A PACIFIC POWER ASSOCIATION PUBLICATION

VOLUME 32 ISSUE 4 - December 2024

PPA 31st Annual Conference & Trade Exhibition, Keynote Speaker, Ximing Peng, Senior Energy Specialist & Energy Program Coordinator in the Pacific, World Bank

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December 2024, Volume 32 Issue 4

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Pacific Power Association, Suva, Fiji Islands. The PPA is an inter-governmental agency and member of the Council of Regional Organisations in the Pacific (CROP) established to promote the direct cooperation of the Pacific Island Power Utilities in technical training, exchange of information, sharing of senior managment and engineering expertise and other activities of benefit to the members.

PACIFIC POWER magazine is published four times a year.

Advertising
Reena Suliana
Pacific Power Association,
Suva, Fiji Islands

Layout & Design
Star Printery PTE Limited

This magazine is read by an audience of opinion leaders in governments, development partners, the public service, the academic community, the media in the Pacific and members of the Pacific Power Association. Subscription to Pacific Power magazine is available at US $60 a year from the association.

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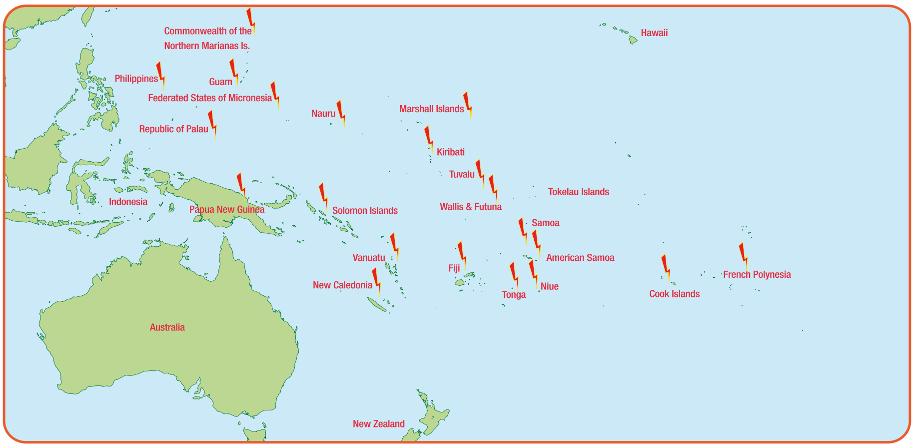

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Editor's Note

Gordon Chang
Executive Director

Greetings from Suva

As we farewell an eventful and exciting 2024, we wish to thank you all our financial members and donor partners for your continued support and entrusting our team with your events.

We were delighted to see so many friendly and familiar faces coming and going through the PPA Secretariat door and excited to welcome a host of new events and plans for the upcoming year.

The year 2024 has been busy for the Association with the closing of projects and planning of new activities to implement such as the Benchmarking project now funded by the ADB. The Secretariat looks forward to the active members to support and providing data to make this project a success as we implement the first year with new data fields to be added.

In this issue of the magazine, you can read a few papers that were presented at the Association's 31st Annual Conference and Trade Exhibition in Tonga.

The PPA Secretariat would also like to welcome back any former allied members who may have withdrawn their membership in 2024.

Wishing all the readers a Blessed Merry Christmas and a Prosperous New Year 2025.

Vinaka Vakalevu

Right-Sizing Renewables through Smart Metering Technology

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Abstract:
Large nations are looking to replace existing generation capacity with matching renewable capacity. This is resulting in complex market models that cannot be sustained by small nations. There is an opportunity in a more fluid closed environment to develop alternative strategies to match supply and generation through better understanding Consumer behaviour and their capacity for short-term demand alteration.

The paper looks at how it is important to look at not just matching supply and demand at any point in time, but how we can now expand our decision making to "use now" or "store for later". We look at a definition for a high-level optimization framework for evaluating the best strategy for incorporating solar generation, battery charging & Customer supply. To illustrate this concept, we introduce how forgoing consumption to build battery reserve may be a strategy to make the best us of expensive storage assets and how that choice can be equitably evaluated through a simple implementation of the optimisation problem.

With this premise, the paper then looks at the foundational need to understand Consumer usage patterns and determine what consumption is essential, discretionary and shiftable. Coupled to available means to then enact and control consumption, this builds a picture of what leeway there is to "store more later", how that could be conducted, and thus maximize renewable use over the whole day while inconveniencing consumers in an acceptable manner.

Background

As nations embrace the need to replace their existing fossil-fuel based generation capacity for renewable technologies, each develops their own strategies for dealing with the problem. What is abundantly clear from the last 5 years is that, while aiming for a common goal (near complete renewable use), each has specific problems to overcome and the regulatory framework for how Consumers and Utilities interact differs – meaning that the manner in which control and changes must be carefully considered on a case-by-case basis.

For instance, in the US, as Consumers transition to renewables, the rise of Electric vehicle (EV) use is now putting significant pressure on grid infrastructure. The US car company, Tesla, sold more than 120,000 of it's Tesla Model Y & 3 cars in the first quarter of this year alone, re-igniting the 23% year on year growth that globally stalled last year but seems to be returning. The issue then for Planners in the US is how to deal with the inclusion of these extra loads. While 120,000 EV's may not sound a great number compared to the size of country, if they are clustered within the same geography – such as California, then this brings burdens on the MV and LV network that significantly stresses both local renewable generation as well as transformer assets.

Ultimately though, with vertically integrated Utilities, the Utility can control largely the problem within their domain and put in place plans for Generation, Battery Energy Storage Systems (BESS) and through registration processes limit and monitor the behaviour of Consumers.

But if we look to Australia, Australia has a different problem. The size of the country and lack of significant incentives has meant that EV's have not taken off in the same numbers. But faced with rising energy costs, Consumers have jumped whole-heartedly into investing in rooftop Solar systems (PV). As we moved into 2024, the extent of uncontrolled solar penetration was illustrated by the Victorian daily average spot price for electricity hitting an all-time low on New Year's Eve at (negative)-73.02/MWh[1]. Literally there was so much domestic electricity, you couldn't give it away, as high rooftop PV generation (almost all of which doesn't receive or respond to market prices) squeezed out most other forms of generation in this period. Not only did this cause a threat to network stability, but also the financial viability of reliable fossil-generation.

In clearly showing the different problems, these two nations are dealing with at the Low Voltage (LV) end of the network, the last point about financial viability illustrates also the way the regulatory framework of the Utilities also plays a part in how the green transition is constrained. Australia's de-regulated and market force-led model means that power is delivered by the lowest bidder. Secondary markets ensure that there is enough emergency capacity, but largely the lowest offered price wins. This model has worked well, but intermittent cheap generation sources now severely threaten the viability of large plants which even when not dispatched, still incur running costs and cannot be easily sustained if only earning an income from partial and reduced capacity.

To counter this potential for traditional generation collapse, Australia is currently putting in place complex mechanisms to ensure that domestic rooftop can be curtailed through issuing dynamic limits called Dynamic Operating Enveloped (DOE) to protect and maintain the need for a baseline of grid-connected generation for the present. But limiting power export will not facilitate the transition to renewables. So on the other hand, the legislation and the NEM Reform Program also aims to make it financially viable for Consumers to over-install capacity on their rooftops and purchase battery storage which can collectively then ramp the country forwards to it's target of 82% renewable energy production by 2030. In effect these market rules are aiming to gain back an element of centralised control and planning into a devolved market that if left unchecked would become unstable.

The Problem with Planning

The two stories above highlight that unconstrained implementation of renewables leads to either network or financial issues or a combination or both. In the cases above, we've looked at the LV end of the network and the demand side of the equation and how that can differ. But if we look at the grid generation end of the equation, the same two factors exist. A Utility must plan for how they will supply renewable energy to match the needs of the Consumers and how to phase in that transition against targets set by Governments and the finances they have available.

PV technology has advanced to the extent that taking the Levelized Cost of Ownership (LCOE) over a period such as ten years, the cost per kWh of solar generated power has now dropped to levels of $0.04 for utilities. This is forecast to drop further to around $0.02 by 2050. Battery storage on the over hand is still relatively expensive with LCOE for battery storage still around the $0.30/kWh for 100MW utility grade storage. However, both technologies are advantageous when compared to typical diesel generation costs that can be as high as $0.52/kWh for island communities.

However, both battery storage and solar are becoming cheaper with prices dropping as technologies mature. Figure 1 shows the expected world average costs for these two technologies, and this in turn presents the planner with an additional dimension – when to invest in the technology. The longer that one can wait to solve the problem, in theory the lower the total cost of ownership, but that must be balanced against the cost of the enduring existing generation media. In the case of large interconnected continental grid-connected systems this choice presents a dilemma, but to an island community where the cost of diesel is greater than both, the decision is then a pure financial one of how best to allocate finance.

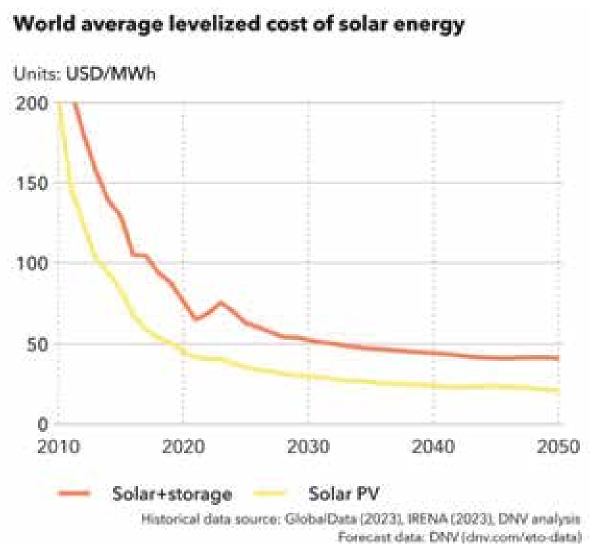


Figure 1 - The Cost of Ownership of Renewable technologies is decreasing over time.

Where to Spend the Money

Just as we can model the flow of energy around an electrical network and then enact decisions to ensure the optimum flow of energy, we can formulate a mathematical model to determine how to decide upon the optimal balance for a portfolio of renewable energy technologies. Such a model needs to account for first and foremost the demand pattern that the generation is aiming to supply. For instance, if all the consumption of a network is conducted during the daytime (an obviously artificial scenario) then there is no need for battery storage systems if an existing solar plant can balance supply against demand. Conversely, if the demand of the population peaks at times of the day when solar energy production is low, then the demand can be satisfied by either BESS charged earlier or alternative technologies such as hydro or wind. If we include all of these contrasting factors into a single model alongside the demand profile that needs to be satisfied, then we can look to formulate the problem into something that we can minimize and solve – providing an indication of the strategy that needs to be implemented for a renewable transition.

Recently, Itron have been looking into what such a model would look like from two points of view.

- Firstly, how this relates to the decision making that a Utility undertakes as it looks to invest in technologies to meet its needs.
- Secondly, how this relates to the micro-scale decisions that are made by individual Consumers – such as how they can minimize financial outlay for Solar PV, BESS, and EV usage.

The result of this analysis has resulted in the formulation of a class of equations that are suited to standard techniques for minimisation so that we can look at the gross characteristics – what equipment to purchase and what that means to the profile usage of the two groups.

The common characteristic in the formulation of the problem is to set out the problem domain as a function of % usage. We define the factors that could interact to provide generation for a demand profile and then we look for the optimum fractional usages of each technology over the course of the profile. For example, if we had two competing power sources (solar and diesel) at a specific time of day, what we want to understand is what proportion of the demand should be satisfied by each to result in an optimal solution.

Now, in that case, the intuitive answer is "all solar". But if we take into account the need to charge up a battery for nighttime energy capacity, then some of these black-and-white decisions become blurred. The formulation of the problem needs to take into account the dynamics of the time-dependant nature of the problem. As a core principle (and given we are looking to optimize the cost of the renewable portfolio) we need to factor in the cost of electricity

1. https://wattclarity.com.au/articles/2024/01/bang-or-whimper/
2. https://www.pv-magazine.com/2023/10/11/solar-pv-lcoe-expected-to-slide-to-0-021-kwh-by-2050-dnv-says/
3. https://reneweconomy.com.au/wind-and-solar-power-half-the-cost-of-coal-and-gas-one-third-the-cost-of-nuclear-says-lazard/
4. https://www.sciencedirect.com/science/article/pii/S2667095X24000084

as it varies across the day (from the renewable sources) as well as that of usage. What we don't want to be doing, is having to "dump" solar PV generated power as there is an over capacity and either no viable / or lesser means to store it as illustrated below.

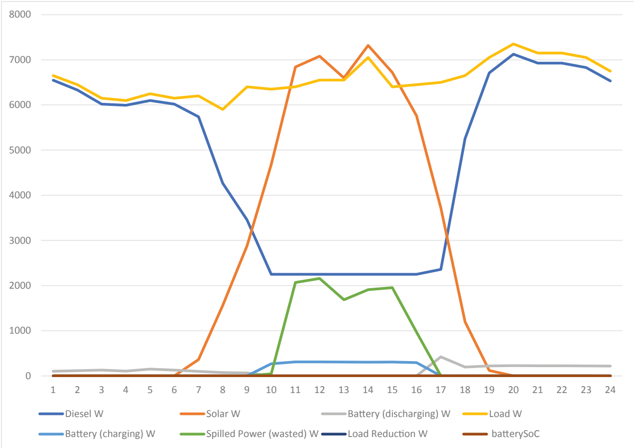


Figure 2- Dumped Power (in green) caused by Solar PV (orange) exceeding demand and baseload capacity setting (blue) and with only a minimal battery storage component (grey)

Optimisation Problem Formulation

Defining the problem as one of determining the optimal fraction of total generation capacity to meet the demand profile allows a minimization function to be defined. Let's take the simplest case we can think of – determining which of a range of generators should be dispatched at each time interval (e.g., 5-minutes, 15-minutes, 30-minutes, 60-minutes) during a day. In this case, the optimization can be constructed in the format below.

Optimization Statement One. Formulating the problem to solve for optimal energy dispatch from a range of Grid-Connected Generation resources.

Find the least cost mix of grid-connected generation that satisfies aggregate demand for power subject to the operating constraints of the High, Medium, and Low Voltage networks and the operating constraints of the grid-connected generation units.

Equation 1 - Formulating the problem to solve for optimal energy dispatch from a range of Generation sources.

The objective of the least cost dispatch problem is to minimize the total cost of delivered generation. The value of the delivered power is quantified using the Locational Marginal Price (LMP) each end user pays for each unit (e.g., kWh) of power delivered. The LMP is composed of three cost elements.

• The first is the market clearing price for power. This price is determined where the aggregate demand for power intersects with the aggregate supply curve. The latter represents the bid-offer curves of each grid-connected generation unit sorted from least to highest cost.

• The second element of the LMP accounts is the value of power lost due to Transmission & Distribution losses.

• The final element of the LMP represents the relative cost of delivering power to network nodes (n) that are highly congested.

Of the three components the market clearing price represents roughly 95% of the LMP.

While it looks complicated, it can be simplified when you realise than two of the summation terms (that of d and t) account for finding how the fraction of generation varies for each period t over each day d – e.g. when each generator should be dispatched.

Equations such as this are easily solved using standard computational packages, like for instance Python's, SciPi package, and the result gives the optimal mix of each generator, given the demand curve you have to match as well as the price each generator is willing to provide energy for. Should that generator be a supplier of grid-connected Solar Energy, then this optimizer works equally well for determining, on a pure financial basis the split between fossil and PV generation. The fact that PV is only generated during the day being accounted for in the range of time periods to which there is capacity. We can further extend this optimization to include BESS supply. The extra term is almost identical to that of the previous formulation in structure but is needed separately because the capacity of the BESS is not uniform across the time dimension.

Optimization Statement Two. Formulating the problem to solve for optimal energy dispatch from a range of Grid-Connected Generation and BESS resources.

Find the least cost mix of grid-connected generation and BESS that satisfies aggregate demand for power subject to the operating constraints of the High, Medium, and Low Voltage networks, and the operating constraints of the grid-generation and BESS units.

Equation 2 - Problem Formulation for Generation and BESS

In theory a power plant can generate the same energy at any point in the day, but a battery needs to charge up before it can supply energy, and thus though the optimization function is the same between the two sources of power, the constraints that are applied to the solution terms are different; the battery's supply capacity is determined by the amount of energy that it has accrued through charging and thus there needs to be over-capacity in a period of the day prior to the batteries discharge.

If one applies suitable Pricing for the Generation types (Solar, Diesel, Wind, Hydro) and then the LCOE for a battery system alongside the capacity of the system, then with the constraints, a model of the solar output (derived from the prevailing weather) thus allows a closed network to determine the optimum discharge times during the day alongside the scheduling of diesel and solar generation. By then repetitively iterating an increase in the BESS capacity it is possible to plot a graph of renewable capacity against investment.

The Importance of Looking at the Whole Problem

Equation 2 is where a lot of studies and simulations end. The Objective function returns the running costs of the generation mix and the time dependant elements describe when battery discharge / charge cycles should be schedules. Given set Weather and a set Demand profile, the calculation provides an answer.

However, by stopping at this point you are implicitly accepting that the sole solution to converting to renewables is implementation of generation sources. The demand side of the equation has not been considered. What we would like to do is introduce an additional factor so that rather than considering any demand side activity in isolation of changes in generation, we can consider them on a par with generation, thereby enabling us to directly compare, and optimise, the effect of any demand side management within the overall strategy.

Equally, equation 2 is biased to renewable sources if they are cheaper than their fossil-based counterparts. At times of the day when there is excess generation it is likely that on an Island model, scheduling of diesel generation would be curtailed to zero. Doing that in practice though would be highly risky as should there be intermittency in solar or excess demand that minimum baseload required for network stability would not be present. So, from the point-of-view of modelling for reality this solution provides a theoretical generation / BESS mix, but not a practical and stable one.

Optimization Statement Three. Formulating the problem to solve for optimal energy dispatch from a range of Grid-Connected Generation and BESS resources and Distributed Energy Resources.

Find the least cost mix of (a) grid-connected generation and BESS and (b) consumer-side generation and (c) load control that satisfies aggregate demand for power subject to the operating constraints of the High, Medium, and Low Voltage networks, the operating constraints of the grid-generation and BESS units, and the operating constraints of consumer side generation and load control.

Equation 3- A practical formulation including load management and base load stability.

Here, the optimization framework is extended to include active and passive control of end user appliances and end-use equipment. This level of control is required when network constraints prevent sufficient power being delivered to end users to avoid rolling brown outs or black outs, a network operator activates load control programs. In the equation formulation, the first elements are unchanged from the previous formulation. But we've now added a further element that need consideration:

• And the last term is the important one here – it introduces the Load profile we are serving. By introducing another solution variable, the minimisation function is now allowed to change the shape of the load profile – e.g. conduct load control operations. And just as in the previous terms, we can attribute a cost to such activity. In effect we are saying that we have the power to manipulate the overall load profile shape (for example to conduct a demand response programme or load limiting etc) and with this change we assign a "cost \$/kWh to forgoing a unit of usage" of appliance or end-use equipment.

So, rather than accept that the load side part of the problem is immutable, and the only tool we have for moving energy generated by Solar (during the day) into the night (by storage through a battery), we have the opportunity to change the nighttime demand profile and move some of the demand into a time period where it can be immediately satisfied by that solar generation.

The Benefit of a Holistic Modelling Framework

Now, it is possible to not only look at when generation / battery mix is needed for a given starting load profile, but also what load manipulation controls would be suggested to make the demand and generation profiles more compatible. The cost for each of these load control strategies compared to the corresponding generation costs drive which are selected on an "apples – with - apples" comparison basis to the cost for implementing renewables.

For instance,
• if the cost of implementing a load limiting program with a customer segment is \$0.20 / kWh, then this is a more viable option than the dispatch of diesel to supply this demand or procuring a BESS to provide that demand.
• if a Customer can be incentivised through tariffs or direct control of appliances to shift their usage from nighttime (where solar PV is unavailable) to daytime where it is, then if the cost of this programme again is under the cost of differential between the two generation costs and the discount to the Customer, then there is a net value in implementation.

There are two generic classes of load control programs.
• Passive load control programs rely on end users to take actions to reduce their loads. Market participants are notified via public information announcements or price signals that load reduction is requested.

• The class o f Active load control programs utilizes direct third-party control of appliances and end-use equipment to reduce demand for power. Both classes of load control programs are initiated.

Importantly though, the net effect of both examples would be to increase the headline proportion (%) of energy delivered through renewables, reduce overall costs as well as reducing the net import litres of diesel fuel – all key metrics to the goal of the renewable energy transition. Policy makers are also then able to view whether it is more prudent to defer purchasing elements of the portfolio of BESS required until a later time, by which point the cost of assets will have come down, and savings generated in the interim time are able to be rolled up towards their procurement.

Types of Load Control

What Equation 3 allows us to do is directly compare the benefits of load control against that of the explicit purchase of renewable energy assets. Effectively building a “non-wires” alternative to combat renewable integration in much the same vein as Australia’s NEM Reform initiatives will achieve. And this introduces an array of “tools” which we can now evaluate to see which would be most effective in enabling us to “right-size” our renewable assets.

• Passive Tools
 - Time of Use Tariffs designed to incentivise Customers to change behaviour patterns.
 - Load Limiting
• Active Tools
 - Real-time and Critical Peak Pricing.
 - Direct Load Control
 - Interruptible / Curtailable Services
 - Emergency Demand Response

The question now is what would be the cost of a load control program and how would it stack up against that of the costs for various generation types? Figure-2 shows a range of renewable technologies and the levelized cost of ownership of each[5].

Figure 3- Levelized Cost of Ownership for Renewable Technologies

So, how would various load control strategies compare against these costs? Should they be comparable or able to be made cheaper, then they form a viable approach to renewable transition as both a “stop-gap” approach while the cost of battery technology falls, but also as part of the end portfolio for an alternative to battery power as well as also dealing with intermittancy and responding to intra-day events.

In 2006, the US Department of Energy published a report into the benefits of Demand Response . And within this they highighted the various costs involved in an overall demand control program which is outlined in Figure-3.

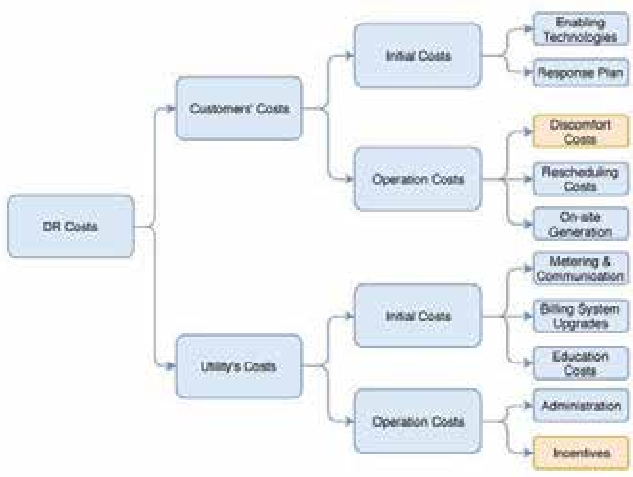


Figure 4- Cost Breakdown for Setting and Running a Demand Response Program

At that time, the studies reviewed in the report showed overall gross benefits to the Utility over a 20 year timescale of around $2.00/kWh, with the overall costs to setup the (US based program) being in the range of $0.13 to $1.00.

A recent study in Finland has also addressed this topic by providing a qualitative estimate of the cost of a DR program. They specifically looked at DR in the context of the move to renewables with a view to matching supply with demand by managing the demand (shifting uninterruptible or schedulable loads) unlike the other solutions where supply is regulated to match the demand. The work not only looked at the cost involved in implementing a peak shifting program, but also considerable attention was paid to evaluating Customer impact and how / what loads would be moveable.

Their conclusions (and it should be noted this is Finland with significant heating requirements) were that shifting the time period of usage for loads was economically viable for requests to move appliance usage up to an hour from the appliances current ToU. At this point, Customer incentives plus costs amounted to a programme cost around $0.33/kWh, though if Customers were asked to shift loads by 180 minutes, this cost was modelled to start to balloon out to $1.61/kWh as incentives to participate needed to be increased to overcome discomfort / habits. The lesson there was that “incremental” change in Customer behaviour would be more successful than “big bang” requests for peak load management.

We conducted some modelling using these concepts. For comparison, we tool a model whereby we used only a mix of solar, battery and load and then optimised these three to provide the most economic Battery charging use. This is illustrated in Figure 6.

5. https://reneweconomy.com.au/wind-and-solar-power-half-the-cost-of-coal-and-gas-one-third-the-cost-of-nuclear-says-lazard/
6. https://eta.lbl.gov/publications/benefits-demand-response-electricity
7. https://www.mdpi.com/1996-1073/12/9/1617#B33-energies-12-01617

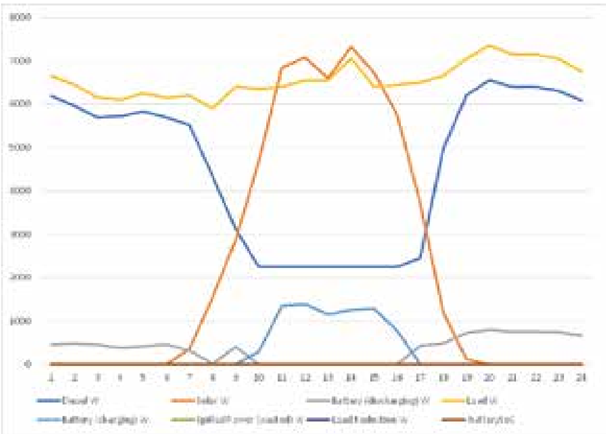


Figure 5- Optimisation of Solar, Battery and Load

Then we took the same model and provided an incentive for Customers to move demand usage. We assigned a cost (to the Utility) proportional to the time difference between when the usage would have occurred to where it could be moved to. E.g. if (as in the Finish study) you wish to move usage by 5 mins, this has a significantly lower cost than asking for demand to be moved by many hours.

We then reran the optimization model to work out at what time periods it is MOTS VAULABLE to move demand, and what proportion of the demand can be moved (% of use in a given time period). Each of these factors was an independent variable in the optimisation problem and allowed to vary. As before, the eventual solution forms the least cost solution (e.g. most economic).

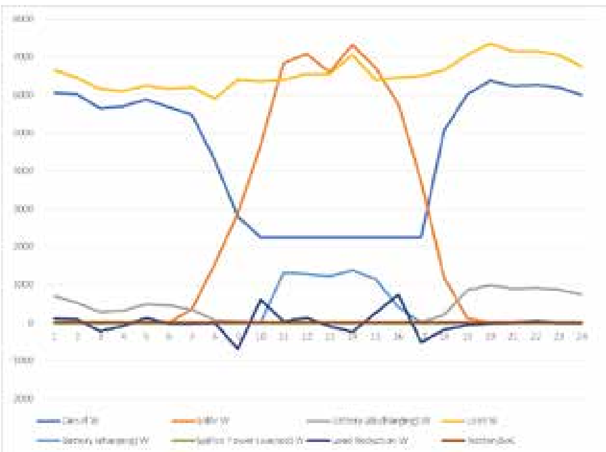


Figure 6- Optimisation of Solar, Battery and Load allowing for optimal load profile change to complement battery and solar usage.

What can be seen in Figure 6 is a new blue line that shows the movement of load from one period (if under the axis) to adjacent time periods (displayed as an excess above the axis). Not unexpectedly the optimisation algorithm found that the best times to conduct peak shifting (which in essence is what we have encouraged the algorithm to select) is at the beginning and end of the daylight hours. The more interesting fact is that the algorithm decided that there was any advantage to be gained by conducting demand shifting as it should be remembered this solution is cost optimised and thus this is a more efficient scheme than applying battery storage alone. And while the extent of the amount of load that can be transferred is related to the proportional cost of BESS against the cost of "shifting", this proves the viability of load shifting as an equally important equivalent to BESS purchase – especially if Consumer action can be achieved at an affordable cost.

The Importance of Smart Metering

Both the US and Finnish studies have both considered the importance of understanding what element of load is transferrable and the willingness of Consumers and Industry to participate in programs. A critical precursor in this evaluation is understanding how Consumers use power at present. As while an overall island's generation can provide the gross characteristics of demand, it cannot show you the Customer view, which is the behaviour scale you need to change, and which when aggregated up, forms the lever to enable change.

Smart metering provides that visibility, enabling the Utility to understand the usage pattern. However, modern smart meters provide so much more information that can then be leveraged to both understand which load control program may be the most economically beneficial one to implement, as well as then provide control tools for programme implementation. For instance,

• Load Limiting – AMI meters allow for load limiting (at optionally various times of day). This provides a direct and automatic mechanism to shave peak demand at times where a more expensive battery discharge would be the other option.
• Direct Load Control – both directly at the meter, but also behind the meter (through communications like Wi-Fi), AMI meters possess the ability to interact with Consumer devices to change demand patterns.
• AMI meters not only provide accurate ToU load patterns but can provide this information with low latency to within 15 minutes of its usage for large populations, but also on-demand in near-real time to Consumers.
• Some advanced AMI meters can even analyse and detect the types of appliances being used (Load Disaggregation) allowing the Utility to both see trends in purchasing and load growth and then specifically target schemes that discomfort consumers the least.
• And lastly, supply can be curtailed through direct disconnection / connection.

With understanding of usage comes the ability to define the type of load control program that may be achievable, understanding what loads exist at contentious times of day / night and also understanding what proportion of loads can be moved based upon what they are. This information can then be fed back (in the same manner as the Finnish study) to determine what the cost of each different load control programme would be – and then finally to be able to put those figures into the overall optimizer equation. The result being, as the US study describes, to allow the three demand factors involved "Forgo, Shift or Generate" to be analysed on a level playing field.

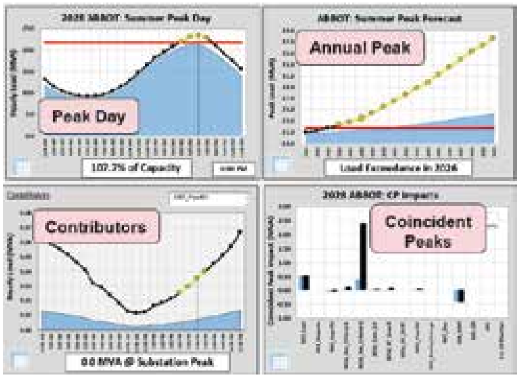
The Other Form of Load Profile Change - Growth

Demand changes over time. A load profile for a developed industrialised nation is different to that of an emerging one. Equally Consumer domestic profile changes as expectations on standard of living improve with overall economic prosperity.

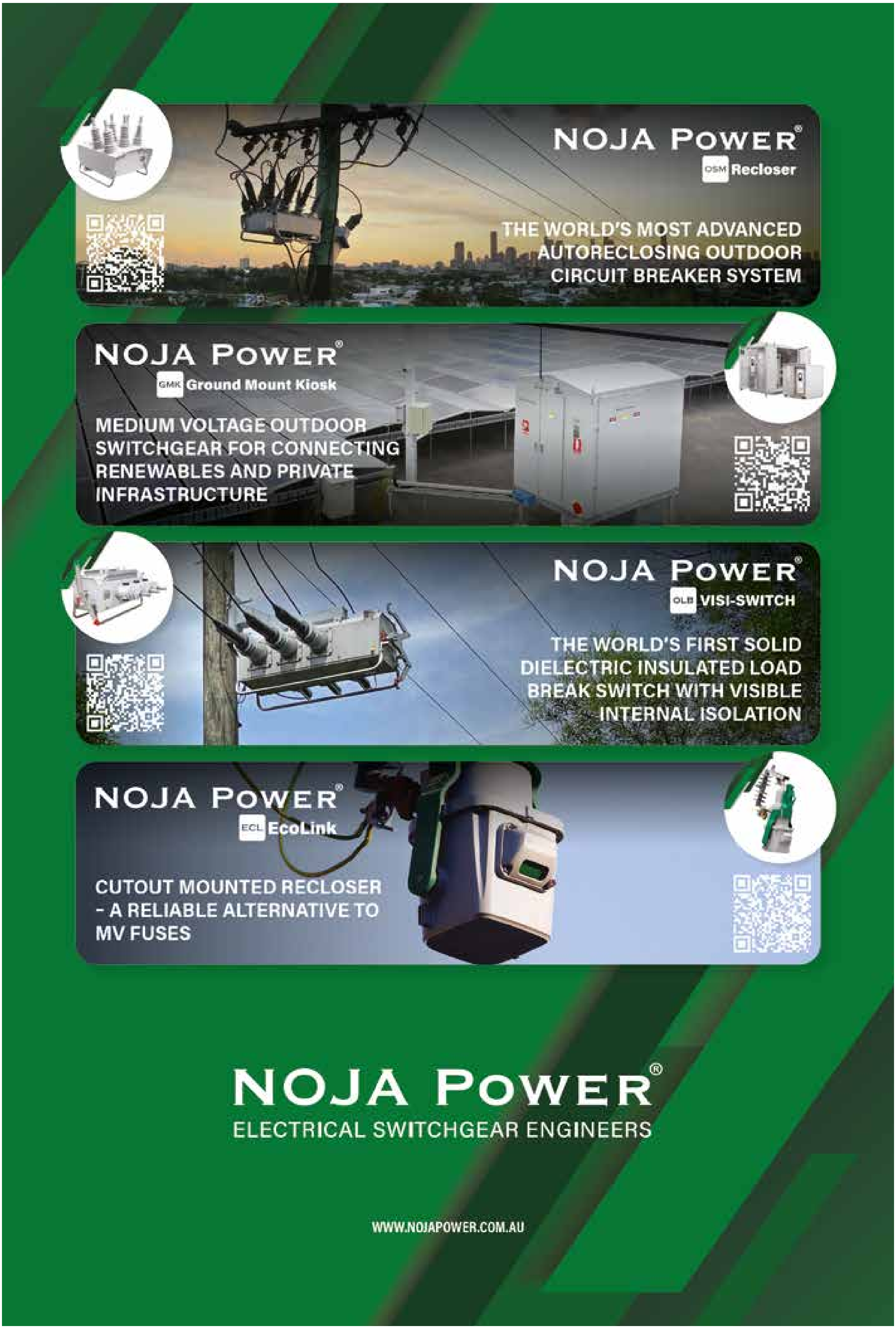
The Optimizer framework above was introduced as a means to determine the optimum financial measures to take (generation and demand management) with e view to maybe deferring purchases until the cost of technology reduces. Equally though, it can be used to study how load growth could affect purchasing decisions or force home the need to manipulate excess load growth into time of the day where it can be satisfied by lower cost renewable technology such as PV.

The Finnish study showed that Customers can more load usage, and significant movement can be achieved, but only by iterative steps if the programme is to be economically viable. Looking at the projected load growth is thus essential to ensure that any "stepping stones" to cater for significant growth at a problematic time of day can be put in place through targeted technology purchase and cooperative load controls. If you don't consider load profile change as part of the inherent components necessary to a successful renewable policy you will always be "chasing your tail". Worst still if you cannot see the emerging trends in Consumer behaviour, you will never be in front of the change and always constantly having to amend and potentially purchase additional services and assets to contend with the issue.

Much better to be able to monitor consumer demand and be vigilant to changes.
- Good forecasting then allows you to predict where this change will take you (and thus what the overall program will look like at timet).
- The optimization framework can then be used progressively to determine whether any identified trend warrants a load control or asset-based response to ensure an optimal outcome.



It is almost impossible to believe that the optimal solution to the renewable issue will not include changes in the load profile you have to date. And thus, if you wish to aim for the most cost-effective transition, there is a need to be able to monitor and control Consumer load.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Advanced Containerised Solar and Battery Solutions for the Pacific Islands

Florent Duthoit, Asia Pacific Sales Manager - Ecosun Innovations

1. Introduction to Ecosun Innovations

Since 2015, Ecosun Innovations has been a leading French manufacturer of solar and battery container solutions. With over 200 units installed worldwide, Ecosun provides efficient, environmentally friendly energy solutions that meet a wide range of needs across industries and geographical locations.

2. Typhoon-Proof and Portable Solar Containers

One of Ecosun's flagship products is the Typhoon-Proof Solar Container Mobil-Grid 500+ Solarfold®, designed for resilience in extreme weather. This containerized solar solution features 130 kWp of pre-wired photovoltaic panels and a 110 kVA inverter. Thanks to its motorized system, the Mobil-Grid 500+ can be automatically deployed and folded within 30 minutes, extending up to 130 meters when fully deployed.
The key benefits of the Typhoon-Proof Solar Container include:
• Safety in extreme weather conditions due to retractable solar panels.
• Mobility as a renewable, temporary energy source without the need for land acquisition.
• Fuel savings and suitability for off-grid operations.
• Labor cost reduction through rapid deployment and folding.
• No need for civil engineering infrastructure, making it adaptable to various terrains.

3. Benefits for Pacific Islands: A Tailored Solution for Unique Challenges

Ecosun Innovations' mobile solar solutions offer significant advantages for the Pacific islands, which face unique energy challenges due to their geographic and environmental conditions. These islands often struggle with developing off-grid networks, are highly vulnerable to extreme weather events like typhoons, and encounter logistical issues with construction and energy infrastructure deployment.

The typhoon-proof Mobil-Grid 500+ Solarfold® container is particularly suited to these conditions, as its retractable solar panels can withstand high winds, protecting the equipment during storms. Additionally, the mobility and rapid deployment of Ecosun's solutions eliminate the need for extensive civil engineering and reduce labor costs. For islands with limited land availability and challenging terrain, the compact, plug-and-play design allows for installation in areas where traditional infrastructure would be difficult or costly to establish.

Moreover, by reducing reliance on imported diesel fuel, Ecosun's hybrid solar systems help these islands achieve greater energy independence and sustainability. This solution offers a resilient, clean, and cost-effective alternative that aligns with the sustainability goals of many Pacific island nations, contributing to their resilience against climate change impacts and reducing logistical complexities in energy provision.

ECOSUN INNOVATIONS
To what extent saving diesel can be more profitable than you think ?

	Diesel Generator 25 kVA (8 hours a day)	Containerised Solar PV + Batteries 30 kWp – 30 kVA – 50,4 kWh
Initial CAPEX - Investment	3000 €	100 000 €
Cost of fuel per year	23 500 €	0 €
Maintenance / year	3000 €	1000 €
Total cost over 1 year	**29 500 €**	**101 000 €**
Total cost over 4 years	**109 000 €**	**104 000 €**
Total cost over 10 years	**268 000 €**	**110 000 €**
Total cost over 20 years	**533 000 €**	**120 000 €**

4. Diverse Range of Solar Solutions

In addition to the Mobil-Grid 500+ Solarfold®, Ecosun Innovations offers a full range of compact and mobile solar solutions to suit diverse applications. These include:

• Mobil-Grid®: A versatile container solar solution available in multiple capacities.
• Fix-Watt®: An on-grid or off-grid container with insulated control cells and optional battery systems.
• Trailer-Watt®: A mobile solar trailer that offers flexibility for temporary or mobile sites.
• Frame-Watt®: A solar frame solution, ideal for stationary or semi-permanent installations.
• Solar Hybrid Box®: Advanced lithium battery systems designed for energy storage and hybrid use.

5. Hybrid Systems: Solar Containers with Diesel and Battery Integration

Ecosun's innovative solar containers can integrate seamlessly with diesel generators and battery systems, providing an off-grid or hybrid energy solution. These systems are ideal for remote locations and industries where grid connectivity is limited or unavailable. By reducing fuel consumption, these hybrid systems offer significant operational savings and environmental benefits.

6. Economic and Environmental Impact

Switching to Ecosun's solar solutions presents clear economic and environmental advantages. For instance, deploying these solar containers results in substantial fuel savings and carbon footprint reductions. Ecosun's plug-and-play design minimizes setup costs and enables a rapid return on investment.

7. Ecosun's Vision and Partnerships

Ecosun Innovations actively collaborates with a network of partners worldwide, including diesel generator distributors, solar EPC companies, developers, and utilities. The goal is to drive creative financing models (such as PPAs and leasing) and expand access to renewable energy in remote and underserved areas. Ecosun is also open to partnerships with Development Finance Institutions to enhance the reach and impact of its solutions.

Ecosun Innovations demonstrates how solar and battery solutions can offer robust, scalable, and sustainable energy options. With their range of resilient, mobile solar containers, Ecosun paves the way for a cleaner, more flexible energy future.

For more information, contact Ecosun's Sales Manager:
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WhatsApp and Phone : +62 819 07 66 77 14

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Solar Containers

Trailer-Watt®
Solar Trailer

Frame-Watt®
Solar Frame

Solar Hybrid Box®
Battery systems

A Case Study: Tonga – Tanoa Tusitala International Dateline Resort

The German 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).

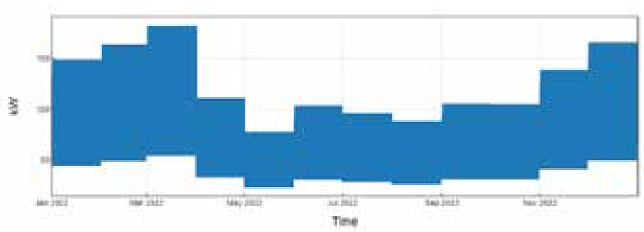
The three-star Tanoa International Dateline Resort is located in the capital of Tonga (Nuku'alofa). It is connected to the national power grid but also owns and operates a backup diesel generator for occasional power outages (once or twice a month for 2-3 hours). In the following, all important input parameters for this case study will be introduced. Then, there will be a brief overview of the key results of the energy system modelling for the resort.

1. Electricity Consumption

1.1. Tanoa International Dateline Resort

The load estimation for the Tanoa International Dateline Resort in Tonga is based on a monthly electricity bill provided by the resort for a period of one year. On this basis, a possible load profile was simulated assuming three peak loads per day (breakfast, lunch, and dinner). The following illustration visualizes the monthly fluctuations in the resort's electricity consumption. Notably, there is relatively low consumption in May and over a longer period in the summer (July, August, September).

Illustration 1 Annual Load Profile for the Tanoa International Dateline Resort



The key demand characteristics are listed in the table below.

Illustration 2 Tanoa International Dateline Resort

Parameter	Unit	Value
Peak Load	kW	182
Average Consumption	kW	80
Annual Consumption	kWh	699.234

2. Solar Potential

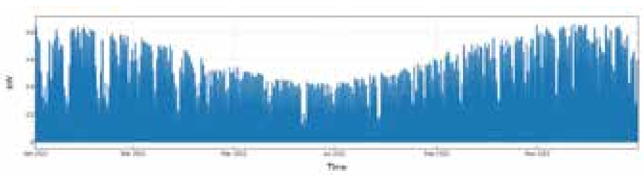
The online tool "Renewables.ninja" was used to calculate the hourly electricity generation from PV systems at the location of the Tanoa International Dateline Resort. The tool takes into account weather information and data, especially solar irradiance at specific locations, and calculates it using the GSEE model (Global Solar Energy Estimator) (Pfenninger and Staffell, 2016). The selected coordinates mark 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 Tanoa International Dateline Resort

Coordinates (Lat., Long.)	-21.134926230726172, -175.19422982323678
Tilt Angle	22 °
Azimuth Angle	0 ° (geographic North)

The following illustration demonstrates the specific PV potential over the course of a year. The annual potential is 1,515 kWh/kWp, with peak production occurring in the winter months, reaching up to 0.87 kW/kWp.

Figure 4 Annual Solar Potential for the Tanoa International Dateline Resort



2.2. Site-Specific Input Parameters

The site-specific input parameters important for scenario calculations are summarized in the following table. The data are based on information provided by the resort or from online research. Additionally, it is important to note that the resort regularly experiences power outages (about once or twice per month) lasting 2-3 hours, which are managed with the resort's diesel generator.

Illustration 5 Input Parameters Tanoa International Dateline Resort

Parameter	Unit	Value	Source
Weighted average cost of capital (WACC)	%	9,22	ADB, verified by resort
Electricity Price	EUR/kWh	0,36	Bill provided by resort
Dieselpreis	EUR/l	1,29	Statement from resort
Installed Diesel Generator	kW	350	Statement from resort

2. Summary of Results

The Tanoa International Dateline Resort would benefit from the installation of a PV system, a battery storage, and hydrogen technology as supplements to the grid power supply, potentially reducing its electricity costs by 60% in the long term. In this case, the diesel generator would no longer be needed to bridge occasional power outages. The break-even point for the investment would be reached after 7 years.

The following are the summarized results for three calculated scenarios. The following table first lists the energy system components and their capacities for each scenario.

Illustration 6 Evaluation Tanoa International Dateline Resort

Componen t (Unit)/ Szenario	Diesel Generator (kW)	PV (kWp)	Battery Storage (kWh)	Electrolyser (kW)	Fuel Cell (kW)	Hydrogen Storage (kg H_2)	Grid Power Peak Load
Status quo	350	-	-	-	-	-	182
Cost Optimizati on	-	807	503	232	53	67	182
100 % EE (PV, H_2)	-	1.163	-	542	182	581	-
100 % EE (PV, Bat, H_2)	-	1.075	419	445	109	548	-

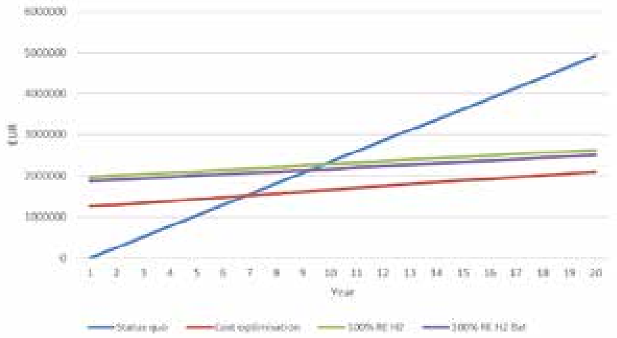
In addition to the design parameters, economic indicators such as the share of renewable energy, surplus electricity, and CO2 emissions are also important to consider in the analysis. These parameters are summarized in the following table, and Illustration 6 visualizes the calculation of the break-even point.

Illustration 7 Scenario Parameters Tanoa International Dateline Resort

Metric (Unit)/ Szenario	LCOE (€/kWh)	RE Share (%)	Net Present Value (NPV) (€)	Initial Investment Costs (€)	Operation/ Maintenan ce Costs (€/year)	Break Even Point (years)	Surplus Electricity (MWh/ years)	Emissions (kgCO2eq/ year)
Szenario	€/kWh	%	€	€	€/y	a	MWh/a	$kgCO_2eq/a$
Status quo	0,405	0	4.631.585	0	258.805	-	0	146.633
Cost Optimizati on	0,162	95	1.853.940	1.256.188	44.769	7	169	12.455
100 % RE (PV, H_2)	0,197	100	2.252.070	1.972.248	34.666	10	367	0
100 % RE (PV, at, H_2)	0,193	100	2.202.160	1.872.848	33.070	9	302	0

Electricity generation costs for this case study range from 0.16 EUR/kWh to 0.41 EUR/kWh. The cost-minimizing scenario can reduce electricity generation costs compared to the status quo by 60% and no longer requires diesel generator capacity to bridge occasional grid power outages. Both 100% renewable energy scenarios include hydrogen technology and can also lead to cost savings compared to the current power supply (PV plus hydrogen technology by 51% and an additional 2% if a battery storage is added). The break-even points are reached, as visualized in the following illustration, after 7 years (cost minimization), 10 years (100% renewable energy with PV and hydrogen technology), and 9 years (100% renewable energy with PV, hydrogen technology, and battery storage).

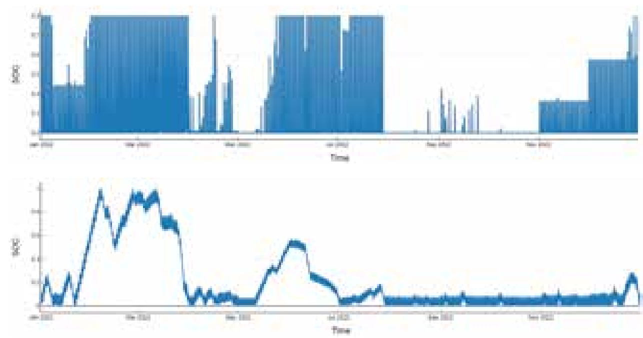
Illustration 8 Visualization of the Break-Even Points Calculation



Compared to the status quo, CO2 emissions can be significantly reduced in the cost-minimizing scenario (92%). This results in surplus electricity, which could potentially be used elsewhere (grid feed-in under appropriate regulations or operation of a seawater desalination plant). In this case study, water consumption for hydrogen production is assumed at 9 litres per kilogram of hydrogen produced, requiring a water amount of about 94,743 litres per year. This corresponds to a daily consumption of 260 litres in the cost-minimizing scenario if the hydrogen cycle cannot be operated as a closed system. In the scenario with 100% renewable energy, based on PV, battery storage, and hydrogen technology, the annual water consumption amounts to 151,452 litres (415 litres daily), while in the scenario with 100% renewable energy without battery storage, 171,828 litres or 471 litres of water per day are needed. The majority of the costs for the individual system components and the operating costs (annuities) in the cost-minimized scenario fall on the PV plant (47%). This is followed by the projected costs for grid power consumption (21%), hydrogen technology (17%), and the battery storage with 15%.

To more precisely analyse the operational characteristics and functions of the two storage technologies (battery and hydrogen), the following illustrates their storage states (SOC) over a year.

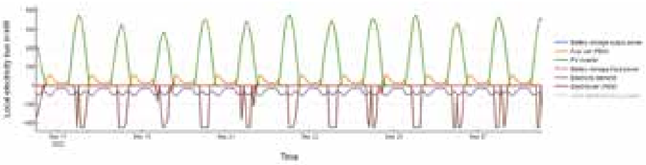
Illustration 9 Visualization of the State of Charge (SOC) of the Battery Storage (top) and the Hydrogen Storage (bottom) for the 100% Renewable Scenario (PV, Battery, Hydrogen) Over a Year



While the battery storage (top) shows strong daily fluctuations (amplitudes) and almost daily deep discharge states, the hydrogen storage is less deeply discharged throughout the day but shows strong changes over the year. Especially in March and June, a high proportion of hydrogen is re-electrified. In both profiles, there are also strong declines in power supply from the storages over the course of the year (second half of May and August/September). This is due to the relatively low consumption compared to the available solar potential, resulting in increased direct solar electricity generation.

To illustrate this, the following illustration visualizes the power flows for a few days in September. The power consumption (purple) is significantly below the electricity generation from the solar plant (green).

Illustration 10 Exemplary Visualization of the Power Flow for a Few September Days or the 100% Renewable Scenario (PV, Battery, Hydrogen)



3. Sensitivity Analysis

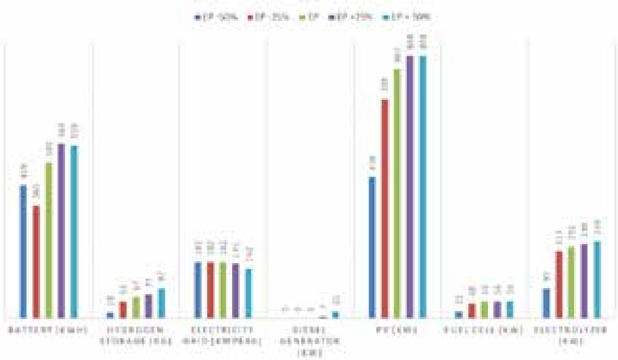
3.1. Electricity Price

Initially, the influence of electricity price fluctuations on the simulation results was examined. For this case study in Tonga with an electricity price of 0.358 EUR/kWh, the following changes in electricity prices occur for the various sensitivity cases (25% and 50% higher and lower electricity prices):

- +50% => 0.45 EUR/kWh
- +25% => 0.27 EUR/kWh Status Quo = 0.358 EUR/kWh
- -25% => 0.27 EUR/kWh
- -50% => 0.18 EUR/kWh

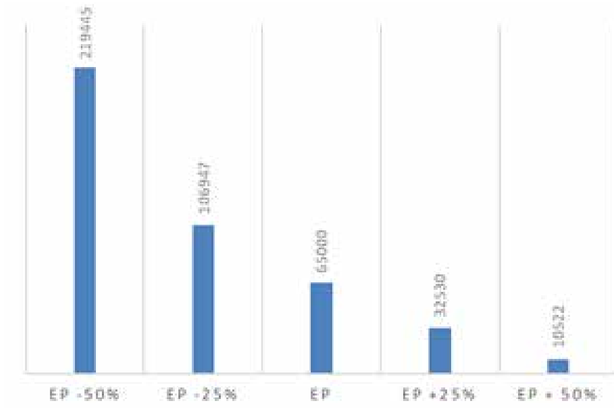
Simulated in MVS for the cost-minimizing scenario, the results are visualized in the following graph. The capacities of the individual system components are displayed. Green (centered) represents the reference scenario under current prices for comparison.

Illustration 11 Optimized Capacities of Individual Technologies with Electricity Price Fluctuations



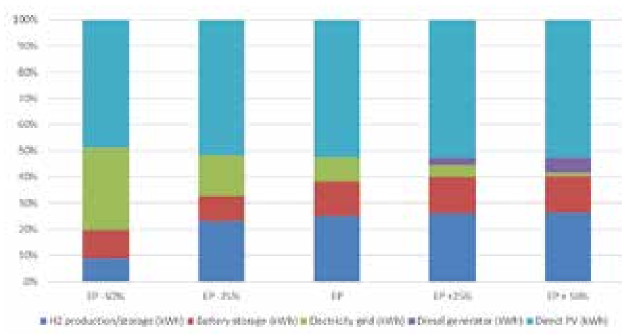
Overall, changes in the dimensioning of the energy system for the Tanoa International Dateline Resort are evident with electricity price developments in both directions. The absolute largest capacity fluctuations are observed in the PV and battery storage components, while the composition of the hydrogen system varies significantly relative to others. Both capacities increase with higher electricity prices (electricity prices – EP), as the system becomes more autonomous and grid power consumption decreases. In this case, the diesel generator is also used (lower peak load coverage through grid power), but it is significantly smaller compared to the previously installed generator. In the case of declining electricity prices, especially the installed hydrogen capacities and the size of the PV plant decrease, with the sharpest cut occurring with a halving of the current electricity price. The installed battery storage capacity initially decreases as well, but increases again at -50% lower electricity prices, as it now stores not only solar but also grid electricity to bridge occasional power outages. The following illustration clearly shows how strongly grid power consumption overall depends on electricity price fluctuations:

Illustration 12 Grid Power Consumption in kWh for the Calculated Sensitivity Cases (Electricity Price Fluctuations)



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

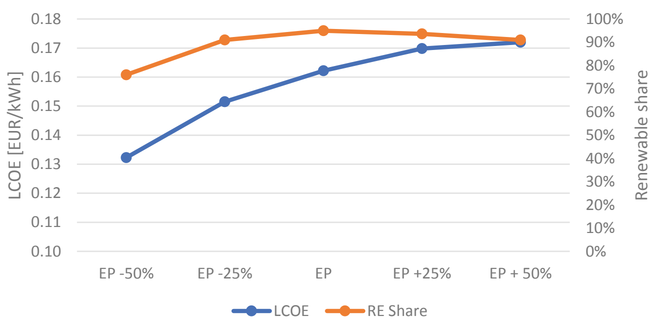
Illustration 13 Share in Covering Power Demand with Electricity Price Fluctuations



The majority of the electricity consumption at the Tanoa International Dateline Resort is fed directly via the PV plant (turquoise) in all scenarios. The lower the electricity price, the more electricity is sourced from the grid (green). The share of hydrogen technology (blue) in load coverage remains largely the same except in the case of a 50% electricity price drop, where its contribution to demand coverage is significantly lower.

As the last illustration of this sensitivity analysis, the development of electricity generation costs and the share of the renewable energy system is visualized.

Illustration 14 Development of Electricity Generation Costs and the Share of Renewable Energy with Electricity Price Fluctuations



Electricity generation costs fluctuate between 0.13 – 0.17 EUR/kWh (the higher the electricity price, the higher the electricity generation costs). The share of renewable energies in the system remains relatively high at 80% to 94%. The highest share of renewable energies is achieved in the status quo. With rising electricity prices, this share decreases slightly due to the integration of the diesel generator into the system, while it decreases somewhat more strongly with decreasing electricity prices due to increased sourcing of grid power.

Investment Costs of Hydrogen Technology

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

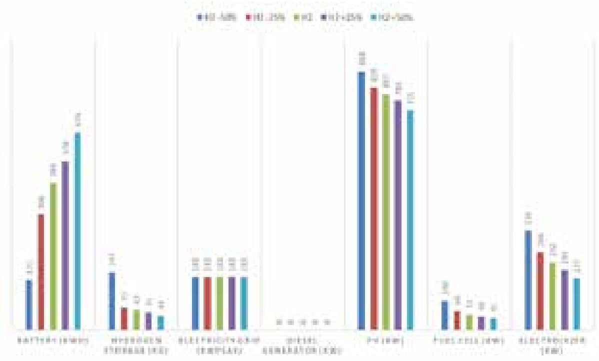
Hydrogen Storage (original price at 350 EUR/kg):
- +50% => 525 EUR/kg
- +25% => 438 EUR/kg
- -25% => 263 EUR/kg
- -50% => 175 EUR/kg

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

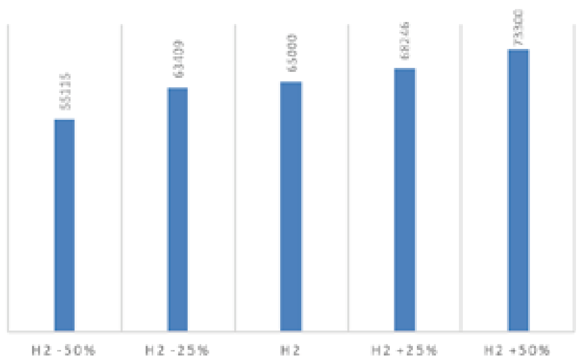
Analogous to the sensitivity analysis of electricity prices, the development of the capacities of the individual system components with price fluctuations in the investment costs of the hydrogen components was shown. Here too, the simulation of the reference scenario (cost minimization) with status quo prices is displayed in green.

Illustration 15 Optimized Capacities of Individual Technologies with Fluctuations in Hydrogen Investment Costs



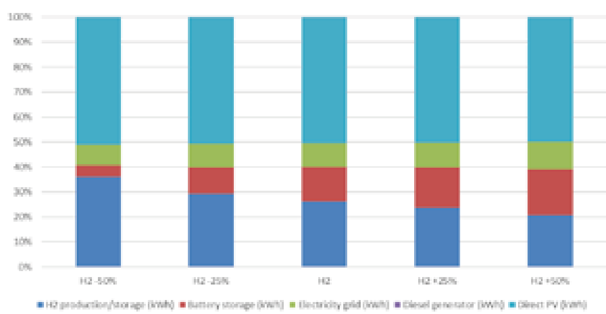
With increasing costs for hydrogen technology, both the capacity of the hydrogen components and that of the PV plant decrease. The battery storage, on the other hand, is dimensioned larger to cover the resulting storage need. If the costs of the hydrogen components decrease, the importance of the PV plant and hydrogen components increases, and a correspondingly smaller battery storage capacity is recommended. Especially with a price reduction of 50%, a clear trend towards more hydrogen and less battery storage is evident. The peak load (182 kWp) is covered from the grid in all cases, and an additional diesel generator is not needed in any sensitivity scenario. As the total amount sourced from the grid decreases slightly when the costs for hydrogen components go down, it increases with an increase in these costs, and the system loses autonomy (see the following illustration).

Illustration 16 Grid Power Consumption in kWh for the Calculated Sensitivity Cases (Investment Costs of Hydrogen Components)



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

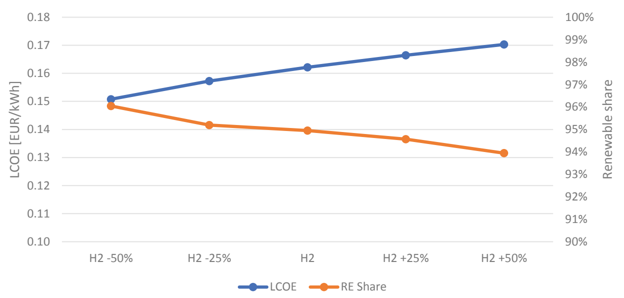
Illustration 17 Share in Covering Power Demand with Fluctuations in Hydrogen Investment Costs



The share of direct PV electricity generation thus remains largely constant, and there are only minor fluctuations in the grid power share (higher hydrogen component costs increase, as mentioned above, the grid power consumption). Thus, the overall share of storage technologies in demand coverage also remains largely constant, and there are only changes in the type of installed technology: Intuitively, the shares of hydrogen components increase or decrease with an increase or decrease in their costs. It is interesting to note that the share of hydrogen technology, even with a cost increase of 50%, never falls below half of the total installed storage capacity, underscoring the importance of the technology as a long-term storage for the system.

Finally, here are the developments of the electricity generation costs and the share of renewables:

Illustration 18 Development of Electricity Generation Costs and the Share of Renewable Energies with Fluctuations in Hydrogen Investment Costs



Electricity generation costs fluctuate only slightly between 0.15 EUR/kWh and 0.17 EUR/kWh, with LCOE increasing slightly at higher hydrogen component costs. The share of renewable energies decreases with rising hydrogen component prices, here too, however, only slightly by a maximum of 2% in the cases considered.

5. Conclusion

The Tanoa International Dateline Resort would benefit from the installation of a PV plant, a battery storage, and new hydrogen technologies to supplement grid power consumption. This could reduce the electricity costs of the facility by up to 60% in the long term and achieve a high share of renewable energies (95%). The backup diesel generator would become redundant, with small capacities only recommended from a 25% increase in electricity prices. Both 100% renewable energy scenarios include the use of hydrogen technologies and promise a cost reduction compared to the current power supply. Hydrogen technology plays a role in all sensitivity cases, its relevance only decreases in the case of a 50% collapse in electricity prices. In the case of declining technology prices, hydrogen would be used as the primary system storage, and even with significant price increases, its share of the total installed storage capacity would never fall below 50%, while the relevance of battery storages with decreasing investment costs for hydrogen components declines significantly.

Powering The Pacific: The Cost Implications of Renewable Energy

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

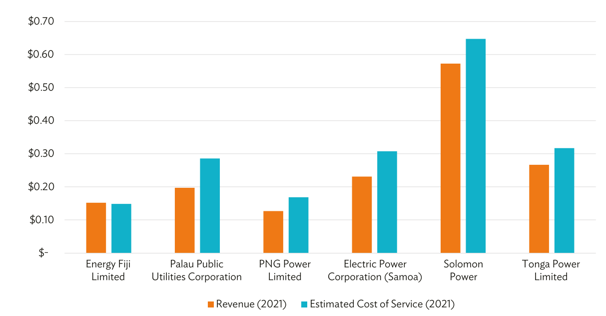
Section 3: Relationship Between Electricity Costs And Tariffs

Cost savings will not necessarily translate into immediate reductions to end-user tariffs. Various factors can intervene to shape end-user tariffs, most notably government policy and the regulatory framework. Most utilities in the Pacific are state-owned monopolies. While utilities and regulators generally aim to set tariffs that allow utilities to recover the entirety of their revenue requirements, policymakers can and do intervene, often requiring the utilities to shoulder the cost of subsidy programs, in some cases contrary to the tenets of state-owned enterprise legislation in the region.[22]

A characteristic of electric utilities in many Pacific countries is that they fail to recover their revenue requirements.[23] Policymakers and the utilities themselves are often hesitant—for political reasons or concerns about customer affordability—to increase tariffs to the levels required to recover a utility's total cost of service. Some utilities (such as PPUC in Palau) receive explicit subsidies from the government to bridge some or all of the gap between the utility's revenues and its actual costs. Others do not, which usually means they cannot spend sufficient amounts to maintain and replace assets and cannot easily make new investments. Figure 13 compares each utility's average revenue to its average cost of service, calculated using the rate-of-return approach described in section 2. These were calculated from utility financial statements for 2021. Estimated average costs for 2021 are higher than average revenues in all cases, though many are close to full cost recovery.24,[25]

The factors described in section 3 are likely to mute the impact of renewable energy generation on tariffs. Since electricity tariffs are already below full-cost recovery levels for many Pacific utilities, any anticipated savings from renewable energy are effectively already rolled into the tariffs. Any further reductions—ostensibly to accommodate the lower cost of renewable energy generation—would further jeopardize the financial condition of the utilities.

Figure 13: Comparing Utility Revenues and Costs ($/kWh)



kWh = kilowatt-hour
Source: Utility financial statements 2021; author calculations.

Regulatory frameworks can also foster a disconnect between a utility's costs of service and the revenue it can recover through tariffs. This can occur through the treatment of:

i. Grant-funded infrastructure. International development partners make grant funding available to many countries of the Pacific. This raises questions and often inconsistent practices on how to treat grant-funded assets in the rate base, depreciate them, and what (if any) rate of return to use. The most common practice internationally is to exclude such assets from the rate base (which would also exclude them from any depreciation charges). Still, some Pacific utilities include them in the rate base and/or depreciate them over time. The disadvantage of including grant-funded assets in the rate base is that it passes along to customers costs the utility never incurred.

ii. Return on equity. Some countries—such as the Solomon Islands—have tariff methodologies that explicitly allow for a return on equity recovery and sometimes pay dividends to shareholders. Others—such as Samoa—do not consider returns on equity as a cost; instead, they use a cash needs approach in which the only returns to investors are principal and interest payments on debt.

22 There may be disagreements between regulators and utilities about the reasonableness or "prudence" of some of the costs included in each component, but there is rarely disagreement that all of the components mentioned in Section 2 should be included in estimating the revenue requirement.

23 It is important to note that a utility (such as Fiji's EFL) may be profitable but may still not recover its full costs of service. This may be for many reasons, but one is that returns to equity (a cost in the revenue requirement) is not considered to be an expense on a company's profit and loss statement (P&L) and therefore would not have any impact on profitability. Alternatively, a utility may make a loss, but still recover its revenue requirement. This could happen, for example, if a utility has high interest payments on its loans. It may bring in enough revenue to make the interest payments, but such payments would be treated as expenses in the P&L, and hence a drag on profit margin (Earnings Before Interest, Taxes, Depreciation, and Amortization, however, would likely be positive).

24 Palau's electricity tariffs are now closer to, if not at, cost-recovery levels subsequent to a series of tariff studies supported by the Asian Development Bank during 2020–2022.

25 Fuel costs are often an important driver of the revenue shortfall. Many Pacific countries have adopted a regulatory mechanism which allows forthe periodic (monthly or quarterly) pass-through of fuel costs into tariffs. This mechanism is semi-automated in that it requires only a minor review by the sector regulator or government owners of the utility. It is a much less burdensome process than a full revision of tariffs. Fiji, Palau, and Samoa (among others) allow for more frequent pass-through of fuel purchase costs. These mechanisms were put on hold, however, in some countries during the coronavirus disease (COVID-19) pandemic, as a way of protecting consumers, leaving the utilities to bear fuel price risk, and putting additional strain on cashflows.

26 Noting that scale benefits also play a part in this pricing reduction.

iii. Subsidies. Direct subsidies (government transfers to utilities), indirect subsidies (such as fuel price subsidies), and cross-subsidies between customer classes (most commonly, commercial customers cross-subsidizing residential customers) are all distortive price signals customers receive relative to the underlying costs of service. Any of these factors could increase or decrease a utility's service costs relative to the revenue it can recover, making renewables look more or less attractive relative to thermal generation alternatives.Tariff regulation is critical when considering scaling up renewable energy generation in Pacific utilities.

Introducing renewable energy generation may not always translate into underlying cost savings. Factors that threaten to undermine the advantage of renewable energy generation relative to thermal are the following:

i. Planning considerations. Electricity planners are often concerned with choosing the technology with the lowest levelized or "all-in" cost. Such costs depend heavily on fuel or resource availability. For renewable energy generation, the availability of solar, wind, hydro, or biomass resources determine how much and how often a plant can run during a given period (the plant's "capacity factor"). Lower resource availability (e.g., less rainfall for run-of-river hydro) means a lower capacity factor. A lower capacity factor means the total CAPEX for a plant needs to be spread across fewer units of electricity generated, increasing the cost of generation per kWh. From a planning perspective, solar, wind, or hydro may not have the lowest LCOE at all capacity factors. A diesel plant may, for example, have a lower LCOE if it is only operated for a few hours a day to serve peak load. Plant capacity factors can be improved—as noted in section 2.2—by installing battery storage, but such storage means a higher CAPEX cost and, thus, a higher LCOE.

ii. Operational considerations. System operators face decisions every minute of every day about which plants to run or "dispatch" to meet demand. Their overall approach is referred to as "security constrained economic dispatch". This means that they try to dispatch the plants with the lowest O&M costs to save customers money, but that there are many technical considerations—related to system security and reliability—that require them to deviate from always dispatching the plant with the lowest marginal cost. Variations in seasonal resource availability (e.g., dry and rainy seasons) and unpredictable spikes in customer demand (e.g., celebrations during the holidays) require deviations from economic dispatch, which are essential for keeping the lights on but ultimately have a cost.

iii. Procurement methodologies. Governments and utilities have a choice to run competitive tenders for new generation or entertain unsolicited proposals. Many unsolicited proposals received by Pacific utilities have offered solar at or near the avoided cost of diesel, offering very little savings. Competitive tenders in the region have achieved much better results—as Tonga's experience demonstrates—with its two most recent solar IPP tenders yielding offtake pricing 27% and 43% lower than a sole-sourced 2016 IPP.[26] International experience indicates that successive competitive tenders (for multiple plants over time) achieve successively lower-cost bids.

iv. Perceptions of market risk and scale. Potential solar developers are often focused on larger, more familiar markets with more potential to expand than the relatively small and less known markets of the Pacific. Such perceptions will increase the cost of debt and equity.

v. Taxation. Governments may tax the import of renewable energy technologies. Some regional governments have or are considering waiving taxes on imports of renewable energy technologies and their components. To successfully introduce more renewables, policies and regulations in the energy sector and across sectors must be consistent. Care must also be taken to ensure that adequate investments in system reliability accompany the introduction of interruptible electricity generation.

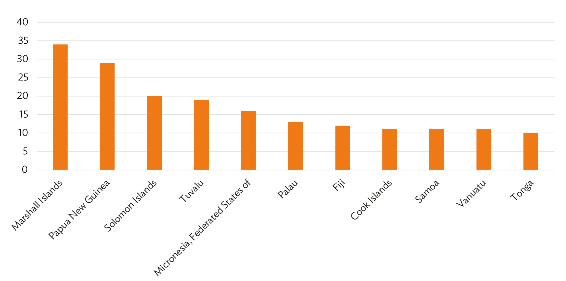
Section Four: Bringing Down Electricity Costs

This policy brief has outlined the main elements of electricity service costs and how planning, dispatch, technology, policy, and regulation impact those costs. Additional factors—some directly under the control of power utilities and others dependent on broader sector structure and management—can also exert downward pressure on costs. The most impactful are the following:

4.1 Operational Efficiency

Pacific utilities suffer from high system (technical and non-technical) losses, resulting in lost revenue and driving up costs per kWh sold. Technical losses represent electricity lost during transmission and distribution, typically due to aging and/or faulty infrastructure. These losses differ between systems because of how the networks are designed, the condition of the assets, and ambient factors. Technical losses are much lower on high voltage networks than low voltage, and long distribution lines have higher losses than shorter ones. Poorly maintained transmission and distribution equipment typically has higher technical losses, and technical losses increase as ambient temperature increases.

Figure 14: System Losses in Pacific Countries, 2021 (%)



Source: 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

Non-technical losses are most often the result of the absence of electricity meters, faulty meters, illegal connections, or customers tampering with meters. They represent electricity delivered but not invoiced by the utility. System losses averaged 10%–27% in 2021 in the sample group of six utilities (Figure 14). Collections losses further erode the revenue of these utilities, as they represent invoices never paid, including those from government clients. Reducing these losses would increase utility revenue and reduce costs for each kWh produced.

4.2 Commercialization

Four of the six utilities in this survey are governed by legislation that requires them to operate efficiently and profitably, limiting shareholding ministers' powers to impose non-commercial activities.27 Directors and management are to be selected for the skills and experience they bring to the utility and held accountable for their ability to meet pre-agreed performance targets. Strict adherence to the tenets of this state-owned enterprise legislation would allow the utilities to set and achieve commercial results without interference from government shareholders. All but two of the utilities in this sample are burdened by non-commercial activities for which they receive inadequate compensation, driving up costs per kWh produced.[28]

4.3 Regulation

Each of the utilities in this sample is a majority stateowned monopoly service provider, and all but two operate under the guidance and scrutiny of a sector and/or tariff regulator. Effective tariff regulation should incentivize utilities to reduce costs and improve efficiencies based on relevant benchmarking and rate of return indicators. Importantly, this tariff regulation should not be subject to ministerial approval lest it result in tariff caps that do not allow the utility to recover its regulated costs. Where policymakers wish to provide subsidies, these are most effectively delivered directly, without burdening the utility through unfunded community service obligations.

4.4 Competition

International experience has demonstrated the effectiveness of competition in reducing the cost of services in the electricity sector, as companies vie to gain market share by offering better and cheaper services than their competitors. In large electricity markets, this can be done by unbundling generation, transmission, and retail and introducing competition in each segment. In smaller Pacific markets, competition has been introduced for the operation of service concessions in Vanuatu and in the competitive tendering of renewable energy IPP contracts in Palau, Samoa, and Tonga. This has allowed the private sector to bring innovation and ensure that public utilities achieve value for money in their renewable energy investments.

SECTION FIVE: PLANNING FOR IMPACT

To maximize the cost savings from renewable energy, the transition should be incorporated within a least cost generation plan. Most Pacific utilities have developed these plans which consider their renewable energy resources (such as wind, solar, geothermal, biomass), availability of land, remaining useful life of assets, and needed investments to support transmission and distribution infrastructure.29 The plans lay a pathway for the transition, which is then regularly updated as costs evolve. Adhering to these plans ensures that each successive investment contributes to the overall goal of increasing the share of renewable energy generation while supporting the financial viability of the utilities. It also allows utilities to fend off unsolicited proposals that do not contribute to their overall goals.

A least-cost generation plan should help determine whether and how to add solar generation capacity. In areas with good solar irradiation, solar generation can be assessed for its cost –benefit against other renewable energy sources (such as hydro or wind). In making this assessment, the configuration of the generation investment is considered, i.e., utility-scale solar farms, grid-connected solar rooftop programs, or a combination of both.

Utility scale solar farms are increasingly contracted under public–private partnership arrangements in the Pacific, where land and a supportive regulatory regime are available. These solar plants benefit from economies of scale, so they typically have lower CAPEX costs per kW than grid-connected rooftop programs. They can, however, require investment in transmission infrastructure to minimize losses as power is distributed to customers. In the Pacific—where an estimated 80%–90% of land is held under customary tenure—securing commercial leases for utility-scale solar farms can be difficult.

Utilities are exploring floating solar and gridconnected solar rooftop programs where land is unavailable. The solar rooftop programs allow gridconnected customers to invest in solar rooftop systems and sell the power back to the utility. This way, the utility expands its solar production capacity without acquiring land or investing in a larger production facility. Rooftop programs typically reduce technical losses in the network since the solar power is generated near the load, further improving efficiency. As with utility-scale solar farms, as the amount of rooftop solar increases, so does the renewable energy penetration, and with it comes the need to install additional BESS to limit spilled energy and help stabilize the grid. Consideration needs to be given to who funds and owns this BESS.

Fundamentally, rooftop solar programs should generate savings for a utility because customers pay for the system, and the utility buys the electricity at a price that they determine. This price is set at a level that:

i. is cheaper than it costs the utility to generate using diesel, and

ii. is attractive enough to encourage customers to participate in the program and install solar. The savings made by the utility can be used to fund any infrastructure upgrades required by the program—including BESS—and/or to reduce electricity tariffs. The structure of the program, i.e., gross or net metering, determines the regulatory requirements and revenue streams for both the utility and the participants:

i. Net metering: Participants consume the power they

27 Papua New Guinea, Samoa, Solomon Islands, and Tonga all have legislation governing state-owned enterprises that cover their electric utility. Fiji's electric utility is not governed by Fiji's Public Enterprise Act, and Palau does not have a state-owned enterprise act.

28 Solomon Power does not declare any community service obligations, and Energy Fiji Limited's regulated tariff allows a cross-subsidy to cover community service obligations.

29 Some Pacific utilities are working with development partners to establish energy transition plans which incorporate these principles and help to identify financing gaps.

generate and sell any excess to the utility at an agreed price. Then, they buy any additional power needed from the utility, resulting in lower power consumption from the grid each month.

ii. Gross metering: Participants sell all the power they generate to the utility at an agreed price and then buy their power from the utility as before; this creates revenue for the participants, reducing their monthly electricity bill. As a variation on gross metering, utilities can finance and install rooftop systems for participants, paying them a monthly lease fee for the rooftop space.

While net metering has the potential to generate higher savings for customers—since they purchase less power from the utility each month—it comes at a higher cost and risk to the utility, as demand for power drops when users are generating and consuming their own power. This requires careful program rollout and tariff management to ensure the utility remains whole. Gross metering allows the utility to more easily predict and manage the quantum of power being supplied into the grid and subsequently distributed to consumers. This facilitates better revenue and network management.

Utilities can and have introduced solar rooftop programs on a gross metering basis and transitioned to net metering when their systems and market have made this attractive. As the costs of solar photovoltaic systems and batteries have declined during 2014–2024, the interest in solar rooftop programs has increased in the Pacific, with pilot programs undertaken in Cook Islands, Palau, PNG, Samoa, Tonga, and Vanuatu. While each of these programs has been structured differently, they have yielded some critical lessons:

i. Rooftop solar programs must be fully incorporated into the least-cost generation strategy of the utility and aligned with demand forecasts.
ii. The development of a supportive regulatory regime must precede rollout.
iii. Feed-in tariff structures must benefit both consumers and the utility.
iv. Established standards for solar installers and equipment improve reliability.
v. Maintenance responsibilities must be clearly allocated.

SECTION SIX: CONCLUSIONS

This paper has outlined how transitioning from fossil fuels to renewable energy sources can impact the cost of power generation and resulting tariffs for Pacific consumers. While Pacific utilities have been relatively slow to add renewable energy capacity during 2014–2024, recent investments in solar energy are already having an impact on reducing the overall cost of production. This cost reduction is concentrated in fuel savings since renewable generation in the Pacific typically displaces diesel. As illustrated in section 2.1.5, fuel costs represented \$0.02–\$0.21 per kWh generated in the six utilities surveyed for this paper, so the cost savings generated by renewables will be greater for those with the highest fuel costs.

Cost savings from renewables will not necessarily translate into a directly proportional reduction in tariffs for customers, as a range of factors can intervene to shape end user tariffs, most notably government policy and the regulatory framework. While utilities and regulators generally aim to set tariffs that allow utilities to recover the entirety of their revenue requirements, policymakers can and do intervene, often requiring the utilities to shoulder the cost of subsidy programs, in some cases contrary to the tenets of stateowned enterprise legislation in the region.

As electricity tariffs are already below full-cost recovery levels for many Pacific utilities, anticipated savings from renewable energy are effectively already rolled into the tariffs. Additional reductions—to reflect the lower cost of renewable energy generation—could further jeopardize the financial condition of the utilities.

The transition from thermal to renewable energy carries other important benefits beyond cost savings, most notably security of supply and lower carbon emissions. These are critical factors driving the renewable energy targets in many Pacific countries and should contribute to economic growth and resilience. A further benefit of renewable energy investment—which has the potential to generate further cost reductions—is carbon offset credits from reduced diesel consumption.

Once Pacific countries have developed the regulatory mechanisms needed to identify, certify, and monetize these credits, they have the potential to generate additional revenue to offset the cost of renewable energy investment. Renewable energy investment can reduce the levelized cost of electricity in Pacific countries. To maximize this impact, utilities and their shareholders should ensure that this transition also incorporates:

i. Aligning sector policy, regulation, and shareholder oversight to allow utilities to operate commercially;

ii. Making adequate investments in system reliability when introducing renewable electricity generation;

iii. Ensuring that renewable energy is fully integrated into a least-cost generation plan that includes realistic costing forecasts;

iv. Improving energy transition planning;

v. Improving operational efficiency;

vi. Allowing competition where appropriate; and

vii. Ensuring robust competitive tendering processes for generation IPPs.

31st Annual Conference & Trade Exhibition Report 2024, 30th September – 3rd October 2024, Nukualofa, Tonga

Pacific Power Association

The recent PPA 31st Annual Conference and Trade Exhibition 2024 was held in Nukualofa, Tonga at the Falemasiva Hall from the 30 September to the 3rd of October, themed **"The Cost of Renewables to Transition"** brought together Active members, Allied Members, Affiliate Members, Donor Partners, Researchers and Experts to explore the financial, technological and strategic challenges of shifting towards renewable energy. The event provided a platform for in-depth discussions on how to balance economic costs of renewable energy adoption with the urgent need for sustainable and clean energy solutions. The conference emphasized the importance of understanding the true costs associated with renewable energy projects, from initial investments and infrastructure development to long-term maintenance and integration into existing energy grids. The Keynote Speaker, Chief Guests and presenters addressed topics such as the impact of technological innovations in reducing costs, and strategies for accelerating the transition while ensuring economic viability. The accompanying trade exhibition with **38 exhibitors** showcased the latest advancements in renewable technologies, offering attendees the opportunity to engage in cutting-edge solutions in solar, wind, hydro and other sustainable energy sources. This convergence of thought leadership and technological innovation highlighted the collaborative effort required to overcome cost barriers and accelerated the global transition to a more sustainable energy future.

The conference and trade exhibition attracted **221 delegates** in total where 68 delegates from 19 power utilities, 97 delegates from 58 Allied member companies, 1 Observer, 5 spouses & 1 child, 35 delegates from Affiliate members, donor partners, government representatives and 14 delegates from the PPA Secretariat & Tonga Power Limited organizing committee.

Sunday 29 September 2024

The conference began with a lunch hosted and sponsored by the host utility, Tonga Power Limited, at the Likualofa Restaurant for all delegates followed by registrations from 1-5pm at the Tanoa Dateline Hotel.

Figure 1: Delegates having lunch at Likualofa Restaurant

After the lunch, all delegates were transported to the Tanoa Dateline Hotel for registrations and collection of their conference satchels. The PPA Secretariat acknowledges the kind sponsorship from Sulzer for the Conference Satchels, Solomon Power for the program, CBS Power for the conference shirts, Pacific Engineering Projects for the Caps and Generator Rental Services for the T-shirts.

Figure 2: Registrations at Tanoa Dateline Hotel

Monday 30 September 2024

CEO's Retreat

The CEO's retreat was held at the Faonelua Convention Centre. 19 Power Utilities attended the retreat which were the CEOs and senior representatives. The retreat was coordinated by Ms. Jane Romero of the Pacific Regional Infrastructure Facility (PRIF) which was also attended by representatives from donor partners such as the World Bank (WB), Asian Development Bank (ADB), Department of Climate Change, Energy, the Environment and Water (DCCEEW), Australian Infrastructure Financing Facility for the Pacific (AIFFP)-Department of Foreign Affairs and Trade (DFAT), Australia, International Finance Corporation (IFC), the Ministry of Foreign Trade New Zealand (NZMFAT), British High Commission, FSM Department of Resources and Development and Hawaii Natural Energy Institute. A total of fifty participants attended the retreat.

Figure 3: CEOs Retreat in session

The following presentations at the CEOs retreat were as follows.

1. Camco – Building Resilient and affordable power supply in the Pacific Islands
2. ADB – Emerging Areas in Energy Transition
3. ADB –ADB's engagement in shifting fossil fuel to renewable energy in power sector
4. ADB – Energy Sector Overview
5. MEC – Reform, IRRP and Performance Improvements at MEC
6. AIFFP – Energy, Pacific Islands, PNG & Timor-Leste
7. DCCEEW–Australia Pacific Partnership for Energy Transition
8. Hawaii Natural Energy Institute – Capacity Building on Renewable Energy Integration in Pacific Island Countries
9. IFC – Powering Pacific Island Countries Renewable Electricity Generation in the Pacific
10. MFA – New Zealand's Renewable Energy Cooperation in the Pacific
11. Foreign, Commonwealth & Development Office – Support for the Clean Energy Transition in the Pacific

Engineers Workshop

Alongside the CEOs retreat was the Engineers Workshop which took place on Monday, Tuesday and Thursday and this was facilitated by Mr. Abraham Simpson and Mr. Eugene Singh. The workshop was also held at Faonelua Convention Centre with engineers from the 19 Power Utilities attending this workshop. The following topics were covered in this workshop.

1. Introduction to Performance Management & Balanced Scorecard
2. BSC Perspectives & Strategic Objectives
3. Financial Objectives
4. Customer Objectives
5. Process & Operational Objectives
6. Measures (KPIs)
7. Case Study – Nauru
8. Renewable Technology
9. Introduction to the Benchmarking Application
10. Performance Monitoring of Power Utilities
11. Pacific Women in Power
12. Presentations from Allied Member: Wartsila, Aggreko, Geogas, ITP Renewables & Karpowership
13. FWE Solutions

Figure 4: Engineers Workshop in session

Utility Board Directors Workshop

The Utility Board of Directors Workshop was a two-day event which was also held at the Faonelua Convention Centre facilitated by representatives of the University of New South Wales, Dr. Iain McGill, Dr. Anna Bruce, Mr. Janendra Prasad and Mr. Edoardo Santagata.
The discussions covered the following topics.

1. Electricity Sector Transition
2. Barriers to RE Uptake a Sectoral Review
3. Rooftop PV Study – A Case Study for Efate Grid
4. Tariffs
5. Energy Planning Framework
6. The Energy Transition Model (ETM)

Figure 5: Utility Board Directors Workshop in session

Allied Members Formal Meeting

The Allied members formal meeting was held after their informal meeting and afternoon tea. The Allied members Chairman, Mr. Joe Reed together with PPA's Executive Director and Board Chairman conducted the meeting at the Faonelua Convention Centre.

The PPA acknowledges the kind sponsorship from Nauru Utilities Corporation for the morning and afternoon teas and Pohnpei Utilities Corporation for lunch on Monday.

Figure 6: Allied Members formal meeting in progress

All Delegates were treated to dinner and entertainment at the welcome dinner held at the Katea Resort, kindly hosted and sponsored by the host utility Tonga Power Limited.

Figure 7: Welcome dinner reception

Tuesday 1 October 2024

Official Opening

The conference was officially opened by the Deputy Prime Minister of Tonga, Honourable Samiu Kuita Vaipulu, with the keynote address delivered by Mr. Ximing Peng, Senior Energy Specialist and Energy Program Coordinator in the Pacific, World Bank.

The Hon. Samiu Kuita Vaipulu emphasized during his speech that regional collaboration is the key to addressing the energy challenges that the Pacific faces and through forums like the PPA conference, can pool knowledge, recourses and expertise to build stronger, more resilient energy systems for our island nations.

The Keynote address by Mr. Peng further focused on three key issues which were the 5 pillars of energy transition, utilities' critical role in promoting transition in the Pacific as well as regional institutions and finally the cost of transition to renewables.

Figure 8: The Chief Guest, the Deputy Prime Minister of Tonga, Honourable Samiu Kuita Vaipulu

Figure 9: The Keynote Speaker, Mr. Ximing Peng, Senior Energy Specialist and Energy Program Coordinator in the Pacific

Figure 10: Delegates attending the official opening of the conference at Falemasiva Hall, Tonga

The World Bank, Pacific Women in Power project also launched their Baseline Report during the official opening.

Figure 11: Pacific Women in Power team, Lilika Fusimalohi and Helle Bucchave

The official opening was followed by the group photograph session and morning tea.

Session 1: Presentations

Chair: Mr. Joseph Pedro, GM, Kwajalein Atoll Joint Utilities Resources, Kwajalein.

Figure 12: Mr. Rob Whitmore of Radian Research

1030-1100 – Reference Standards and traceability ensuring the Integrity of the Revenue Meter (cash register) is important to the consumer and the electric utility. Its a matter of fair commerce, Mr. Bod Whitmore, Radian Research

Figure 13: Mr. Florent Duthoit of Ecosun Innovations

1100-1130 - Deployable Solar Power Stations for remote islands and emergency response – Mr. Florent Duthoit, Ecosun Innovations

Figure 14: Ms. Laure Darcy of the Private Sector Development Initiative

1130-1200 – Powering the Pacific: The cos of Implications of Renewable Energy – Ms. Laure Darcy, Private Sector Development Initiative (ADB)

Session 2: Presentations

Chair: Mr. Mafalu Lotolua, GM, Tuvalu Electricity Corporation

Figure 15: Mr. Nick Philips of Itron

1300-1330 – Right-sizing Renewables through Smart Metering Technology – Mr. Nick Phillips, Itron

Figure 16: Mr. Jamie Roodenrys of Wildfire Energy

1330-1400 – Reliable and cost-effective energy from Waste in the Pacific – Mr. Jamies Roodenrys, Wildfire Energy

Figure 17: Mr. Pelangi Saichu of SMA Australia

1400-1430 – New Flexible SMA Solution for off-grid System till 2MW, Mr. Pelangi Saichu, SMA Australia

Figure 18: Mr. Sandip Kumar of Sustainable Energy Industry Association of the Pacific Islands

1430-1500 – Boosting solar inspections to ensure safe and sustainable systems – Mr. Sandi Kumar, Sustainable Energy Industry Association of the Pacific Islands

Session 3: PPA Board Meeting

The PPA Board meeting is open to all members began at 4.07pm and concluded at 5.01pm.

Figure 19: Board meeting members in session at the Falemasiva Hall

The PPA acknowledges the kind sponsorship from Marshalls Energy Company for morning and afternoon tea and S&C Electric Company for the lunch on Tuesday.

Opening of the Trade Exhibition

On Tuesday evening the opening of the trade exhibition was officially opened by the Deputy Prime Minister of Tonga, Honorable Samiu Kuita Vaipulu where he emphasized that the exhibitors, companies and organizations are the sectors that make the exhibition possible through their invaluable participation to the success of the event. He further stated that the exhibitor's products, services and technologies enable utilities to gain access to new solutions that are essential for modernizing and strengthening the energy infrastructure.

The PPA acknowledges the kind sponsorship of Hawthorne CAT for the opening trade exhibition cocktail.

Figure 20: The Deputy Prime Minister of Tonga, Honourable Samiu Kuita Vaipulu

Figure 21: Delegates participating at the opening of the trade exhibition cocktail

A total of 38 exhibitors had exhibition tables and all from the PPA Allied members.

Exhibition Table #	Allied Members
1.	S&C Electric Company
2.	Sustainable Energy Industry Association of the Pacific Islands
3.	AVO NZ Ltd
4.	Arthur D Riley
5.	Hitachi Energy NZ Ltd
6.	inHance Utilities
7.	
8.	Vergnet
9.	Elemental Group
10	Hawthorne
11.	Sino Soar Hybrid
12.	Channell Pty Limited
13.	Delstar
14.	Itron
15.	TOTAL Energies
16.	Aggreko
17.	Komaihaltec Inc.
18.	ETEL Transformers
19.	Nan Electrical Cables
20.	Cummins South Pacific
21.	Karpowership
22.	Turbo Systems Australia
23.	Wartsila
24.	
25.	Pacific Engineering Projects
26.	EIF International
27.	Generator Rental Services
28.	Transnet
29.	Carptrac
30.	Power & Marine Engineering
31.	ITP Renewables
32.	ComAp Ltd
33.	CBS Power Ltd
34.	Energy Pool Development
35.	Ecosun Innovations
36.	OHM International
37.	EMACS
38.	Sunergise
39.	HDF Energy
40.	Radian Research

Figure 22: Edoardo Soares, Jason and Melanie Lander of S&C Electric Company

Figure 26: John Morgan of Hitachi Energy NZ 6

Figure 23: Sandip Kumar & Geoff Stapleton of SEIAPI with Praneel Kumar & Mohammed Tazil of Sunergise & Nishant Pratap of Pacific Engineering Projects

Figure 27: Caitlin Freemark & Andrew Jordan of inHance Utilities

Figure 24: Mark Leach of AVO NZ Ltd

Figure 28: Matthieu Leflon of Vergnet

Figure 25: Peter MacKenzie & Mark Candy of ADR

Figure 29: Cliff Yuen of Hawthorne CAT

Figure 30: Stephanie Luan & Yu Dian of Sino Soar Hybrid

Figure 31: Michael Congreve of Channel Ltd

Figure 32: Ravi Khire of Delstar

Figure 33: Karl Renner, Alex Beveridge & Nicholas Phillips of Itron, Ravi Khire of Delstar

Figure 34: Eroni Verevukivuki, Isireli Taoi & Finau Elder of TotalEnergies

Figure 35: David Chute & Finn Mac Dermont of Aggreko

Figure 36: Ekaterina Zalitko of Komaihaltec

Figure 37: Brian Hemingway from ETEL

Figure 38: Scott Lomate of Cummins

Figure 42: Chandar Sen and the Pacific Engineering Projects team

Figure 39: Jeremy Szopa of Karpowership

Figure 43: Marty Wood & Sean Johnstone of Generator Rental Services

Figure 40: Anthony Abela & Hasan Quazi of Turbo Systems Australia

Figure 44: Troy Balderston of Transnet

Figure 41: Paul George & Padmanabhan Jayaraman of Wartsila with Michael Uiari of NiuPower

Figure 45: Amit Charan & Dharmend Prasad of Carptrac

Figure 46: Sarang & Neil Bhat of Power and Marine Engineering

Figure 47: Julia MacDonald & Ravuni Uluilakeba of ITP Renewables

Figure 48: Harry Robinson & Chris Gricks of ComAp

Figure 49: Shelvin Chand, Ajay Prasad & Amit Singh of CBS Power with Sandip Kumar of SEIAPI

Figure 50: Agnieszka Rychlicka & Alain Dardy of Energy Pool

Figure 51: Florent Duthoit of Ecosun Innovations

Figure 52: Lane Petersen of OHM International

Figure 53: Michael Guiness and Scott Byers of EMACS

Figure 54: Praneel Kumar & Mohammed Tazil of Sunergise

Figure 55: Bryan Dumail & Ildo Agnetti of HDF Energy

Figure 56: Robert Whitmore of Radian Research

Figure 57: Speed Networking in progress

Wednesday 2 October 2024

Speed Networking & Field Trip

Day 3 of the conference started off with the speed networking at the Oholei Beach Resort. The speed networking was facilitated by the PPA Allied Members Chairman, Joe Reed, Mana Pacific. Each Allied member was given 2 minutes each with the 19 Active member utilities. After lunch, all delegates were taken on a field trip to both Tonga Power Limited's Wind Turbine farm in Li o Manumataongo and Popua Power Station in Anana.

Figure 58: Field Trip at the Wind Turbine Farm and Power Station

The PPA acknowledges the kind sponsorship from the Elemental Group for morning tea, lunch from inHance Utilities and Boroko Motors Power Generation for the Networking Day on Wednesday.

Conference Closing Dinner

In the evening the delegates were treated to dinner and entertainment at the closing dinner event at Katea Resort. The dinner was kindly sponsored by World Bank.

Figure 59: Delegates enjoying dinner and entertainment

Thursday 3 October 2024

Session 7: Presentations

Chair: Mr. Hasmukh Patel, CEO, Energy Fiji Limited.

Figure 60: Dr. Iain McGill of University of New South Wales

0830-0900 – Hydrogen Roadmap for the Pacific – Dr. Iain McGill, University of New South Wales

Figure 61: Ildo Agnetti of HDF Energy

0900-0930 – Cost of Energy Storage and Ancillary Services for Renewable Energy – Mr. Ildo Agnetti, HDF Energy

Figure 62: Damon Schmidt of Hawaii Natural Energy Institute

0930-1000 – Capacity Building on Renewable Energy Integration in the Pacific Island Countries – Mr. Damon Schmidt, Hawaii Natural Energy Institute

Session 8: Presentations

Chair: Ms. Lesley Katoa, CEO, Te Aponga Uira

Figure 63: Eduardo Soares of S&C Electric Company

1030-1100 – Improving Grid Reliability – Palau Public Utilities Corporation – Mr. Eduardo Soares, S&C Electric Company

Figure 64: Janendra Prasad of University of New South Wales

1100-1130 – Capacity Expansion Modelling to Support Vanuatu's Energy Roadmap (NERM 2016-2030) Mr. Janendra Prasad, University of New South Wales


Figure 65: Goran Stojadinovic of Transnet

1130-1200 – The Hidden Costs of Transition to Renewables – Mr. Goran Stojadinovic, Transnet

Session 9: Presentations

Chair: Mr. Faumui Iese Toimoana, GM, Electric Power Corporation


Figure 66: Agnieszka Rychlicka of Energy Pool Development

1300-1330 – Power Pacific Islands: Advance Energy Management System Energy Transition – Ms. Agnieszka Rychlicka, Energy Pool Development


Figure 67: Clarence Kitalong of Palau Public Utilities Corporation

1330-1400 – Recent Renewable Transition Experience, Issues and Lessons Learned in Palau – Mr. Clarence Kitalong, Palau Public Utilities Corporation


Figure 68: Finau Katoanga of Sunergise

1400-1430 – 1MW Solar Farm with 500kw/1MWH Battery Storage – Mr. Finau Katoanga of Sunergise

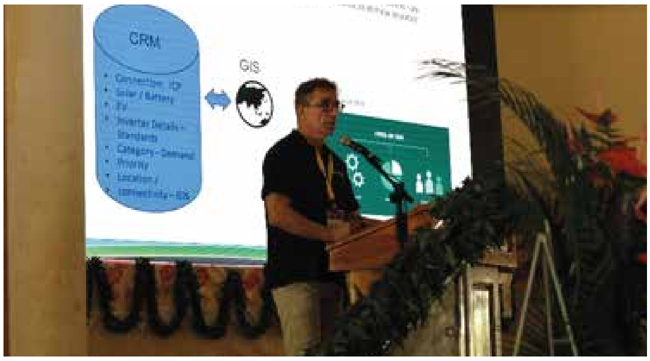


Figure 69: Richard Coomber of Elemental Group

1430-1500 – Technology Landscape for Transitioning Utility: Technology can Assist in Mitigation Transition Costs and Impacts. Experience of a large New Zealand Network Utility – Mr. Richard Coomber, Elemental Group Limited

Annual General Meeting

The AGM was held at the Falemasiva Hall. Nukualofa, Tonga.

Figure 70: Annual General Meeting in progress

At the meeting the PPA Board Chairman provided a summary of the resolutions from the Board meeting held on Tuesday. During the meeting a conference theme committee was formed. The committee consists of Ms. Lesley Katoa of Te Aponga Uira, Mr. Trevayne Esiel of Pohnpei Utilities Corporation and Mr. Ildo Agnetti of HDF Energy. The committee then elected Lesley Katoa to be the Chair.

Closing Trade Exhibition

The Closing of the Trade Exhibition was closed by the Tonga Power Limited's Board Chairman, Mr. Tapu Panuve. The closing exhibition cocktail was kindly sponsored by Total Energies.

Figure 71: Mr. Tapu Panuve closing the trade Exhibition at the Falemasiva Hall

Figure 72: Delegates at the closing trade exhibition cocktail

The PPA acknowledges the kind sponsorship from Wartsila for the morning and afternoon teas, and lunch from Carptrac on Thursday.

Acknowledgements

The funding and sponsorships from members below have ensured a successful 2024 conference and trade exhibition.

Events	Sponsor
Monday Morning Tea & Afternoon Tea	Nauru Utilities Corporation
Monday Lunch	Pohnpei Utilities Corporation
Tuesday Morning Tea & Afternoon Tea	Marshalls Energy Company
Tuesday Lunch	S&C Electric Company
Tuesday Opening of Trade Exhibition	Hawthorne CAT
Wednesday Morning Tea	Elemental Group Limited
Wednesday Lunch	inHance Utilities
Wednesday Networking Day	Boroko Motors Power Generation
Wednesday Conference Dinner	World Bank
Thursday Morning Tea & Afternoon Tea	Wartsila
Thursday Lunch	Carptrac
Thursday Closing of Trade Exhibition	TOTAL Energies
Conference shirt/blouse	CBS Power
Conference Polo shirts	Generator Rental Services
Conference caps	Pacific Engineering Projects
Conference Satchels	Sulzer
Conference Program	Solomon Power

Other Major Sponsors:

1.	Asian Development Bank (ADB)
2.	Department of Foreign Affairs and Trade – Australia
3.	Department of Climate Change, Energy, the Environment and Water – Australia (DCCEEW)
4.	Australian Infrastructure Financing Facility for the Pacific (AIFFP)

The PPA Secretariat would like to commend and acknowledge all the sponsors of the event, all its Allied and Active members, Donor Partners and Affiliate members for a successful conference. We also thank all the delegates who made all the effort to attend the conference and the presenters and workshop facilitators who have taken the time to prepare. Acknowledging Tonga Power Limited for a hospitable welcome and hosting the delegates during the week. Without you all, the conference would not be the same. Thank you all so very much for all the support, hard work and effort put in. We invite you all to come and join the PPA for the 32nd Annual Conference and Trade Exhibition that will be held in Palau 2025.

World Bank- Power Factory Workshop in Honiara, Solomon Islands 14th to 18th October 2024

Abraham Simpson, Training Coordinator

1. Introduction:

A crucial capacity need of power utilities in the Pacific Islands is the use of power system analysis application software. This will enable the analysis of the power grid to identify stabilit and argumentation requirements and to enable a higher penetration of renewable energy, especially variable renewable energy sources such as solar PV and wind generating sources.

Unused funds from the SEIDP project of US$ 250,000.00 is available for use by the PPA. This proposal is for the use of these funds for capacity building in power system analysis using the PowerFactory application and upgrading the VPN for the PPA server to allow the use of the PPA PowerFactory by remote parties. Due to the demand for this training, the program incorporated three sessions:

Session	Date	Power Utilities
Honiara, Solomon Islands	14th to 18th October, 2024	Solomon Power, PNG Power Limited and UNELCO of Vanuatu
Nadi, Fiji	21st to 25th October, 2024	EFL, EPC, TPL, TEC, NUC,
Guam	20th to 24th January, 2025 (tentatively)	MEC, KAJUR, KUA, PUC, CPUC, YSPSC, PPUC

This report summarizes the training session held in Honiara, Solomon Islands. Solomon Power is acknowledged for hosting the training at its training room at its head office in Ranadi, Honiara.

2. Summary of Program:

The program was conducted over 5 days involving presentations and practical work as follows:

Day 1	• PowerFactory Fundamentals • PowerFactory User Interface • PowerFactory Data Structure and Model Development • Introduction to Load Flow Calculations
Day 2	• Short Circuit Calculations • Analysing results in PowerFactory • Medium Voltage Network Analysis
Day 3	• Operation Scenarios • Parameter Characteristics • Quasi-Dynamic Simulation • Protection Elements
Day 4	• Time Overcurrent Protection Analysis • Introduction to Time Domain Simulations • Motor Start Up Simulations
Day 5	• Introduction to Power System Harmonics in PowerFactory • Harmonic Load flow Analysis Tools • Harmonic Network Frequency Response

3. Trainer:

DIgSILENT GmbH founded in Germany is the developer of the PowerFactory power system analysis software. DIgSILENT Pacific based in Australia, a member of the DIgSILENT group, designated Wayne Ong to deliver the week-long training. He has over 12 years of service with the company and delivered dozens of PowerFactory trainings including to international customers in the Pacific Islands, Timor-Leste, Mongolia, Bangladesh and New Zealand.

The trainer observed the participants in Honiara to be very attentive with a desire to develop their skills in power system analysis using the PowerFactory software. This is exhibited by their deep motivation in working through the PowerFactory exercises, to the very end of the scheduled day.

Most of the participants were new users of the PowerFactory software. By the end of the weeklong training, they have confidence to navigate the power system analysis tool to build network models, conduct basic power system analysis and present results through plots and diagrams.

Participants with prior PowerFactory experience improved their effectiveness in using the power system simulation tool. In addition, broader advanced power system analysis functions, data interchange and model management were discussed with these experienced users.

Photo 1: Wayne Ong - The Trainer from DIgSILENT Pacific Australia at the Certificate Award Ceremony (on the left)

Regular use and practice are vital to solidify knowledge learnt and expand into advanced areas of power system analysis. Building on the participants' fundamental skills in PowerFactory, future training may extend their competence on advanced subject matter as suggested by the participants in their feedback.

4. Participants:

Sixteen participants completed the training. Table 1 lists the participants and their position within the utility they work for. All participants work in the planning and operations areas which would largely benefit from the use of the PowerFactory.

Name	Utility	Position
Zarren Galokale	Solomon Power	Asset and Standards Engineer
Roland Tabu	PNG Power Ltd	Specialist, Supply Side Management
Wesley Kuka Ramo	Solomon Power	Electrical Engineering Coordinator
Ian Domikar	PNG Power Ltd	System Planning Engineer Ramu
David Jonah	PNG Power Ltd	Senior Manager National Grid Control
Larry Rausi	Solomon Power	Switching Coordinator
Craig Waletafisia Quan	Solomon Power	Planning Engineer
Carlos Soso	Solomon Power	Planning Engineer
Jacob Alopitu	Solomon Power	Planning Engineer
HAIDI WANYA	PNG Power Ltd	Team Leader Network Planning
Amos Silas	Solomon Power	Outstations Coordinator-Eastern Region
Robert Fuabu	Solomon Power	Technical Support Team Engineer
Lawrence Terry	Solomon Power	Electrical Engineer
Humphrey Danny	Solomon Power	TST Assistant Engineer
Emile Joelyne	Unelco Engie	Design & GIS officer
Ron Jacquier	Unelco Engie	Head of design office

Table 1: List of Participants

5. Attendance:

Sixteen participants attended the course each day although on the first day an alternative for a nominated participants attended in his place. The nominated participant attended for the rest of the days of training.

Sixteen participants were awarded certificates for completion of the training course. The certificates were awarded by the Acting Chief Executive of Solomon Power, Delilah Homelo. Two of the sixteen (12.5%) participants were of the female gender.

The attendance sheet for each day of the course is provided in Appendix 1.

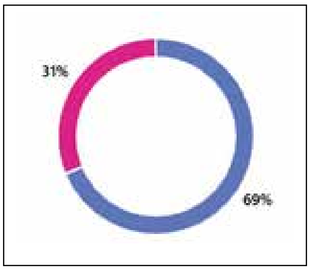
Photo 2: Haidi Wanya of PNG Power receiving her Certificate of Completion

6. Evaluation and Feedback from Participants:

An online survey was conducted to which all 16 of the participants who completed the course responded. The survey questions and responses are summarised as follows:

1. How satisfied are you with the knowledge you gained from the course?

Very Satisfied	11	
Satisfied	5	
Neither satisfied nor dissatisfied	0	
dissatisfied	0	
Very dissatisfied	0	



2. Do you feel you achieved your desired learning outcome?

Yes	16
No	0
Not Sure	0

3. How would you rate the instructor's overall teaching performance?

Average rating 9.81/ 10

4. Level of Agreement/ Disagreement to Statements Regarding the Instructor.

Agrement/ Disagreement to the following Statements.	Strongly Agree	Somewhat Agree	Neutral	Somewhat Disagree	Strongly Agree
The instructor prepared well at the start of each class	16	-	-	-	-
The instructor communicated clearly on course expectations	16	-	-	-	-
The instructor delivered course in a clear and easy-to-understand approach	14	2	-	-	-
The instructor encouraged students in-class participation	15	1	-	-	-
The instructor maintained my interest throughout the whole course	14	2	-	-	-
The instructor thoroughly answered questions from students	16	-	-	-	-
The instructor had good time management during class	16	-	-	-	-

5.

Teaching Effectiveness	Extremely ineffective	Somewhat ineffective	Neutral	Somewhat effective	Extremely effective
Instructional materials used in this course	-	-	-	4	12
Learning activities used in this course	-	-	-	2	14
Use of technologies in the class	-	-	-	2	14

6.

Usefulness of Topics Covered	Very useful	somewhat useful	Not so useful	Not very useful
PowerFactory fundamentals - User interface, network model building, introduction to load flow and short-circuit calcul	16	-	-	-
Analysis of results and distribution feeder - Operation scenarios, parameter characteristics, quasi-dynamic load flow	16	-	-	-
Protection analysis - Time-overcurrent plots, relays, fuses, protection coordination	15	1	-	-
Time-domain analysis - Setup and run dynamic simulation, short-circuit event, motor-startup analysis	14	2	-	-
Harmonics, cable analysis, other - Power system harmonics, distortion diagrams, network frequency response, cable an	12	4	-	-

7.

Rating Out of Five	Rating
Travel arrangements (To be completed those who traveled to Honiara)	5.00
Accommodation was satisfactory. (To be completed by those who travelled to Honiara	5.00
The quality of the training room and facilities	4.44
Catering services, refreshments and lunch	4.88

8. Sixteen (100%) of participants responded that the course met their expectation.

9. Sixteen (100%) of the participants recommended advanced training in PowerFactory.

10. On a scale of 10 from unlikely to likely, that they would recommend the training to a workmate or friend, 14 participants responded with a score of 10 for likeliness, 1 responded with a score of 9 and 1 responded with a score of 8. The likeliness that participants would recommend the training to others is 9.81 out of 10.

11. The participants were requested to proposed topics they

would like to be included in this training or in advanced training. The responses received were as follows:

a. Advanced Dynamics would be an excellent choice for future training.
b. More of Dynamic Modelling, specially building AVRs and Governors.
c. Model Verification Methods
d. Protection
e. Scripting & Automation"
f. The training was excellent, especially the fundamentals of Power Factory. In the case of Solomon Power, we already have the Power Factory model for our Honiara network. I would recommend that in future trainings, the instructor asks participants to bring their own network files. This way, we can go through them and identify any issues we're facing with our models and explore how we can improve them.
g. Outage Planning, Optimal Power Restoration, Transmission Network Tool, Economic Analysis Tool & Contingency Analysis
h. Governor Modeling and excitation Modeling that are align to dynamics Modeling of the network. Apart from that formal report compilation of system studies of the network either steady state or dynamics.
i. Occupational Health & safety.
j. Distribution Network Analysis
k. Outage Management
l. Reliability Analysis
m. Economic Analysis"
n. Generation adequacy analysis
o. Grid impact analysis for integration of renewable energy systems"
p. Building a real-life power system network model from scratch.
q. Economic Analysis
r. Transmission Analysis Tools
s. Distribution Network Analysis
t. Demand Forecasting Scenarios and needs"
u. I would recommend the training can also capture the model of how to utilize the differential protection systems and setting the relays according to zones optimum zones. Meaning that the clear coordination of protections system needs be clearly thought during the training session.
v. More detail training on operation scenarios, quasi-dynamic simulation & protection elements.
w. I suggest that the course is more specific/in depth to Protection and would recommend use of one base/same grid to do all the examples on - not different grids. Also can the slides be updated to reflect the Digsilent 2022 software
x. For a starter, I would prefer a simple break down of the software and how to navigate through it. A complete instruction or guideline on function or command within the software.
y. For UNELCO Design and GIS section, we would like this training to also include imports and exports of data from a GIS software in Digsilent and vice versa.
z. For basic training, the current content is sufficient. However, for Unelco, we would like another training that focuses on Protection (including procedures/standards for carrying out a protection study) and stability (time domain simulations) as currently the study is done by 3rd party. We are also in the process of modelling our LV network therefore a training on DGS import/export function would be beneficial for expand/update of the model through our GIS database. Modelling of PV rooftop systems is also in our interest.

7. Conclusions & Recommendations:

The conclusions and recommendations arising from the evaluation of the training are:

1. Power utilities need to analysis their power network under all operating conditions, to identify congestion, understand stability boundaries, and improve efficiency of supply. This becomes even more critical with the connection of vatable renewable power sources and especially distributed renewable energy sources. This analysis forms the basis of any power development and network augmentation requirements to meet the increasing demand for electricity, provide adequate protection, minimise the risk of damage to equipment, and enable stable operation. The training on

PowerFactory was appropriate, useful and meets this need of the Pacific Island utilities to enable the acceleration of the connectivity of renewable energy sources to the electric grid.

2. Advanced training on PowerFactory is recommended. This involves deep dives into each
particular topics such as:

a. load flow analysis and medium feeder analysis. This would be very useful to understand the impact of distributed renewable energy sources such as roof top solar power plants and formula the strategy for connectivity.

b. Protection coordination to ensure proper and adequate protection of the network elements and stable operation of the grid under various events and operating scenarios.

c. Dynamic modelling and analysis of the grid under various conditions and control modes/ devices to develop operating policies and procedures for operating the network to provide a safe and secure power supply to consumers.

d. Navigating around the PowerFactory application to provide enhanced modelling and presentation of results, including the import and exporting of data and linking to other applications such as a GIS system.

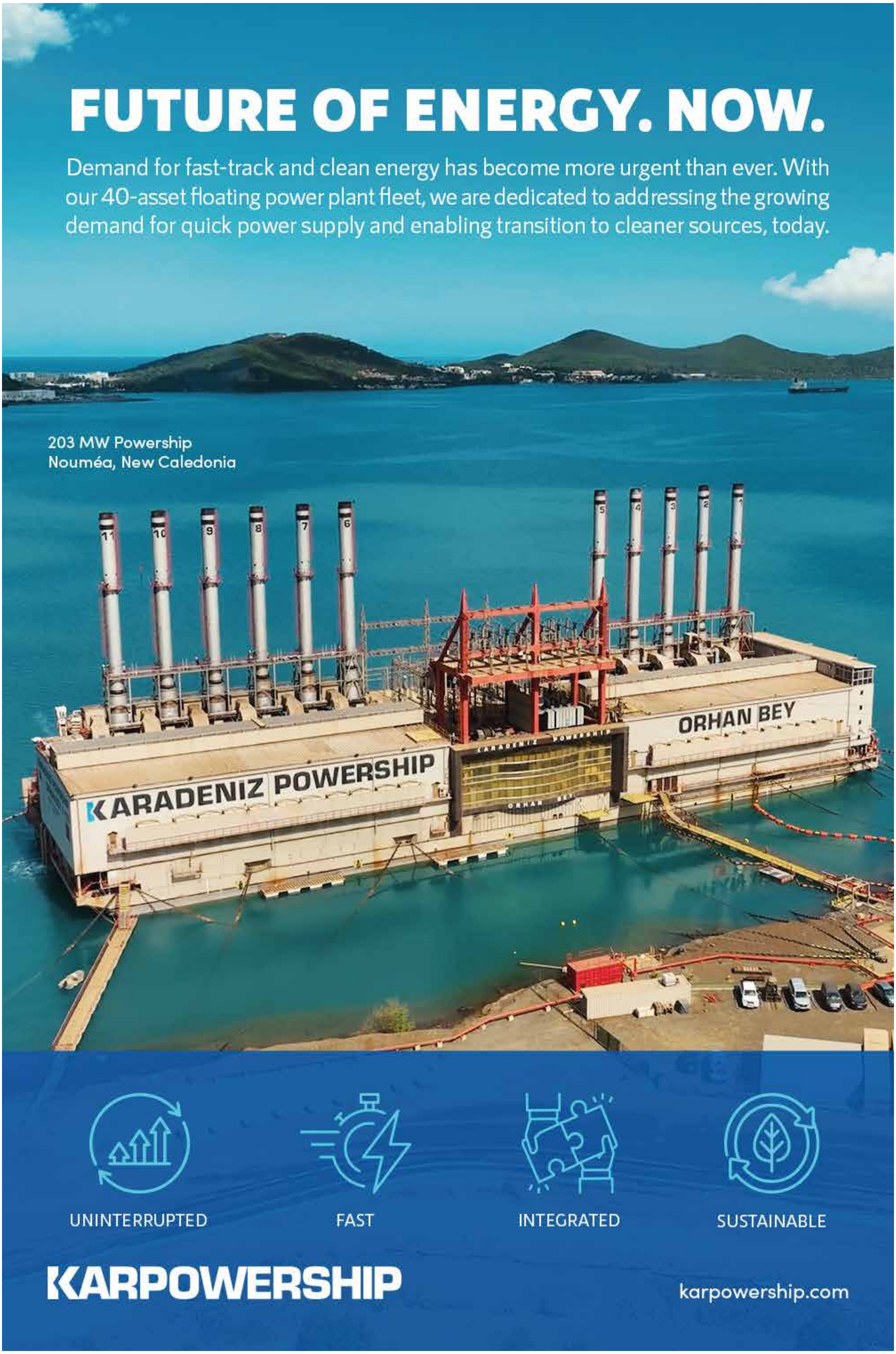
8. Acknowledgements:

The following are acknowledged for their contribution to this successful program.

1. The World Bank is to be commended for funding and coordinating this program that provided the Pacific Island utilities with the knowledge and skills to improve their networks and meet the needs of the economy and well-being of the island nations and territories, and accelerate the connection of renewable energy sources to meet the United Nations SDG 7 goals.

2. The Pacific Power Association is commended for facilitating the coordination of the training program.

3. DIgSILENT Pacific, Australia for providing the expertise and training to execute the program.


FUTURE OF ENERGY. NOW.
Demand for fast-track and clean energy has become more urgent than ever. With our 40-asset floating power plant fleet, we are dedicated to addressing the growing demand for quick power supply and enabling transition to cleaner sources, today.
203 MW Powership
Nouméa, New Caledonia
KARADENIZ POWERSHIP
ORHAN BEY
UNINTERRUPTED
FAST
INTEGRATED
SUSTAINABLE
KARPOWERSHIP
karpowership.com

World Bank – Power Factory Workshop in Nadi, Fiji Islands 21st to 25th October 2024

Abraham Simpson, Training Coordinator

1. Executive Summary

The section summarizes the PowerFactory training session held in Nadi, Fiji from October 21-25, 2024, aimed at enhancing the power system analysis skills of Pacific Island power utilities.

Training Overview: The training was conducted at the Novotel Hotel in Nadi, Fiji, from October 21-25, 2024, and included participants from various Pacific Island power utilities.

Introduction to PowerFactory: The training focused on the PowerFactory software, which helps analyze power grids for stability limits, protection requirements, and renewable energy integration.

Funding and Sessions: The World Bank provided $250,000 from the SEIDP project for the training, which included three sessions in Solomon Islands, Fiji, and Guam.

Program Structure: The five-day program included presentations and practical work on various topics such as PowerFactory fundamentals, short circuit calculations, and harmonic analysis.

Trainer and Participants: Wayne Ong from DIgSILENT Pacific conducted the training, and participants ranged from graduate engineers to executive managers, most of whom were new to PowerFactory.

Participant Engagement: Participants were highly motivated and attentive, showing significant improvement in their PowerFactory skills by the end of the training.

Evaluation and Feedback: Sixteen participants responded to an online survey, with 69% being very satisfied and all recommending advanced training in PowerFactory.

Proposed Topics for Future Training: Participants suggested topics for future training, including load dispatching, advanced protection, renewable energy integration, dynanmic modelling and simulation of events and more.

Conclusions and Recommendations: The training met the needs of Pacific Island utilities, and there is a need for advanced training in specific areas like load flow analysis, protection coordination, dynamic modelling and simulation and navigation of PowerFactory.

Acknowledgements: The World Bank, Pacific Power Association, and DIgSILENT Pacific were acknowledged for their contributions to the successful program.

2. Introduction:

A crucial need of power utilities in the Pacific Islands is the use of power system analysis application software to better understand their electric grid. This will enable the analysis of the power grid to identify stability limits, protection and argumentation requirements to enable a higher penetration of renewable energy, especially variable large and distributed renewable energy sources such as solar PV and wind generating sources.

Unused funds from the SEIDP project of US$ 250,000.00 was made available by the World Bank for use by the PPA. PPA proposed that the funds be used for capacity building in power system analysis using the PowerFactory application, and upgrading the VPN for the PPA server to allow the use of the PPA PowerFactory remotely by Pacific Island power utilities.

Due to the demand for this training, the program provided for three sessions:

Session	Date	Power Utilities
Honiara, Solomon Islands	14th to 18th October, 2024	Solomon Power, PNG Power Limited and UNELCO of Vanuatu
Nadi, Fiji	21st to 25th October, 2024	EFL, EPC, TPL, TEC, NUC,
Guam	20th to 24th January 2025 (tentatively)	MEC, KAJUR, KUA, PUC, CPUC, YSPSC, PPUC

This report summarizes the training session held at the Novotel hotel in Nadi, Fiji.

3. Summary of Program:

The program was conducted over 5 days involving presentations and practical work as follows:

Day 1	• PowerFactory Fundamentals • PowerFactory User Interface • PowerFactory Data Structure and Model Development • Introduction to Load Flow Calculations
Day 2	• Short Circuit Calculations • Analysing results in PowerFactory • Medium Voltage Network Analysis
Day 3	• Operation Scenarios • Parameter Characteristics • Quasi-Dynamic Simulation • Protection Elements
Day 4	• Time Overcurrent Protection Analysis • Introduction to Time Domain Simulations • Motor Start Up Simulations
Day 5	• Introduction to Power System Harmonics in PowerFactory • Harmonic Load flow Analysis Tools • Harmonic Network Frequency Response

4. Trainer:

DIgSILENT GmbH founded in Germany is the developer of the PowerFactory power system analysis software. DIgSILENT Pacific based in Australia, a member of the DIgSILENT group, designated Wayne Ong to deliver the week-long training. He has over 12 years of service with the company and delivered dozens of PowerFactory trainings including to international customers in the Pacific Islands, Timor-Leste, Mongolia, Bangladesh and New Zealand.

The trainer observed the participants in Nadi to be very attentive with a desire to develop their skills in power system analysis using the PowerFactory software. This is exhibited by their deep motivation in working through the PowerFactory exercises, to the very end of the scheduled day.

Most of the participants were new users of the PowerFactory software. By the end of the weeklong training, they have confidence to navigate the power system analysis tool to build network models, conduct basic power system analysis and present results through plots and diagrams.

Participants with prior PowerFactory experience improved their effectiveness in using the power system simulation tool. In addition, broader advanced power system analysis functions, data interchange and model management were discussed with these experienced users.

Regular use and practice are vital to solidify knowledge learnt and expand into advanced areas of power system analysis. Building on the participants' fundamental skills in PowerFactory, future training may extend their competence on advanced subject matter as suggested by the participants in their feedback.

5. Participants:

Eighteen participants completed the training program. Table 1 list the participants and their position within the utility they work for. All participants work in the appropriate sections of the power utility that will benefit from the use the PowerFactory software.

Table 1: List of Participants

PowerFactory, Power System Analysis Program, Nadi, Fiji - 21-25 October, 2024						
	Country	Participant		Position	Email Address	Utility
1	Tonga	Painitu'uua	Lie	Engineering Manager	plie@tongapower.to	TPL
2	Tonga	Siosiua	Lavemai	Electrical Engineer	slavemai@tongapower.to	TPL
3	Nauru	Ken	Blake	G/M Power Generation	ken.blake@nuc.com.nr	NUC
4	Nauru	Jonpeal	Rodiben	G/M Distrubution	jonpeal.rodiben@nuc.com.nr	NUC
5	Samoa	Godspromise	Matagi	Graduate Engineer	matagig@epc.ws	EPC
6	Samoa	Katherine	Samau	Graduate Engineer	samauk@epc.ws	EPC
7	Fiji	Mohammed	Alim	System Planning Engineer	mohammedz@efl.com.fj	EFL
8	Fiji	Rohitesh	Lal	Network Design Engineer	rohiteshl@efl.com.fj	EFL
9	Fiji	Shaneel	Nand	Graduate Engineer - System Studies & Protection	shaneeln@efl.com.fj	EFL
10	Fiji	Prasheel	Chand	Graduate Engineer - System Planning	prasheelc@efl.com.fj	EFL
11	Fiji	Anishal	Chandra	Graduate Electrical Engineer	anishalc@efl.com.fj	EFL
12	Fiji	Richa	Kantharia	Graduate Engineer - Network Design & Planning	richak@efl.com.fj	EFL
13	Fiji	Anthony	Goundar	Graduate Engineer - Network Design & Planning	anthonyg@efl.com.fj	EFL
14	Fiji	Kunal	Prasad	Protection Engineer	kunalp@efl.com.fj	EFL
15	Fiji	Karteek	Naidu	System Control Engineer	karteekn@efl.com.fj	EFL
16	Tuvalu	Polu	Tanei	Electrician	fatutofaga@gmail.com	TEC
17	Kiribati	Simon	Reiher	Engineering Planning Manager	simon.reiher@pub.com.ki	PUB
18	Kiribati	Teebwatia	Takau	Electrical Draughtsman	teebwatia.takau@pub.com.ki	PUB

The participants comprised a mix of seniority ranging from Graduate Engineers to Executive Management positions. All participants indicate that this was the first time they were using PowerFactory.

6. Attendance:

Seventeen participants attended the training course on the first day and were joined by a second participant from PUB, Kiribati on the second day.

Each participant was awarded certificates for completion of the training course. The attendance sheet for each day of the course is provided in Appendix 1.

7. Evaluation and Feedback from Participants:

An online survey was conducted to evaluate the training program. Sixteen participants responded to the on-line survey. The survey questions and responses are summarised as follows:

1. How satisfied are you with the knowledge you gained from the course?

Very Satisfied	11	69%
Satisfied	4	25%
Neither satisfied nor dissatisfied	1	6%
dissatisfied	0	
Very dissatisfied	0	

2. Do you feel you achieved your desired learning outcome?

Yes	14
No	0
Not Sure	2

3. How would you rate the instructor's overall teaching performance?

Average rating 9.56/ 10

4. Level of Agreement/ Disagreement to Statements Regarding the Instructor.

Agrement/ Disagreement to the following Statements.	Strongly Agree	Somewhat Agree	Neutral	Somewhat Disagree	Strongly Agree
The instructor prepared well at the start of each class	15	1	-	-	-
The instructor communicated clearly on course expectations	15	1	-	-	-
The instructor delivered course in a clear and easy-to-understand approach	14	2	-	-	-
The instructor encouraged students in-class participation	13	3	-	-	-
The instructor maintained my interest throughout the whole course	15	1	-	-	-
The instructor thoroughly answered questions from students	13	3	-	-	-
The instructor had good time management during class	16	-	-	-	-

5. Teaching Effectiveness

Teaching Effectiveness	Extremely ineffective	Somewhat ineffective	Neutral	Somewhat effective	Extremely effective
Instructional materials used in this course	-	-	-	4	12
Learning activities used in this course	-	-	-	2	14
Use of technologies in the class	-	-	-	2	14

6.

Usefulness of Topics Covered	Very useful	somewhat useful	Not so useful	Not very useful
PowerFactory fundamentals - User interface, network model building, introduction to load flow and short-circuit calcul	16	-	-	-
Analysis of results and distribution feeder - Operation scenarios, parameter characteristics, quasi-dynamic load flow	16	-	-	-
Protection analysis - Time-overcurrent plots, relays, fuses, protection coordination	16	-	-	-
Time-domain analysis - Setup and run dynamic simulation, short-circuit event, motor-startup analysis	14	2	-	-
Harmonics, cable analysis, other - Power system harmonics, distortion diagrams, network frequency response, cable an	14	2	-	-

7.

Rating Out of Five	Rating
Travel arrangements (To be completed those who traveled to Honiara)	4.83
Accommodation was satisfactory. (To be completed by those who travelled to Honiara	5.00
The quality of the training room and facilities	4.75
Catering services, refreshments and lunch	4.06

8. Fifteen participants responded that the course met their expectation. One participant was not sure if the course met his expectations.

9. Sixteen participants recommended advanced training in PowerFactory.

10. On a scale of 10 ranging from unlikely to likely, that they would recommend the training to a workmate or friend, 11 participants responded with a score of 10 for likely, 3 responded with a score of 9 and 2 responded with a score of 8. The likeliness that participants would recommend the training to others is 9.56 out of 10.

11. The participants were requested to proposed topics they would like to be included in this training or in advanced training. The responses received were as follows:

1. Load Dispatching
2. Advance Protection
3. Renewable energy sources integration to existing Diesel Genset and grid
4. All essential concepts are covered in this training and maybe further in-depth training could be provided for specific fields to their designated users.
5. Repeat training: For us, we don't have the software, if we have the software, we need to redo the same topic because it's too much. We do not cover it all in one week and get the ideas and familiar with them, we need more time to cover these useful and helpful topics. But we need to include the addition of renewable energy and BESS to load flow.
6. Reliability analysis and Monte Carlo simulations
7. Renewable Integration Studies
8. Network Expansion Planning
9. Optimal Power Flow"
10. More on protection system, dynamic power flow analysis and power generation/renewable modelling and integration.
11. i really appreciate the opportunity to be involved in this crucial training, introducing us with this powerful software. i also want to acknowledge that since this software provide massive features and capabilities, i believe that it requires more time to adapt and learn. i think there is too much module for a one-week training session. However, it is better to consolidate on few topics according to the time of training, so that we can absorb the information probably. short time training will not be an issue if we have access to the software in order to learning after the training.
12. Contingency Analysis and N-1 Security Assessment
13. Renewable Energy Integration and Stability Studies
14. Optimal Power Flow (OPF) and Economic Dispatch
15. Reliability and Asset Management Studies
16. Voltage Stability and Reactive Power Control
17. Power System Restoration Studies
18. Distributed Energy Resources (DER) Management
19. Advanced Protection Coordination Studies
20. Request more case studies on system protection, system harmonics and motor startups.
21. Nothing in particular but request if each module taught have detailed training in future.
22. Most of the topics were covered
23. The topics covered in this one week were sufficient.

8. Conclusions & Recommendations:

The conclusions and recommendations arising from the evaluation of the training are:

1. Power utilities need to analysis their power networks under all operating conditions, to identify stability operating limits, protection coordination requirements and augmentation needs to cater for increasing demand and improve operational efficiency.

This is especially needed for the connection of variable renewable power sources and distributed sources. The result of this analysis forms the basis of any power development and network augmentation development plans. The training on PowerFactory was appropriate, useful and met the need of the Pacific Island utilities to enable the acceleration of the connectivity of renewable energy sources to the electric grid.

2. There is a need for advanced training that involves deep dives into each particular topic such as:

a. load flow analysis and medium feeder analysis. This would be very useful for understand the impact of distributed renewable energy sources such as roof top solar power plants.

b. Protection coordination to ensure proper and adequate protection of the network elements and stable operation of the grid under various events and operating scenarios.

c Dynamic modelling and analysis of the grid under various conditions and control modes/ devices to develop operating policies and procedures for operating the network to provide a safe and secure power supply to consumers.

d. Navigating around the PowerFactory application to provide enhanced modelling and presentation of results, including the import and exporting of data and linking to other applications such as a GIS system.

e. Studies required to connect renewable energy in the electric grid.

9. Acknowledgements:

The following are acknowledged for their contribution to this successful program.

1. The World Bank is to be commended for funding and coordinating this program that provided the Pacific Island utilities with the knowledge and skills to improve their networks and meet the needs of the economy and well-being of the Pacific island nations and territories, and accelerate the connection of renewable energy sources to achieve the United Nations SDG 7 goals.

2. The Pacific Power Association is commended for facilitation the coordination of the training program.

3. DIgSILENT Pacific, Australia for providing the expertise and training to execute this program.

PPA and World Bank Report Highlights Opportunities for Women to Lead The Pacific's Power Transition

Mue Bentley Fisher, Senior Communications Consultant - World Bank

The Pacific Power Association (PPA) and World Bank have launched the 'Baseline Report on Women's Employment in the Pacific Power Sector' highlighting the challenges and opportunities of increasing women's participation in the sector.

The report was launched at the 31st Annual PPA Conference held in Nuku'alofa, Tonga, 30th September-3rd October 2024, hosted by Tonga Power Limited.

Speaking at the report launch, Chief Guest and Acting Prime Minister for Tonga, Hon. Samiu Kuita Vaipulu said: "the Pacific Power Association and the World Bank's Pacific Women in Power Program aligns perfectly with our national energy aspirations, and it underscores our ongoing commitment to empower women in the energy sector.

Chief Guest and Acting Prime Minister for Tonga, Hon. Samiu Kuita Vaipulu speaking at the baseline report launch

"Together, I know we can create a supportive and an enabling environment where women can thrive and actively contribute to our energy goals."

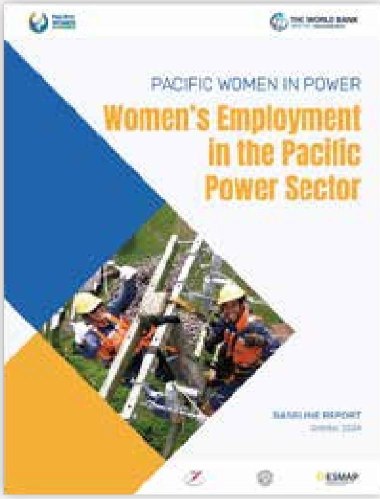
The Acting Prime Minister added that Tonga is committed to fostering an inclusive and diverse energy sector, with the Tonga Energy Road Map Plus (TERM Plus) 2021-2035 as the source of the nation's vision for a sustainable and equitable energy future.

"We recognize that achieving our ambitious goals of 70% renewable energy by 2025 and 100% by 2035 requires the talents and contributions of all Tongans, regardless of gender," Hon. Samiu Kuita Vaipulu said.

"TERM Plus emphasizes gender inclusion as a critical component of our energy strategy. We are dedicated to creating opportunities for women to participate and lead in the energy sector."

The Acting Prime Minister highlighted that Tonga's energy roadmap includes specific measures to ensure that women are not only participants but also leaders in the transition to renewable energy. This includes targeted training programs, mentorship opportunities, and policies that promote gender equality.

The Pacific Women in Power Program (PWIP) and baseline report findings



The Pacific Women in Power Program was **launched and endorsed by Pacific Energy Ministers in May 2023** at the 5th Pacific Regional Energy and Transport Minister's Meeting held in Port Vila, Vanuatu. The program's development objective is to enhance women's employment across various Pacific Island energy institutions to build a strong energy sector with a diverse workforce.

Pacific Women in Power is implemented by the Social Inclusion and Energy Global Practices of The World Bank in partnership with the PPA and in collaboration with the Pacific Community (SPC). The program is funded by the Canada-World Bank Clean Energy and Forest Climate Facility under the World Bank Energy Sector Management Assistance Program (ESMAP).

Following its launch, the program collected baseline data from participating PPA member utilities, as well as government entities responsible for the energy sector.

The data collection has been completed with seven government agencies responsible for the energy sector and 14 energy utilities across 10 World Bank member countries, including Tonga Power Ltd and the Tonga Government Department of Energy.

World Bank Global Gender Lead and Task Team Leader Pacific Women in Power, Ms Helle Buchhave, said, "Our program supports energy utilities across the Pacific to take action to increase women's employment in the energy sector, because to prepare for tomorrow, the energy sector will need to draw from all the talent in the Pacific."

World Bank Global Gender Lead and Task Team Leader Pacific Women in Power, Ms Helle Buchhave

Ms Buchhave added that formal gender strategies are rare among utilities, with women often concentrated in administrative roles.

"Currently less than 19 percent of employees are women, and only five percent hold technical positions."

Other key findings from the report include opportunities for utilities and government departments to take action in the following areas to increase women's employment:

- Gender equality policies and procedures
- School-to-work programs and targeting women's recruitment
- Appropriate retention policies
- Women's leadership and succession planning
- Gender safety, workplace equipment and facility audits
- Development of company gender profiles

"Going forward, the World Bank Pacific Women in Power Program will support energy utilities across the Pacific in these actions, including the PWIP trailblazer, Tonga Power," Ms Buchhave said.

Tonga Power commitment

Tonga Power CEO, Finau Moa, affirmed the company's commitment to addressing gender gaps and working closely with the World Bank's Pacific Women in Power Program.

"A gender-balanced workforce makes business sense, and we look forward to addressing the opportunities identified in the survey," Mr. Moa said.

Mr Moa added that TPL would regularly monitor related progress and work closely with the World Bank's Pacific Women in Power Program to promoting gender equality and women's employment.

"We are grateful for this opportunity and also wish other participating government departments and utilities the best in their efforts towards a brighter, more inclusive future for our Pacific energy sector."

The report provides a roadmap for increasing gender diversity in the Pacific energy sector, offering tangible steps for governments and utilities to enhance women's participation and leadership.

SEIAPI Holds Standards Workshop and Training for EFL Inspectors

Sandip Kumar, Pacific Technical Officer - SEIAPI

As part of its 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 organize an open forum to deliberate on this important aspect.

A 1-day workshop was organized on Monday 15th July at USP Pacific TAFE, Statham Campus in Suva 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 questions of the representatives of EFL and FCCC. Geoff Stapleton, Executive Officer of SEIAPI facilitated the 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 FCCC and EFL during the open forum on day 1

The 2nd day, Tuesday 16th July convened at EFL's 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 trial inspections of two grid connected PV systems at Fiji Ports. This training was organized for the EFL electrical inspectors by SEIAPI to build the capacity of electrical inspectors to inspect grid connected PV systems.

EFL electrical inspectors undertaking training on day 2

A similar one-day training was organized 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 solar industry 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.

Pacific Regional Sustainable Energy Training Centre Update

Sandip Kumar, Pacific Technical Officer - SEIAPI

The tender for the much-awaited Pacific Regional Sustainable Energy Training Centre building construction was released by USP's Estates and Infrastructure department in September and closed on 30th September, 2024 at 11am (Fiji time). The training centre building is funded by a private foundation and is being built at USP Pacific TAFE, Statham Campus, Suva, Fiji.

The funding includes:

- Construction of a new training centre building
- A PV/Battery system for the building
- Equipment for undertaking practical training
- Two Fiji-based full-time trainers

The training centre building will comprise a large training workshop space, a lecture/tutorial room, storage space, office space for two trainers and a washroom. There will be a simulated roof at the back where trainees will practice mounting of solar panels. The building will have a roof-top grid connected solar PV system and a battery energy storage system. The PV/BESS system is designed to power all the centre loads under normal conditions.

Architectural drawing (front view) of the planned Pacific Sustainable Energy Training Centre Building

The training centre will initially focus on providing the following training courses:

- design and installation of grid connected PV systems
- design and installation of PV based off-grid systems (including PV/fossil fuel hybrids)
- design and installation of residential/commercial battery storage systems on the grid.

Design only and install only courses for the three technology applications will also be available. After those courses are established, the training team will develop other short courses to meet the needs of the private industry, the electricity utilities and interested individuals including O&M, inspector training etc.

The Fijian solar industry will benefit from this regional initiative as this will provide an avenue for existing technicians who wish to upskill in design and installation practices of solar PV systems.

In July 2022, Global Sustainable Energy Solutions Pty Ltd (GSES) signed a partnership agreement with USP Pacific TAFE. Under this agreement USP Pacific TAFE has is already offering the above three courses online.

The online design courses will be available for face-to-face training once the centre is operational. Refer to **https://www.training.ac.fj/info/solar/** for more information.

87 students from Fiji, Vanuatu, Solomon Islands, Tonga, Niue and PNG have enrolled for the online courses. Those who complete them will be eligible to undertake practical training in late 2025.

The courses are similar to those GSES conducts in Australia. Those who successfully complete the course are eligible to apply for their PPA/SEIAPI design/install accreditation. For more details, see **https://www.seiapi.com/seiapi-ppa-accreditation**

Energy Pool Launches Pioneering Highpower Microgrid in the Kingdom of Tonga

Bastien Couture, Communications Officer - Energy Pool

Energy Pool has successfully launched a state-of-the-art microgrid project in the Kingdom of Tonga, bringing cleaner, more reliable electricity to approximately 80,000 residents of Tongatapu, Tonga's main island. The project, which was commissioned on 26 June 2024, marks an important milestone in Tonga's journey towards sustainable energy.

Tonga's Ambitious Path to Renewable Energy

The archipelago of Tonga, located in the South Pacific, has undertaken a significant energy transition to reduce its dependence on imported fossil fuels and improve its energy sustainability.

In 2010, the Tonga government launched the Tonga Energy Road Map (TERM) to promote renewable energy and improve energy eBiciency. The aim was to generate 50% of the country's electricity from renewable sources by 2020.

In 2021, the national energy policy was renewed, resulting in a 15-year roadmap (TERMPLUS). The GDMS (Generation and Distribution Management System) project is a critical component of Tonga's energy transition, designed to optimize the management of renewable energy resources. By enhancing the efficiency and reliability of the energy generation and distribution systems, it plays a vital role in helping Tonga achieve its ambitious goals of 70% renewable electricity by 2025 and 100% by 2035.

Tonga Power Limited , the Kingdom's transmission system operators (TSO), has been entrusted with most of the responsibility for the project. By 2024, 6 PV plants (around 11 MW capacity) and 1 wind farm (around 1.3 MW capacity) had already been installed in Tongatapu. This comes in addition to the 9 existing generators with capacities ranging from 1.5 MW to 2.7 MW used to produce electricity for the whole island.

Niuouta wind farm (1.3 MW) and Maama Mai solar facility (1.3 MW) at Popua Power Station

A complex technical challenge

While integrating intermittent renewable energies is already a challenge, interfacing them with diesel generator sets is even more challenging, especially with an aging diesel genset fleet.

In addition to having strong load variation, generators have minimum load constraints. When they are switched on, they must operate at a minimum of 30% of their rated power, otherwise they will "drown," causing a general blackout. On the other hand, renewable energies have production peaks that do not coincide with consumption peaks, which complicates their management. It is particularly necessary to review stability during the day, when renewable energies are highly variable, as well as the management of energy flows in the morning and evening, during peaks in consumption.

To partially compensate for this new challenge, Tonga Power Limited implemented two large-scale battery energy storage systems (BESS), making it the largest storage facility in the South Pacific. The two plants fulfil complementary functions: the first, with a capacity of 5 MWh / 10 MW, is designed to stabilise the electricity grid during high variation (voltage and frequency regulation), while the second, with a capacity of 23 MWh / 7 MW, meets the need for load transfer.

BESS TREP 1 (5 MWh / 10 MW)

This totally isolated energy ecosystem, which connects fossil fuel generation, renewable energies, and storage systems, is known as an islanded microgrid. A complex system of energy that requires smart energy and power management to handle its unique challenges.

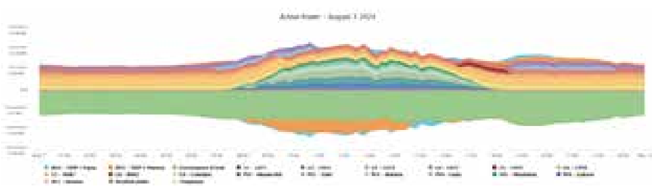
Thus, Tonga Power Limited turned to Energy Pool and its advanced integrated solution combining Energy Management System (EMS) and Power Management System (PMS) that addresses the need to reduce operating costs by maximising the use of renewable energies and optimising the use of batteries, while guaranteeing a stable network.

Firstly, it maximises the utilisation of renewable energy and optimises battery usage by eBiciently storing excess power and strategically managing battery charge and discharge cycles.

This approach minimises energy waste, reduces reliance on fossil fuels, and ensures that renewable energy is used to its fullest potential, further driving down costs and enhancing sustainability.

Additionally, Energy Pool's EMS maintains network stability by providing real-time control and management of batteries and other assets, ensuring a stable power supply even during fluctuations in energy production.

Furthermore, by optimising the use of diesel generators while integrating renewable energy sources, the system significantly reduces the dependence on diesel, which is costly and environmentally harmful due to the high expenses of transportation and storage. This shift not only lowers operational costs and harmful emissions but also enables the provision of more affordable, cleaner electricity to residents. By addressing these challenges, Energy Pool's EMS significantly enhances the eBiciency, stability, and sustainability of the islanded microgrid.



Tonga Power Ltd power flow profile on August 7, 2024

A Major Step Forward for Tonga and the Planet

As technically challenging as it was exciting, the successful implementation of our solution in Tonga is a genuine source of satisfaction for our company, as Jean Dobrowolski Microgrids Solution Manager, who oversaw the entire project for Energy Pool, points out:

"The GDMS project was particularly challenging for the Energy Pool teams. First of all, we had to get sub-systems to communicate with each other that either didn't or had never done so. Secondly, we had to automate and optimise the operational control of a plant that had always been managed manually. The result is even more satisfying: Tonga Power Limited's teams now have a state-of-the-art tool, enabling them to optimize power flows on their electrical network, asset maintenance and operating costs, and monitor the distribution network."

In terms of figures, we estimate an annual saving of 2,500 tonnes of CO_2, or 3.5 million euros, thanks to the reduction in the use of diesel generators.

As climate change continues to be a pressing concern, especially for island nations like Tonga, projects like this oBer a vision of a more sustainable future. The Tonga microgrid serves as a model for other islands looking to reduce their carbon footprint while improving energy security.

Finau Moa, Acting CEO of Tonga Power Limited, emphasizes the significance of this transition:

"At Tonga Power Limited, we are proud to be leading the way in overcoming the challenges of transitioning to renewable energy—a key theme of the 31st Pacific Power Conference held in Tonga in October 2024. Energy Pool's EMS has been instrumental in addressing these challenges, particularly in managing the intermittency of renewable energy sources. With this system, our operators have the confidence to maximize renewable energy during peak generation while maintaining grid stability. The EMS optimizes battery storage and eWiciently balances energy flows between solar, wind, and diesel generation, allowing us to reduce reliance on costly diesel fuel. Real-time monitoring enables our team to make fast, informed decisions, ensuring that we meet demand with as much renewable energy as possible. By implementing Energy Pool's innovative solution, Tonga Power Limited is not only advancing our own renewable energy goals but also setting an example for other Pacific utilities facing similar challenges in the transition to cleaner energy. We are proving that with the right tools and systems, this transition is not only possible but sustainable."

Energy Pool is incredibly proud and salutes the efforts and dedication of its team members involved in the project since its inception, and we thank Tonga Power Limited for its trust in us. Our achievement in Tonga marks a significant step forward in microgrid technology and renewable energy integration.

This project serves as a prime example of how innovative energy solutions can profoundly impact people's lives while contributing to global eBorts to combat climate change.

Technical Insights into Transformer Turns Ratio and Winding Resistance Testing

Daniel Hurley, General Manager - AVO New Zealand

Transformer testing is a vital practice in maintaining and ensuring the reliability of electrical power systems. Two fundamental tests, Transformer Turns Ratio (TTR) testing and winding resistance testing, provide essential data on the health and integrity of transformer windings, core condition, and overall functionality. In this article, we will explore the technical aspects of these tests, their importance, and the role advanced instruments like the Megger TTRU1 (fig 1), TTRU3 (fig 2), and TAU3 (fig 3) testers play in field applications.

Fig 1


Fig 2


Fig 3

Transformer Turns Ratio (TTR) Testing

The primary objective of TTR testing is to verify the ratio of the primary to secondary winding voltages in a transformer. This ratio must match the transformer's design specifications to ensure proper voltage transformation and efficient operation. Deviations from the expected ratio can indicate problems such as shorted turns, incorrect tap connections, or core damage.

TTR testing is typically performed by applying a low AC voltage to the primary winding and measuring the induced voltage in the secondary winding. The ratio of these voltages gives the turns ratio, and any deviation can signal mechanical or electrical issues within the transformer.

For example, even a minor variation in the turns ratio may point to winding deformation, incorrect connections, partial or shorted turns, or an issue with the tap changer.

One of the advancements in TTR testing is the use of simultaneous three-phase testing, as seen with the TTRU3 ratiometer. Traditional methods excite one phase at a time, introducing possible errors from unexcited phases. However, the **TTRU3** excites all three phases simultaneously, reducing test time by up to 80% and minimizing errors caused by the loading effect of unexcited phases. This is especially important in large transformers with complex configurations such as delta or zigzag windings, where phase shift and vector group validation are crucial.

Key Technical Benefits of TTR Testing:

• **Accuracy:** Modern TTR testers like the TTRU1 and TTRU3 offer accuracy levels as tight as ±0.05%, ensuring even minute deviations are detected.

• **Polarity and Phase Angle Measurement:** These features help diagnose phase shift issues, especially in transformers with complex winding configurations.

• **Simultaneous Three-Phase Testing:** Reduces testing time and eliminates phase-loading errors, providing more reliable results.

Winding Resistance Testing

Winding resistance testing is crucial for evaluating the condition of transformer windings. It helps identify problems such as:

- Loose or degraded connections
- Shorted turns
- Contact issues in the tap changers
- Deterioration of winding insulation

The test involves applying a low DC current to the windings and measuring the resistance. Significant variations in the expected resistance can indicate mechanical issues like loose windings, inter-turn shorts, or even more significant faults within the transformer core or tap changer. A rise in resistance can also indicate high contact resistance in connections, which could lead to overheating or failure if not addressed.

Advanced winding resistance testers, such as the **TAU3,** are designed to provide stable, repeatable measurements even under challenging conditions, such as electromagnetic interference. These instruments are engineered to deliver reliable results quickly, allowing engineers to detect and address potential issues before they lead to failure.

Key Technical Considerations in Winding Resistance Testing:

• **Connection Integrity:** Resistance measurements provide insight into the physical and electrical integrity of transformer windings and their connections.

• **Winding and Core Health:** Helps detect winding deformation, shorted turns, and other internal faults.

• **Reliable Results:** Modern equipment ensures consistency and stability in measurements, even in difficult field environments.

Magnetic Balance Testing

Magnetic balance is an advanced diagnostic test, commonly conducted during transformer construction, to identify issues like inter-turn and interstrand shorts, external loops around the core, or incorrect interleaving joints. It also helps detect transformer core magnetization and assess whether the mechanical integrity of the core and windings has been affected, particularly following a fault. This test is crucial for ensuring the transformer remains electrically balanced and structurally sound.

Integrating TTR, Winding Resistance, and Magnetic Balance Testing

While TTR and winding resistance tests offer insights into the transformer's electrical and mechanical health, integrating magnetic balance testing provides a more comprehensive picture of transformer performance. Simultaneously using these diagnostic methods allows engineers to detect issues related to winding integrity, core stability, and phase shift, giving a full assessment of transformer condition.

Conclusion

Transformer Turns Ratio (TTR) testing, winding resistance testing, and magnetic balance testing form the cornerstone of transformer diagnostics and maintenance. Modern equipment like the Megger TTRU1, TTRU3, and TAU3 streamline these processes, providing accurate, reliable results that help engineers maintain transformer health and prevent costly failures. By incorporating these testing methods into routine maintenance schedules, transformers can operate efficiently, safely, and with minimal downtime, ensuring the continuity of electrical power systems.

AVO New Zealand: Your Partner in Transformer Testing

At AVO New Zealand, we specialize in transformer testing solutions and are committed to providing comprehensive application support. Our team of experienced application engineers is based in New Zealand and is always ready to assist with any transformer testing queries or challenges… we are happy to visit any of our pacific neighbours! Whether you're troubleshooting a specific issue or need advice on implementing testing best practices, our experts are available to offer engineering support and guidance tailored to your needs. Contact us to discuss how we can help you maintain your transformers with confidence.

Product Summary:

• **TTRU1:** A portable, low-cost transformer turns ratio tester, ideal for both singlephase and three-phase testing. Offers high accuracy, ease of use, and is perfect for technicians working in the field.

• **TTRU3:** Advanced three-phase transformer tester designed for simultaneous phase testing, reducing test time and improving accuracy, especially in complex transformer configurations.

• **TAU3:** Flag-ship transformer test system covering both winding resistance and turns ratio testing. Provides precise measurements to detect loose connections, shorted turns, and tap changer issues, ensuring thorough transformer diagnostics.

WELCOME!!

TO THE NEW ALLIED MEMBERS

Three (3) new Companies have joined the PPA as Allied Members since our last PPA Magazine.

The new Allied Members are:

TOTALENERGIES MARKETING (FIJI) PTE LTD:
TotalEnergies Marketing (Fiji) Pte Limited is based in Suva, Fiji. Their primary activity is the importation, storage, distribution and retailing (B2B/B2C) of petroleum fuels and lubricants. Their secondary activity is business development in new energies & non-fuels activities & exportation of fuels & lubricants to PICTs.

KARPOWERSHIP:
Karpowership is based in Istanbul, Turkey. Their primary activity is power generation.

ENTURA:
Entura is based in Tasmania, Australia. Their primary activity Engineering Consulting Services – Pacific Island Hybrid Renewables.


A//
From a single engine to your whole fleet
Move further at
accelleron-industries.com
We develop, produce and service turbochargers and digital solutions: these make engines more powerful and efficient, while also reducing emissions. Our advanced products are used in a wide-range of sectors including marine, energy and rail. These industries make our world turn and we power them, reliably and sustainably, while also helping them decarbonize.
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24hrs: +61 400 064 278
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Accelleron