 MW.

From this summer, the plant will finalize its industrial process. In 2025, it will start the pre-production phase and the fuel cell test platform. Industrialization will begin in 2026, with the aim of producing 1 GW per year by 2030.

HDF Energy benefits from major public support. As early as 2018, the Nouvelle-Aquitaine Region provided financial support for the start-up of the company's fuel cell business. And, on 28 May 2024, the European Commission approved the financing of HDF Energy's industrial project by the French government as part of the Hy2Move wave of IPCEI hydrogen financing (Important Project of Common European Interest), dedicated to the reindustrialization of Europe.

An environmentally friendly factory

For its construction, the plant was awarded BREEAM 'very good' certification, an international standard for assessing the environmental impact of a building to promote greener architecture. This certification will be extended to the operation of the building. The criteria that will be monitored during operation of the plant are energy management, water management, waste recovery, access to sustainable transport and the health and well-being of occupants.

About hydrogène de france (HDF energy)

Hdf energy is a leading global player in the hydrogen industry, dedicated to developing large-scale hydrogen infrastructure and advanced multi-megawatt fuel cell technology.

These fuel cells generate electricity from hydrogen, driving the decarbonization efforts across the power generation, heavy maritime and rail mobility sectors. Set to commence mass production in 2025 at HDF Energy's facility near Bordeaux, these fuel cells serve as the cornerstone of the power plants and heavy mobility solutions developed by HDF Energy.

HDF Energy's Renewstable® power plants deliver non-intermittent renewable, stable and baseload power by seamlessly integrating intermittent renewable energy sources with substantial on-site energy storage in the form of green hydrogen. HDF Energy is also developing extensive infrastructure for the mass production of carbon-free hydrogen.

Backed by a team of over 150 hydrogen experts boasting more than a decade of operational experience across the value chain, HDF Energy is currently developing a portfolio of projects valued at over €5 billion.

Headquartered in France, HDF Energy has regional offices in Latin America, the Caribbean, Asia, Africa, and Oceania with 35+ nationalities among its staff. Since 2021, the Group has been listed on the Euronext Paris stock market, member of the Euronext Tech Leaders segment.

More information, visit: www.hdf-energy.com

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SEIAPI Facilitates Standards Workshop And Training For EFL Inspectors

Sandip Kumar
SEIAPI Secretary/ GSES Pacific Technical Officer - Sustainable Energy Industry Association of the Pacific Islands & Global Sustainable Energy Solutions

SEIAPI Secretary/GSES Pacific Technical Officer, Sustainable Energy Industry Association of the Pacific Islands & Global Sustainable Energy Solutions.

As part of their drive in enabling consistent and structured procedures on the overall grid connection process, SEIAPI approached the Fijian Solar Industry, Fijian Competition & Consumer Commission (FCCC) and Energy Fiji Limited (EFL) to create an open forum to deliberate on this important aspect.

A 1-day workshop was organised on Monday 15th July at USP Pacific TAFE, Statham Campus to provide an overview of the EFL and FCCC grid connected PV systems application process. The objective was to help the Fijian Solar Industry understand the process and provide the opportunity to ask question with representatives from EFL and FCCC. Geoff Stapleton, Executive Officer, of SEIAPI facilitated this one-day workshop. Geoff has been a member of relevant Australian Standards committees for over 30 years and has represented Australia on the International Electrotechnical Commission standards for 10 years.

The workshop provided an overview of the key requirements of AS/NZS 5033 and AS/NZS 4777 standards including an overview of the inspection check sheets that have been developed for inspectors by SEIAPI. The application requirements for grid connected PV systems and the licensing and approval process undertaken by FCCC and EFL respectively were presented by their representatives. The day finished with an open forum between SEIAPI members and non-members, EFL Inspectors/Planning and Regulatory staff and FCCC.

Group photo of EFL Inspectors and SEIAPI Representatives on Day 2

Presenters from EFL and FCCC during the Open Forum on Day 1

The 2nd day, Tuesday 16th July convened at Kinoya Depot Training Room where EFL Electrical Inspectors from all around Fiji gathered to gain fundamental knowledge on solar PV inspections and also to develop skills on completing Inspection checklists as part of commissioning grid connected PV systems. The Electrical Inspectors undertook a trial inspection of two grid connected PV systems at Fiji Ports site. This training was organised for the EFL Electrical Inspectors by SEIAPI to build capacity of Electrical Inspectors to inspect grid connected PV systems.

EFL Electrical Inspectors undertaking Training on Day 2

A similar one-day training was organised by SEIAPI for Electric Power Corporation (EPC) Inspectors and engineers in Samoa earlier this year. SEIAPI believes that inspecting systems to verify that the systems are safe and compliant helps promote renewable energy technologies. There are plans to provide more training to the Solar Industry stakeholders and Electrical Utility staff in the Pacific through donor funding support.

Acknowledgement

SEIAPI would like to acknowledge USP Pacific TAFE and Global Sustainable Energy Solutions (GSES, Australia) who assisted with the venue and refreshments respectively.

Guam's Energy Future Approaches

Guam Power Authority

The Guam Power Authority (GPA) continues progress on achieving its goals in addressing the island's energy capacity shortfall and remains committed to ensuring a stable and reliable power supply for Guam. GPA's broad approach and collaborative efforts with partners like Aggreko and Guam Ukudu Power demonstrate a strong commitment to moving energy on Guam into the future.

After the Ukudu Power Plant is commissioned, customers can expect a significant reduction in their power bills. The current rate of 26 cents per kWh will drop to about 13 to 16 cents, saving customers an average of $130 to $102 per bill (savings are highly dependent on the cost of fuel). This reduction is attributed to the retirement of Cabras and the adoption of more efficient generation methods using less expensive fuel. Using more efficient fuel (Ultra Low Sulfur Diesel or ULSD) will result in 879,000 fewer barrels of fuel imports annually.

The current reliance on older baseload generators requires significant consumption of expensive fuel, leading to substantial annual costs. Retiring Cabras 1 & 2 will directly benefit customers by reducing their bills. GPA's long-term goal of providing sustainable and affordable energy has faced challenges, but recent smart investments in solar energy and battery storage will soon deliver the intended direct relief to Guam's families.

PUC Approves 2025 Deadline for Ukudu and GPA's $13.6M Savings Plan for Customers

The Public Utilities Commission (PUC) has granted approval for amendments to the Energy Conversion Agreement (ECA) between GPA and Guam Ukudu Power, LLC (GUP). The amendments, initially approved by the Consolidated Commission on Utilities (CCU) in March, set an accelerated deadline for the Ukudu Power Plant project, which is projected to generate approximately $13,688,556 in fuel cost savings for GPA customers.

John M. Benavente, P.E., General Manager of Guam Power Authority, expressed his appreciation for the PUC's decision, stating, "Rising fuel costs impact every facet of our lives and pose a significant challenge to our island's financial well-being. By securing approval for these amendments, we will not only be lowering energy bills for customers but also providing much-needed relief to families and businesses from continued escalating expenses and keeping those funds in the local economy."

The amendments to the ECA provide for an incentive with an early commissioning date by September 15, 2025 and a strict deadline for completion by September 30, 2025, with penalties imposed for any delays thereafter. This adjustment was necessary due to Typhoon Mawar damaging fuel and water storage tanks.

With an accelerated date for commissioning the Ukudu Power Plant and an overall reduction in costs from $571 million to $527 million, testing is expected to begin by early 2025.

Ukudu Power Plant Progress

The Ukudu Power Plant has recovered from the damages it incurred from Typhoon Mawar. As of June 30, 2024, the project's overall progress, including engineering, procurement, and construction, stands at 88.35%.

Key updates include:

- Completion of hydrostatic testing for large fuel tanks and near-completion of water storage tanks.
- Installation of building sidings, ongoing piping, and electrical activities.
- Successful energization of a new bus and transmission line from the Harmon Substation to the Ukudu switchyard in June.
- Pipeline work is nearly complete with areas along Route 16, Route 6, and Route 1 in Dededo and Piti still ongoing.

Mid-Term Solutions Allow for Big Bump in Capacity

GPA has successfully added 76MW as part of its mid-term plans to address the capacity shortfall. Additionally, the rainy season has brought lower peak demands, providing relief to the system and opportunities for maintenance without impacting necessary reserves.

The Aggreko generators achieved full operational status and integration into the Island Wide Power System (IWPS) as of July 2024. As part of a temporary power agreement, the 20MW power package has been commissioned for 24 months, featuring high-efficiency, ultra-low emission generators. The additional capacity to the IWPS allows GPA teams to provide needed maintenance for generators that have been operating at capacity for the past year.

Ongoing mid-term measures also include upgrades to the Manenggon Power Plant and further maintenance to the recently repaired Yigo CT. After returning to service in April, the Yigo CT commenced hot section work on July 23rd. The unit is expected to return to service earlier this month, increasing output from 16MW to 20MW.


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Palau Solar - Growing Our Regional Presence

Ross Waddington
Chief Executive Officer - Utilligence Group

In 2022, UK electrical engineering company, Utilligence was awarded a contract to design and install 800 domestic solar systems in the Micronesian Republic of Palau, through a partnership with The Asian Development Bank.

Palau is grappling with the effects of global climate change and currently relies heavily on diesel-generated power. However, the country has committed to ambitious net-zero goals and is seeking to significantly increase its use of renewable energy. By deploying renewable energy on a larger scale, island communities can work towards energy independence with a focus on low-cost, low-carbon solutions. To facilitate the transition, the project offers government-backed low interest loans to households in the region to install solar photovoltaic (PV) panels. This allows residents to dramatically reduce their energy bills, with the cost savings more than covering the cost of the loan repayments.

Utilligence is a UK company with significant expertise in renewable energy technologies, working on several high-profile projects in wind, solar and hydrogen energy. Committed to sustainable and ethical business practices, the company was eager to establish Palau Solar as a locally run and managed venture. After setting up offices in Koror, Palau, the company hired and trained a local workforce in solar engineering. This not only ensured cost-effectiveness by using local labour, but also supports the local community by providing employment and skills development opportunities. The local Palau Solar team is responsible for conducting site surveys, designing systems and installing and maintaining domestic solar systems, to help Palau transition away from its reliance on high-cost fossil fuels.

The Palau Solar team has the full engineering expertise of Utilligence and their experience of power networks, in-house design, build and testing to rely on. To date, Palau Solar has completed over 400 solar installations, making us one of the largest solar installers in the Pacific island community.

Grid Consultancy & Design

Adding solar power to the grid comes with its own challenges, particularly in regions like Palau where the power network faces limitations and instabilities. Utilligence's experience of helping western grids to integrate renewable energy sources has been shared and applied to help support local island grid operators in their transition away from diesel generators.

Combining solar, battery and diesel power takes considerable expertise, requiring the building of power system models to understand the effects of voltage rise, reverse power flow and harmonic issues, to mitigate the effects on the wider network.

The Palau Solar team is working to model the impact of multiple micro systems on macro networks, as well as the impact of large solar farms, to ensure that the addition of renewable energy does not impact negatively on the local grid.

Commercial Projects

From our initial work in the region, Palau Solar's focus has now extended beyond the scope of domestic solar and is now working on several high-profile commercial projects throughout the Palau islands.

One such project is the design and installation of a 4MW power system for a prestigious new luxury hotel opening in Palau in 2025. The hotel group is commitmed to sustainability and incorporating renewable energy as a core facet of their operations. The Palau Solar team is designing a system that will meet a significant portion of the hotel's electricity needs, helping to reduce their carbon footprint and operating costs.

Another major commercial undertaking is a solar power system for the Camp Katuu military installation in Palau. This project requires careful integration with the existing infrastructure and power distribution network. Palau Solar's expertise in grid modelling and integration is proving to be essential in ensuring a seamless transition to renewable energy for this critical facility.

The company is growing its work in supporting local government administrations in the energy transition through Utilligence's advisory services and technical expertise, helping shape renewable energy and grid modernisation strategies. Simultaneously, the knowledge gained by Palau Solar has enabled Utilligence to understand local challenges and draw on global best practice and experience, making them a trusted partner for this development.

Pacific Island Renewables

The demand for local renewable engineering experience and on-the-ground skills has seen Palau Solar establish a new venture, Pacific Island Renewables, to further extend and offer its full range of renewable energy services across the wider Pacific region.

Pacific Island Renewables builds upon the successful model established by Palau Solar, harnessing the company's expertise in solar, wind and smart grid technologies. The new entity will serve as a regional hub, providing comprehensive engineering, procurement and construction services for renewable energy projects in island nations throughout the Pacific.

A key priority for Pacific Island Renewables is to foster strong local partnerships and develop its skilled local workforce. This approach ensures that the benefits of renewable energy deployment are accrued by the local communities, while also building long-term sustainability and self-reliance.

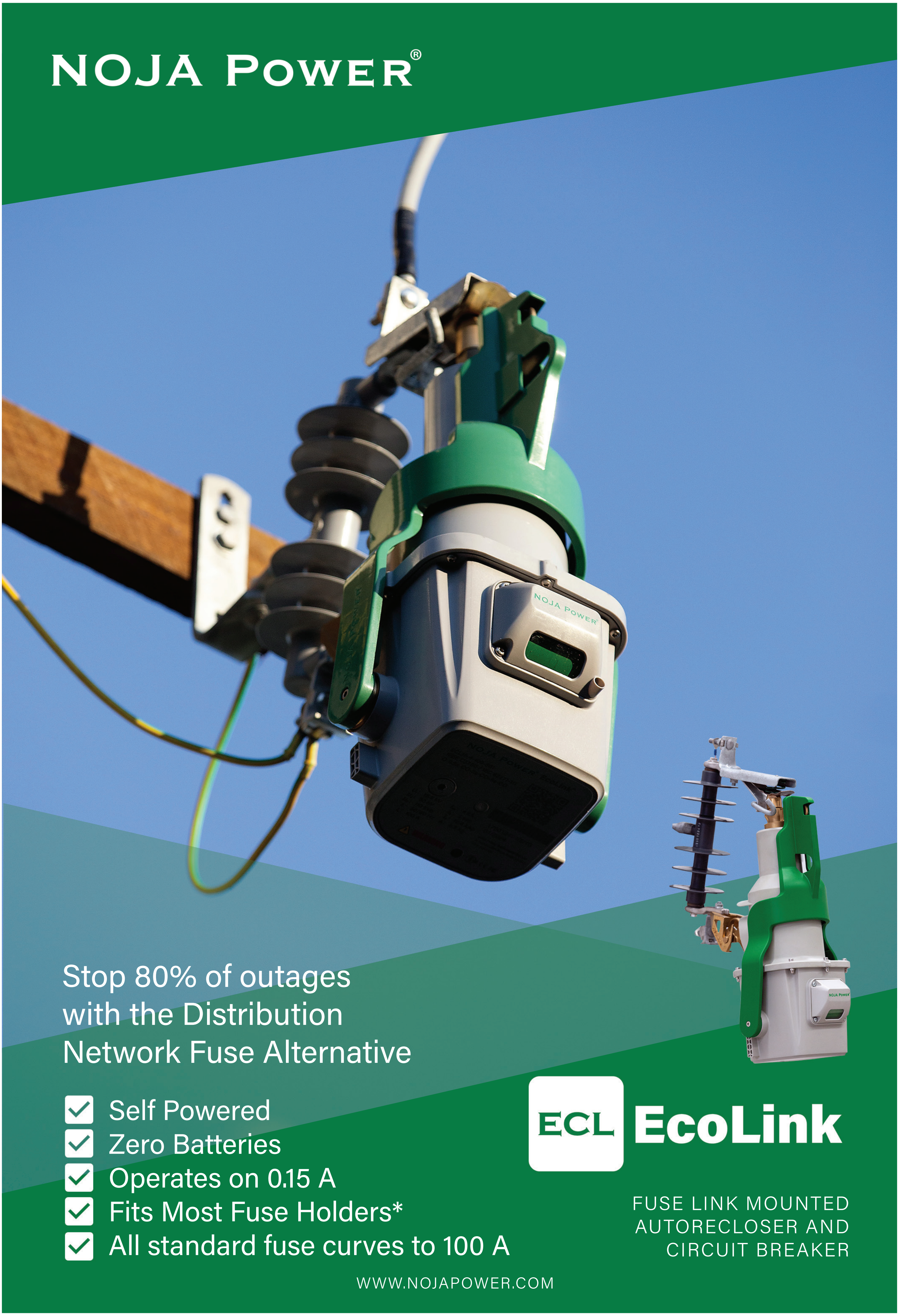
Pacific Island Renewables is tailoring its energy solutions to the unique infrastructure challenges faced by Pacific island countries. This holistic approach to renewable energy integration, including grid modernisation and storage will be crucial in supporting these nations' transitions to low-carbon, resilient power systems.

Our journey has highlighted the significant potential for renewable energy to transform the power landscape of the Pacific island nations. Partnering with local communities, sharing global expertise and delivering bespoke energy solutions is driving forward the region's transition to a more sustainable, resilient, and self-sufficient energy future.

Palau Solar's team in Koror, Palau. Employing and training a local workforce was a key focus for the company.

The team supplies and installs domestic and commercial solar throughout the Palau archipelago.

The team is used to working with the unique challenges of the Palauan climate and infrastructure.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WELCOME!!
TO THE NEW ALLIED MEMBERS

Four (4) new Companies has joined the PPA as Allied Members since our last PPA Magazine.

The new Allied Members are:

WILDFIRE ENERGY PTY LTD:
Wildfire Energy Pty Ltd is based in Queensland, Australia. Their primary activity is electricity from waste. Their secondary activity is construction aggregate, H2 and biofuels (methanol/SAF) from waste.

ANKUR SCIENTIFIC ENERGY TECHNOLOGY PVT LTD:
Ankur Scientific Energy Technology PVT Ltd is based in Gujarat, India. Their primary activity is gasification technology for converting biomass and waste to energy – technology can also be used for converting biomass to biochar.

CANADIAN SOLAR:
Canadian Solar is based in Melbourne, Australia. Their primary activity is solar products manufacturer and energy storage.

POWER & MARINE ENGINEERS LTD:
Power & Marine Engineers Ltd is based in Auckland, New Zealand. Their primary activity is diesel power generation equipment. Their secondary activity is electrical conductors and cables.

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