CNMI Integrated Resource Plan

Commonwealth Utilities Corporation

March 27, 2025

The Power of Commitment

Project name	CNMI CUC Integrated Resource Plan
Document title	CNMI Integrated Resource Plan
Project number	12582615

Status Code	Revision	Author	Reviewer		Approved for issue		
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The Power of Commitment

Executive Summary

This Integrated Resource Plan (IRP) outlines a strategic roadmap designed to guide the Commonwealth Utilities Corporation (CUC) toward achieving their energy goals over the next 20 years, focusing on optimizing energy resources, minimizing costs, and increasing sustainability and system reliability. The updated roadmap aligns with the CUC's ambition to achieve a minimum of 40% renewable energy penetration by 2030 while transitioning to a more efficient and sustainable power supply portfolio.

Current Energy Landscape

The islands of Saipan, Tinian, and Rota currently rely almost entirely on ultra-low sulphur diesel fuel for power generation. With no natural oil reserves, the CUC depends on costly fuel imports. This dependency not only impacts economic stability but also limits opportunities for reducing emissions and enhancing energy resiliency.

Demand Forecast

The demand forecast outlines the assumptions and presents the results of the 20-year stochastic energy demand forecast for the islands. This analysis is intended to be considered alongside the financial model to establish a robust baseline energy demand forecast for the islands. Given the dynamic nature of energy demand, the forecast provides valuable insights to assist the CUC in formulating planning options. The demand forecast also forms the basis of pre-feasibility techno-economic modelling for in the Energy Options Assessment.

The forecast is structured around three scenarios to capture a range of potential outcomes:

1. **Low Case**: This scenario assumes lower growth rates, resulting in a lower overall peak energy demand.
2. **Base Case**: Representing the most likely scenario, the Base Case includes moderate growth assumptions and incorporates a moderate diversity assumption of future project loads provided by the CUC.
3. **High Case**: This scenario assumes higher growth levels, including factors such as lower diversity of future project loads provided by the CUC and electric vehicle uptake.

Staging of projects is indicative only based on local knowledge.

Energy Options Assessment

The IRP identifies substantial opportunities to integrate renewable energy supply options for the islands. Following a comprehensive screening assessment of various established and emerging technology options for the islands alongside the existing diesel. Following the screening, large scale solar PV and lithium-based battery energy storage systems (BESS) were found to be the most viable options for meeting the CUC's goals. By supplementing the existing diesel generation with renewables and energy storage, the CUC can significantly reduce reliance on imported fuel and lower operational costs while achieving environmental benefits. The study evaluated various scenarios, including business-as-usual (BaU), solar-only, and Solar + BESS options. In addition, the study identified potential viable locations on each island for Solar and BESS options based on three criteria: located on public land, relative flatness, and proximity to the network.

> **Saipan**: With a higher demand forecast and diverse viable locations for solar and BESS, Saipan offers significant potential for renewable energy development. Three potential locations identified were As-Gonno, Naftan and Kalabera/Talofofo. A staged approach to implementation is recommended to address network constraints and ensure reliable energy supply. An opportunity for aggressive development far beyond 40% renewable penetration was identified but not assessed for Saipan.
>
> **Tinian**: Renewable opportunities on Tinian are constrained by limited publicly owned land. The only viable site, Marpo Heights, is sufficient to meet the optimal renewable solution identified but leaves little room for additional capacity. A server project, a proposed large-scale project with a significant load and additional generation capacity, was excluded from the analysis due to its unconfirmed status.

Rota: Similar to Tinian, Rota faces land availability constraints, with only one identified site, As Nieves. The lack of additional public land limits the optimal solution and further expansion opportunities.

Across all load scenarios and islands, the Solar + BESS option consistently outperformed other alternatives, demonstrating the lowest levelized cost of energy (LCOE) and highest renewable penetration. While BaU offers minimal capital expenditure, its high operational costs and emissions make it the least favorable option compared to the others. Options are assessed using a multicriteria analysis (MCA) process and isolating quantitative parameters that were agreed upon with the CUC.

The optimal solution for the base case load scenario is presented for further analysis for power system modelling and detail financial modelling.

Table 1 System configurations proposed for further investigation on each island

Island	Option	Solar PV MW	BESS MW	BESS MWh
Saipan	Solar + BESS	60	48	192
Tinian	Solar + BESS	10	8	32
Rota	Solar + BESS	3	2	2

System Impact Studies

Power system studies are required to be carried out as part of the CNMI IRP. These studies are conducted on each island (Saipan, Tinian and Rota) based on the CUC's IRP options. For this study, load flow and short circuit steady-state studies have been undertaken to ensure that the voltage limits, thermal loading and equipment ratings have not exceeded in the renewable energy integrated network during maximum and minimum load scenarios.

Below are the key findings from the steady state studies for each island:

Saipan

– **Generators/BESS Constraints**: No thermal constraint has been identified at the existing synchronous generators, and the proposed PVs and BESS.

– **Voltage Constraints**: Approximately 17.5 MVAr of reactive power support is needed at the existing power plant (i.e., STAT_1/MV_BB terminal), achievable through reactive power compensators or using the reactive power capabilities of existing synchronous generators.

– **Thermal Constraints**: Network reinforcements, such as line upgrades, are required to connect Naftan, As Gonno, and Kalabera PV and BESS. In addition:

  - A new 2 km line (modelled using the existing conductor type: 13.8kV_Cond_556_Al, rating 0.704 kA) is required to connect the Naftan site to the nearest 13.8 kV terminal where the upstream distribution network has sufficient capacity for the 15 MW maximum active power output from the PV and BESS at this site.
  - A new 0.5 km line (modelled using the existing conductor type: 13.8kV_Cond_556_Al, rating 0.704 kA) is required to connect the As Gonno site to the nearest 13.8 kV terminal where the upstream distribution network has sufficient capacity for the 5 MW maximum active power output from the PV and BESS at this site.
  - New 2x12 km lines (modelled using the existing cable type: 34.5kV_500kcmil_Al, rating 0.45 kA) are required to connect Kalabera site to 34.5 kV terminals which have sufficient capacity for the 40 MW maximum active power output from the PV and BESS at this site.

Tinian

– **Generators/BESS Constraints**: No thermal constraints were found in the existing synchronous generators or the proposed PV and BESS.

– **Voltage Constraints:** Approximately 5.2 MVAr of reactive power support is needed at the existing power plant (i.e., Power Station 4.16 kV terminal), achievable through reactive power compensators or using the reactive power capabilities of existing synchronous generators.

– **Thermal Constraints:**

  - Thermal analysis shows that transformers and cables are operating within safe loading limits, reducing the risk of overloading.
  - A new 1.5 km line (modelled using the existing conductor type: 13.8kV_Cond_556_Al, rating 0.704 kA) is required to connect Marpo Heights PV and BESS to the 13.8 kV distribution network.

Rota

– **Generators/BESS Constraints**: No thermal constraints were found in the existing synchronous generators or the proposed PV and BESS.

– **Voltage Constraints:** Approximately 1 MVAr of reactive power support is needed at the existing power plant, achievable through reactive power compensators or by using the reactive power capabilities of the existing synchronous generators.

– **Thermal Constraints:** Thermal analysis shows that transformers and cables are operating within safe loading limits, reducing the risk of overloading.

Financial Analysis

The Financial Analysis Section of this report provides a concise summary of the results of the 20-year Present Value of Revenue Requirements (PVRRs) for the cost of each supply option, for each of the three islands. This cost analysis includes all costs associated with each option, such as network augmentation costs, capital costs and ongoing operating costs. A sensitivity analysis around key unknown variables is also included, which focuses on capital costs and fuel costs.

The financial analysis is completed based upon the Optimum System Configuration that is determined in Section 4 of this report. A summary of the Net Present Value and the Levelized Cost of Energy at a 7% discount rate is shown in the Table 2 below[1].

Table 2 Summary of Financial Analysis Results

Island	Net Present Value (7% discount rate)	Levelized Cost of Energy (7% discount rate)
Saipan	-$86.4M	$0.311 per kwh
Tinian	-$31.2M	$0.383 per kwh
Rota	-$42.6M	$0.953 per kwh

SCADA Staffing and Skills Assessment

A comprehensive desktop assessment was conducted to evaluate the CUC’s current capabilities and infrastructure related to Supervisory Control and Data Acquisition (SCADA) systems. This assessment, informed by online interviews and data regarding the monitoring and control infrastructure for the islands' power systems, identified several key findings and recommendations.

To effectively integrate diverse generating assets—including existing thermal generation, new solar PV and Battery Energy Storage Systems (BESS)—a unified control system, commonly referred to as a grid controller, is deemed essential. The grid controller will facilitate the dispatch of generation facilities and ensure frequency stability and network reliability. However, based on the information provided, the CUC has no prior experience implementing a grid

[1] Refer to Section 5.5 for further details, including a definition for Levelized Cost of Energy

controller or managing large-scale renewable energy systems. The CUC's exposure to such systems has been limited to rooftop solar systems, which typically operate independently without consideration for secondary control.

Key areas identified for future development include:

- **Technical Infrastructure Requirements**: Establishing reliable communication links between all generating assets, potentially through telephone or wireless networks in the absence of fiber optic cabling. These networks must support both control and monitoring functionalities.
- **Skills Development**: Building capacity in understanding and managing grid controllers, renewable technologies (e.g., solar and BESS), Ethernet network protocols, SCADA operation & design and fiber optic infrastructure.
- **Centralized Control**: Determining an ideal location for central control systems that meets environmental and technical requirements.
- **SCADA System Enhancements**: Developing SCADA software, conducting off-site functional testing, commissioning, and ensuring robust documentation.
- **Grid Operating Philosophy**: Creating a comprehensive grid operating philosophy to define how the system should operate with the integration of future renewable facilities.

Given the critical role of SCADA and grid control in achieving renewable energy targets, these recommendations form a pivotal part of the roadmap for the CUC's transition to a more sustainable energy system.

Next steps and proposed future works

It is recommended that the CUC progress with a serious consideration of integrating renewables into the future power supply options for Saipan, Tinian and Rota. Each stream in this IRP demonstrates this. The next steps and proposed future works for the IRP are as followings:

- Progress with more detailed feasibility studies to develop a better understanding of expected costs development timeline and optimal financial, technical and environmental impact of large scale or staged renewables on each island, using the optimal generation mix proposed for each island as a guide and starting point.
- Develop a staging plan for renewables based on current constraints with funding, local resources, contractor mobilization and land availability.
- Develop an infrastructure upgrade plan that aims to develop the existing infrastructure to be able to interface modern systems that would be installed from both a network reliability and SCADA perspective.
- Undergo internal development and training to build capability to work with modern technologies and systems for renewable systems and power system operation.
- Assess and identify the risk profile for the CUC in adopting different contracting strategies for such assets when development is moving forward (such as owning the assets vs undergoing some form of power purchasing agreement).

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Acronyms

Table 3 Acronyms

Acronym	Description
AC	Alternating current
AEMO	Australian energy market operator
BaU	Business as Usual
BESS	Battery Energy Storage System
CAPEX	Capital expenditure
CBA	Cost Benefit Analysis
CNMI	Commonwealth of the Northern Mariana Islands
CO2	Carbon dioxide
CRI	Commercial readiness index
CUC	Commonwealth Utilities Corporation
DC	Direct current
EV	Electric Vehicle
GIS	Geographic Information System
Ha	Hectares
HMI	Human-machine interface
IPP	Independent power producer
IRP	Integrated Resource Plan
kV	Kilovolt
LCOE	Levelized Cost of Energy
LFP	Lithium iron phosphate
LV	Low Voltage

Acronym	Description
MAC	Marginal Abatement Cost
MAC	Marginal abatement cost
MCA	Multi-criteria analysis
MT	Metric tons
MV	Medium Voltage
MVAr	Mega Volt Ampere Reactive
MW	Mega Watt
MWac	Mega watts AC
MWh	Mega Watt Hour
NMC	Nickle manganese cobalt
NPC	Net Present Cost
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operation and maintenance
OEM	Original equipment manufacturer
OPGW	Optical Ground Wire
OSI	Open Systems Interconnection
p.u.	Per unit
ph	Phase
PoC	Point of Connection
PPA	Power purchase agreement
PV	Photovoltaic
PVRR	Present value of revenue requirements
RE	Renewable Energy
RES	Renewable energy smoothing
RTU	Remote terminal unit
SAT	Single axis tracking
SEP	[CNMI] Strategic Energy Plan
TEM	Techno Economic Modelling

1. Introduction

In 2022, the Commonwealth Utilities Corporation (CUC) announced their intent on updating the 2016 Integrated Resource Plan (IRP), which was designed as a long-range plan to achieve the most cost-effective mix of energy resources available at that time. This updated IRP will reflect the CUC's ambitious goal of reaching a minimum of 40% renewable energy penetration for their power supply of the islands of the CNMI: Saipan, Tinian and Rota by 2030.

Beyond renewable integration, this updated resource plan also focuses on optimizing the power supply portfolio to minimize costs while prioritizing sustainability and resiliency. By incorporating renewables and enabling technologies, the CUC aims to create a more robust, sustainable, and economically efficient energy framework for the future in line with the CUC's key drivers.

1.1 Purpose of this report

This IRP offers a comprehensive roadmap designed to guide the CUC's energy strategy over the next 20 years. It includes a demand forecast for each of the populated islands in the CNMI with energy systems (Saipan, Tinian and Rota) that are based on projected economic growth data provided by the CUC and publicly available information published by the United Nations on the projected population growth. The IRP includes an evaluation of various supply options using a multi-criteria analysis approach tailored to the CUC's priorities and drivers. Additionally, the IRP includes a system impact study on the identified supply options and the required upgrades, if any.

To further support the CUC's transition to a new electricity system, this report also outlines a potential revenue model that highlights pathways for achieving a sustainable and resilient energy future.

1.2 Scope and limitations

This report: has been prepared by GHD for Commonwealth Utilities Corporation and may only be used and relied on by Commonwealth Utilities Corporation for the purpose agreed between GHD and Commonwealth Utilities Corporation as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than Commonwealth Utilities Corporation arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

GHD has prepared this report on the basis of information provided by Commonwealth Utilities Corporation and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information provided and reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer Section 1 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

1.3 Current Infrastructure

Presently, the power supply for each of the islands – Saipan, Tinian, and Rota is nearly entirely produced using ultra-low Sulphur diesel fuel. Without any natural oil reserves, the CUC relies on fuel imports, which are subject to high shipping costs and variable rates. In 2021, refined petroleum products represented the largest share of imports, accounting for 18% of the total import costs that year.

This heavy reliance on imported fuel underscores both the economic and logistical challenges the CUC faces in sustaining a stable energy supply. It should also be noted that much of the existing diesel facilities across the CNMI are aging and have already undergone multiple overhauls. Further details on the existing infrastructure and plants are detailed in Section 3.1.

There is a substantial opportunity for the CUC to expand renewable energy generation, which would significantly reduce reliance on fuel imports and help mitigate the 50% capacity loss impact in the typhoon prone region. Presently, it is understood that there will be at least 2-3 weeks of no power if there is a 50% power capacity on any given island.

1.4 Stakeholder engagement activities

GHD has performed stakeholder engagement per the Scope of Services, but has also used the Rural Utility Standards (RUS) procedure on long range master plans as a basis to their stakeholder engagement approach in this IRP. The RUS procedure[2] outlines at least four stakeholder engagement workshops.

The four (4) workshops conducted by GHD comprise of the following:

- Preliminary Conference for discussion of distribution system data – Kick-off meeting on May 22, 2023. The intent of the kick-off meeting is to go over the project scope and review the request for information (RFI's) GHD provided on May 12, 2023 regarding available distribution data, financial data, and benchmark standards.
- Engineering and economic criteria conference for review, discussion, and comment on design criteria –Scorecard Workshop with key CUC staff on February 21, 2024. The attendees included CUC staff from various CUC divisions power generation, transmission and distribution, finance, administrative office, and CUC representatives on Tinian and Rota. The meeting was to determine the key drivers for the CUC and develop a scorecard methodology.
- Presentation of the preferred plan, economic analysis and sensitivity studies to key stakeholders – Stakeholder engagement workshop on January 22, 2025. The workshop consisted of various stakeholders from the CUC, NMC, PSS, Legislature, CUC PCUP, Saipan Chamber of Commerce, and others. The Stakeholder Engagement Workshop Mural board can be seen in Appendix E.
- Final report presentation for action by the system's board of directors – Tentatively scheduled for March 28, 2025 to present the IRP findings to the CUC Board of Directors.

[2] Bulletin 1724D-101A RD-GD-2017-85

1.5 Acronyms

Table 4 Acronyms

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AC	Alternating current
AEMO	Australian energy market operator
BaU	Business as Usual
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MVAr	Mega Volt Ampere Reactive
MW	Mega Watt
MWac	Mega watts AC
MWh	Mega Watt Hour
NMC	Nickle manganese cobalt
NPC	Net Present Cost
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operation and maintenance

Acronym	Description
OEM	Original equipment manufacturer
OPGW	Optical Ground Wire
OSI	Open Systems Interconnection
p.u.	Per unit
ph	Phase
PoC	Point of Connection
PPA	Power purchase agreement
PV	Photovoltaic
PVRR	Present value of revenue requirements
RE	Renewable Energy
RES	Renewable energy smoothing
RTU	Remote terminal unit
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2. Demand Forecast

This Section of the report outlines the assumptions and presents results of the 20-year stochastic energy demand forecast for the CNMI. The analysis contained within this section is intended to be considered alongside the financial model *CNMI Demand and Energy Forecast – GHD Analysis – Draft (Model)* which is detailed within Appendix C.

This analysis will establish a robust baseline energy demand forecast for the islands of Saipan, Tinian and Rota; given various assumptions outlined below. The results of this analysis assisted GHD and the CUC in formulating planning options to meet expected energy demand levels in the future, while also influencing the design of the overall optimized resource plan. As energy demand is highly dynamic and subject to many different factors, this analysis is separated into three scenarios for each of the three islands:

1. Low Case;
2. Base Case; and
3. High Case

The Base Case is considered as the most likely case, where the Low Case assumes lower growth and therefore has a lower overall peak energy demand. Conversely, the High Case assumes a higher level of growth and a corresponding higher peak energy demand. Factors that are included in building the various cases includes:

– Population growth
– Electric vehicle uptake
– Discrete loads that are expected to either be developed or become grid-connected

2.1 Key Assumptions

A critical element of the demand forecast process is the development of assumptions, which drive scenario development and ultimately influence the accuracy and robustness of the results. Based upon discussions with CUC, the demand forecast extends over a 20-year period beginning in January 2024. This Section summarizes the key assumptions developed, which are based upon the most recent available information obtained from CUC and publicly available data. It is noted that GHD has not verified the veracity of the energy demand data provided by CUC. As such, the analysis includes a comprehensive sensitivity analysis for the major input variables, to ensure that a wider range of possible outcomes is tested.

The energy demand forecast for each of the three islands is based upon historical peak energy demand data provided by CUC. Specifically, GHD has relied upon the following:

- CUC Daily Peak Demand Data for Saipan (January 2019 to December 2019)S;
- CUC Monthly Peak Demand Data for Tinian (January 2019 to May 2023);
- CUC Monthly Peak Demand Data for Rota (January 2017 to May 2023);
- CUC Expected Growth Projects for Saipan and Tinian; and
- Population Growth Forecasts for CNMI from the United Nations and United States Energy Information Administration.

GHD developed a forecast model that captures the estimated peak demand associated with each of the following sectors: (1) Residential; (2) Commercial; and (3) Government. Each of these sectors are considered separately, as the expected demand growth trajectory over the next 20 years for each element is likely to be different.

Table 5 below sets out the explanatory variables that are utilized for each sector in the monthly peak demand forecast model for the Base Case. It is noted that for the Low Case and the High Case, different factors are applied to the population growth forecast to analyse the effect of higher/lower forecasted growth. Benchmarks for population growth by sector is based on benchmarks from GHD's internal database.

Table 5 Energy Demand Forecast – Key Explanatory Variables

Sector	Low Case	Base Case	High Case
Residential	A factor is **0.50x** of population growth.	A factor is **1.0x** of population growth.	A factor is **2.0x** of population growth.
Commercial	A factor of **0.25x** of population growth and expected discrete load additions (i.e. development of commercial properties such as hotels and resorts).	A factor of **0.5x** of population growth and expected discrete load additions (i.e. development of commercial properties such as hotels and resorts).	A factor of **1.0x** of population growth and expected discrete load additions (i.e. development of commercial properties such as hotels and resorts).
Government	A factor of **0.25x** of population growth and expected discrete load additions (i.e. anticipated military asset development).	A factor of **0.5x** of population growth and expected discrete load additions (i.e. anticipated military asset development).	A factor of **1.0x** of population growth and expected discrete load additions (i.e. anticipated military asset development).

Table 6 below illustrates the key assumptions that are foundational for the 20-year stochastic energy demand forecast.

Table 6 Key Assumptions

Key Assumption	Value	Notes / Comments
Population Growth	Various – refer to Appendix C.	The population growth forecasts are derived from the most recent United Nations and United States Energy Information Administration forecasts for the CNMI at the time of writing.
Discrete Load Additions (Expected Growth Projects)	As provided by CUC for Saipan and Tinian – refer to Appendix C for further details.	The discrete load additions are expected projects that will have a material impact on the peak demand forecast in the future. Some are classified as commercial projects such as Hotels and Casino's, and some are considered as Government as they relate to military asset developments (this applies only to Tinian). The expected growth projects are assumed to begin adding to energy demand at a point in time, noting the expected load demand for each project has been provided by CUC. Expected diversity of the loads is lower in the low case and higher in the high case.
Distribution of Energy Demand, from sources: Commercial; Residential; and Government	**Saipan:** Commercial – 53%, Residential – 29%, Government – 17% **Tinian:** Commercial – 25%, Residential – 70%, Government – 5% **Rota:** Commercial – 25%, Residential – 70%, Government – 5%	This estimate has been derived from research obtained from the US Department of Energy (for Saipan only). For Tinian and Rota, the estimates are based on economic indicators obtained from a desktop review.
Seasonality Factors	Various – refer to Appendix C.	By examining the historical peak demand data for the three islands separately, GHD has identified that the fluctuation in peak energy demand displays a seasonality trend. For example, the peak energy demand for Saipan reaches a maximum during the 'wet season' which occurs from July to November each year. This historical trend is taken into account in the 20-year stochastic demand forecast and is formulated based upon the most recent historical 12-month trend for each of the three islands.

Key Assumption	Value	Notes / Comments
Peak Demand (kW) 2024	**Saipan** – 38,000 kW **Tinian** – 2,700 kW **Rota** – 1,750 kW	Saipan data is derived from the December 2019 Peak Demand. Tinian and Rota are derived from May 2023 Peak Demand. In all cases, this is the most recent data that is currently available.
Electric Vehicle Uptake		Electric Vehicles (EVs) can play a key role in reducing dependence on fossil fuels in transportation, and in increasing demand flexibility, as they can absorb excess energy at times of peak generation and serve as additional energy storage capacity. The small size of the islands put the CNMI at an advantage because EVs would require less frequent charging, and the limited road network means that massive investment in charging infrastructure is not required. An increasing number of EVs would lead to an increase in power demand, but if charging and discharging is timed according to a smart control strategy, EVs can effectively serve as flexible and decentralized storage capacity.

2.2 Scenario Analysis

GHD developed a stochastic, 20-year demand forecast based upon historical load data, as well as demographic and econometric data provided by CUC for all three islands.

To account for the random variance in predicting possible outcomes, GHD has formulated three forecast demand cases for each of the three islands. Table 7 below provides details pertaining to each case.

Table 7 Scenario Analysis – Assumptions

Case	Details
Base Case	Baseline, low and high population growth forecast derived from the United Nations and United States Energy Information Administration publicly available data Discrete load additions assumed to be in line with data provided by CUC
Low Case	
High Case	

2.3 Results

This section provides a concise summary of the results of the preliminary draft 20-year stochastic energy demand forecast for CNMI, noting that the three islands Saipan, Rota and Tinian are analyzed separately.

2.3.1 Saipan

Figure 1 and Figure 2 below present the energy demand forecast for the island of Saipan. As evidenced in Figure 2, the annual Peak Demand is expected to reach close to 60 MW in 2034 for the Base Case and 70 MW for the High Case. Importantly, the expected peak demand is expected to increase materially from 2023 to 2024, as the expected growth projects that have been identified by CUC enter the network. From 2024 to 2043, the peak demand increases at a slower rate, which is correlated to the expected growth in population for Saipan during this period.

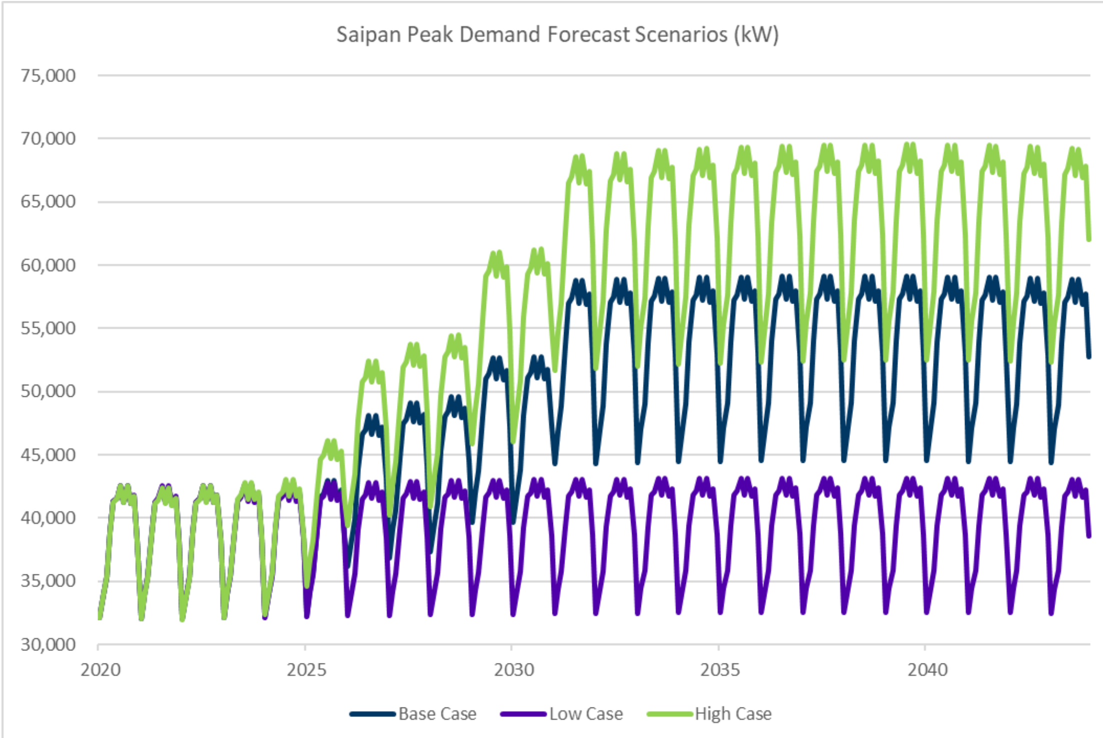

Figure 1 *Saipan Peak Demand Forecast Scenarios (Monthly) (kW)*

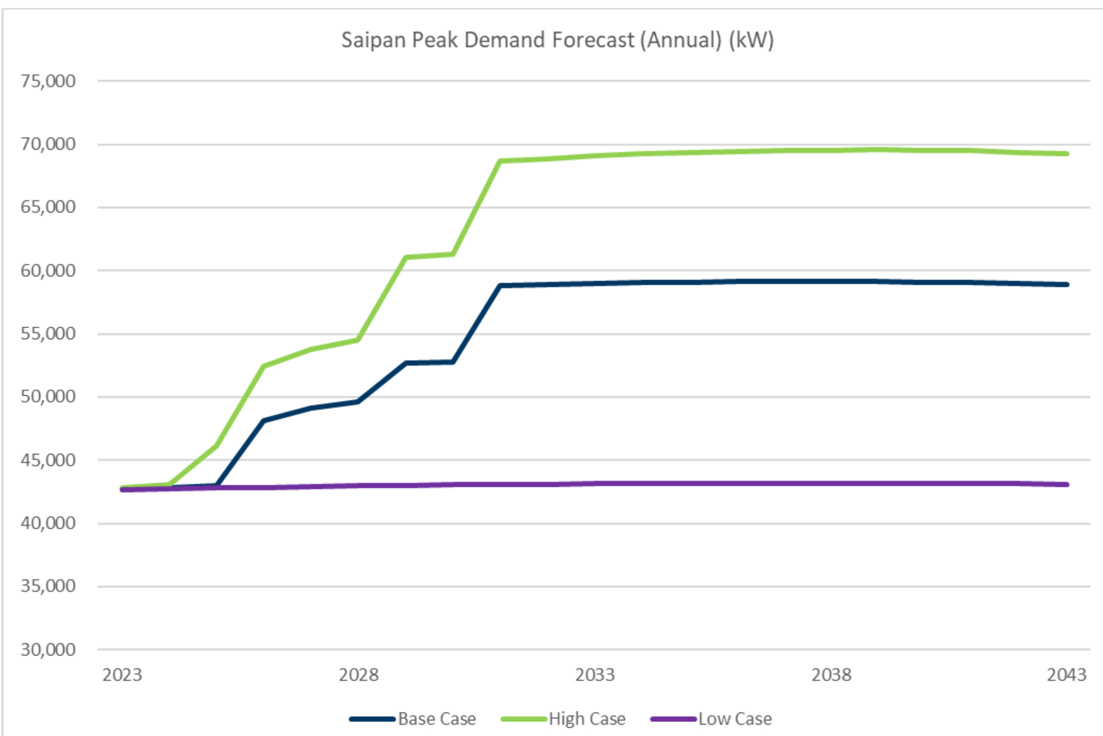

Figure 2 *Saipan Peak Demand Forecast (Annual) (kW)*

2.3.2 Tinian

Figure 3 and Figure 4 below present the energy demand forecast for the island of Tinian. As shown in Figure 4, the annual Peak Demand is expected to reach close to 6 MW in 2029, for the Base Case, and 10 MW for the High Case. This difference between the Base Case and the High Case is attributable to a possible large confidential military project which is expected to reach completion by 2029 . This project is included within the High Case, as it has not been confirmed and therefore does not apply in the Base Case (or most likely case).

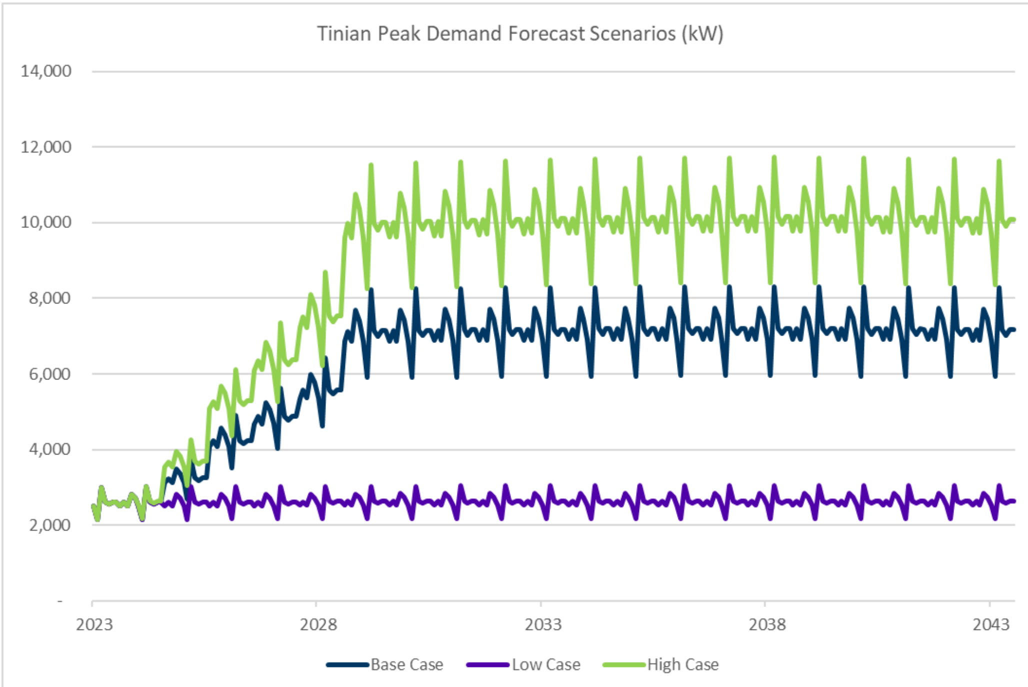

Figure 3 *Tinian Peak Demand Forecast Scenarios (Monthly) (kW)*

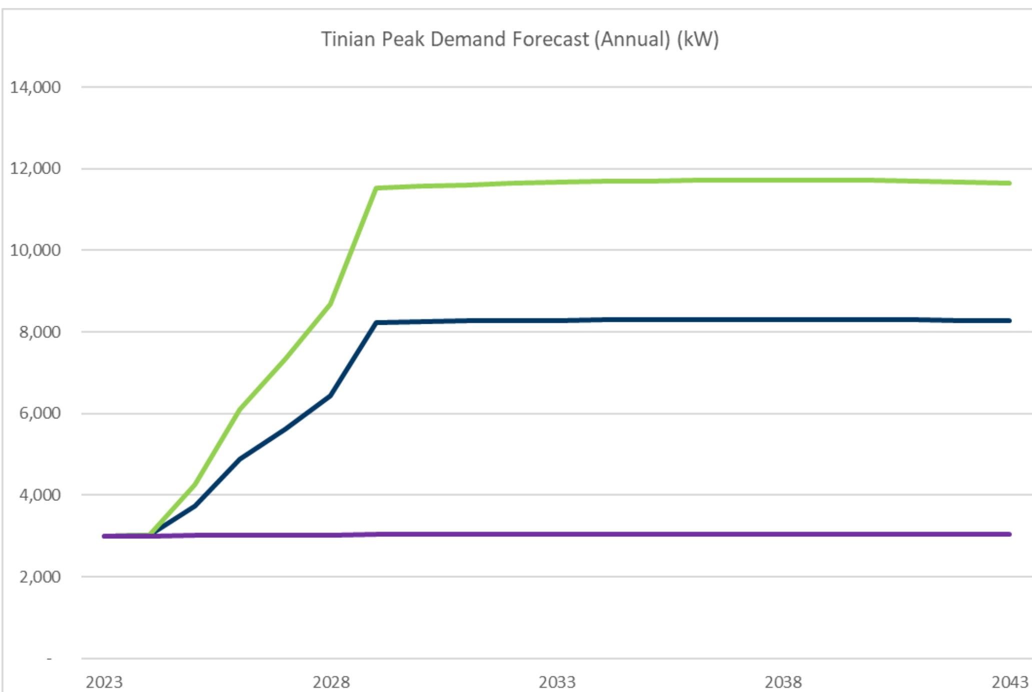

Figure 4 *Tinian Peak Demand Forecast (Annual) (kW)*

2.3.3 Rota

Figure 5 and Figure 6 below present the energy demand forecast for the island of Rota. As shown in Figure 5, the annual Peak Demand is expected to reach 1.8 MW in 2038. Due to minimal expected population growth and tourism on the island of Rota the trends differ from that of Saipan and Tinian and show far less growth over the 20-year period.

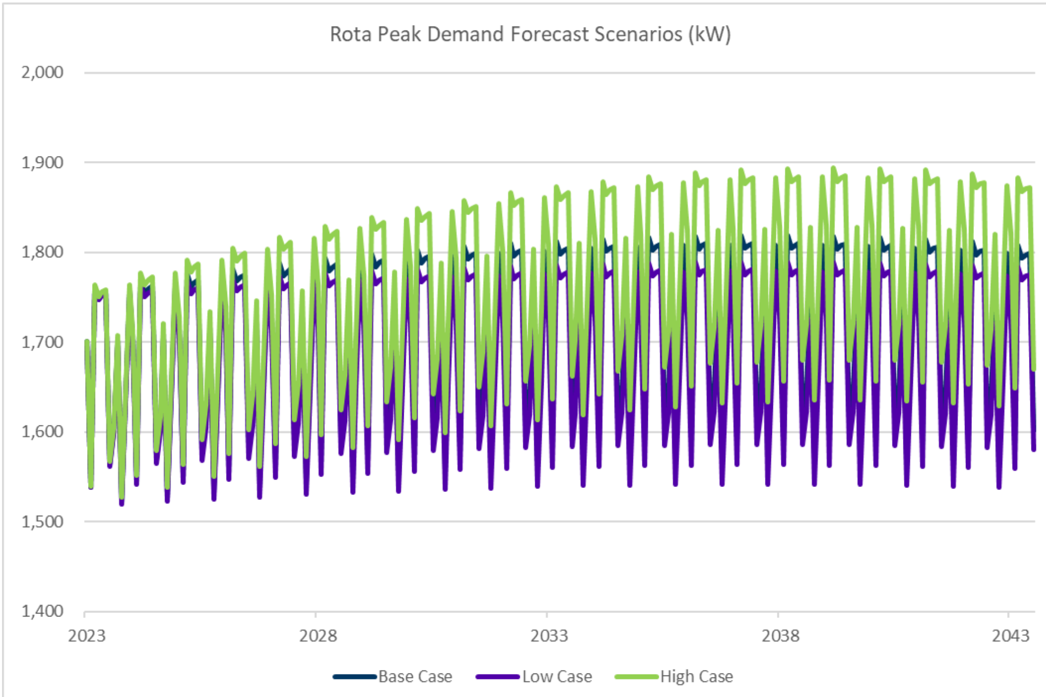

Figure 5 *Rota Peak Demand Forecast Scenarios (Monthly) (kW)*

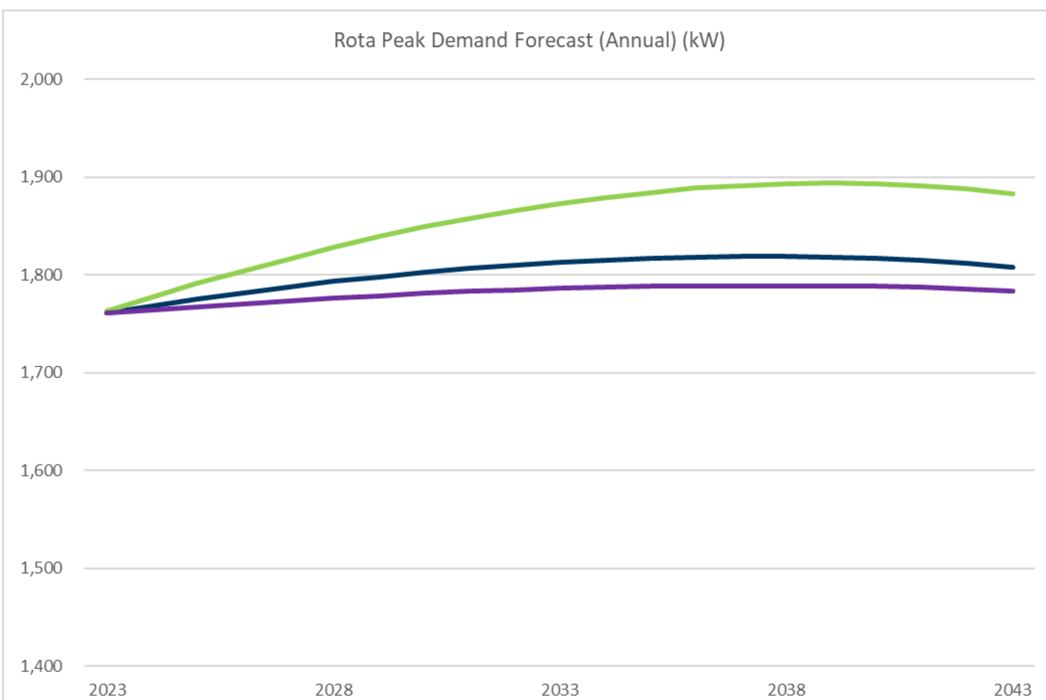

Figure 6 Rota Peak Demand Forecast Base Case (Annual) (kW)

2.4 Further Considerations

This section provides commentary as it relates to other factors that have been identified that have the ability to materially impact future peak energy demand on the three islands.

Each of these factors is extremely difficult to forecast on a standalone basis due to many factors including the lack of historical data available. Furthermore, each factor is dependent upon highly dynamic macroeconomic conditions, and as such, these have not been accounted for in the Model.

2.4.1 Rooftop Solar

There are currently some small-scale public and private solar PV installations around the CNMI. The recent explosive growth of the rooftop PV industry in the USA has the potential to extend to the CNMI, given the high cost of electricity on the islands. It is worth noting, several new and upcoming public facility construction projects have included rooftop solar into their designs, however, these buildings have not yet been constructed.

Key factors influencing the amount of rooftop solar PV installed at the residential level include the population density, affordability, and utility approvals. Over the forecast period, it is possible that the amount of commercial and residential customers that install rooftop solar PV may increase. This would have the effect of reducing the future load demand to be supplied by the grid. It is understood that there are minimal commercial and residential installations currently installed on the islands, making for a negligible impact on the initial conditions for the demand forecast. Some commercial projects in Saipan does potentially allow for under 200 kWac of solar installed on various new buildings on the island. This amount of additional generation in the future is considered negligible and has not been accounted for in the demand forecast.

3. Energy Options Assessment

This Section provides an options assessment of different available technologies and based on their suitability, proposes a generation and storage mix for CNMI that will decarbonize their energy supply. This section discusses options screening which will sort the technologies on a go/no-go basis for further assessment in a pre-feasibility model. Following the findings of the pre-feasibility study, a recommendation will be given for the energy mix for CNMI.

3.1 Existing network and supply

Currently, the power supply to Saipan, Tinian and Rota are almost entirely via ultra-low Sulphur diesel fossil fuelled generators. There are a few small renewable energy systems, small scale solar PV (0.222 MW total) and wind (0.144 MW total) projects have been installed at public facilities and schools[3], it is understood that the CUC does not own or operate any renewable generation plants. There are no natural oil reserves on the islands, meaning that the CNMI is dependent on fuel imports with high shipping prices and rates. A summary of the power plants in the CNMI is tabulated below:

Table 8 CNMI Power Plant Summary

Location	Generation Capacity MW	Number of engines[4]	Peak Demand MW	Fuel Storage capacity Days	Distribution voltage(s) kV	Number of feeders	Network Type	50% loss impact[5]
Saipan	62.1[6]	12[7]	30.6	7	13.8	9	Mesh	2-3 weeks without power
Tinian	17.5	5	2.2	5	13.8 / 4.16	3	Radial	30 days without power
Rota	5.6	1	1.5	5	4.16	3	Radial	30 days without power

Saipan has the largest network and the largest population and is followed by Tinian and then Rota.

Limited information is presented regarding the age of all assets across the islands. Detailed running hours is provided for diesel generators at Power Plant 1 on Saipan shows the total running hours at 20+ years with overhauls being overdue by 10,000+ hours. Detailed information on overhauls and running hours are not provided for all assets in Saipan, no information on run hours is provided for generators for Tinian and limited information on running hours is provided for Rota. Seeing as the overhaul of the diesel engines is a fixed cost for each of the islands and overhaul of all engines are overdue as of June 2023, and a complete profile of the state of all generators was not provided, for the purposes of the Pre-Feasibility Study, it is therefore assumed that the existing diesel generation for all islands is in a state where they can maintain continuous operation for 20 years with a typical assumption for O&M costs for the diesel plant. These O&M costs allow for major overhaul of the diesel generators over the lifetime of the project.

Seeing as the primary driver for this IRP is "40% renewables by 2030"[8], a higher efficiency or lower emissions diesel option or diesel replacement options were not considered. It should be noted that the 2015 IRP produced by Leidos Engineering explored resource options where thermal generation provided by an independent power provider (IPP)

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[3] National Renewable Energy Laboratory, Energy Snapshot Commonwealth of the Northern Mariana Islands, June 2015
[4] GHD has assumed that all currently online diesel generation as of CUC's RFI response dated June 2023
[5] Based on data provided by the CUC.
[6] Based on operational engine information provided in CUC RFI Response. It is understood that capacity has changed recently, and replacements are also currently underway to increase capacity. These changes have not been captured.
[7] Aggreko counted as a single "engine" as they contractually provide 12 MW to the CUC network as a power provider
[8] As stated in CUC's Request for Architectural and Engineering Services "CUC-RAESP-22-024"

with various fuel changes to replace existing power plants in the CNMI. The renewables options in this 2015 IRP explores a maximum solar PV capacity of 10 MW on any given island. For Saipan alone, this would amount to a significantly lower renewables proportion of the CUC's generation mix. With this priority shift on high penetration renewables in this iteration of the IRP, the diesel technology is therefore kept as "Business as usual" with no alternative diesel technology or fuel options considered in the techno-economic modelling performed in this Energy Options Assessment.

A key constraint for renewable generation will be integration into the existing distribution network and power balancing. Figure 7 shows the geographical network diagram for each of the main islands in the CNMI.

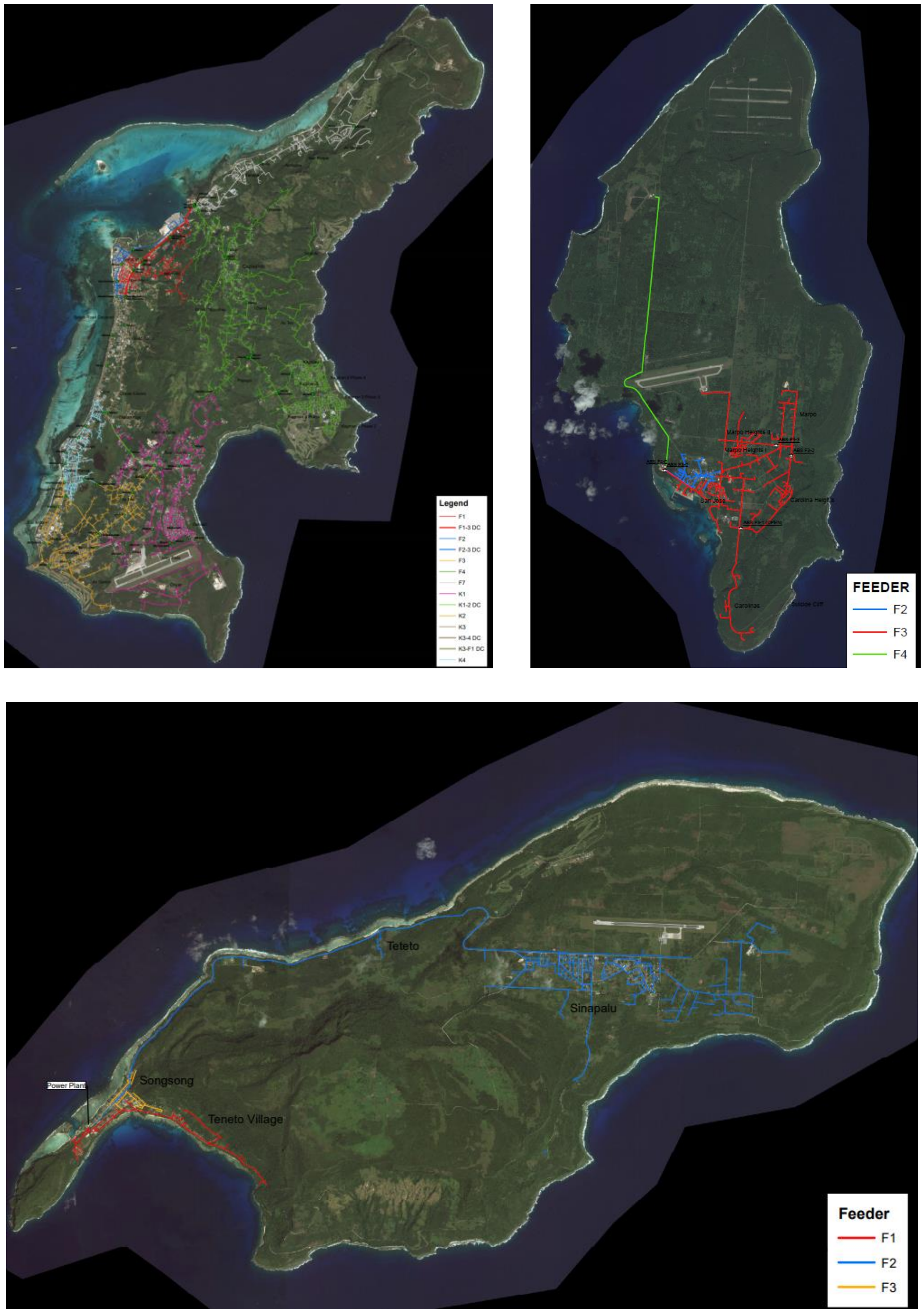


Figure 7 Network Diagrams: Saipan (top left), Tinian (top right) and Rota (bottom)

3.1.1 Distributed Energy Resources

As of 2022, there is a total generation capacity of 5 MW net metered customer-sited solar power capacity in the entire CNMI region[9]. No data is available on the distribution of this 5 MW of solar PV across market sectors (residential vs commercial installations) or island basis.

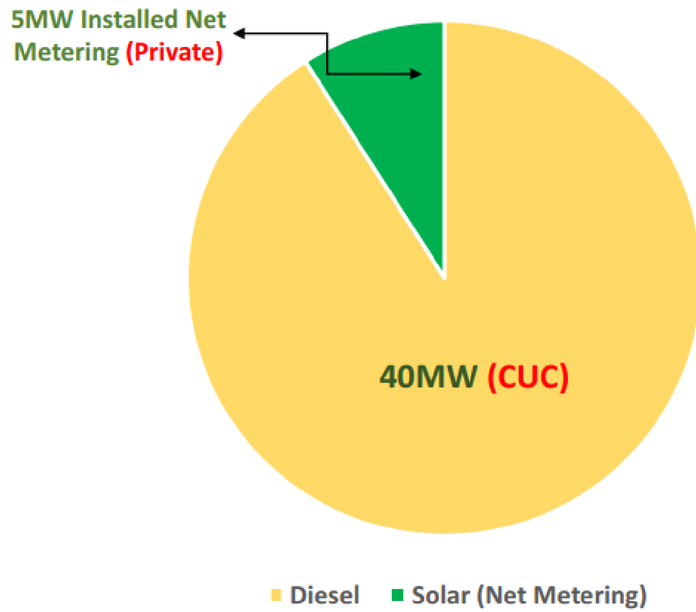


Figure 8 CUC's Power Generation and Renewable Energy Portfolio[9]

It should be noted that the current power generation capacity of Saipan alone at the time of writing this report is 62.1 MW. Assuming minimal adoption of solar PV, the proportion of solar PV adoption across the islands accounts for less than 6% of the total generation mix.

While development of DER for customers is not within the scope of the IRP, a preliminary estimate can be done to approximate the impact of high adoption of small-scale solar PV in the residential market sector based on current information known about the islands:

Assumptions

Table 9 Preliminary DER assessment assumptions

Description	Assumption	Data source and commentary
Number of households	10,015	**2020 Census DHC Summary File for the CNMI**
Adoption rate	33%	Assuming highest PV adoption rate possible in US using Hawaii as basis of comparison. **Spring 2023 Solar Industry Update** (NREL)
Median solar system size	7.4 kW	2023 median solar system size in the US **Tracking the Sun Tool | Energy Markets & Policy** (Lawrence Berkeley National Laboratory)

Using the assumptions in Table 9, a preliminary estimate for capacity of solar in the CNMI if there was large-scale adoption is estimated to be approximately 24.5 MW across the islands. It should be noted that there are several factors that impact the adoption rate of solar PV which includes but are not limited to:

[9] CUC, CNMI, Territorial Climate and Infrastructure Workshop, Multi-Source and Renewable Power Supply System Development (March 2022)

– Local policy and incentives
– Local electricity rates
– Local resource (sunshine) and climate
– Level of community engagement, education and attitudes around solar technology

High adoption of solar can also introduce problems into the network from the CUC's perspective:

– Islanding of households during planned or unplanned outages – whereby a household is still "live" due to a solar system still generating during an outage. Modern inverter systems are designed to monitor this and prevent islanded operation (anti-islanding). Local regulations would need to be updated to mandate appropriate anti-islanding requirements ahead of large-scale adoption for the safety of the CUC operators.
– Solar induced "duck" curve - During the day, when the sun is shining, solar panels generate a lot of electricity, causing a dip in the demand for electricity from other sources. As the sun sets and solar energy production drops, the demand for electricity from other sources rises sharply, creating a steep upward slope. This demand curve changes resembles a duck as shown in the example curve in Figure 9. This large daily fluctuation can cause issues with power system stability.

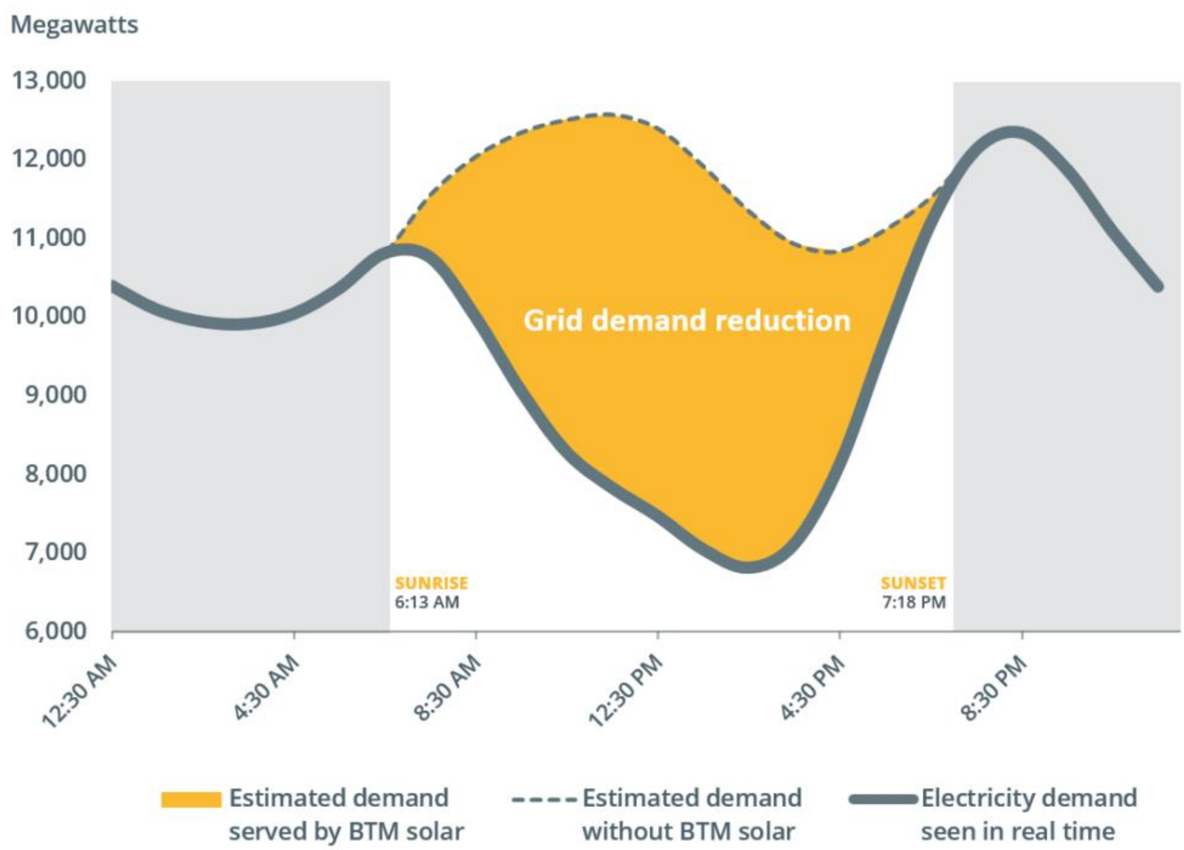


Figure 9 ***Example of demand duck curve caused by large scale solar***[10]

As such, facilitating adoption of community based solar requires multiple interventions from local and federal government, the CUC and the public market. This IRP focuses on the development pathways that the CUC can take to introduce renewables into their energy supply portfolio. It should be noted however the significant opportunity that large scale DER represents. The CUC may benefit from investigating policy and infrastructure changes to embrace large scale DER in the future.

[10] Image source: **'Duck curve' days becoming more frequent as solar power spreads - ISO Newswire**

3.2 Technology Selection - Options Screening

This Section is a technology screening that will determine what will be considered in the Pre-Feasibility Study. This section lists the technologies that will be included in the screening, the criteria that will be used to assess them and present a shortlist of technologies for further assessment in the Pre-Feasibility study in Section 3.3.

3.2.1 Initial Considerations for Diesel and Emerging Technologies

Diesel

Based on consideration for diesel fired reciprocating engines and assuming an average utilization of 4,000 hours/annual a reciprocating engine will achieve approximately 160,000 hours of operation over 40 years. During that period the unit will have had several minor overhauls and possibly 2 to 3 major overhauls involving replacement of the engine block or at least repair/modification of the engine block. It is considered that engines of that age will have an increased forced outage rate therefore reduce their reliability to generate power when needed. Also, engines of the age will have higher heat rates (lower efficiency) and hence consume more fuel per MWh generated.

A combined cycle power plant[11] will be much more efficient and have better reliability compared to an existing engine having an age of greater than 40 years. A combined cycle power plant however is significantly more complicated than a diesel fired reciprocating engine generator set (in Open Cycle), and more expensive with little benefit of achieving a higher efficiency. For a location like Saipan with the power demand as it currently is, it would be required to configure several small, combined cycle power plants which will result in a higher CAPEX.

Using larger units in a combined cycle plant will improve the economics greatly as is the case in for a new power plant on Guam (a total of 198MW combined cycle power plant). However, a single power block capacity likely to be installed on Saipan would be limited to 8 to 10 MW which is small for a combine cycle power block.

Currently a new diesel reciprocating engine generator set would provide a higher reliability than the existing engines installed on Saipan, as well as lower fuel consumption (44%-46% efficiency) and a higher capability for generating flexibility. As described in Section 3.1, an uplifted OPEX figure is factored in to all financial modelling to account for uncertainty in timing of replacement of the old diesel plant to maintain baseline load fulfillment.

Emerging technologies

There are many emerging technologies of interest to the CUC, such as hydrogen and supercapacitors for energy storage. These technologies are still developing, meaning they would have a significant premium for CAPEX that may be prohibitive for use on the islands. This applies for other novel opportunities, as such, they have not been included in the technology screening.

Hydrogen, while promising as a clean energy source, involves high capital costs for production, storage, and enabling infrastructure. The efficiency losses in converting electricity to hydrogen and back to electricity further reduce its viability. Additionally, the safety concerns associated with hydrogen storage and handling, coupled with the need for extensive infrastructure development, make it less practical for the CNMI with limited resources and relatively lower energy demands.

Supercapacitors, on the other hand, are known for their high-power density and rapid charge-discharge cycles. However, their lower energy density compared to batteries means they are not suitable for long-term energy storage, which is crucial for maintaining a stable power supply on an island. The high cost of supercapacitors, along with their higher self-discharge rates and sensitivity to temperature variations, further limits practicality.

[11] The assumption here is that gas turbines are used that are fired on diesel fuel heat recovery from the unit's exhaust will be require adding a waste heat recovery boiler that produces high pressure steam which will be put through a steam turbine that will generate power from the steam produced. The efficiency of a small-scale gas turbine will be approx. 26% and after the adding the additional power from the steam cycle, the total efficiency may be improved to approximately 44%. Modern diesel fired reciprocating engines have efficiencies in the range 44-46%.

3.2.2 Technologies Considered

Technologies evaluated in this screening are aligned with the primary technologies identified in the previously issued CNMI Strategic Energy Plan (SEP). The SEP identified new technologies to utilize alongside existing diesel generation which provides firming, or base load for the islands. This approach ensures continuity with the CUC's long-term vision and leverages key insights from SEP. A summary of the shortlisted technologies from the SEP which will be considered in this technology screening are listed below:

Table 10 Summary of Technologies Considered

Technology	Description
Wind (Onshore / Land based)	Wind turbines installed on land to generate electricity from wind energy.
Wind (Offshore)	Similar to onshore wind, but it utilizes wind turbines placed in bodies of water to utilize coastal winds, which tend to be higher and more uniform.
Large scale solar PV	Solar Photovoltaic cells (crystalline or thin film) convert sunlight (global horizontal irradiation, GHI) into DC power which is converted by an inverter into AC power.
Large scale battery (BESS)	Enabling technology for generation. BESS stores electricity and discharges energy for grid stabilization and reliability. Where BESS is mentioned, this report is referring to lithium-based sub-chemistries such as LFP or NMC.
Gas plant	Use of combined cycle gas turbines to generate electricity burning natural gas or methane.
Geothermal	Electricity production using geothermal resources at or below the surface of the Earth.
Energy from waste	Generation of electricity (or typically heat) by processing various waste streams. Waste streams are processed via burning, gas capture or anaerobic digestion.
Pumped hydro energy storage	Energy storage is achieved by moving water between two reservoirs at different elevations. Electricity is generated by passing running water through a turbine as it flows between the two reservoirs via gravity.

Each of the technologies were assessed using a combination of qualitative and quantitative criteria to determine their suitability to be implemented between the present and post 2040. The key metrics observed are listed in Table 11. Figure 10 shows the commercial readiness of each technology

Table 11 Technology screening criteria

Criteria	Description	Analysis Metric
Viable Local Resource	Good quality renewable energy resource available in the region Yield potential based on resource specific units compared against national and global benchmarks.	Qualitative + Quantitative
Cost Competitive	LCOE competitive against competing technologies both currently and in the future.	Quantitative
Technology Maturity	Technology is proven and ready for commercial development. For current implementation CRI (Commercial Readiness Index) ≥ 3 Proven track record/global installed capacity	Qualitative + Quantitative
Safety	No unacceptable safety risk to operating personnel and surrounding community	Qualitative
Reliability	Technology can provide consistent power to the site	Qualitative
Reputational and Policy/Legal	No potentially unacceptable apparent risk is perceived	Qualitative

3.2.3 Options Screening Assessment

The options assessment was conducted using a traffic light assessment to compare each technology against the selection criteria outlined in Table 11. In this framework, a green rating signifies strong performance relative to competing or established technologies, amber indicates moderate or mediocre performance, and red denotes poor performance or non-viability for technology in the CNMI.

This assessment draws upon multiple data sources, including internal benchmarks from CNMI-specific information and constraints provided by the CUC, Australian projects of similar scope completed by GHD, and publicly available industry data. Additionally, insights from the previously issued SEP were incorporated to ensure a comprehensive evaluation.

Each traffic light rating is accompanied with commentary justifying the assignment. Any technology receiving a red rating in any selection criterion is considered not viable for implementation in the CNMI. Overall viability assessment can be seen in Table 12.

3.2.4 Options Screening Findings

As indicated by the screening assessment in Table 12 only large-scale solar PV and BESS demonstrated sufficient performance to justify further evaluation. These technologies will undergo a detailed multi-criteria assessment to determine their suitability for inclusion in the CUC's updated IRP for renewable energy solutions. All assessed renewable energy options shall be assessed on the basis of the existing diesel generation capacity for each island. This is due to the current electrical infrastructure being built around a dependence on diesel generation plants on each island. In assessing renewable options, there is an opportunity for the existing diesel generation to serve as a firming technology, providing base load for all the islands.

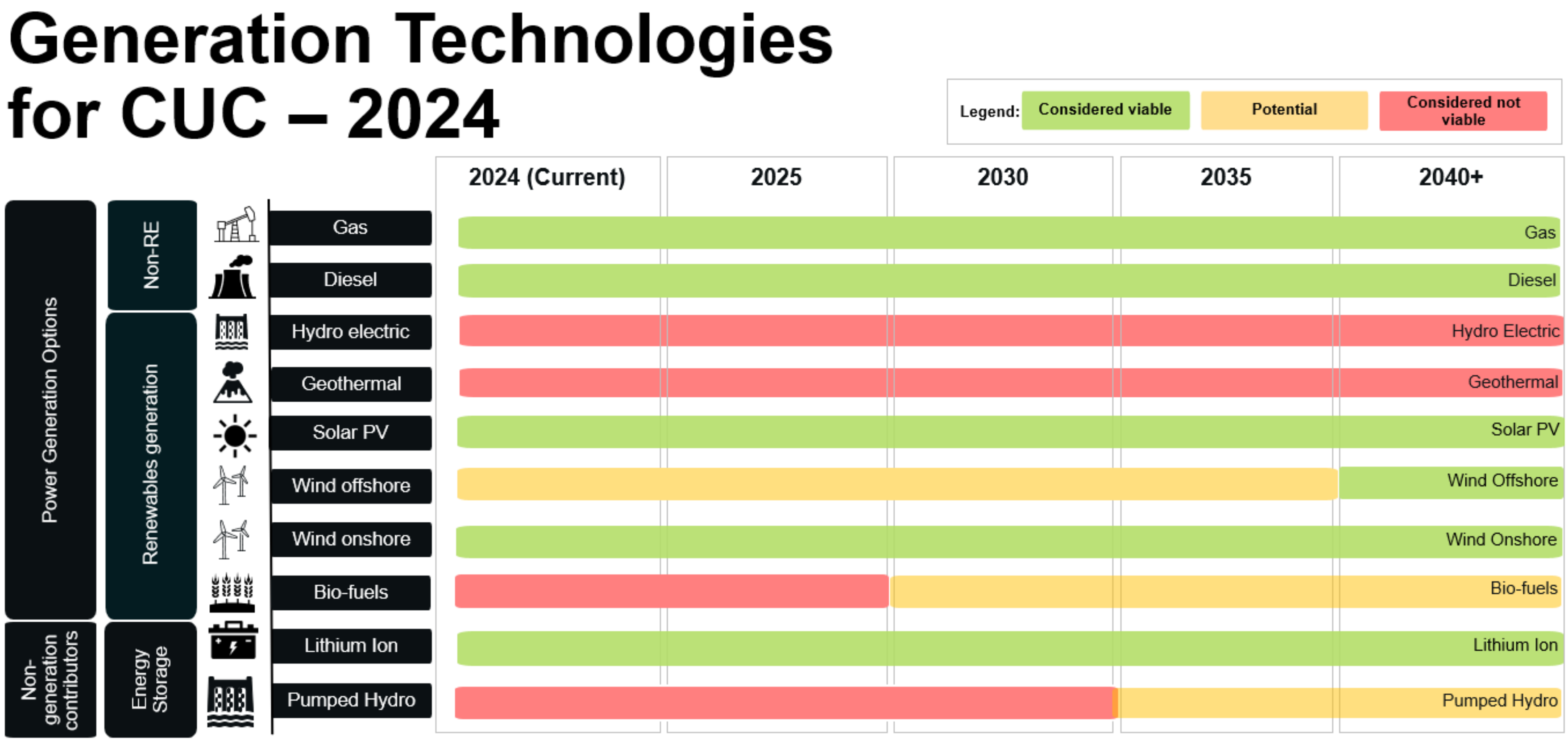


Figure 10 *Generation and storage technology commercial readiness – Diesel included for comparison*

Table 12 Viability of technologies for CNMI

Technology	Local resource viability	Commercial Readiness	Environmental	Cost Competitiveness[12]	Reliability/ Intermittency	Reputational and Policy/Legal	Cost source
Wind (Onshore / Land based)	High wind resource, however, region is prone to typhoons.	6. Known technology with proven track record	Smaller footprint, however, impact on fauna, particularly birds/marine life. Noise level impacts on local residents. Requires assessment	$1,330 / kW + 20-30% Risk of mobilization constraints and civil constraints in mountainous regions and typhoon prone regions.	Location is constrained to use tilt down turbines to avoid damage during typhoons	Potential issues with environmental impact due to civil requirements and impact on bird life.	NREL
Wind (Offshore)				+$3,780 / kW + 50-100% High risk of mobilization constraints being cost prohibitive.	Reasonably reliable, with forecastable output. Subject to cut out at high wind speeds	Potential issues with environmental impact on local bird and marine life.	NREL
Large scale solar PV	Good solar resource. Cyclone prone region constrains technology to fixed axis tilt (FAT) only.	6. Known technology with proven track record	Would require land clearing but not constrained as to limit land to sensitive wildlife areas.	$1,390 / kW	Reasonably reliable, with forecastable output using cloud cameras and satellite imaging	Potential issues with local ecology, however minimal environmental impact expected.	NREL
Large scale battery (BESS)	Minimal land requirements	5. Market competition driving widespread deployment	Would require land clearing but not constrained as to limit land to sensitive wildlife areas.	$280 / kW + $270 / kWh	Reliable technology. High response time.	Potential issues with local ecology, however minimal environmental impact expected.	Australia AEMO benchmark
Gas plant	No local gas resources or infrastructure.	6. Known technology with proven track record	Similar management levels to Business as Usual case. Emissions intensive	$1,300 per kW + 20-30% To build out supporting gas infrastructure and storage.	Reliable technology	Reputational risk due to minimal environmental improvement. Gas is also emissions intensive.	EIA

[12] $/kW costs obtained from multiple publicly available data sources to establish a baseline price comparison. Costs used in all techno-economic modelling will be determined based on current location specific market data, GHD internal knowledge base and internal benchmarks based on similarly scoped projects.

Technology	Local resource viability	Commercial Readiness	Environmental	Cost Competitiveness[12]	Reliability/ Intermittency	Reputational and Policy/Legal	Cost source
Geothermal	Islands do not have a viable geothermal resource locally.	3. Few large-scale projects implemented	Impacts of fracking would need to be assessed	$6,920 per kW + 100-150% Depending on technology adopted. Price excludes geographical studies.	Reliable, with consistent output	Potential issues with local ecology.	NREL
Energy from waste	Requires steady input of biomass which is unlikely to be achieved given population.	3-4. Few large-scale projects implemented	Requires steady input of water to create steam for turbines.	$13,000 per kW[13]	Dependant on fuel supply availability	Potential issues with use of local waste as resources	Gencost 2022-2023
Pumped hydro energy storage	Potential locations have been screened in previous work. Selected areas have protected ecology	3. Few large-scale projects implemented	High environmental impact risk. Impact on local flora and fauna requires assessment.	$3,000 per kW	Reliable with consistent, controllable output.	High risk of reputational damage and impacting protected ecology.	Gencost 2022-2023

[13] Price includes carbon capture storage.

3.3 Pre-Feasibility Study

This Section describes a pre-feasibility study that explores the potential of combining different mixes of the shortlisted technologies with the islands' existing diesel generation.

Using a method called multi-criteria analysis (MCA), this study compares different options using the shortlisted technologies using metrics that are important to the CUC. This highest performing hybrid system will then be examined in more detail in future sections.

3.3.1 General

The CUC is aiming to provide cost effective energy and reduce emissions across the three islands Saipan, Tinian and Rota over the next 20 years. In developing their energy strategy, this feasibility study aims to achieve at least 40% renewable penetration for each of their islands.

Previously, GHD has performed a preliminary techno-economic model (TEM) with less precise yield models for each of the islands as part of the SEP. This study and associated modelling will utilize dedicated, location specific yield modelling data to optimize renewable sizing for each of the islands.

The modelling was developed to take a quantitative approach to economic lifecycle costs[14] and optimization analysis of different installed solar and BESS capacity options. Optimization was based on the weighted sum method and used the following metrics considered for the project drivers as follows:

- Affordability: System CAPEX - $M
- Cost of energy (COE): Cost of generation after capital has been invested ($/MWh)
- Emissions abatement: CO_2 tonnes abatement p.a. compared to Business as Usual (BaU) and maximized renewable penetration
- Affordability and emissions abatement: Marginal abatement cost (MAC) - $/$CO_2$ tons abatement p.a (per annum). A negative MAC relates to an NPV positive project that generates income every tonne abated whereas positive means there is a cost per tonne abated. All MACs provided in this report are based on the renewable facility's first year of operation and will specify which carbon intensity has been used in the results.
- System reliability: Unmet load

3.3.2 Multi Criteria Analysis - Agreed Criteria and Weightings

The various options considered were ranked against criteria agreed between the CUC and GHD. The criteria that will be used to assess each option and respective weightings are listed in Table 13.

Table 13 Summary of key criteria and weightings

Criteria	Unit	Weighting
Capital cost (CAPEX)	$M	15%
Levelized cost of energy (LCOE)	$/MWh	25%
Marginal Abatement Cost (MAC)	$/MT of CO2 reduced	10%
Emissions abatement	MT of CO2	15%
Unmet load	% of kWh demand	10%
Renewable Penetration	%	25%
Total		100%

[14] All costs (including CAPEX and OPEX) are in $USD unless otherwise stated.

The options were min-max normalized, meaning that the best option scores a 100% and the worst option scores 0%. Weightings were then applied to each to determine a final score that was used to score any given option. This allows for a numerical assignment of the performance of any given option identified in the modelling.

3.3.3 Modelling Methodology

A HOMER Energy techno-economic model was developed to calculate the levelized cost of energy (LCOE) in order to take a quantitative approach to economic lifecycle costs and optimization analysis of different installed solar capacity options. HOMER Pro is the global standard software package for optimizing microgrid and grid connected design. All modelling uses site specific load, solar irradiance and ambient temperature data and system cost calculations to account for capital, replacement, operation and maintenance, fuel, and interest costs.

HOMER Pro simulates the operation of a system by making energy balance calculations in each time step (interval) of the year. For each time step, HOMER Pro compares the electric demand in that time step to the energy that the system can supply in that time step and calculates the flow of energy to and from each component of the system.

A system model is developed for each island (Saipan, Tinian, and Rota) based on information provided by the CUC and data collected during the development of the SEP including one-line diagrams, layout drawings, the GHD internal knowledge base and publicly available information. A register of assumptions and inputs into the model can be seen in Appendix A.

3.3.4 Option Selection

3.3.4.1 Option 1 – Diesel only (Business as Usual)

"Business as Usual" (BaU) reflects the existing system configuration to be used as the comparison scenario for financial assessment. In this model the system is connected to the existing diesel plant without any new storage or renewables. With the data provided, the system was simulated in the HOMER modelling software.

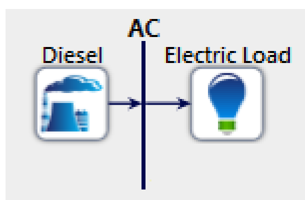


Figure 11 Option 1 – Diesel Only

3.3.4.2 Option 2 – Solar only

This model focuses on the addition of PV which is integrated into the existing system of diesel generation. Solar PV is sized to achieve optimal affordability and emissions abatement. The existing diesel generation is used to provide base power and power when solar is not available.

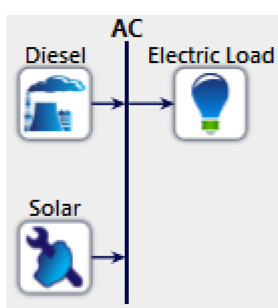


Figure 12 Option 2 – Solar only

Option 3 – Solar + BESS

This model focuses on the addition of PV which is integrated into the existing system of diesel generation and supported by a BESS which provides renewable energy storage. Both the PV and BESS are sized to achieve optimal affordability and emissions abatement for this mix of technologies.

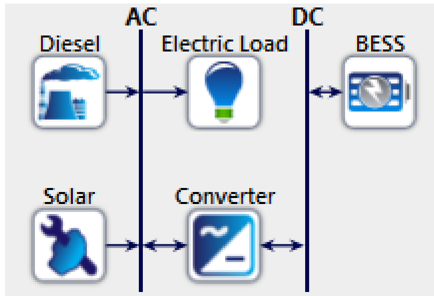


Figure 13 Option 3 – Solar + BESS

3.3.5 Load profile

A load profile was generated based on the following key inputs:

– Outcomes from the demand forecast as described in Section 0;
– General daily trends observed in sample historical load data provided by the CUC; and
– Inbuilt HOMER load synthesizer for community scale load profile.

The community scale load profile was adjusted based on the diurnal trend observed in load data provided by the CUC. The load data presented was observed to have two peaks with a smaller peak at approximately 3 PM and the largest peak occurring at 7 PM. HOMER was utilized to account for daily variances in load. Seasonal variation was also adjusted based on data provided by the CUC. A data sample of the load profiles can be seen in Figure 14 to Figure 16.

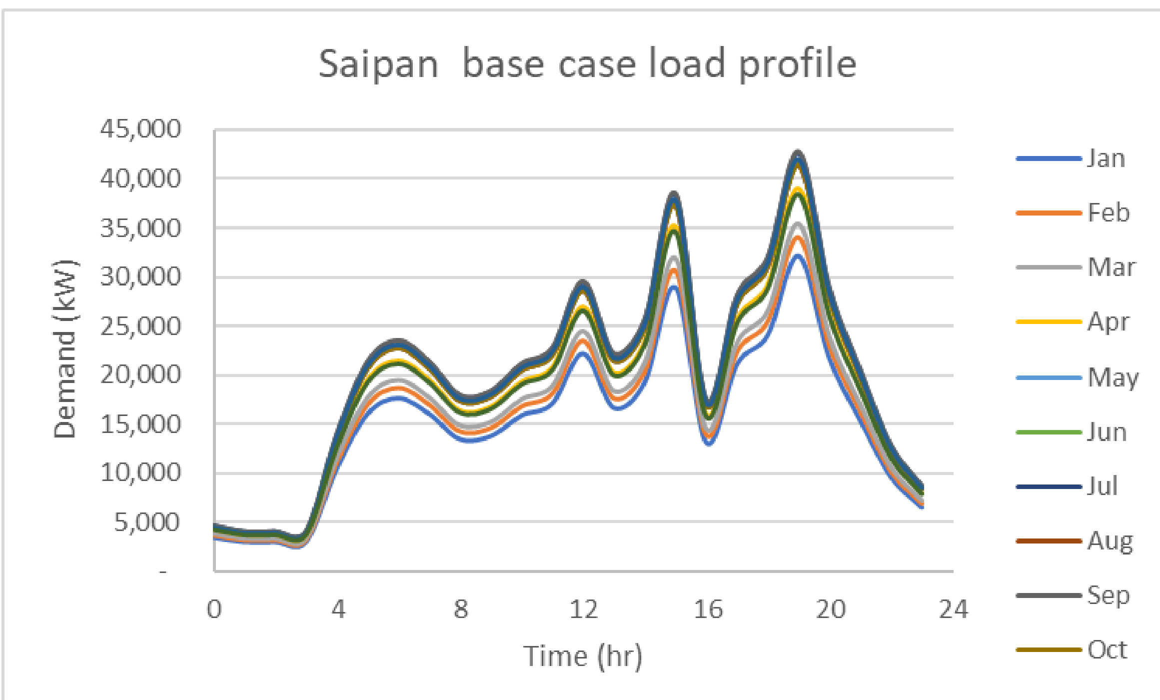


Figure 14 Load profile sample – Saipan base case load

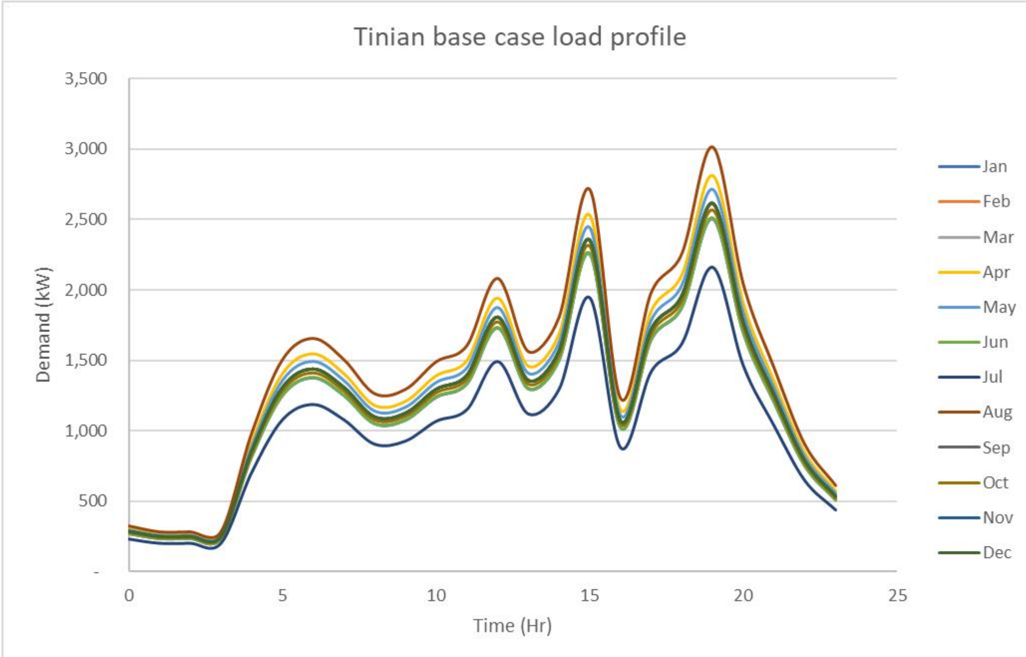


Figure 15 ***Load profile sample – Tinian base case load***

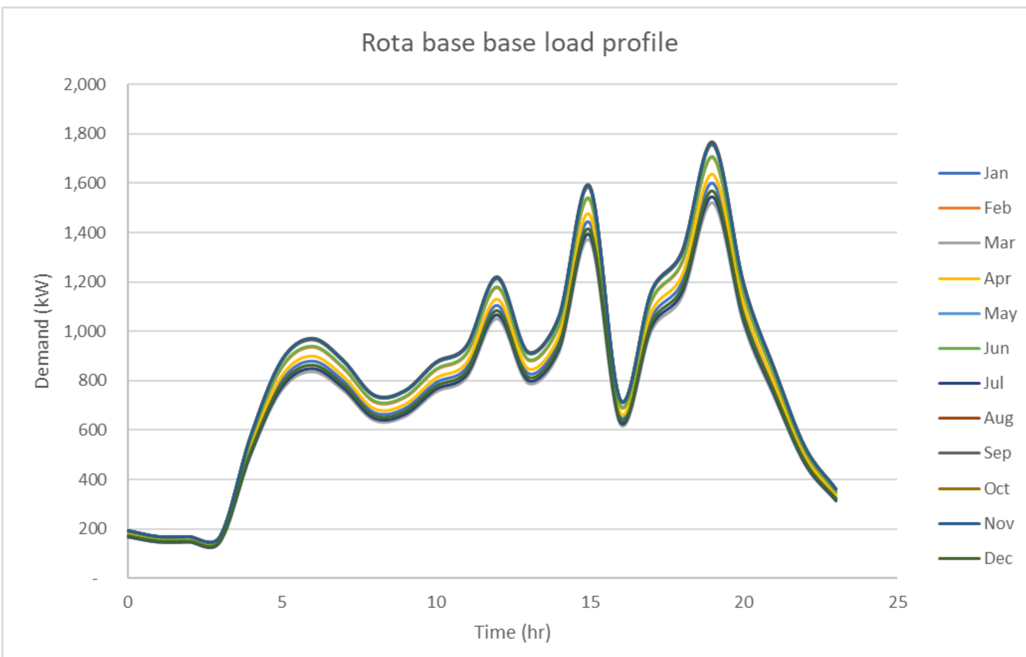


Figure 16 ***Load profile sample – Rota base case load***

The expected load growth is as described in Section 2.3. The Base, Low and High load profile scenarios are based on the corresponding load scenarios described in Section 2.3.

3.3.6 Existing Diesel Generation

In this pre-feasibility study, data was provided for existing diesel generation capacity for each island. The diesel capacity for each island was broken down on a per-engine basis, along with some information about the current operational lifetimes of some engines (mainly for Power Plant 1 diesel engines on Saipan).

To account for potential replacements, the O&M fixed costs for each engine that are factored into the HOMER modelling, it is assumed that major overhauls will take place at every major milestone from beginning of life of a new diesel engine (8000 hours, 10,000 hours, 20,000 hours etc.). This is expected to account for and offset potential replacements for any given diesel engine as it is known that many are close to or exceeding their operational lifetime and are overdue for overhaul. These assumptions, documented in the assumptions register (see Appendix A), account for the remaining operational lifetimes of the diesel generators at each power plant.

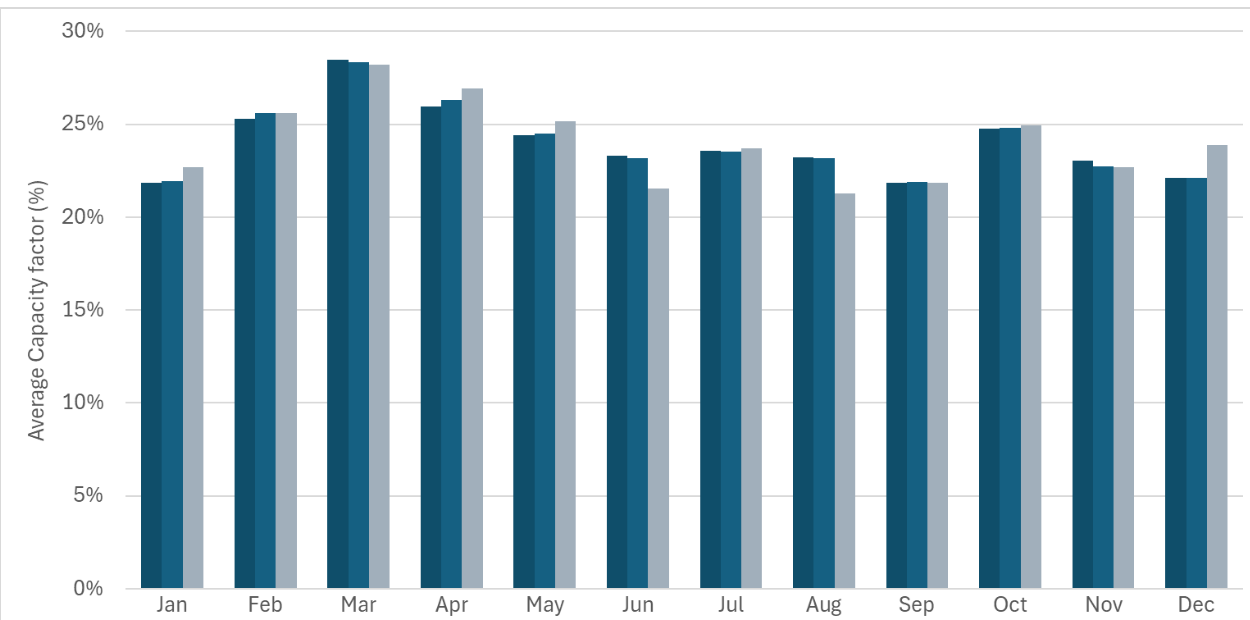
Currently, it is understood that all diesel generators on Saipan's Power Plant 2 and Power Plant 4 are over 60 years old. Power Plant 1 engines are over 35 years old and are overdue for overhaul by at least 10,000+ hours. Limited asset condition information was provided for diesel engines on Tinian and Rota.

As such, the techno-economic modelling of all diesel engines was not constrained by their operational life over the 20-year project period. The costs of overhauls during the engine's lifetimes are built into the O&M cost for the diesel generators.

3.3.7 Renewable Energy Yield Assessment

A solar yield model for each of the islands was created using PVSyst as part of this study. The solar yield models account for cell shading, temperature derating and estimated inverter losses. The yield models assume mono-facial modules that are ground mount installed with fixed tilt. Each of the islands are prone to severe cyclones, as such using single axis tracking systems to improve the solar yield is not possible due to the typical wind loading capabilities of such systems being constrained.

Generally, across the islands, the generation profile for solar was found to be consistent annually, with peaks occurring in March and a lower peak in October. Figure 17 shows the month-to-month average solar capacity factor across the islands. The marginal variation between the islands is likely attributed to the islands being geographically concentrated. Rota, being the southernmost island is closest to the equator and has a slightly larger average capacity factor.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Saipan	22%	25%	28%	26%	24%	23%	24%	23%	22%	25%	23%	22%
Tinian	22%	26%	28%	26%	25%	23%	24%	23%	22%	25%	23%	22%
Rota	23%	26%	28%	27%	25%	22%	24%	21%	22%	25%	23%	24%

Figure 17 ***Average solar capacity factor for islands***

The average capacity factor for each island is summarized in Table 14.

Table 14 PV capacity factor per island

Island	Average Capacity Factor PV
Saipan	23.99%
Tinian	24.1%
Rota	24.03%

3.3.8 BESS Basis of Sizing Minimum Capacity

In addition to the techno-economic optimization regarding energy balancing (i.e. BESS energy/power sizing to reduce renewable curtailment/spillage), an additional technical feasibility overlay was applied to BESS minimum power capacity. The BESS basis of sizing for the following modelling considers the following key criteria:

- **Renewable Energy Smoothing (RES)**: Sufficient power and energy capacity to cover the intermittency of the renewables including with solar when cloud events occur or in the case of the wind farms with wind stalling (i.e. wind speeds below turbine cut-in level). While there is site and layout specific methodology, GHD has developed a general high-level reference:
  - Solar – 80% of nameplate capacity[15] based on installations under 130 MW

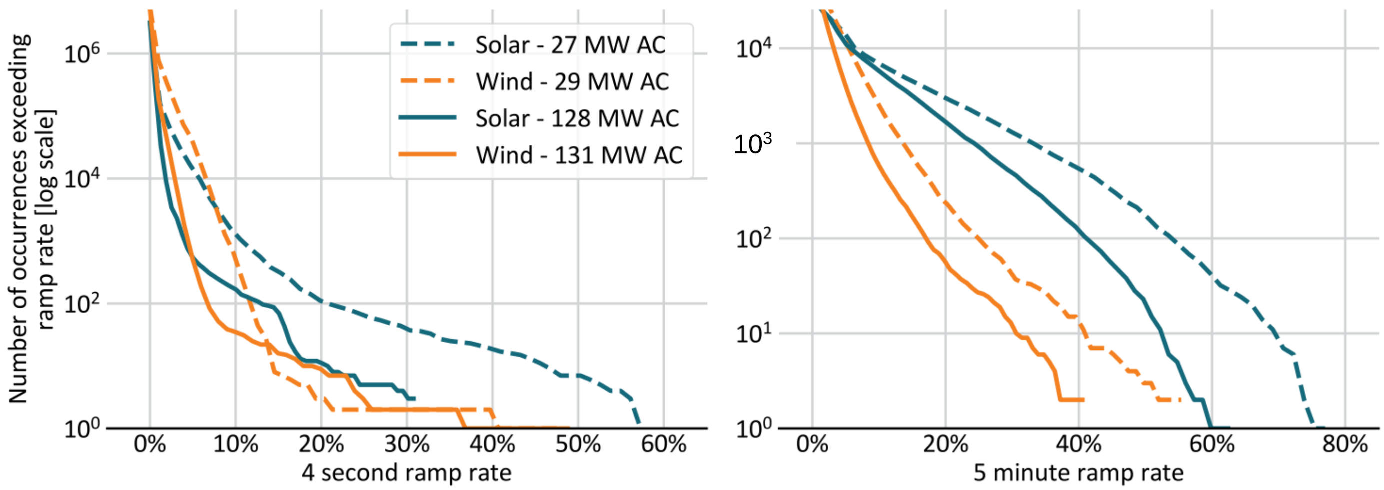


Figure 18 Historical solar and wind reduction ramp rates[15]

- **Maximum demand**: BESS inverter name plate capacity is sufficient to supply whole of system maximum demand at project start as per Sections 2.3. Even in the event when the required BESS installed power capacity required for RES exceeds the maximum demand (i.e. generation is greater than the maximum demand), there is no reason to install additional ESS power capacity beyond the maximum demand from a loss of supply/system security perspective.
- **Energy/Power ratio**: To align with current established systems, one, two, four, and eight-hour BESS were considered in the modelling (i.e. high C rate options were not considered).
- **Duration**: A minimum duration of 30 minutes (2C) is considered to allow for sufficient start-up times for existing firm generation (diesel) in the worst-case scenario. Common commercial durations will be considered in this study (30 minutes, 1, 2, 4 and 8 hour systems)

[15] ARENA "The Generator Operations Series- Report Two: Ramp Rates for Solar and Wind Generators on the NEM"

3.4 Feasibility Study Results and Discussion

The optimum configurations are applied to the results of the HOMER model to assess the highest performing power supply option for each island.

3.4.1 MCA Findings

Full results including hybrid system configurations selected for each option is in Appendix B. Across the board, a 4-hour duration BESS was found to be the most feasible option when considering the following constraints:

– Achieving at least 40% renewable penetration
– Supply the required demand with no unmet load
– Optimizing performance in other MCA criteria

The high load scenarios for Saipan and Tinian have two configurations for the Solar + BESS options. The options are labelled (A) and (B), the descriptions for these configurations are listed below:

- Configuration (A) – The Solar + BESS configuration that was found to have the best performance in NPC, emissions abatement and meets the renewable energy penetration of 40% minimum when modelled against the high case load scenario. This is considered a more aggressive option.
- Configuration (B) – The Solar + BESS configuration that was found to be the most optimal for the base case load scenario is reimplemented for the high case load scenario[16]. This would be considered a neutral option, being optimal for the base case load scenario.

Table 15 Saipan options system description

Load Scenario	System changes from BaU			
	Business as usual (BaU)	Solar	Solar + BESS (A)	Solar + BESS (B)
Base case	-	+60 MW PV	-	+60 MW PV +48 MW / 180 MW BESS
Low case	-	+40 MW PV	-	+60 MW PV +45 MW / 180 MW BESS
High Case[16]	-	+60 MW PV	+80 MW PV +64 MW / 48 MW BESS	+60 MW PV +48 MW / 180 MW BESS

Table 16 Saipan MCA score

Load Scenario	MCA Final Score			
	Business as usual (BaU)	Solar	Solar + BESS (A)	Solar + BESS (B)
Base case	25%	74%	-	85%
Low case	25%	70%	-	85%
High Case[16]	25%	68%	85%	73%

[16] Note that for Saipan, a new 10 MW installation of diesel plant is required to meet baseline load requirements when assessing the high case load scenario.

Table 17 Tinian options system description

Load Scenario	System changes from BaU			
	Business as usual (BaU)	Solar	Solar + BESS (A)	Solar + BESS (B)
Base case	-	+8 MW PV	-	+10 MW PV +8 MW / 32MW BESS
Low case	-	+10 MW PV	-	+4 MW PV +3 MW / 12 MW BESS
High Case	-	+8 MW PV	-	+10 MW PV +8 MW / 32MW BESS

Table 18 Tinian MCA score

Load Scenario	MCA Final Score			
	Business as usual (BaU)	Solar	Solar + BESS (A)	Solar + BESS (B)
Base case	25%	64%	-	85%
Low case	25%	40%	-	85%
High Case	25%	69%	85%	79%

Table 19 Rota options system description

Load Scenario	System changes from BaU			
	Business as usual (BaU)	Solar	Solar + BESS (A)	Solar + BESS (B)
Base case	-	+6 MW PV	-	+6 MW PV +2 MW / 8 MW BESS
Low case	-	+6 MW PV	-	+6 MW PV +2 MW / 8 MW BESS
High Case[17]	-	+6 MW PV	-	+6 MW PV +2 MW / 8 MW BESS

Table 20 Rota MCA score

Load Scenario	MCA Final Score		
	Business as usual (BaU)	Solar	Solar + BESS
Base case	25%	51%	85%
Low case	25%	51%	85%
High Case	25%	52%	85%

[17] In the case of Rota, (A) and (B) ended up being the same system.

Table 21 Optimal system configurations for each island

Island	Option	Solar PV MW	BESS MW	BESS MWh	Additional Diesel MW
Saipan	Solar + BESS (A)	80	64	256	-
Saipan	Solar + BESS (B)	60	48	196	10[18]
Tinian	Solar + BESS (A)	12	9.6	38.4	-
Tinian	Solar + BESS (B)	10	8	32	-
Rota	Solar + BESS	6	2	8	-

Following determining the optimal generation mix for all islands, land availability data from the Department of Public Lands was provided to GHD by the CUC. Section 3.5 provides further detail on available land and potential install locations for the solar and BESS. It was found in the preliminary stage of assessing the data that available land in Rota was constrained to a maximum of 4 MW solar PV, not accounting for buffer regions and collocated BESS. Saipan and Tinian were found to have sufficient land to accommodate the first iteration of techno-economic modelling.

A second iteration (Iteration 2) of modelling was therefore conducted for Rota with this constraint in mind, taking a conservative estimate for solar, the maximum solar installation, if installed with co-located BESS was assumed to be 3 MWac. Following a second round of techno-economic modelling, the MCA results for Iteration 2 for Rota are as follows:

Table 22 Rota Iteration 2 MCA score

Load Scenario	MCA Final Score		
	Business as usual (BaU)	Solar	Solar + BESS
Base case	25%	61%	85%
Low case	25%	60%	85%
High Case	25%	61%	85%

Comparatively the Solar only option in Iteration 2 for Rota performs better than in the first iteration. Seeing as the solar generation is constrained, there is less excess generation that can be leveraged by the BESS to improve the performance gap between the Solar + BESS option and the Solar only option.

The final recommendation for further assessment for each island is as follows:

Table 23 System configurations proposed for further investigation on each island

Island	Option	Solar PV MW	BESS MW	BESS MWh
Saipan[19]	Solar + BESS (B)	60	48	192
Tinian	Solar + BESS (B)	10	8	32
Rota	Solar + BESS	3	2	2

The optimal solution for the base case across is presented for Saipan, Tinian and Rota due to the base case demand forecast for all three islands already showing a relatively aggressive demand growth compared to the low case. Saipan's load growth is projected to be at least 35% in 20 years and Tinian's growth is over 100% in 20 years. Rota has minimal changes across the three scenarios.

[18] Only required in the high case load scenario to meet baseline load requirements
[19] Seeing as the base case is presented for further investigation, an additional 10 MW diesel generation is not proposed to be added to the power system to meet baseload requirements

The recommended BESS duration for Rota is shorter than Saipan and Tinian, this is due to the land constraints restricting the potential for solar, meaning less excess generation. Further details are provided in Section 3.5.3.

3.4.2 Indicative Outcomes

With a high cost of diesel for operation ($4.13 per gallon or $1.09 per liter), the BaU option proves to be the least favorable choice across all islands, regardless of the load scenario—whether base, low, or high. With its combination of high emissions, expensive operational costs, and no current renewable energy integration, the BaU option only offers the advantage of minimal capital expenditure (CAPEX).

In contrast, both the Solar and Solar + BESS options consistently outperform the BaU option across all load scenarios when assessed against the criteria outlined in Section 3.3.2. The renewable energy generated by the solar plants helps offset the high cost of diesel, and in both the Solar and Solar + BESS options, this leads to a reduction in the project's Levelized Cost of Energy (LCOE) over the course of a 20-year lifetime.

Among the various options, the highest-performing solution across all islands and load scenarios was the Solar + BESS option. While it typically involves the highest upfront CAPEX, Solar + BESS excels in all other performance metrics across all islands:

Table 24 Solar vs Solar + BESS key metrics comparison for each island

Island	Parameter	Solar vs Solar + BESS option improvement		
		Base case	Low case	High case (A)
Saipan	Emissions	53%	84%	76%
	MAC	68%	151%	115%
	Renewable Fraction	54%	84%	77%
Tinian	Emissions	82%	68%	66%
	MAC	127%	99%	80%
	Renewable Fraction	87%	83%	72%
Rota	Emissions	57%	58%	55%
	MAC	30%	31%	28%
	Renewable Fraction	81%	83%	76%

Moreover, there is the factor of excess electricity. With a large solar installation that can meet a lifetime renewable fraction of 40% (Solar option), a significant portion of electricity generated may be above the current demand and in practice will have to be curtailed.

When considering the Solar + BESS option for Saipan, excess electricity was significantly reduced, dropping between 5% and 20% depending on the island and load scenario (See Appendix B to see a detailed curtailed electricity information for every scenario and option). By integrating BESS, the Solar + BESS solution helps manage excess generation but also enhances the overall efficiency of the system.

As shown in Figure 19, the Solar + BESS option has advantage of the BESS being able to store excess renewable energy during peak solar generation and dispatching that during low solar generation periods to avoid using cost intensive diesel generation. As such, the Solar + BESS option tends to reduce excess, or wasted renewable energy, improving the renewable fraction, emissions abatement and overall LCOE.

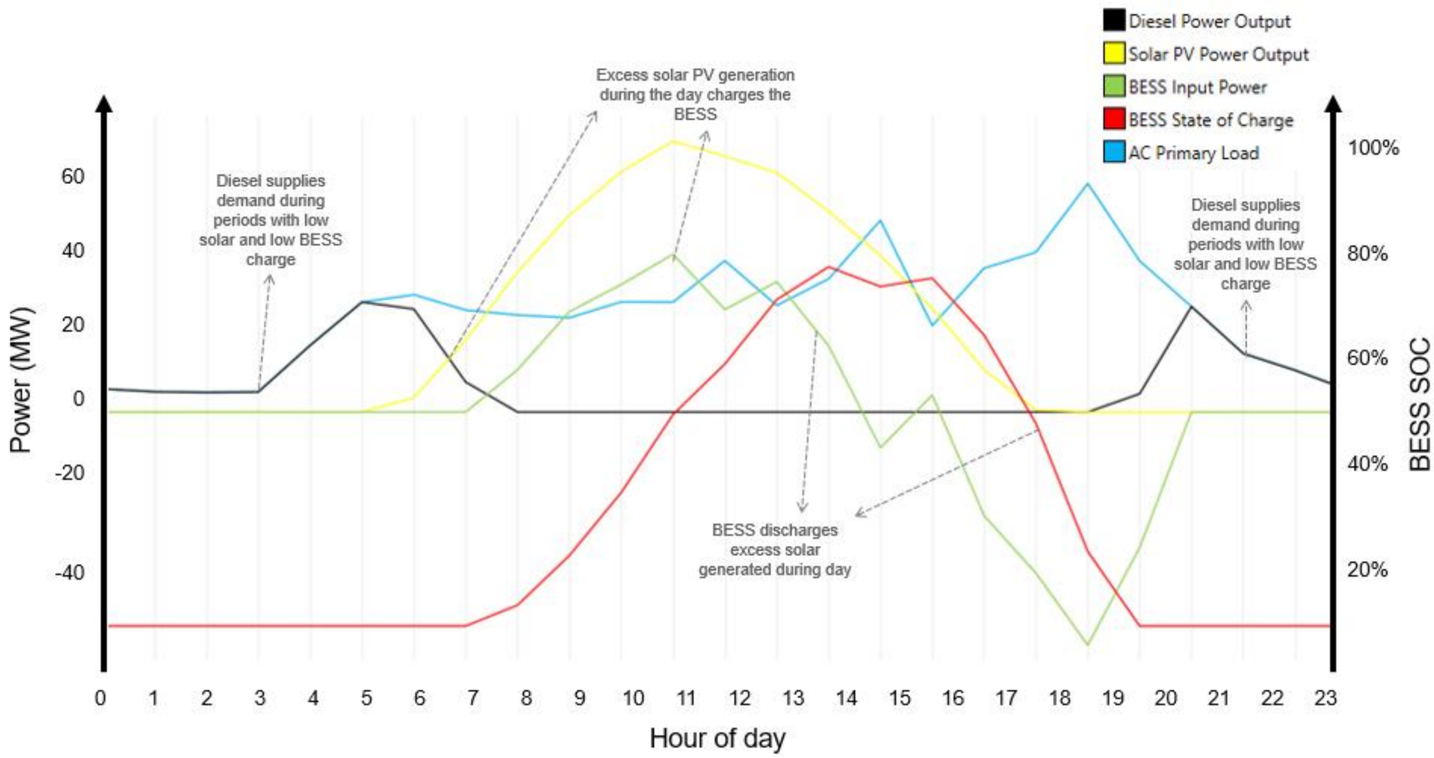


Figure 19 Typical 24hr profile for Solar + BESS option – Data from Solar + BESS HOMER scenario. Axes are for diagrammatic purposes only

In addition, as highlighted in Section 3.3.8, solar plants are inherently subject to intermittency, with the potential for significant loss of generation capacity over short periods, typically ranging from 4 seconds to 5 minutes, and sometimes lasting up to a minute. One example of such an event is the rapid drop-off in generation caused by cloud movements blocking sunlight, leading to a sudden decrease in solar generation.

At the large scale proposed for the Solar options, these brief but sharp fluctuations in generation can present challenges to system stability and the reliability of energy supply for the islands. While weather station monitoring can help mitigate some of these issues by predicting changes in solar generation, the short duration of these events may require additional measures. Specifically, without the use of a BESS, it may be necessary to keep a higher capacity of diesel generation in operation as spinning reserve, leading to higher costs for fuel.

BESS technology on the other hand has a very fast response time compared to diesel generation (less than 1 second to full power dispatch). In addition, BESS is an enabling technology, as in it produces no renewable electricity itself and is best placed to be coupled with a renewable generation source like a solar plant.

3.5 Potential Locations

There are several essential criteria when selecting suitable locations for a renewable energy system on each island:

– **Publicly owned land**: Only publicly owned plots were considered, focusing on areas designated by the Department of Public Lands (DPL) as publicly owned, including plots specifically highlighted by the CUC. This ensures alignment with community planning and public interest, and minimises capital, and administrative requirements of acquiring privately owned land.

– **Land area**: The total land area needed for each renewable energy system is largely determined by the space required for solar installations. Co-locating the BESS with the solar plant(s) is recommended for the use case described in Section 3.3.8. Due to the comparatively minor land requirements for the BESS, the primary focus of this criteria remains on accommodating the solar plant's footprint. Expected land requirements for the solar with co-located BESS is based on GHD's extensive internal database which includes delivered projects and market information. The current land footprint assumption approximately 2.2 Ha per MWac of installed solar capacity. This footprint assumption is expected to accommodate co-located BESS.

– **Land suitability**: After identifying plots with sufficient land area, these areas are further assessed for elevation consistency, being a requirement for BESS and because ground-mounted solar plants perform most effectively on level ground. This assessment was done at a high level using publicly available data for the topology of each island.

3.5.1 Saipan

The initial land considered was from a pool of publicly owned land, which was provided by the CUC based on information from the CNMI Department of Public Lands (DPL). All publicly owned land is shown in Figure 20(a).

In assessing the Saipan's topology, data from the U.S. Geological Survey shows a comprehensive gradient map, see Figure 20(b), which offers a detailed view of elevation changes across the island. This gradient map allows for careful evaluation of each land plot's suitability by examining the degree of elevation change for each area considered. Furthermore, plots were strategically analysed based on their proximity to existing network infrastructure, as shown in Figure 20(c) allowing for minimal requirements for network upgrades. This information is visually presented in Figure 20, showing how multiple layers of analysis were overlayed to propose suitable locations for large scale solar with co-located BESS.

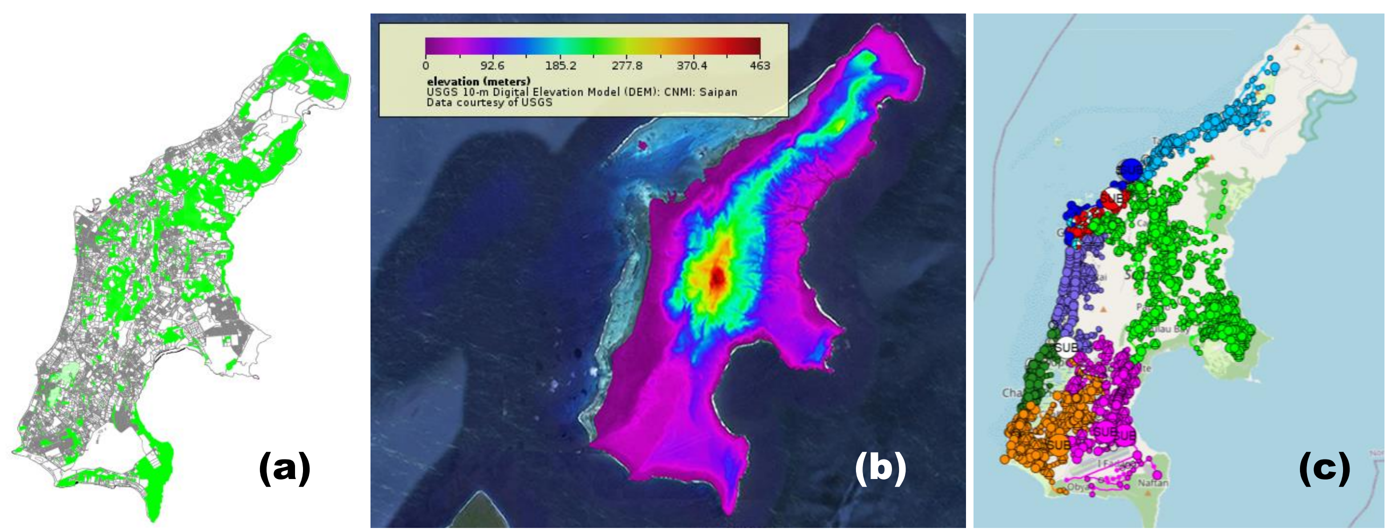


Figure 20 Publicly owned land in Saipan (a), elevation profile (b)[20] and existing network infrastructure in PowerFactory (c)

[20] Data source: U.S. Geological Survey (USGS), updated Oct 2023. **https://catalog.data.gov/dataset/usgs-10-m-digital-elevation-model-dem-cnmi-saipan**

Figure 21 presents a shortlist of locations identified as the most promising based on the location assessment procedure outlined above. Notably, Kalabera stands out, offering the largest area of available land and the capacity to support up to 52.5 MW of solar PV, along with co-located BESS capabilities. Tapochao also emerged as a viable option, with sufficient land for 11 MW of solar and the added advantage of close proximity to the existing network infrastructure.

Lastly, As Gonno and Naftan, which were initially highlighted by the CUC, have been validated as potentially viable candidates. Both these sites meet key criteria, being publicly owned, relatively level, and conveniently situated near the current network.

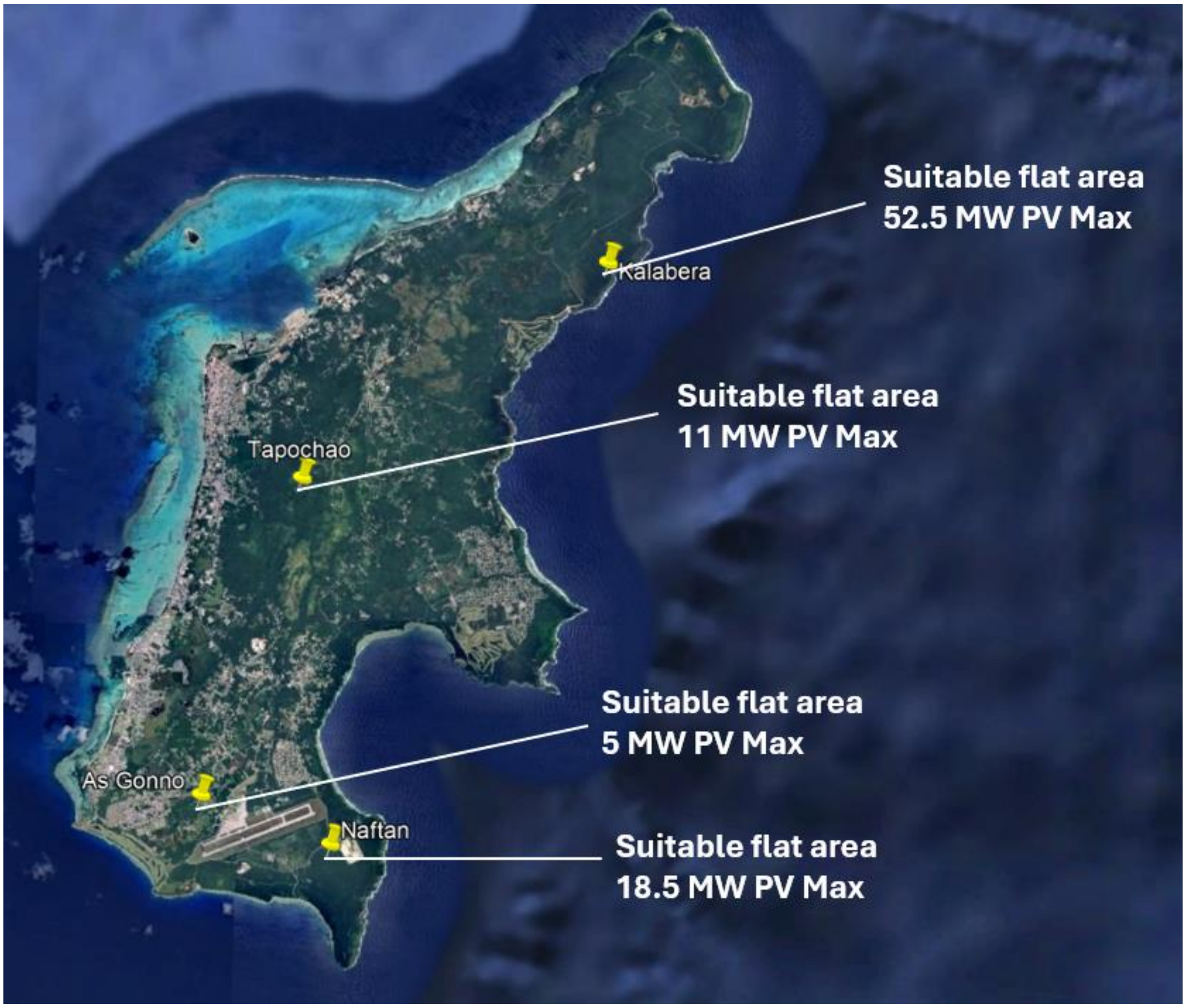


Figure 21 ***Saipan potential locations for PV with co-located BESS based on publicly available land and suitable topography***

3.5.2 Tinian

Tinian presents significant limitations in comparison to Saipan, as most of the land suitable for large-scale solar and BESS installations is owned by the U.S military. The only publicly owned parcel presented by the DPL for Tinian is located in the Marpo Heights area on the island.

Fortunately, the maximum potential capacity for installed solar and BESS at Marpo Heights exceeds the renewable energy requirements established as the optimal solution for Tinian, ensuring that the site can meet the island’s renewable energy goals effectively despite land constraints. The site location and approximate plot can be seen in Figure 22.

Figure 22 ***Key location in Tinian provided by CUC based on data provided by DPL***

3.5.3 Rota

Similar to Tinian, Rota faces constraints regarding the availability of publicly owned land along with suitable topography. DPL has identified just one parcel, located at As Nieves which has been confirmed to be a viable option as it is close to the network and is relatively level. This constrains renewable options for Rota, the optimal solution as described in Section 3.4 would not fit on this parcel and requires a non-optimal solution that maximises the available land. Under this configuration, the proposed system for Rota is still capable of meeting the CUC's renewable penetration target by 2030.

Figure 23 ***Key location in Rota provided by CUC based on data provided by DPL***

3.6 Staging

This section outlines a preliminary staging plan for rolling out renewable energy installations on the islands, tailored to their individual demand forecasts. The main approach is intended to meet the CUC's primary driver: achieving and sustaining 40% renewable energy by 2030 and maintaining this level for the next 20 years.

3.6.1 General

Required network upgrades for the optimal solution is presented in Section 4.6. The Section outlines required upgrades, equipment and network reinforcement that would be required in the power system to be able to operate with the optimal hybrid system installed on each island. As a minimum, the staging of network upgrades required alongside any staged works for each island would be required to be completed or staged to be complete before renewables development commences. This also applies to any control system infrastructure, such as a grid controller and any enabling communications and control infrastructure such as fiber, radio, or otherwise.

3.6.2 Tinian and Rota

Tinian and Rota are positioned to achieve a renewable energy penetration of at least 40% by 2030 with minimal staging. This goal can be met by installing the optimal renewable generation mix for each island, as detailed in Section 3.4 for operation before 2030. Given that the proposed renewable systems for both islands are relatively modest in scale, these projects do not require phased development and can be implemented in a single stage, streamlining the process and facilitating a more efficient transition to renewable energy for Tinian and Rota.

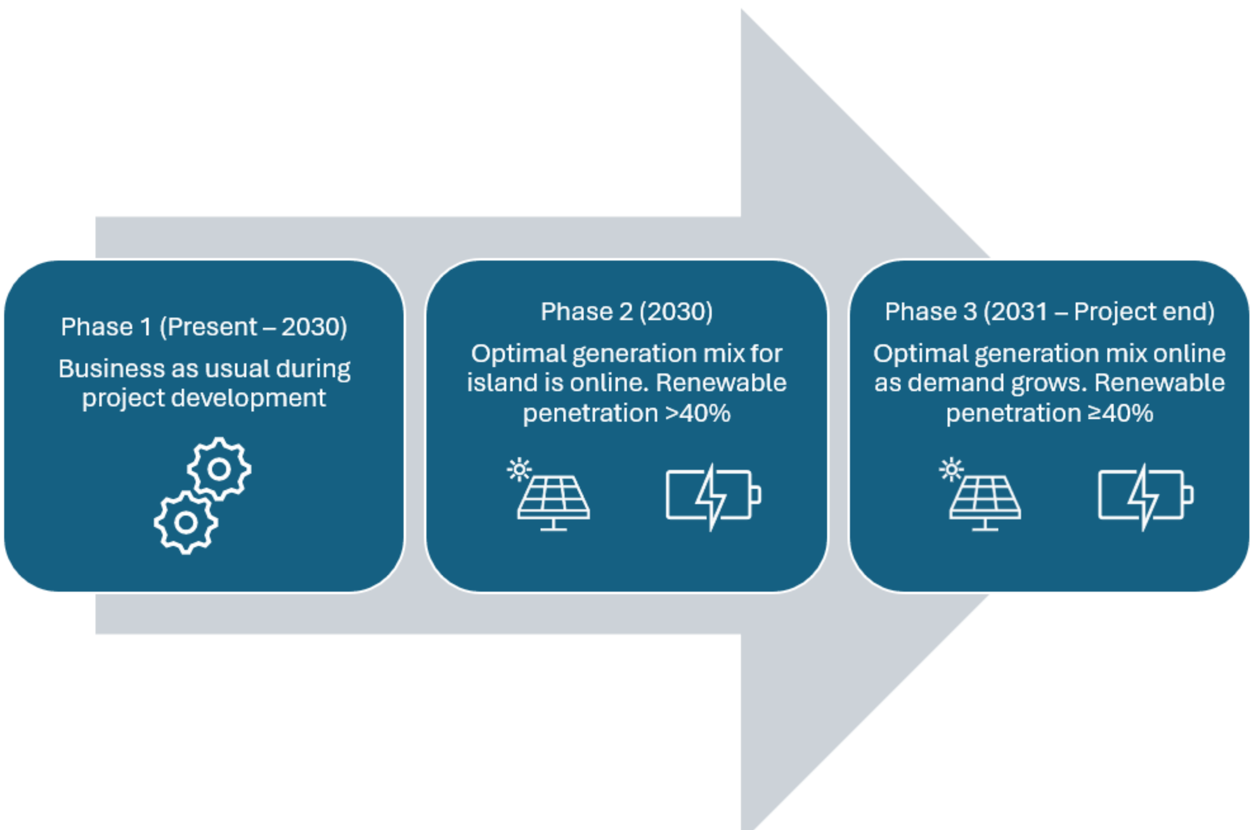


Figure 24 Proposed timing for installed solar and BESS for Tinian and Rota

3.6.3 Saipan

Saipan, in contrast, presents a more complex challenge due to its aggressive demand forecast growth, as well as the significantly larger scale of both load and generation. As a result, a carefully considered staged approach to rolling out renewable energy solutions may be necessary.

Another key factor is its larger and more widely distributed population. Instead of opting for a centralized, large-scale installation of solar and BESS, it would be more strategic to distribute these systems across various locations on the island's network. This approach helps to mitigate potential strain on the network. This decentralized strategy aligns well with the diversely located range of viable sites identified in Section 3.5.1.

To achieve this strategy, the optimal solution for Saipan as described in Section 3.4 can be divided into two phases. The initial phase would involve an investment in 20 MW solar and 15 MW / 60 MWh BESS, which could be staged for short-term deployment. Following that, a final investment in 40 MW solar and 33 MW / 132 MWh BESS, staged for installation and operation before 2030, will ensure that Saipan reaches a renewable energy penetration of at least 40% by 2030 and continues to meet future energy demands as projected in the demand forecast while maintaining this renewable penetration goal. Figure 25 shows the timeline of this potential staging strategy for Saipan.

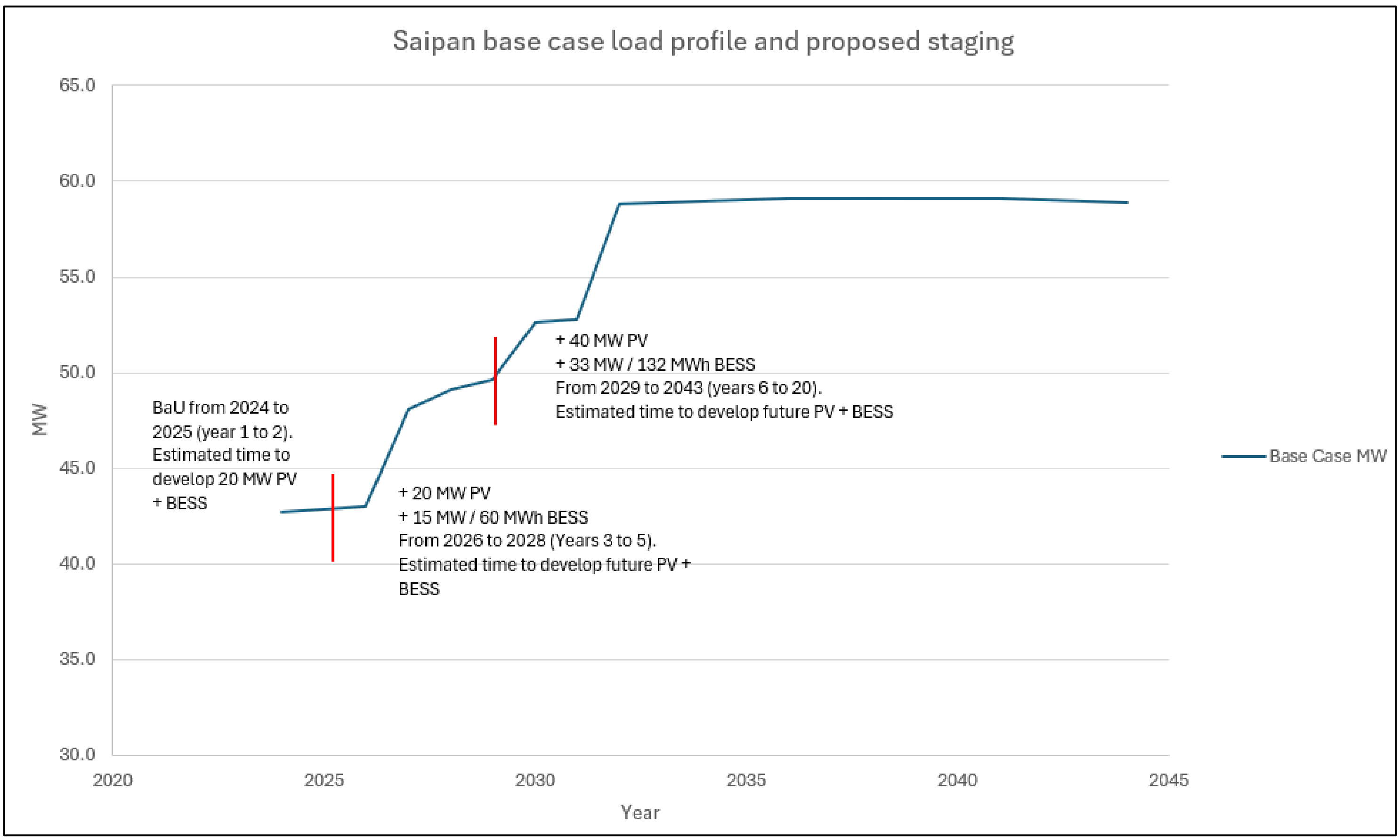


Figure 25 Proposed staging of optimal solution

3.7 Future works and opportunities

3.7.1 Potential for Advancements in Technology

Although a relatively mature technology, solar PV is continuously undergoing advancements in design, installation, and technology. Some of the advancements that are anticipated to provide beneficial impacts are summarized below:

– Bifacial modules generate power from both the front and rear faces of the module, with the rear relying on diffuse reflected solar radiation from the ground and surrounding environment. The quantity of reflected light, or albedo, greatly impacts the yield quantity from the rear face, with OEM data sheet claims of ~7 % additional yield. However, real-world yields are seen to be in the order of 3% to 5% and is largely dependent on the ground conditions and vegetation. Bifacial PV modules have seen a rapid increase of market share in recent years. In the short term, the use of bifacial modules will be heavily dependent on the albedo for the project site, however as market share increases and module price becomes more comparable to monofacial modules it is expected that bifacial modules will become the industry norm.

– Although presently not available in the market, past enquiries with OEMs have indicated that cyclone rated SAT systems are currently in development. These are expected to be available in the near future and may become a viable option for use in the CNMI, opening the door for higher energy yield. It should be noted that that SAT is normally more expensive compared to fixed axis and there may be an additional premium for sufficiently cyclone rated mounting.

Lithium-ion BESS are seeing improvements in safety, system performance and energy density progressively over time. BESS system performance is expected to improve steadily over time as more systems are developed globally.

3.7.2 Aggressive Development of Solar and BESS in Saipan

Saipan offers a unique opportunity for a more aggressive approach to the development of solar and BESS, driven by the higher availability of viable locations across the island. This strategy aims to maximize renewable energy penetration by fully utilizing all identified viable solar and BESS sites shown in Figure 21. Additionally, Naftan is set for expansion, allowing for the use of all available publicly owned land that meets the necessary criteria for being sufficiently level. This comprehensive development scenario is designed to maximize the island's renewable energy potential.

A high-level assessment was conducted using the Saipan power system model to evaluate the current network constraints associated with aggressive investment in renewables. To complement this, Table 25 also includes key commentary on the minimum necessary network upgrades to support this level of development. Additionally, the operational conditions assumed during this high-level assessment are clearly outlined. While these findings highlight the potential for growth, they also underscore the importance of understanding the infrastructure adjustments needed to accommodate this scale of renewable energy investment.

These opportunities offer insights for long-term planning and could contribute to further enhancing Saipan's renewable energy infrastructure beyond the proposed optimal generation mix presented for Saipan. As such, this should be viewed as a starting point for future considerations.

Table 25 Proposed aggressive generation mix across viable locations on Saipan – All BESS are 4-hour duration

Site	BESS Installed (MW)	Solar Installed (MW)	Comments
Naftan – Minimized network upgrades	12	15	At least 2 km of new 13.8 kV conductor to CUT 2724. Assuming that total system output is constrained is 15 MW to accommodate the maximum allowable generation on the existing network with minimum upgrades.
Naftan – maximized	29	36	At least 10 km of new 34.8 kV conductor with additional reactive support to STAT 5 Substation on Chalan Monsignor Guerrero (Road). Assuming total system (Solar + BESS combined) output is constrained to 36 MW.

Site	BESS Installed (MW)	Solar Installed (MW)	Comments
Naftan – Minimized network upgrades	12	15	At least 2 km of new 13.8 kV conductor to CUT 2724. Assuming that total system output is constrained is 15 MW to accommodate the maximum allowable generation on the existing network with minimum upgrades.
As Gonno	4	5	No upgrades required. System is connected to closest feeder (separate from Naftan for diversity). Assuming that total system output constrained is 8 MW to accommodate the maximum allowable generation on the existing network.
Tapochao	8.8	11	At least 4 km of 13.8 kV new conductor run from the nearest feeder location to POL 8194 with additional reactive support. Assuming that total system output is constrained is 15 MW to accommodate the maximum allowable generation on the existing network.
Kalabera – Minimized network upgrades	12	15	At least 8 km of new 13.8 kV conductor to power station at Power Plant 1. Assuming that total system output is constrained is 15 MW to accommodate the maximum allowable generation on the existing network with minimum upgrades.
Kalabera – Maximized	42	52.5	At least 2 x 12 km (24 km total) of 34.8 kV new conductor to the nearest power station (CUC Power Plant 1). Assuming that total system output is constrained for 52.5 MW.

Preliminary techno-economic modelling was performed for the generation mix above and shows that with a maximum generation capacity of 104.5 MW solar PV with a total BESS capacity of 83.8 MW / 335.2 MWh, the indicative lifetime renewable penetration of the island is as high as 90%.

While aggressive development presents a promising opportunity, it must be approached with careful consideration. To ensure its success, it is strongly recommended that the following critical components be incorporated into the project development roadmap as a minimum:

– Land access, approvals, environmental and historic considerations
– Design and engineering including:
  - Grid connection and transmission route definition
  - Geotechnical investigation
  - Topographic survey and Civil site development
  - Detailed yield assessments
  - Dynamic and steady state modelling
  - Development of as-built drawings of current infrastructure
  - Development of grid controller and grid controller philosophy
  - Development of SCADA system for remote monitoring and control of all generating and distribution assets
– Project risk controls in line with industry best practice
– Structuring business, procurement, and contracting strategy in line with industry best practice
– Mature project controls

A summary of the expected challenges that would need to be considered as a minimum would include:

– Acquisition significant amounts of land - With significantly larger solar farms, more land is required. It is understood that land allocation and acquisition across the islands requires careful involvement and engagement with local stakeholders and the community.
– Funding – With the opportunity for an almost 50% increase in total solar capacity compared to the optimal solution (almost 90 MW) and the significantly larger BESS required to provide system stability. There are significantly higher

costs. Whether an IPP is engaged to pass on this large system cost to the customer or the where the CUC would procure funding otherwise must considered

– Staging and delays – Larger systems may necessitate longer lead times for construction as there would be significantly more civil works. Should the CUC consider this route, stages can be performed in more aggressive stages (larger capacity per stage), more frequent stages over the project life of 20 years, or extending the project life. Key factors that drive timing include:
  - Which CUC key driver is the priority long term
  - Outcomes of preliminary engagements with OEM(s) and/or IPPs, should the CUC consider this contracting strategy

– Existing limitations in power system control – Higher penetration systems would require advanced control systems to ensure system stability and optimal usage of the renewable energy to avoid curtailment during operation together with existing diesel.

– Establishing system feasibility – Further studies and more detailed feasibility studies would be required to establish changes to the network and develop a more accurate estimate of cost.

3.7.3 Future projects on Tinian

The CUC has indicated that on Tinian a proposed Data Center Project is expected to match or exceed the present-day maximum demand for the entire island. This project is intended to be grid-tied with supplementary solar generation, approximately 3.6 MW in capacity, to help offset emissions. However, due to the unconfirmed status of the project and the potential significant impact of such a large load and new generation source on the island's network, it was decided that this project will be excluded from all analyses.

This project should be closely monitored, however, accounting for 50% of total island demand in present day at least 35% in the base case within 10 years. It would have a significant impact on the optimal solution for Tinian and may even change the optimal generation mix to achieve 40% renewable penetration by 2030.

3.7.4 Improvements to existing diesel plant and further developments

It is understood that the CUC is actively developing their existing thermal generation to install and operate newer engines with improved efficiency and improved control and communication capabilities. A new 8.7 MW diesel generator, at the time of writing, is being commissioned which has remote control and monitoring at Power Plant 1 on Saipan.

Another potential technology is to use a combined heat and power system, or cogeneration system where excess heat from the thermal plant is used to produce electricity and increase overall efficiency. The CUC would benefit from considering upgrading the existing diesel generation with modern diesel generators that have automated control systems for remote monitoring and control of all assets as a minimum (like the current upgrade happening at Power Plant 1 on Saipan).

Full thermal plant replacement

The CUC have expressed interest in a full thermal plant replacement of all existing diesel generation across all islands to gas-based generation. It is understood that the intent is for the new thermal plant capacity shall be sufficient to supply the high case load scenario for each island. New plants with more modern operation and control schemes would significantly impact the emissions, OPEX and SCADA capabilities of the CUC’s power system infrastructure. The CUC have advised that his development would take place after any early-stage renewables and/or energy storage have been implemented.

3.7.5 Development of SCADA capabilities and infrastructure

It is understood that there are significant limitations across the islands for centralised control and monitoring of power generating assets (see Section 6 and 7 for more information and a detailed assessment). CUC would benefit from upgrading existing infrastructure to allow for centralised control of generating assets for each island. Currently, there are some developments taking place, such as network and feeder upgrades to facilitate the development of SCADA on Saipan.

4. System Impact / Network Augmentation

The steady state power system studies have been carried out for the Saipan, Tinian and Rota networks to determine whether:

– The electrical equipment proposed for installation at the site is adequately rated to safely provide power to the connected loads at the maximum output capacity (i.e., thermal constraints during load flow analysis).
– The electrical equipment and associated design have acceptable voltage regulation.

These studies are conducted on each island (Saipan, Tinian and Rota) based on the CUC's IRP options. This report outlines the study results and highlight any non-compliance or deterioration of the existing non-compliances which are caused by the proposed renewable energy (RE) connection. The study results are presented in the next subsections followed by recommendations for system augmentation to implement these supply options.

The studies are conducted based on the reasonable worst case loading scenarios that each island network may experience in the study year. This approach will determine the necessary network upgrades to maintain thermal and voltage constraints after connection of the proposed PV generators and BESS. Analysing the worst-case scenarios ensures that the identified network upgrades will also be adequate for other operating conditions.

4.1 Scope

Power system studies are required to be carried out as part of the CNMI IRP. For this study, Steady State Studies have been undertaken to ensure that the voltage limits, thermal loading and equipment ratings have not exceeded in the renewable energy integrated network during maximum and minimum load scenarios:

– Load flow studies including:
  - Thermal loading
  - Voltage regulation
– Short circuit studies.

4.2 Modelling Methodology and Assumptions

DIgSILENT PowerFactory (PF) modelling is used to carry out power system studies for each island. Two PF base models were provided by CUC for the existing Saipan and Rota networks. For Tinian electrical network, GHD prepared a PF base model using the network data provided by CUC. These models are used to assess the connection of the proposed PV generators and BESS.

The following assumptions have been made for the Steady State power system studies. The PF model of the proposed PV generator and BESS connected to the existing network is shown in Figure 26 to Figure 30.

4.2.1 Saipan PF Modelling

A summary of Saipan RE connection and PF modelling are presented below:

– The PF model provided by CUC has been used as the base model to develop the study scenarios.
– The base model is augmented with the foreseen future projects/load growth, as specified in Table 26.

Table 26 Saipan future loads

Name of Project/ Load	Feeder Location	Load Demand (MW)
Saipan Globe Hotel	Feeder 7	4.2
Forson Dormitories	Feeder 7	0.06

Name of Project/ Load	Feeder Location	Load Demand (MW)
Imperial Pacific Resort Hotel	Feeder 2	9
Honest Profit Saipan Resort Hotel	Feeder Kiya 2	7.55
Ocean Vista Resort	Feeder 4	1.17
H.S. Lee Commercial Building	Feeder 2	0.27
Villora Condotel Residence	Feeder 7	0.54
Beach Road Ocean Resort Complex	Feeder Kiya 3	0.23
Marianas Beach Resort (former Hyatt) - currently off-grid	Feeder 2	0.869
Aqua Resort – currently off-grid	Feeder 7	0.248

– Two scenarios are considered:
  - **Maximum Load Scenario:** All existing loads and forecast loads are scaled to match 52.8 MW total load required for the maximum load scenario.
  - **Minimum Load Scenario:** All existing loads and forecast loads are scaled down to match 3 MW total load required for the minimum load scenario.

– The power factor of all existing loads is as per the provided PF model. For the future loads it is assumed that they will have their own capacitors to compensate for the absorbed reactive power (unity power factor). In the case where this does not apply, additional reactive power compensator will be required.

– CUC plans to install RE system at three sites in Saipan as part of their IRP: Naftan site (15 MW PV and 11 MW BESS) with the maximum output of 15 MW, As Gonno site (5 MW PV and 4 MW BESS) with the maximum output of 5 MW, and Kalabera site (40 MW PV and 33 MW BESS) with the maximum output of 40 MW.

– **Naftan site:**
  - Terminal POL_2724 at Feeder Kiya 1 (Near Hawaiian Rock) has been proposed as the PoC for Naftan as it is the nearest 13.8 kV terminal where the upstream distribution network has sufficient capacity for the 15 MW maximum active power output from the new generators. For this purpose, a new 2 km line was proposed for the connection and modelled using the existing conductor type (13.8kV_Cond_556_Al, rating 0.704 kA) available in the provided PF model (Figure 26).

– **As Gonno site:**
  - Terminal Site 4/BB at Feeder Kiya 2 (near Saipan Southern High School) has been proposed as the PoC for As Gonno as it is the nearest 13.8 kV terminal which has sufficient capacity for the 15 MW maximum active power output from the new generators. For this purpose, a new 0.5 km line was proposed for the connection and modelled using the existing conductor type (13.8kV_Cond_556_Al, rating 0.704 kA) available in the provided PF model (Figure 27).

– **Kalabera site:**
  - Terminal STAT_1/HV_BB1 and STAT_1/HV_BB2 at the main 34.5 kV substation have been proposed as the PoC for Kalabera considering the PV and BESS size (40 MW and 33 MW). To accommodate this, 2x12 km lines were proposed for the connection and modelled using the existing cable type (34.5kV_500kcmil_Al, rating 0.45 kA) available in the provided PF model (Figure 28).

– The reactive power output of the PV and BESS at the Naftan and As Gonno sites is adjusted to achieve 1.0. p.u. at their terminals (i.e., Terminal_Naftan and Terminal_As Gonno). Note that reducing the voltage level setting will result in less reactive power required to be supplied by the PV and BESS.

– The reactive power output of the PV and BESS at the Kalabera site is adjusted to achieve 1.03 p.u. at the terminal (i.e., Terminal_Kalabera).

– The proposed PV and BESS inverters are assumed to be capable of operating at the below power factor range:

- Naftan PV and BESS: between 0.95 lagging and 0.95 leading
- As Gonno PV and BESS: between 0.93 lagging and 0.93 leading[21].
- Kalabera PV and BESS: between 0.95 lagging and 0.95 leading

– For the maximum load scenario, Kalabera site is set as the reference machine.

– For the minimum load scenario, As Gonno site is set as the reference machine.

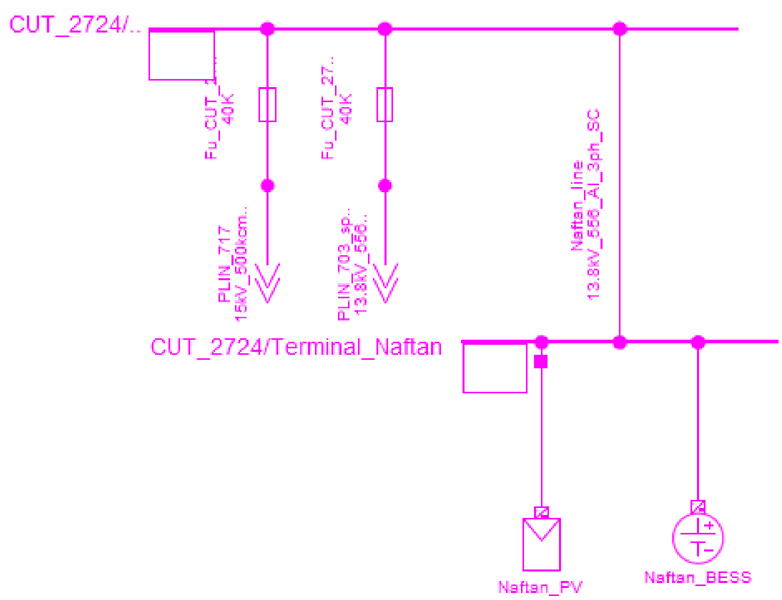


Figure 26 PoC of PV and BESS in Saipan – Naftan site

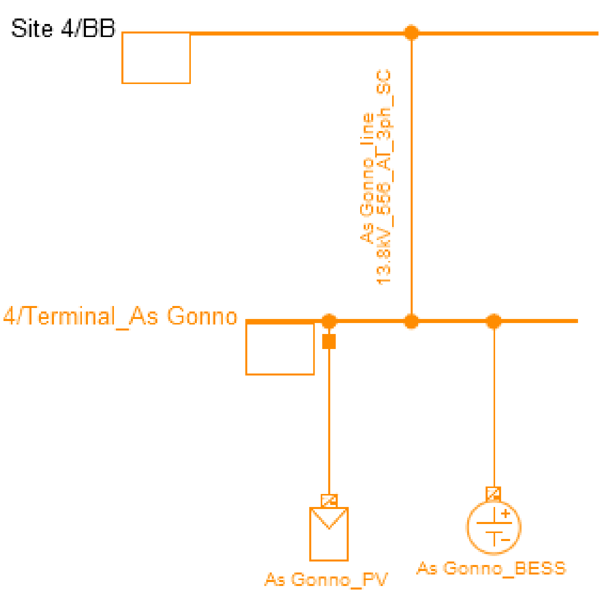


Figure 27 PoC of PV and BESS in Saipan – As Gonno site

[21] As Gonno PV and BESS inverters are assumed to have reactive power capability based on a power factor of 0.93. This is required to achieve PoC voltage of 1.0 p.u. for all maximum and minimum scenarios.

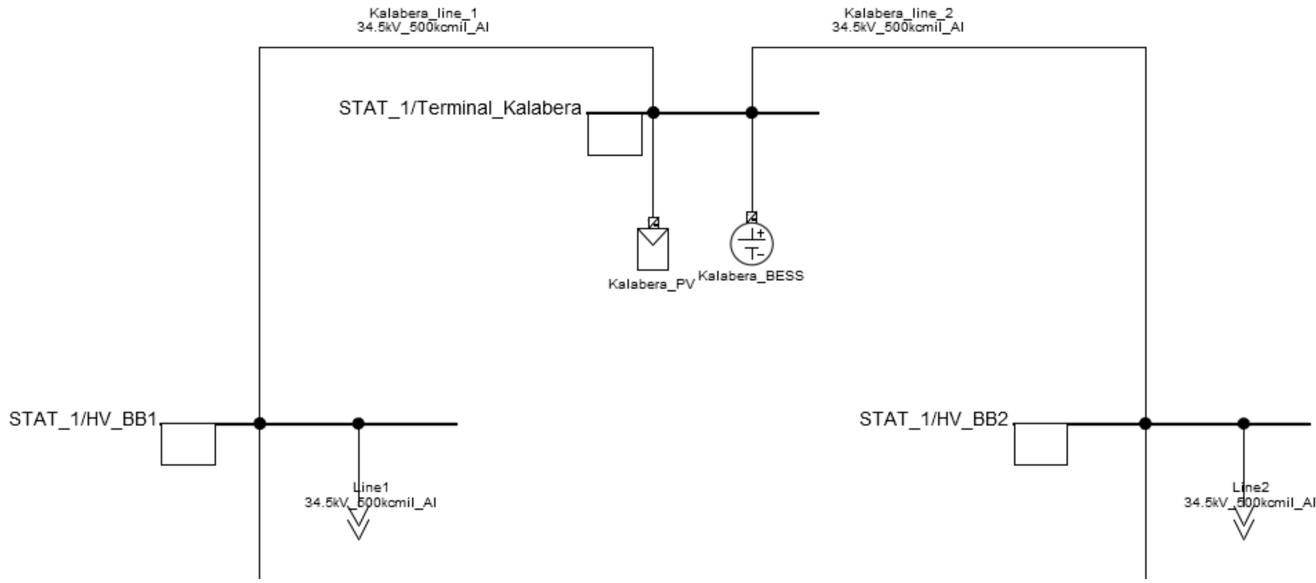


Figure 28 PoC of PV and BESS in Saipan – Kalabera site

4.2.2 Tinian PF Modelling

A summary of the Tinian RE connection and PF modelling are presented below:

- A PF model was developed using GIS software and data (i.e., line schematic, conductor type, load) provided by the Tinian electrical network.
- The base model is augmented with the foreseen future projects/load growth, as specified in Table 27.
- The lumped loads on Feeder 4 are assumed to be uniformly distributed along the feeder. Divert Airfield is connected at the end of the feeder, North of the airport.

Table 27 Tinian future loads

Name of Project/ Load	Feeder Location	Load Demand (MW)
Camp Tinian	Feeder 4	0.3445
Divert Airfield	Feeder 4	0.86
Tinian Diamond Hotel and Casino	Feeder 2	0.0595
Confidential Project - Phase 1	Feeder 4	0.6
Confidential Project - Phase 2	Feeder 4	0.6
Confidential Project - Phase 3	Feeder 4	0.6
Confidential Project - Phase 4	Feeder 4	0.6
Confidential Project - Phase 5	Feeder 4	0.6

- The power factor of all existing and new loads is set at 0.9.
- Two scenarios are considered:
  - **Maximum Load Scenario:** All existing loads and forecast loads are scaled up to match 8.6 MW total load required for the maximum load scenario.
  - **Minimum Load Scenario:** All existing loads and forecast loads are scaled down to match 2.5 MW total load required for the minimum load scenario.

- The missing conductor/ line types (i.e., 13.8kV_Cond_#4_Solid_Cu, 13.8kV_Cond_4/0_Al, 13.8kV_Cond_556_Al, 15kV_500kcmil_Al) are modelled based on the existing parameters available within the Saipan model.
- CUC plans to install RE system (10 MW PV and 8 MW BESS) at Marpo Heights as part of their IRP.
- Terminal 207 along the distribution network of Feeder 4 (around 2.47 km North of Tinian Power Plant) has been proposed as the PoC for Marpo Heights PV and BESS. For this purpose, a new 1.5 km line was proposed for the connection and modelled using the existing cable type (13.8kV_Cond_556_Al, rating 0.704 kA) available in the PF model (Figure 29).
- The reactive power output of the PV and BESS is adjusted to achieve 1.0. p.u. at the terminal (i.e., Terminal 207).
- For both maximum and minimum load scenario, Marpo Heights PV is set at its maximum active power (10 MW) output and BESS as the reference machine.

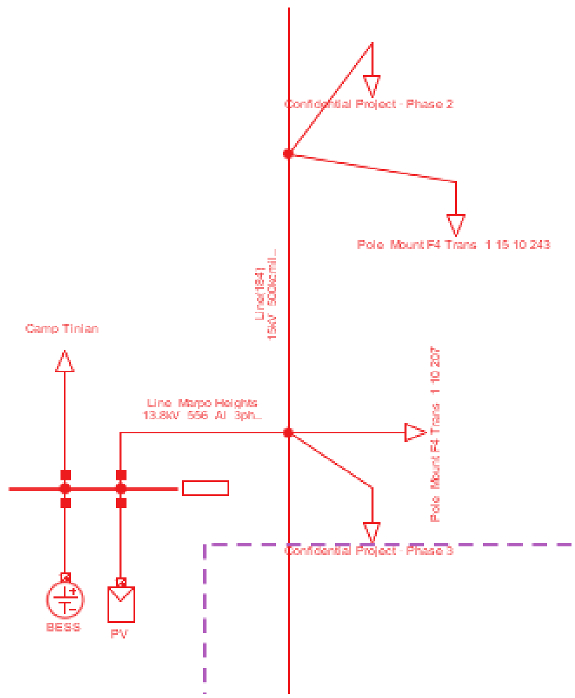


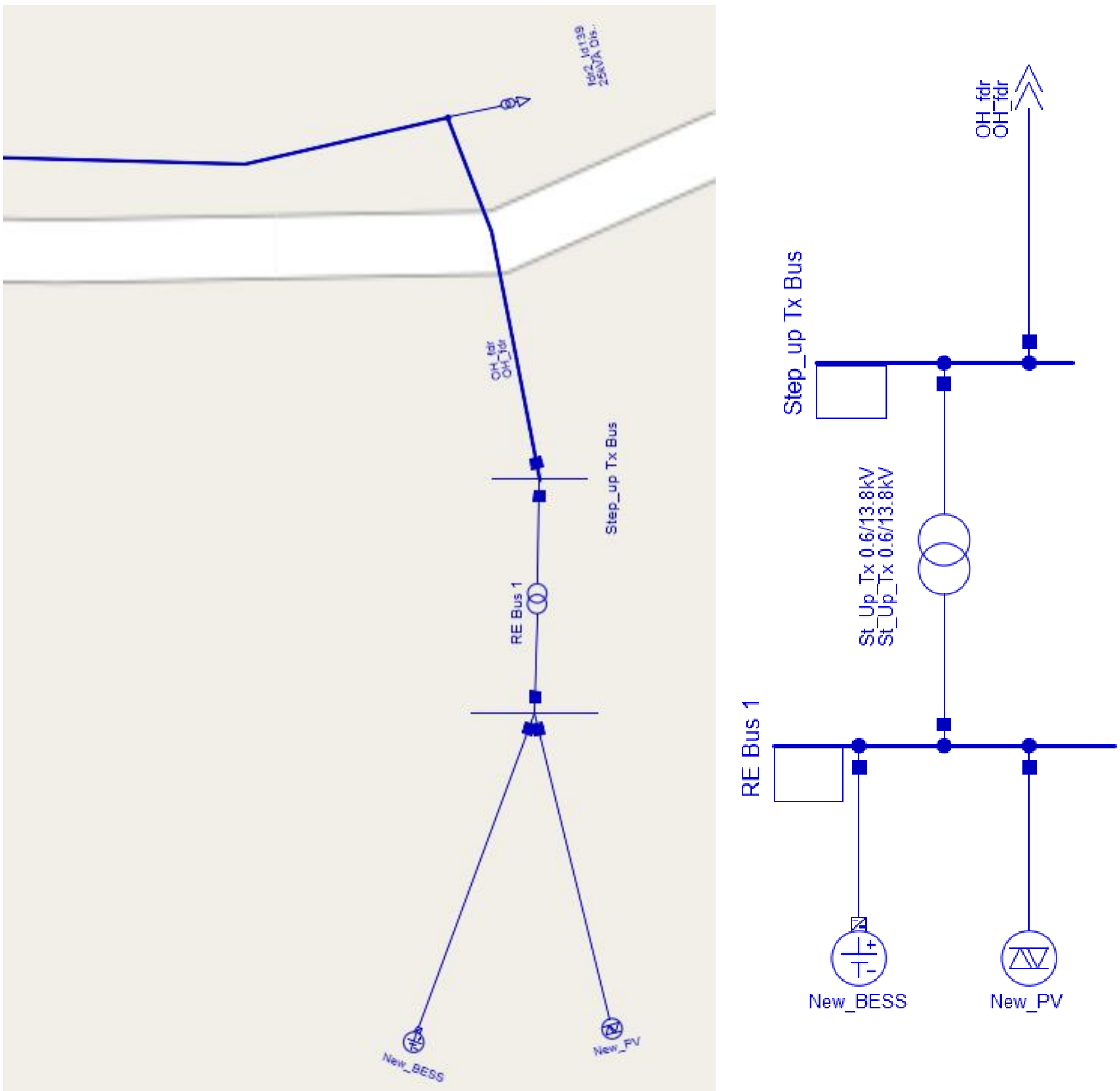
Figure 29 PoC of PV and BESS in Tinian

4.2.3 Rota PF Modelling

PF modelling of the RE in Rota is summarized below:

- CUC plans to install a RE system (3 MW solar PV and 2 MW BESS) in Rota as part of the IRP.
- The proposed PV and BESS are connected to feeder 2 near South-East side of the Rota International Airport.
- The PF model of the proposed PV generator and BESS connected to the existing network is shown in Figure 30.
- The voltage at point of connection of the RE system is 13.8 kV.
- The PF model provided by CUC has been used as the base model to develop the study scenarios.
- The power factor of all existing loads is as per the provided PF model.
- Proposed Rota BESS is set as the reference machine.
- Existing transformer type (St_Up_Tx 0.6/13.8kV) available in the provided PF model (3.15 MVA, 0.6/13.8 kV, Z 7%, DYN11) was used for connection of the proposed PV and BESS to the 13.8 kV CUC network.
- Existing OH line (OH_fdr) available in the provided PF model was used to connect from the Point of Connection (PoC) terminal (fdr2_term6) to the transformer bus (Step_up Tx Bus).
- Two scenarios are considered:

- **Maximum Load Scenario:** All existing loads are scaled up to match 1.8 MW total load required for the maximum load scenario.
- **Minimum Load Scenario:** All existing loads are scaled down to match 0.145 MW total load required for the minimum load scenario.



(a) (b)

Figure 30 (a) PoC - Single Line Diagram - Geographical (b) PoC - Single Line diagram

4.3 Load Scenarios

Load scenarios considered in the studies are summarized in Table 28 below.

Table 28 Load Scenarios

Island Name	Minimum Load (MW)	Maximum Load (MW)
Saipan	3	52.8
Tinian	2.5	8.6
Rota	0.145	1.8

4.4 Generation Capacities and Dispatch

PV and BESS nameplate capacities for the three islands are summarized in Table 29 below.

Table 29 PV and BESS nameplate capacities

Islands	Generation Nameplate Capacities		Maximum Site Output (MW)
	Solar PV (MW)	BESS (MW)	
Saipan (Naftan)	15	11	15
Saipan (As Gonno)	5	4	5
Saipan (Kalabera)	40	33	40
Tinian	10	8	10
Rota	3	2	3

4.5 Modelling Scenarios

Several study cases were established to evaluate the impact of the RE connection to the CUC Distribution Network, and are summarized in Table 32, Table 30 and Table 31 for Saipan, Tinian and Rota respectively.

Table 30 Modelling scenarios – Saipan

Islands	Modelling Scenarios	Load (MW)	Existing Small Static Generators
Saipan	Scenario 1a (Maximum Load)	52.8	On
	Scenario 1b (Maximum Load)	52.8	Off
	Scenario 2a (Minimum Load)	3	On
	Scenario 2b (Minimum Load)	3	Off

Table 31 Modelling scenarios – Tinian

Islands	Modelling Scenarios	Load (MW)
Tinian	Maximum Load	8.6
	Minimum Load	2.5

Table 32 Modelling scenarios – Rota

Islands	Modelling Scenarios	Load (MW)
Rota	Maximum Load	1.8

Islands	Modelling Scenarios	Load (MW)
	Minimum Load	0.415

4.6 Results

This section aims to presents the constraints identified in the distribution network after connection of the new PV and BESS at Saipan, Tinian and Rota islands as well as the proposed reinforcements to address the identified constraints.

For this purpose, steady state load flow and short circuit studies have been completed to ensure that the voltage, thermal and fault equipment ratings are not exceeded in the renewable energy integrated network during the maximum and minimum load scenarios. The results are presented in below sections.

4.6.1 Load Flow Studies

Steady-state load flow studies were carried out on the PF model using Newton-Raphson method to determine the potential thermal and voltage constraints. The results are presented in the following sub-sections.

4.6.1.1 Saipan Results

4.6.1.1.1 Generators/ BESS Output

Table 33 below shows the generators/BESS outputs under all modelling scenarios.

Table 33 Generators/ BESS output – Saipan

Type	Output Active Power (MW)			
	Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b
All existing synchronous generator	0	0	0	0
All existing small generators	3.74	0	3.74	0
Naftan PV and BESS	15	15	0	0
As Gonno PV and BESS	5	5	0.27	3.03
Kalabera PV and BESS	31.8	34.6	0	0

As observed:

- No synchronous generators at PP1, PP2, PP4, Aggreko need to be dispatched to supply the load under all scenarios.
- Within the maximum load scenarios, Kalabera PV and BESS are not running at its maximum output (40 MW), i.e., approximately 8.2 MW (for Scenario 1a) and 5.4 MW (for Scenario 1b) need to be absorbed by the BESS to maintain the load generation balance, as reflected in Table 33. Regardless, having Kalabera PV and BESS running at its maximum output does not lead to any non-compliance issues.

Detailed generators/ BESS output is provided in Appendix D-1.

4.6.1.1.2 Thermal Studies

Table 34 below shows the thermal loading results after connection of the proposed PV and BESS for maximum and minimum scenarios.

Table 34 Overloaded lines as a result of the new generators

Line Name	Feeder Location	Loading (%)			
		Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b
Stat_5-POL_4218_K1	Feeder Kiya 1	123.4	120.8	6.3	6.1
Sub1_MV_N_Feeder2	Feeder 2	117.9	115.8	7.9	6.1

As observed, there are thermal constraints identified under the maximum load scenario (Scenario 1a and Scenario 1b) as highlighted by red color in Table 34. To mitigate this issue, the lines can be either upgraded with higher-rated conductors or new line is installed.

Detailed results of the line and transformer loadings around the vicinity of the PoC are provided in in Appendix D-1.

4.6.1.1.3 Voltage Studies

The voltage levels are calculated for the maximum and minimum scenarios. Below table shows the voltage around the vicinity of the PoC, including the 13.8 kV and 34.5 kV busbars.

Table 35 Voltage study results at PoC – Saipan

Terminal/ Busbar Name	Nominal Line-to-Line Voltage (kV)	Magnitude (p.u.)			
		Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b
Terminal_Naftan	13.8	1.00	1.00	1.00	1.00
CUT_2724/ POL_2724 (PoC)	13.8	0.98	0.99	1.00	1.00
Terminal_As Gonno	13.8	1.00	1.00	1.00	1.00
Site 4/ BB (PoC)	13.8	0.99	0.99	1.00	1.00
Terminal_Kalabera	34.5	1.03	1.03	1.03	1.03
STAT_1/HV_BB1 (PoC)	34.5	1.01	1.00	1.03	1.03
STAT_1/HV_BB2 (PoC)	34.5	0.99	0.99	1.03	1.03

The studies indicate no voltage constraints at the terminal around the proposed RE system.

However, it is observed that after connection of the proposed RE system and switching off the existing synchronous generators, part of the network will experience more voltage drop compared with the base network which was being supplied by the existing synchronous generators. To avoid voltage deterioration compared with the base network, approximately 17.5 MVAr reactive power support will be required at the location of the existing power plant terminal (i.e., STAT_1/MV_BB busbar). The reactive power support can be provided either by installing reactive power compensators or using the reactive power capability of the existing synchronous generators, alternatively achievable by increasing the voltage level at the PV and BESS.

Note that after connection of the proposed PV, BESS, and the proposed reactive support at STAT_1/MV_BB busbar, there are still voltage issues, especially at Feeder 4 around Navy Hill and Capitol Hill, however these are existing issues carried by the base model and not an additional non-compliance issues caused by the PV and BESS connection.

More detailed results are provided in Appendix D-1.

4.6.1.2 Tinian Results

4.6.1.2.1 Generators/ BESS Output

The table below provides the generators/BESS outputs under all modelling scenarios. As observed:

- No synchronous generators at DE#1, DE#2, DE#3, DE#4, DE#5, DE#6 need to be dispatched to supply the load under all scenarios.
- For both scenarios, Marpo Heights PV and BESS are not running at its maximum output (10 MW), i.e., approximately 1.2 MW (for maximum load scenario) and 7.5 MW (for minimum load scenario) need to be absorbed by the BESS to maintain the load generation balance (while the PV is generating 10 MW in both scenarios), as reflected on Table 36. Regardless, having Marpo Heights PV and BESS running at its maximum output does not lead to any non-compliance issues.

Table 36 Generators/BESS output results – Tinian

Type	Output Active Power (MW)	
	Maximum Load Scenario	Minimum Load Scenario
All existing synchronous generator	0	0
Tinian PV and BESS	8.6	2.5

Detailed generators/ BESS output is provided in Appendix D-2.

4.6.1.2.2 Thermal Studies

Thermal loading of the elements is calculated for the maximum and the minimum scenarios. Table 37 below shows the thermal loading results of the line and transformer at the proposed RE site.

Table 37 Thermal study results – Tinian

Name	Type	Loading (%)	
		Maximum Load Scenario	Minimum Load Scenario
Line_Marpo Heights	Line	51.3	16.4
St_Up_Tx 4.16/13.8kV	Transformer	86.0	27.0
St_Up_Tx 4.16/13.8kV (2)	Transformer	68.2	19.5

As observed, the load flow studies show no thermal constraints. Detailed results of the line and transformer loadings around the vicinity of the PoC are provided in Appendix D-2.

4.6.1.2.3 Voltage Studies

The voltage levels are calculated for the maximum and minimum scenarios. The table below shows the voltage at the 13.8 kV connection point of the proposed RE system in Tinian.

Table 38 Voltage study results – Tinian

Terminal/ Busbar Name	Nominal Line-to-Line Voltage (kV)	Magnitude (p.u.)	
		Maximum Load Scenario	Minimum Load Scenario
207 (PoC)	13.8	0.99	0.99
Terminal_Marpo Heights	13.8	1.00	1.00

The studies indicate no voltage constraints at the terminal around the proposed RE system.

However, it is observed that after connection of the proposed RE system and switching off the existing synchronous generators, part of the network will experience more voltage drop compared with the base model which was being supplied by the existing synchronous generators. To avoid voltage deterioration compared with the base network, approximately 5.2 MVAr reactive power support will be required at the location of the existing power plant (i.e., Power Station 4.16 kV terminal). The reactive power support can be provided either by installing reactive power compensators or using the reactive power capability of the existing synchronous generators, alternatively achievable by increasing the voltage level at the PV and BESS.

More detailed results are provided in Appendix D-2.

4.6.1.3 Rota Results

4.6.1.3.1 Generators/ BESS Output

Below table gives the generators/BESS outputs under all modelling scenarios after connection of the new PV/BESS.

Table 39 Generators/BESS output results – Rota

Type	Output Active Power (MW)	
	Maximum Load	Minimum Load
All existing synchronous generator	0	0
Rota PV	3	2.15
Rota BESS	-1.1[22]	-2

As observed, none of the existing generators as well as the new PV/BESS experience overload issue.

4.6.1.3.2 Thermal Studies

Thermal loading of the elements is calculated for the maximum and the minimum scenarios. Below table shows the thermal loading results of the line and transformer at the proposed RE site.

Table 40 Thermal study results – Rota

Name	Type	Loading (%)	
		Maximum Load Scenario	Minimum Loading Scenario
OH_fdr	Line	27.4	2.2
St_Up_Tx 0.6/13.8kV	Transformer	59.5	4.7

The load flow studies show no thermal constraints. Detailed results of the line and transformer loadings around the vicinity of the PoC are provided in Appendix D-3.

4.6.1.3.3 Voltage Studies

The voltage levels are calculated for the maximum and the minimum scenarios. Below table shows the voltage at the 13.8 kV connection point of the proposed RE system in Rota.

Table 41 Voltage study results – Rota

Terminal/ Busbar Name	Nominal Line-to-Line Voltage (kV)	Magnitude (p.u.)	
		Maximum Load Scenario	Minimum Load Scenario
fdr2_term6 (PoC)	13.8	0.992	1.00

The load flow studies show no voltage constraints at the terminal around the proposed RE system. However, it is observed that after connection of the proposed RE system and switching off the existing synchronous generators in the maximum load modelling scenario, part of the feeder 1 will experience more voltage drop compared to being supplied by the existing synchronous generators. To maintain the voltage of feeder 1 as before - A total of approximately 1 MVAr

[22] Negative power represents BESS charging

reactive power compensator is required. This can be by either installing a new reactive power compensator or use the reactive support of one of the existing generators at Rota_Island_PP substation.

More detailed results are provided in Appendix D-3.

4.6.2 Short Circuit Analysis

The short circuit analysis is simulated in DIgSILENT PowerFactory to calculate the fault levels at various points in the system. The short circuit study is summarized below:

- The short circuit study was done for the maximum and minimum scenarios.
- The maximum three-phase and single-phase to-ground short circuit fault levels are calculated using the *IEC 60909* method, while minimum scenario uses *Complete* method.
- During maximum fault studies, the existing synchronous generators which are switched on in the base model are assumed to be switched on (i.e., GenPP1_DE1, GenPP1_DE2, GenPP1_DE7, GenPP2_G2, GenPP2_G4, GenPP2_G5, GenPP4_G3, GenPP4_G10, Gen_Aggreko), while for minimum fault studies, they are assumed to be switched off.
- PV and BESS inverters are modelled as equivalent synchronous machine.

Table 42 Fault study results – Saipan

Terminal/ Busbar Name	Rated Voltage (kV)	Maximum (3ph) Fault Level (kA)		Maximum (1ph-G) Fault Level (kA)		Minimum (3ph) Fault Level (kA)		Minimum (1ph-G) Fault Level (kA)	
		I’’k	ip	I’’k	ip	I’’k	ip	I’’k	ip
Terminal_Naftan	13.8	3.02	6.79	2.23	5.01	2.40	5.44	1.05	2.39
CUT_2724/ POL_2724	13.8	3.31	7.33	3.73	8.28	2.48	5.53	0.90	1.99
Terminal_As Gonno	13.8	2.14	4.57	2.30	4.90	1.64	3.49	1.04	2.22
Site 4/ BB	13.8	2.21	4.71	2.58	5.49	1.68	3.56	1.00	2.12
Terminal_Kalabera	34.5	5.16	11.86	5.08	11.67	1.67	4.04	0.29	0.71
STAT_1/HV_BB1	34.5	5.08	12.38	5.46	13.31	1.57	3.62	0.30	0.68
STAT_1/HV_BB2	34.5	4.88	11.85	5.31	12.89	1.50	3.45	0.30	0.68

Table 43 Fault study results – Tinian

Terminal/ Busbar Name	Rated Voltage (kV)	Maximum (3ph) Fault Level (kA)		Maximum (1ph-G) Fault Level (kA)		Minimum (3ph) Fault Level (kA)		Minimum (1ph-G) Fault Level (kA)	
		I’’k	ip	I’’k	ip	I’’k	ip	I’’k	ip
Terminal_ Marpo Heights	13.8	2.72	6.21	0.004	0.009	0.83	2.05	0.004	0.009
207 (PoC)	13.8	2.96	6.74	0.004	0.009	0.79	1.91	0.004	0.009

Table 44 *Fault study results – Rota*

Terminal/ Busbar Name	Rated Voltage (kV)	Maximum (3ph) Fault Level (kA)		Maximum (1ph-G) Fault Level (kA)		Minimum (3ph) Fault Level (kA)		Minimum (1ph-G) Fault Level (kA)	
		I''k[23]	ip[24]	I''k	ip	I''k	ip	I''k	ip
fdr2_term 6 (PoC)	13.8	0.685	1.397	0.003	0.0057	0.229	0.562	0.002	0.005
RE Bus 1	13.8	14.100	29.997	15.746	33.4998	6.015	14.853	0.4459	1.101
Feeder_1 _busbar	13.8	0.882	1.973	0.0028	0.0062	0.138	0.281	0.0003	0.0007
Feeder_2 _busbar	13.8	0.899	2.051	0.0028	0.0063	0.194	0.389	0.0021	0.0043
Feeder_3 _busbar	34.5	0.486	1.060	0.0001	0.0003	0.138	0.281	0.0001	0.0003

4.7 Summary, Recommendations and Future Works

The Steady State Studies were conducted for the proposed RE projects for Saipan, Tinian and Rota. The following sub-sections aim to summarize the study results and identify constraints for each of the island (refer to Table 45 for overall summary).

4.7.1 Saipan

Below are the key findings from the Steady State Study for Saipan:

Generators/ BESS Constraints:

- No thermal constraint was identified at the existing synchronous generators, and the proposed PVs and BESS.

Voltage Constraints:

- The study indicates that approximately 17.5 MVAr reactive power support is required at the existing power plant (i.e., STAT_1/MV_BB terminal). The reactive power support can be achieved either by installing reactive power compensators or dispatching the existing synchronous generators and using their reactive power capabilities.

Thermal Constraints:

- Several network reinforcements, i.e., line upgrades, are required to connect the Naftan, As Gonno and Kalabera PV and BESS. In addition:
  - A new 2 km line (modelled using the existing conductor type: 13.8kV_Cond_556_Al, rating 0.704 kA) is required to connect the Naftan site to the nearest 13.8 kV terminal where the upstream distribution network has sufficient capacity for the 15 MW maximum active power output from the PV and BESS at this site.
  - A new 0.5 km line (modelled using the existing conductor type: 13.8kV_Cond_556_Al, rating 0.704 kA) is required to connect the As Gonno site to the nearest 13.8 kV terminal where the upstream distribution network has sufficient capacity for the 5 MW maximum active power output from the PV and BESS at this site.
  - New 2x12 km lines (modelled using the existing cable type: 34.5kV_500kcmil_Al, rating 0.45 kA) are required to connect Kalabera site to 34.5 kV terminals which have sufficient capacity for the 40 MW maximum active power output from the PV and BESS at this site.

[23] Initial symmetrical short circuit current - RMS value of the AC symmetrical component of the short circuit current at the instant of the fault
[24] Peak short circuit current - Instantaneous value of a short circuit current, occurring at the first AC peak after fault inception

Short Circuit Constraints:

- The maximum and minimum short circuit currents at the key nodes of the distribution network were calculated.

4.7.2 Tinian

Below are the key findings from the Steady State Study for Tinian:

Generators/ BESS Constraints:

- No thermal constraint was identified at the existing synchronous generators, and the proposed PVs and BESS.

Voltage Constraints:

- The study indicates that approximately 5.2 MVAr reactive power support is required at the existing power plant (i.e., Power Station 4.16 kV terminal). The reactive power support can be achieved either by installing reactive power compensators or dispatching the existing synchronous generators and using their reactive power capabilities.

Thermal Constraints:

- Thermal analysis indicates that the transformers and cables within the network operate within their safe loading limits, mitigating the risk of equipment overloading.
- A new 1.5 km line (modelled using the existing conductor type: 13.8kV_Cond_556_Al, rating 0.704 kA) is required to connect Marpo Heights PV and BESS to the 13.8 kV distribution network.

Short Circuit Constraints:

- The maximum and minimum short circuit currents at the key nodes of the distribution network were calculated.

4.7.3 Rota

Below are the key findings from the Steady State Study for Rota:

Generators/ BESS Constraints:

- No thermal constraint was identified at the existing synchronous generators, and the proposed PV and BESS.

Voltage Constraints:

- The study indicates that approximately 1 MVAr reactive power support is required at the existing power plant. The reactive power support can be achieved either by installing reactive power compensators or dispatching the existing synchronous generators and using their reactive power capabilities.

Thermal Constraints:

- Thermal analysis indicates that the transformers and cables within the network operate within their safe loading limits, mitigating the risk of equipment overloading.

Short Circuit Constraints:

- The maximum and minimum short circuit currents at the key nodes of the distribution network were calculated.

4.7.4 Recommended network reinforcements

In summary, the recommended reinforcement in all islands are as follows:

Table 45 Recommended Reinforcement – all islands

Islands	Recommended Network Reinforcement	Comments
Saipan	Install 2 km/ 13.8 kV line	Line to connect Naftan PV and BESS to the nearest 13.8 kV terminal where the upstream distribution network has sufficient capacity for the 15 MW maximum active power output from the PV and BESS at this site (i.e., POL_2724)
	Install 0.5 km/ 13.8 kV line	Line to connect As Gonno PV and BESS to the nearest 13.8 kV terminal where the upstream distribution network has sufficient capacity for the 5 MW maximum active power output from the PV and BESS at this site (i.e., Site 4/BB)
	Install 2x12 km/ 34.5 kV line	Lines to connect Kalabera PV and BESS to 34.5 kV terminals which have sufficient capacity for the 40 MW maximum active power output from the PV and BESS at this site (i.e., STAT_1/HV_BB1 and STAT_1/HV_BB2)
	Upgrade 13.8 kV Stat_5-POL_4218_K1 line at Feeder Kiya 1	The thermal constraint of the line can be addressed by either replacing it with a higher-rated conductor, or installing a new parallel line/ doubling the line
	Upgrade 13.8 kV Sub1_MV_N_Feeder2 line at Feeder 2	The thermal constraint of the line can be addressed by either replacing it with a higher-rated conductor, or installing a new parallel line/ doubling the line
	Install 17.5 MVAr reactive power compensator	To avoid voltage deterioration compared with the existing network
Tinian	Install 1.5 km/ 13.8 kV line	Line to connect Marpo Heights PV and BESS to the 13.8 kV distribution network (Terminal 207) at the existing network
	Install 5.2 MVAr reactive power compensator	To avoid voltage deterioration compared with the existing network
Rota	Install 0.1 km/ 15 kV line (existing overhead line type)	Line to connect Rota PV and BESS to the nearest 13.8 kV terminal (Feeder_2_busbar) at the existing network
	Install 1 MVAr reactive power compensator	To avoid voltage deterioration compared with the existing network

5. Financial Analysis (Present Value of Revenue Requirements)

Based upon the Energy Options Assessment and Pre-feasibility Study in Section 3, a financial analysis was completed on the 'Optimum System Configuration' for each of the three islands. Financial analysis was not undertaken for the 'Business as Usual' option (fully diesel based) as continuation of the current operational mode (diesel) was not considered to be a viable option. The analysis undertaken is based on a 'whole of life'[25] 20-year financial model.

5.1 Assumptions

The following table details the assumptions for the Present Value of Revenue Requirements (PVRRs) Financial Model.

Table 46 Financial Analysis Assumptions

Key Assumption	Value	GHD Comments
Operational Period and Forecast Start Date	20-year forecast, beginning on 1 January 2025	The model is based upon a project life of 20 years.
Operational Expenditure	Various – Refer to Model	Variable operating expenditures for each of the diesel generators, Solar PV and BESS is derived from the HOMER model as per Section 3. Fixed operating expenditures for each of the diesel generators, is based upon a rate of $1.985M per unit per year. This is an industry standard assumption.
Fuel Expense	Various – Refer to Model	The fuel expense fluctuates over the 20-year forecast period. This has been based upon audit information and cost data in an RFI response from June 2023[26].
Energy Demand	Various – refer to model	The forecasted total energy served to each of the three islands is derived from the HOMER model. This considers factors such as population growth and discrete load additions (see Section 2 for further details of the peak energy demand forecast).
Energy Supply	Various – refer to model	Supply based on the combination of solar, battery and diesel generation.
Construction Timeline	1 year	It is assumed that the construction of all BESS and Solar will take place over a 1-year period for each of the islands. Note, Saipan has a staged construction timeline, with construction occurring in FY25 and FY30.
Discount Rate	4%, 7% and 10%	A range of discount rates are considered.
Population Growth Forecast	Population based on current forecast (Saipan - 52,457, Tinian – 2,509 and Rota – 2,323), escalated at an annual growth rate of 0.46% in 2025 reducing to a rate of 0.01% by 2040.	This is in line with the assumption made in the Energy Demand Forecast in Section 2.
Inflation Rate	2.5%	This is in line with long term expectations for the region, noting inflation is expected to be higher in the short term.
Retail Energy Price	$0.25671 per kwh	This is based upon the 'Commonwealth Utilities Corporation Schedule of Electric Charges and Rates' from April 2023 (most recent available at the time of writing)[26] .

[25] Total cost over the life of an asset
[26] 2023 June IRP Documents Provided to GHD

5.2 Capital Expenditure Summary

As per Section 4, the following illustrates the Optimum System Configuration capital expenditure for each of the three islands. It is noted that the Capital Expenditure for Saipan is staged, as per Figure 25.

Table 47 Capital Expenditure Summary

Island	Capital Expenditure – FY25	Capital Expenditure – FY30
Saipan	Solar – \$31.8M BESS – \$49.4M Network Augmentation – \$0.6M	Solar – \$63.7M BESS – \$53.0M Network Augmentation – \$13.6M
Tinian	Solar – \$15.9M BESS – \$15.0M	N/A
Rota	Solar – \$2.3M BESS – \$2.0M	N/A

5.3 Future use of diesel power generation

The financial modelling in Section 5 of this report is based upon the assumption that the existing diesel plants on each of the islands continue to operate throughout the forecast period. This is required to meet the expected energy demand for each of the three islands.

GHD notes that the fixed cost maintenance for each of the diesel plants is significant at \$1.985M per year per unit. This includes an allowance for an 'Overhaul' every 5 years (this expense is annualized). However, it is likely that during the forecast period, some (if not all) if the existing diesel generators will need to be replaced. The cost to replace the diesel generators is not included in the results below.

At a high level, replacing the diesel generators requires significant capital expenditure. Therefore, the opportunity cost of this investment should be considered. For example, in practice, if a diesel generator reaches its end of life, CUC should consider if the capital expenditure required should be re-invested into a replacement diesel generator, or invested into expanding the Solar / BESS, as per the 'Aggressive Development of Solar and BESS in Saipan' scenario (see Section 3.7.2).

5.4 PVRR Results

This section provides a concise summary of the results of the 20-year PVRRs for the cost of each supply option, for each of the three islands. This cost analysis includes all costs associated with each option, such as network augmentation costs, capital costs and ongoing operating costs. A sensitivity analysis around key unknown variables is also included, which focuses on capital costs and fuel costs.

5.4.1 Saipan

The following table displays the PVRR results for the Optimum System Configuration, for Saipan. The Net Present Value (NPV) (7% discount rate) is -\$86.4M.

Table 48 Saipan PVRR Results

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$641,598,441	$506,659,936	$412,222,059
Residual Value	$9,062,698	$5,277,522	$3,119,581
Capital Cost	$193,130,232	$181,150,702	$170,739,615
Replacement CAPEX	$0	$0	$0
Operational (variable)	$38,353,396	$29,264,471	$22,933,043
Operational (fixed)	$140,250,336	$112,470,330	$92,910,507
Fuel	$331,622,641	$275,442,624	$235,567,808
Present Value of Costs	$703,356,606	$598,328,127	$522,150,973
Net Present Value	-$52,695,466	-$86,390,669	-$106,809,333

5.4.1.1 Saipan – Sensitivity Analysis

Table 49 below shows the impact of increasing the fuel cost by 15% over the life of the project, while Table 50 shows the impact of increasing the capital cost by 10%.

Table 49 Saipan PVRR Results – Sensitivity Case 1

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$641,598,441	$506,659,936	$412,222,059
Residual Value	$9,062,698	$5,277,522	$3,119,581
Capital Cost	$193,130,232	$181,150,702	$170,739,615
Replacement CAPEX	$0	$0	$0
Operational (variable)	$38,353,396	$29,264,471	$22,933,043
Operational (fixed)	$140,250,336	$112,470,330	$92,910,507
Fuel	$381,366,038	$316,759,018	$270,902,979
Present Value of Costs	$753,100,002	$639,644,521	$557,486,144
Net Present Value	-$102,438,862	-$127,707,063	-$142,144,504

Table 50 Saipan PVRR Results – Sensitivity Case 2

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$641,598,441	$506,659,936	$412,222,059
Residual Value	$9,062,698	$5,277,522	$3,119,581
Capital Cost	$212,443,255	$199,265,772	$187,813,576
Replacement CAPEX	$0	$0	$0
Operational (variable)	$38,353,396	$29,264,471	$22,933,043
Operational (fixed)	$140,250,336	$112,470,330	$92,910,507

Description	Discount Rate		
	4.0%	7.0%	10.0%
Fuel	$331,622,641	$275,442,624	$235,567,808
Present Value of Costs	$722,669,629	$616,443,197	$539,224,934
Net Present Value	-$72,008,489	-$104,505,739	-$123,883,294

5.4.2 Tinian

The following table displays the PVRR results for the Optimum System Configuration, for Tinian. The NPV (7% discount rate) is -$31.2m.

Table 51 Tinian PVRR Results

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$85,641,718	$67,057,883	$54,036,207
Residual Value	$1,510,450	$879,587	$519,930
Capital Cost	$30,912,000	$30,912,000	$30,912,000
Replacement CAPEX	$0	$0	$0
Operational (variable)	$7,569,108	$5,938,420	$4,791,651
Operational (fixed)	$56,100,135	$44,988,132	$37,164,203
Fuel	$23,281,448	$17,314,130	$13,194,321
Present Value of Costs	$117,862,690	$99,152,682	$86,062,175
Net Present Value	-$30,710,522	-$31,215,213	-$31,506,038

5.4.2.1 Tinian – Sensitivity Analysis

Table 52 below shows the impact of increasing the fuel cost by 15% over the life of the project (Sensitivity Case 1), while Table 53 shows the impact of increasing the capital cost by 10% (Sensitivity Case 2).

Table 52 Tinian PVRR Results – Sensitivity Case 1

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$85,641,718	$67,057,883	$54,036,207
Residual Value	$1,510,450	$879,587	$519,930
Capital Cost	$30,912,000	$30,912,000	$30,912,000
Replacement CAPEX	$0	$0	$0
Operational (variable)	$7,569,108	$5,938,420	$4,791,651
Operational (fixed)	$56,100,135	$44,988,132	$37,164,203
Fuel	$26,773,665	$19,911,250	$15,173,470
Present Value of Costs	$121,354,907	$101,749,802	$88,041,324
Net Present Value	-$34,202,739	-$33,812,332	-$33,485,186

Table 53 Tinian PVRR Results – Sensitivity Case 2

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$85,641,718	$67,057,883	$54,036,207
Residual Value	$1,510,450	$879,587	$519,930
Capital Cost	$34,003,200	$34,003,200	$34,003,200
Replacement CAPEX	$0	$0	$0
Operational (variable)	$7,569,108	$5,938,420	$4,791,651
Operational (fixed)	$56,100,135	$44,988,132	$37,164,203
Fuel	$23,281,448	$17,314,130	$13,194,321
Present Value of Costs	$120,953,890	$102,243,882	$89,153,375
Net Present Value	-$33,801,722	-$34,306,413	-$34,597,238

5.4.3 Rota

Table 54 displays the PVRR results for the Optimum System Configuration, for Rota. The NPV (7% discount rate) is -$46.2m.

Table 54 Rota PVRR Results

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$22,313,920	$17,876,042	$14,752,327
Residual Value	$217,505	$126,661	$74,870
Capital Cost	$4,304,480	$4,304,480	$4,304,480
Replacement CAPEX	$0	$0	$0
Operational (variable)	$1,295,982	$1,029,430	$841,775
Operational (fixed)	$56,100,135	$44,988,132	$37,164,203
Fuel	$17,362,860	$13,903,149	$11,468,600
Present Value of Costs	$79,063,456	$64,225,191	$53,779,058
Net Present Value	-$56,532,031	-$46,222,489	-$38,951,861

5.4.3.1 Rota – Sensitivity Analysis

Table 55 below shows the impact of increasing the fuel cost by 15% over the life of the project (Sensitivity Case 1), while Table 56 shows the impact of increasing the capital cost by 10% (Sensitivity Case 2).

Table 55 Rota PVRR Results – Sensitivity Case 1

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$22,313,920	$17,876,042	$14,752,327
Residual Value	$217,505	$126,661	$74,870
Capital Cost	$4,304,480	$4,304,480	$4,304,480

Description	Discount Rate		
	4.0%	7.0%	10.0%
Replacement CAPEX	$0	$0	$0
Operational (variable)	$1,295,982	$1,029,430	$841,775
Operational (fixed)	$56,100,135	$44,988,132	$37,164,203
Fuel	$19,967,289	$15,988,622	$13,188,890
Present Value of Costs	$81,667,885	$66,310,664	$55,499,348
Net Present Value	-$59,136,460	-$48,307,961	-$40,672,151

Table 56 Rota PVRR Results – Sensitivity Case 2

Description	Discount Rate		
	4.0%	7.0%	10.0%
Revenue	$22,313,920	$17,876,042	$14,752,327
Residual Value	$217,505	$126,661	$74,870
Capital Cost	$4,734,928	$4,734,928	$4,734,928
Replacement CAPEX	$0	$0	$0
Operational (variable)	$1,295,982	$1,029,430	$841,775
Operational (fixed)	$56,100,135	$44,988,132	$37,164,203
Fuel	$17,362,860	$13,903,149	$11,468,600
Present Value of Costs	$79,493,904	$64,655,639	$54,209,506
Net Present Value	-$56,962,479	-$46,652,937	-$39,382,309

5.5 Levelized Cost of Energy Results

Table 57 below illustrates the Levelized Cost of Energy (LCOE) results for each of the three islands. The LCOE is calculated by dividing the total cost of producing energy (including all capital and operating costs) by the total amount of energy produced over the project life. Both the total cost and total energy produced over the project life are discounted by 7% (central case).

Table 57 Levelized Cost of Energy Results

Island	LCOE ($/kwh)
Saipan	0.311
Tinian	0.383
Rota	0.953

It is noted that Rota has the highest LCOE for the three islands at $0.953 per kwh. This is largely driven by a combination of Rota receiving less revenue (as the forecasted energy served over the project life is lower), and the fixed operating costs being relatively high, compared to Saipan and Tinian.

6. SCADA and Communications Infrastructure

6.1 Current SCADA & Control Systems

The distribution and generation system in CNMI currently comprises of the following:

– ***Saipan -*** Distribution and transmission infrastructure comprises of two substations with 5.5 miles of medium voltage cabling underground between them, and approximately 242 miles of overhead power lines, owned and maintained by CUC. Power is generated by three diesel generator power stations with diesel being delivered by pipeline to the facilities. There is an additional 12MW of generation operated by an IPP (Aggreko). The substations and generation assets are currently operated as separate systems. Currently, operation of all generators is performed manually. The most critical power plant is PP1, which is manned 24/7 with a rotation of 5 operator staff.

– ***Tinian*** – Power was purchased via a Power Purchase Agreement (PPA) with Telesource CNMI. As of November 2023, the CUC has taken over ownership of all assets and is now responsible for generation and distribution of power. Transmission and distribution infrastructure consists of approximately 42 miles of overhead power lines, owned and maintained by CUC. There is one centralized diesel generator power station.

– ***Rota -*** Power is supplied by diesel generator with diesel being delivered by pipeline to the generating plant. Transmission and distribution infrastructure consists of approximately 46 miles of overhead power lines. There is one centralized diesel generator power station.

The average age of the power plants across the three islands is unknown, though the equipment may be around 40 years old. The age of the equipment is significant because, typically, such old systems would not be equipped with a communications interface. A site visit revealed that the dispatch of these units cannot be controlled remotely, and they lack any communication capabilities. The diesel generators are switched on or off manually based on historical load profiles and operate in frequency and voltage droop mode, adjusting the output according to the voltage and frequency level seen on the network. There has been no evidence provided that remote interface for the current generators is possible.

The feeders at each substation are currently being upgraded with remote terminal units (RTU)'s that provide the ability to monitor equipment directly using the Orion SCADA software which is supplied and commissioned by a 3rd party contractor, Novatech. There is no evidence that the implementation of remote operation of the substation equipment will be completed as part of these upgrades. Whilst the Orion software is capable of both monitoring and control of the substation equipment, it is not clear as to whether this level of SCADA has been implemented at this stage of the upgrades.

The human machine interface (HMI) on this control system seems to be a web-based HMI built into the RTU, which is also implemented and maintained by Novatech.

Based on information provided to GHD it appears that the control systems for each generation point and substation are controlled separately and not integrated into a single unified system. The implication is that control systems are not interconnected via an Ethernet network and that the networking skills currently within the CUC team may be at an early stage of development.

6.2 Communications Infrastructure

Communications infrastructure typically involves several technologies, which include fiber optic cabling and telephone lines. The current communications infrastructure in CNMI can be summarized as follows:

– Fiber optic cabling has been recently installed on the islands. However, additional runs of fiber optic cabling will be required to service power generating assets.

– There may be existing telephone lines that can be used for communications between assets in place of fiber optic cabling, but these lines will need to be assessed in terms of condition and suitability before being used as the backbone of the communications infrastructure.

6.3 Communications Infrastructure Improvements

The SCADA, or Grid Controller, will require communications with all generating assets. Communications' links must be capable of control and monitoring of the facilities. In the absence of any fiber optic cabling, telephone cabling or wireless communications links may provide a means of connecting all controllable assets. The telephone infrastructure will need to be investigated to determine what capacity there may be for connecting assets. Failing this, wireless networks may provide the solution to connectivity. As part of any future network improvements the installation of fiber optic cabling should be included in any additions or upgrades made on the electrical network.

Telephone lines are not considered technology of the future and have been omitted from the cost-benefit analysis. Fiber optic and wireless communications' links are being considered, and for this reason, a table of cost-benefit of fiber optic cabling versus wireless communications has been prepared, refer to Table 58.

Table 58 Cost-Benefit Analysis (CBA) of Fiber Optic vs. Wireless Communications

Factor	Fiber Optic Communications	Wireless Communications
Initial Cost	High upfront cost due to the need to lay cables and set up physical infrastructure. Fiber optic cables require trenching, construction work, and equipment installation. Fiber optic cabling can be installed with overhead power lines but still require trenching at the termination points.	Relatively low upfront costs as it involves minimal physical infrastructure (cable laying only at termination points). Antennas do require power with the associated infrastructure (cabling, trenching etc.).
Operating Cost	Moderate to low operational costs after installation. Fiber optics are durable and require minimal maintenance.	Low operational cost but higher long-term maintenance.
Speed/Performance	High-speed communications with very low latency, superior bandwidth (up to 100 Gbps or more), and high reliability.	Generally lower speeds compared to fiber optics, though faster wireless speeds can be achieved by adding additional independent wireless links. Performance can be adversely affected by the weather.
Scalability	Fiber is highly scalable in terms of bandwidth. Upgrading the network to higher speeds involves replacing or upgrading equipment rather than the Fiber cables themselves.	Very scalable and flexible. Additional access points or towers can be deployed without major disruption. Antennas do require power with the associated infrastructure (cabling, trenching etc.).
Security	Generally very secure as fiber optics are difficult to tap into without detection.	Wireless networks can be vulnerable to hacking, jamming, and eavesdropping, especially if proper encryption or protocols are not used.
Flexibility	Less flexible than wireless in terms of expansion. Fiber optic networks are fixed once installed, which can be difficult to adapt or reconfigure.	Wireless networks offer more flexibility, especially for rapidly changing environments. The network can be adjusted and expanded quickly.
Geographic Suitability	Requires laying physical cables, which can be difficult or impossible in remote, mountainous, or underwater areas.	Wireless networks can be set up anywhere without the need for the associated physical infrastructure. Ideal for rural or hard-to-reach areas where minimal infrastructure is required.

From a technical point of view, the following items will need to be investigated as part of the upgrades required to reach the renewable targets in the CNMI:

- Definition of the role that fiber typically plays in these networks, the possible use of point-to-point wireless networks (as opposed to home WIFI which tends to be quite seamless), configuration of networks, and fault finding in networks.

- Understanding fiber optic infrastructure – design, best practices for installation, fault finding in fiber optic networks, the differences between single mode and multi-mode fiber optic cabling.
- The installation of fiber optic cabling, in the form of OPGW, which should be considered in future projects as part of the installation of new power lines.
- The opportunities that may be presented for interconnection of future renewable assets by the installation of fiber optic cabling currently being installed by CUC as part of the upgrades being undertaken for the water system SCADA.
- Assessment of available fiber connection between assets and exploration of alternative solutions such as point-to-point wireless networks.
- Information gathering will be required for all generating assets to determine what communications capabilities each facility has.

6.4 Future SCADA Improvements

To achieve the integration of a mixture of generating assets, it is necessary to install a unified control system, commonly called a grid controller, capable of controlling the dispatch of the facilities (existing thermal generation, new solar and BESS and network feeders), with additional functionality aimed at frequency stability and network reliability.

From the information provided it does not appear that CUC have previously implemented a grid controller. For this reason, a typical timeframe for the implementation of equipment of this nature is included, see Table 59. The following notes apply:

- Timeframes shown are typical only and may vary depending on the supplier of the grid controller.
- Timeframes shown are based on the design, supply and installation of one grid controller connected to three generation assets and may vary as additional generation assets are added.
- Timeframes shown are based on ideal site conditions, no allowance is made for adverse weather conditions or other factors that have the potential to affect the timeline.
- Timeframes shown are based on standard grid controller software functionality, no allowance is made for additional software functionality, nor for interfaces to manufacturing execution or overarching control systems.
- Timeframes shown assume a high level of development of control systems for generation assets and make no allowance for development of generation asset control systems to be run in parallel.

The CNMI have not had exposure to large scale renewable generation and energy storage systems. The most relevant experience that the CUC may have is the introduction of rooftop solar. Rooftop systems are typically self-regulating, and secondary control is normally not considered. In the case of CNMI, these systems are limited to internal consumption, the result being that export is not considered and concepts such as dispatch and power factor control are never encountered.

Table 59 Grid Controller Implementation Time frame - Typical

Activity Location	Task / Month	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18
Office	Contract Signed	■																	
Office / Site	Kick Off Meeting / Site Visit / Workshops	■																	
Office	Functional Design Specifications		■	■	■														
Office	Equipment Interface Definition		■	■															
Office	Data Gathering	■																	
Office	Detailed Design Development					■	■	■											
Office	Finalization of Interfaces							■	■										
Office	SCADA Configuration							■	■	■									
Office	Application Configuration							■	■	■									
Office	Weather Forecast Interface									■									
Office	Test Preparation									■									
Office	Internal Software Testing										■	■							
Office	Software Integration Testing											■							
Site	Site Installation												■						
Site	Site Acceptance Testing / Commissioning												■	■	■	■	■	■	■
Site	Training (optional)													■	■				
Site	Operations and Maintenance Documentation														■	■			

From a technical point of view, the following items will need to be investigated as part of the upgrades required to reach the renewable targets in the CNMI:

- Understanding the function, interface and purpose of a grid controller, and how a grid controller would interact with generation assets in a unified system.
- Understanding the technology being introduced – BESS, Solar, conventional generation, etc.
- Understanding Ethernet network protocols and the role they play in unified systems.
- Location of Central Control for New and Existing Assets: The ideal location for central control could be at one of the power stations, though other options should also be considered. To determine a suitable location, information about areas appropriate for computerized equipment is necessary. Ideally, this location should be dry and free from moisture to accommodate the installation of cabling and equipment
- SCADA software development, off-site function and testing, and commissioning.
- Production of software testing and implementation documents.
- The reliability and availability requirements of the entire installation need to be considered as these have an impact on the proposal.
- Consideration of manned or unmanned operation of the generation facilities

The most effective way to integrate all of the above into future renewable generation facilities is to develop a grid operating philosophy. This is recommended as one of the most critical projects CUC should undertake moving forward. Timing of the grid operating philosophy should be carefully considered if the CUC is implementing large-scale, sweeping changes to the power system such as a full thermal plant replacement as mentioned in Section 3.7.4. The timing of implanting this improvement would be ideal when done together with installing renewables to perform secondary control and minimize curtailment during operation at beginning of life.

7. Staffing and Skills Assessment

7.1 Current Staffing

The CUC has provided a Power Systems Organizational chart and a Power Sections Job Description document that outlines the skills necessary for each position outlined on the organizational chart.

The positions of electrical and renewable energy engineers both outline an acknowledgement of applicable equipment, controls, and systems of assigned area of responsibility. Other than this requirement no other mention of skillsets in control systems, networking or SCADA are mentioned in the job descriptions. Additionally, there are no control systems engineers present on the organization chart. The current organization chart also shows several vacant positions across all streams in the Power Systems organization.

The current vacant positions are as follows:

– Deputy Director for Electric Power System
– Renewable Energy Engineering Manager
– 3 x Renewable Energy Engineers
– Chief Electrical Engineer - Transmission & Distribution
– Engineer - Transmission & Distribution
– Junior Engineer - Transmission & Distribution
– Senior Electrical Engineer – Power Generation
– 2 x Electrical Engineer – Power Generation
– Senior Mechanical Engineer - Power Generation
– Mechanical Engineer - Power Generation
– 23 x Trades Technicians over the Electrical, Mechanical & Operations of Power Generation, and Transmission & Distribution streams

The current staffing shows some opportunities for improvement in both skill sets & resources.

7.2 Future Staffing Improvements

Traditionally, reliability has been achieved by large generating resources that provide a stable base load with smaller resources providing the ability to increase or decrease dispatch. Traditional generating resources have attracted a negative public focus due to their heavy carbon emissions, creating an opportunity to reconsider the type and number of resources used to generate power. This has resulted in the introduction of renewable generating resources such as solar, wind, and battery energy storage systems. This change in direction has impacted the power generation industry in the following ways:

– A larger workforce is required to support and maintain assets that have a smaller generating capacity, and to complicate matters, many of the roles require work in remote areas, leading to a smaller pool of interested candidates.
– The workforce supporting and maintaining the renewable assets requires a different set of skills because the type of equipment in use has changed. The need for a high-speed response to load changes requires the use of equipment not used when generating power in the traditional manner, and the skills required to support and maintain this equipment needs to be developed.
– Traditionally, the pathway to achieving a skillset is developed over a period of time, but due to the increased drive for the introduction of renewable energy sources, the time to develop new learning methods and course material has not been available, leading to skill levels that vary considerably.

The delivery model will greatly influence the skillset and staffing requirements in the CNMI. If an independent power provider (IPP) is engaged to deliver and operate the renewable facilities, then this skillset may not be required, however the CUC will still need to ensure that the grid is improved and operated to be able to accommodate the proposed renewable and storage in an efficient manner which will require the necessary skills outlined in this section.

The staffing of the current vacancies would be a suitable initial approach in developing the capabilities of the CUC's ability to deliver the upgrades required to achieve 40% renewable penetration. The vacancies seen in the renewable energy team may be due to CUC's forecasting the requirement for a renewable team and still being in the process of developing the team. The appointment of the leadership roles that remain vacant are vital in improving the staff capabilities.

The skillsets required to design and operate a centrally controlled grid with distributed large scale renewable assets and BESS require a different and somewhat more complex skillset than may be currently present in the CNMI. This can be addressed through internal trainings, upskilling, and the addition of new engineering staff that can bring new skill sets to the team.

Based on the limited information provided the largest expertise shortfall in the current staffing is the lack of dedicated control systems engineers, SCADA engineers, technical support engineers and control room operators. CUC's focus on developing capability in networking, grid scale control and SCADA skillsets will be vital in the delivery of this plan and future projects.

The staffing of these positions is crucial in being able to achieve the power system, SCADA & control upgrades required. Future improvements to the skillsets of the engineering team should aim to include the following skills:

– Grid Controller Design including interfacing and functionality.
– Integration of Large-Scale Renewables to existing networks
– Fiber optic network infrastructure design and fault finding
– Ethernet networking design and fault finding
– SCADA design, software development and software testing
– Technical support of network operation including fault finding in new technology (renewables, SCADA and network operation)
– Consideration of reliability, availability and system security in hybrid systems

A site assessment of the current CUC staff highlighted a few areas that would need to be addressed to implement a grid controller, or unified control system, with renewable assets interconnected via communications infrastructure. The site assessment was conducted only with a view to the future implementation of a grid controller, substation control system and associated infrastructure.

To provide clarity on the skillsets required to operate renewable facilities via a grid controller, the following skillsets have been produced:

– SCADA Operator, refer to Table 61.
– SCADA Engineer, refer to Table 62.
– Network Engineer, refer to Table 63.

Levels referred to in the SCADA Operator skills matrix are based on the level of achievement detailed in Table 60. Not detailed here, similar levels are envisaged for SCADA Engineer and Network Engineer.

Table 60 SCADA Operator Levels of achievement

Level	Competency Level	Description
Level 4	Competent	Has achieved the level of competency required to be able to operate power plant and related equipment.
		Is able to lead workplace communication

		Is able to apply critical thinking and problem-solving techniques in the workplace
		Is able to practice and lead occupational health and safety policies aligned with the operation of power plant
Level 3	Advanced	Has achieved the level of competency required to be able to operate power plant and related equipment with minimal supervision.
		Is able to participate proactively in workplace communication
		Is able to apply critical thinking and problem-solving techniques in the workplace
		Is able to practice occupational health and safety policies aligned with the operation of power plant
Level 2	Intermediate	Has achieved the level of competency required to be able to operate power plant and related equipment under supervision.
		Is able to participate in workplace communication
		Is able to contribute to critical thinking and problem-solving techniques in the workplace
		Is able to practice occupational health and safety policies aligned with the operation of power plant
Level 1	Beginner	Has achieved the level of competency required to perform minor adjustments in response to SCADA information under supervision
		Is able to participate in workplace communication
		Is able to contribute to problem-solving techniques in the workplace
		Is able to practice occupational health and safety policies aligned with the operation of power plant

Table 61 Typical Skills and Competency Matrix – SCADA Operator

SKILLS AND COMPETENCY MATRIX – SCADA OPERATOR			COMPETENCY			
SKILL DESCRIPTION	**MODULE**	**COMPETENCY**	**SCADA Operator Level 1**	**SCADA Operator Level 2**	**SCADA Operator Level 3**	**SCADA Operator Level 4**
SCADA AND COMPUTER KNOWLEDGE	**SCADA Hardware and Components**	Understand and identify SCADA and control system hardware and components	✓	✓	✓	✓
	Use operator interface	Understand SCADA login prompt and user access levels	✓	✓	✓	✓
		Login using correct level of access relevant to own function	✓	✓	✓	✓
		Use keyboard, mouse, and monitor to navigate SCADA control system HMI, including popups and faceplates	✓	✓	✓	✓
		Identify SCADA graphic screens relevant to own function	✓	✓	✓	✓
		Access alarms and events summary and demonstrate acknowledgement of alarms / events	✓	✓	✓	✓
SCADA USER KNOWLEDGE	**User information**	Understand graphic page layout and associated components	✓	✓	✓	✓
		Understand equipment states, modes and custody	✓	✓	✓	✓
		Understand common controls such as pushbuttons and setpoints	✓	✓	✓	✓
		Understand alarm states, colors, and priority, including filtering of alarms	✓	✓	✓	✓
		Find, use and interpret data and information from SCADA as required, including historical data	✓	✓	✓	✓
		Determine priority of alarms, events and actions	✓	✓	✓	✓
SCADA OPERATION	**Make required changes in accordance with procedures**	Input and output information correctly according to own function and organization requirements	✓	✓	✓	✓
		Perform minor adjustments in response to SCADA information in accordance with own function	✓	✓	✓	✓
		Determine alarm priority, acknowledge alarms and take appropriate action in accordance with own function	✓	✓	✓	✓
ELECTRICAL NETWORK	**Electrical knowledge**	Understand electricity at intermediate level		✓	✓	✓
		Understand Single Line Diagrams		✓	✓	✓

SKILLS AND COMPETENCY MATRIX – SCADA OPERATOR			COMPETENCY			
SKILL DESCRIPTION	MODULE	COMPETENCY	SCADA Operator Level 1	SCADA Operator Level 2	SCADA Operator Level 3	SCADA Operator Level 4
	Electrical network	Identify electrical network components such as IEDs, RTUs, Circuit Breakers etc.		✓	✓	✓
		Understand electrical switching requirements and the associated safety requirements of electrical switching		✓	✓	✓
		Perform isolations/de-isolations as required		✓	✓	✓
INTRODUCTION TO RENEWABLE ENERGY SYSTEMS	Overview of Renewable Energy	Types of renewable energy: Solar, Wind, Biomass etc.			✓	✓
		Environmental and economic benefits of renewable energy			✓	✓
		Key principles behind renewable energy production			✓	✓
	Basic Renewable Energy Generation Principles	Introduction to energy conversion (wind - mechanical, solar - electrical)			✓	✓
		Photovoltaic (PV) Solar Power systems			✓	✓
		Wind turbines and their operation			✓	✓
		Battery storage systems (for solar and wind integration)			✓	✓
	Renewable Energy Optimization	Performance optimization strategies (e.g., adjusting turbine pitch, solar tracking, etc.)			✓	✓
		Battery management systems (BMS) and energy storage optimization			✓	✓
		Charging/discharging cycle optimization			✓	✓
GRID CONTROLLER INTEGRATION	Grid Controller Hardware	Understand and identify typical Grid Controller components				✓
	Communication	Interfacing with centralized monitoring systems				✓
		Understanding control system data communication				✓
	Grid Operations and Integration	Role of renewable assets in the larger electrical grid				✓
		Understanding grid demand, dispatching renewable energy, and load balancing				✓
		Key performance indicators (KPIs) for energy generation (efficiency, uptime, etc.)				✓
		Grid frequency and voltage control issues				✓

SKILLS AND COMPETENCY MATRIX – SCADA OPERATOR			COMPETENCY			
SKILL DESCRIPTION	MODULE	COMPETENCY	SCADA Operator Level 1	SCADA Operator Level 2	SCADA Operator Level 3	SCADA Operator Level 4
		Grid integration and challenges with renewables				✓
TROUBLESHOOTING AND FAULT DIAGNOSIS	Common Issues in Renewable Systems	Faults in wind turbines: mechanical, electrical, and control faults				✓
		Solar power issues: panel degradation, inverter faults, shading effects				✓
	Troubleshooting Techniques	Identifying warning signals and fault codes				✓
		Corrective actions and reporting procedures				✓
		Use of diagnostic tools (e.g., thermal cameras, vibration analysis)				✓
	Safety Protocols in Troubleshooting	Electrical hazards (e.g., high / medium voltage in solar panels and wind turbines)				✓
		Mechanical hazards (e.g., rotor blades, moving parts)				✓
		Personal protective equipment (PPE) and emergency procedures				✓

Table 62 Typical Skills and Competency Matrix – SCADA Engineer

SKILLS AND COMPETENCY MATRIX - SCADA ENGINEER			COMPETENCY			
SKILL DESCRIPTION	**MODULE**	**COMPETENCY**	**SCADA Engineer Level 1**	**SCADA Engineer Level 2**	**SCADA Engineer Level 3**	**SCADA Engineer Level 4**
SCADA FOUNDATIONAL KNOWLEDGE	**SCADA system overview**	Understand SCADA Architecture, components, and how the system works	✓	✓	✓	✓
		Types of SCADA systems used in renewable energy	✓	✓	✓	✓
	Key functionalities in SCADA	Data acquisition, remote control, monitoring, and alarming	✓	✓	✓	✓
		Communication protocols (Modbus, OPC, DNP3, etc.) and data security considerations	✓	✓	✓	✓
RENEWABLE ENERGY BASICS	**Renewable Energy Technology Familiarization**	Overview of renewable energy technologies (wind, solar, hydro, and biomass)	✓	✓	✓	✓
		How wind turbines and solar PV systems generate electricity	✓	✓	✓	✓
		Renewable energy grid integration and challenges	✓	✓	✓	✓
		Role of SCADA in performance monitoring and fault detection in renewable systems	✓	✓	✓	✓
WIND POWER SCADA INTEGRATION	**Wind Power Plants SCADA Systems**	Understanding wind turbine components (blades, nacelle, generator, control system)		✓	✓	✓
		Key performance indicators (KPIs) for wind farms (generation output, wind speed, rotor speed, pitch angle)		✓	✓	✓
		SCADA data sources specific to wind (e.g., turbine controllers, metering systems)		✓	✓	✓
		Troubleshooting common issues in wind turbines using SCADA data (e.g., underperformance, vibration issues, temperature monitoring)		✓	✓	✓
SOLAR POWER SCADA INTEGRATION	**Solar Power Plants SCADA Systems**	Understanding solar PV system components (panels, solar trackers, inverters, charge controllers, batteries)		✓	✓	✓
		Solar power generation performance monitoring (irradiance, temperature, voltage, current)		✓	✓	✓
		SCADA integration with inverters and controllers		✓	✓	✓
		Troubleshooting solar PV system issues via SCADA (e.g., underperformance, inverter faults, shading)		✓	✓	✓

SKILLS AND COMPETENCY MATRIX - SCADA ENGINEER			COMPETENCY			
SKILL DESCRIPTION	**MODULE**	**COMPETENCY**	**SCADA Engineer Level 1**	**SCADA Engineer Level 2**	**SCADA Engineer Level 3**	**SCADA Engineer Level 4**
DATA ANALYSIS AND VISUALISATION	**Renewable Energy Performance Optimization**	Importance of real-time data analysis for system optimization			✓	✓
		Key performance metrics for renewable systems			✓	✓
		Using SCADA for anomaly detection and predictive maintenance			✓	✓
		Data visualization tools (charts, graphs, dashboards) for performance analysis			✓	✓
		Reporting and decision-making based on SCADA data			✓	✓
REMOTE MONITORING AND CONTROL	**Remotely Monitor and Control Renewable Energy Systems**	Remote access to SCADA systems: VPNs, secure communication, cloud-based monitoring			✓	✓
		Remote control capabilities: Start/stop turbines, adjust inverters, reconfigure controllers, diagnostics			✓	✓
		Automating tasks: Alerts, alarms, and scheduled maintenance			✓	✓
		Remote troubleshooting techniques for wind and solar systems			✓	✓
MAINTENANCE AND TROUBLE SHOOTING	**Troubleshooting Common Issues**	Preventive maintenance for SCADA hardware and software			✓	✓
		Identifying and resolving communication issues (e.g. data gaps, signal loss)			✓	✓
		Troubleshooting SCADA software and hardware issues			✓	✓
		Diagnosing system malfunctions: Identifying root causes (e.g., sensor failure, network issues)			✓	✓
CYBERSECURITY AND SCADA	**Importance of Cybersecurity**	Cybersecurity threats specific to SCADA systems				✓
		Best practices for securing SCADA networks and data				✓
		Understanding vulnerabilities in renewable energy SCADA systems				✓
		Implementing authentication, encryption, and intrusion detection systems				✓

Table 63 Typical Skills and Competency Matrix – Network Engineer

SKILLS AND COMPETENCY MATRIX – NETWORK ENGINEER			COMPETENCY			
SKILL DESCRIPTION	**MODULE**	**COMPETENCY**	**Network Engineer Level 1**	**Network Engineer Level 2**	**Network Engineer Level 3**	**Network Engineer Level 4**
ETHERNET NETWORK FOUNDATIONAL KNOWLEDGE	**Overview of Ethernet technology**	History, evolution, and significance of Ethernet technology	✓	✓	✓	✓
		Understanding the OSI model and how Ethernet fits into it (Layer 1, Layer 2 etc.)	✓	✓	✓	✓
	Wired vs. wireless Ethernet	Differences, similarities, and integration	✓	✓	✓	✓
ETHERNET CABLE STANDARDS AND TYPES	**Different types of Ethernet cables**	Cat5e, Cat6, Cat6a, Cat7, Cat8 cabling	✓	✓	✓	✓
	Fiber optics	Types (single-mode, multi-mode), advantages over copper	✓	✓	✓	✓
	Cabling infrastructure	Best practices for installations, cable management, and standards (TIA/EIA-568)	✓	✓	✓	✓
	Testing Ethernet cables	Cable testers, multimeters	✓	✓	✓	✓
WIRED ETHERNET	**Networking Basics**	Ethernet frame structure and MAC addresses	✓	✓	✓	✓
		Understanding switches, hubs, and routers	✓	✓	✓	✓
		Local Area Networks (LAN): IP addressing, subnetting, VLANs, DHCP, DNS	✓	✓	✓	✓
		Spanning Tree Protocol (STP), link aggregation, and redundancy protocols	✓	✓	✓	✓
WIRELESS ETHERNET	**Networking Basics**	IEEE 802.11 wireless standards: a/b/g/n/ac/ax	✓	✓	✓	✓
		Wireless network components: Access points (APs), wireless controllers, and wireless bridges	✓	✓	✓	✓
		Differences between wired and wireless network performance (bandwidth, latency, interference)	✓	✓	✓	✓
		Wireless encryption and security (WPA, WPA2, WPA3, EAP, 802.1X)	✓	✓	✓	✓
NETWORK DESIGN AND ARCHITECTURE	**Network Topologies**	Star, bus, mesh, and hybrid		✓	✓	✓
	Wireless site surveys	Planning, mapping, and optimizing coverage		✓	✓	✓
	Designing for performance	Bandwidth considerations, latency reduction, quality of service (QoS)		✓	✓	✓
		Redundancy and failover strategies for reliability and uptime		✓	✓	✓

SKILLS AND COMPETENCY MATRIX – NETWORK ENGINEER			COMPETENCY			
SKILL DESCRIPTION	MODULE	COMPETENCY	Network Engineer Level 1	Network Engineer Level 2	Network Engineer Level 3	Network Engineer Level 4
ETHERNET SWITCHING AND ROUTING	Switch configuration and management	Port settings, link aggregation, VLAN tagging		✓	✓	✓
	Introduction to Layer 3 switching	Routing protocols (OSPF, EIGRP, RIP)		✓	✓	✓
		Trunking and inter-VLAN routing		✓	✓	✓
	Quality of Service (QoS)	Prioritizing traffic for voice, video, and data		✓	✓	✓
WIRELESS NETWORK CONFIGURATION AND OPTIMIZATION	Wireless channels and spectrum management	2.4GHz vs. 5GHz bands, channel interference			✓	✓
	Access point placement	Power levels, antenna selection, and density			✓	✓
		Wireless standards (Wi-Fi 6, Wi-Fi 6E) and advanced features like MU-MIMO, OFDMA			✓	✓
		Wireless roaming, handoff, and load balancing between access points			✓	✓
NETWORK SECURITY	Security protocols and best practices	Encryption (WEP, WPA, WPA2, WPA3), firewalls, VPNs			✓	✓
		Common Ethernet and wireless network threats			✓	✓
TROUBLESHOOTING	Troubleshooting techniques	Signal interference, channel overlap, link status monitoring			✓	✓
	Tools	Packet analyzers (Wireshark), network monitoring tools, and diagnostic commands (ping, traceroute, ipconfig)			✓	✓
NETWORK PERFORMANCE MONITORING AND OPTIMIZATION	Performance Monitoring	SNMP (Simple Network Management Protocol) and network performance monitoring tools				✓
		Bandwidth monitoring, network load balancing, and congestion management				✓
		Advanced troubleshooting with QoS and latency reduction techniques				✓
	Wireless network optimization	Avoiding dead zones, optimizing access point configuration				✓

8. Summary and Recommendations

This Integrated Resource Plan (IRP) updates the previous IRP that was published in 2016. It provides a strategic roadmap designed to guide the CUC towards their energy goals over the next 20 years focusing on optimizing energy resources, minimizing costs, and increasing sustainability and system reliability. In addition, the updated IRP is a roadmap for the CUC to achieve 40% renewable energy penetration by 2030 while transitioning to a more efficient and sustainable power supply portfolio.

The report used updated data provided by the CUC, and forecasts the demand for the islands of Saipan, Tinian and Rota. In addition, the plan reassesses supply options and develops optimal solutions for the islands. The optimal solution was to incorporate a combination of solar and BESS.

System impact studies were performed on the optimal cases to identify, from a high-level perspective, minimal network changes such as reinforcement and reactive support to integrate large scale solar and BESS into the network for each island.

Financial analysis was performed based on data received and projections developed. The analysis presents a detailed PVRRs and takes into accounts different sensitivity for changes in fuel price, CAPEX and demand.

To incorporate the new emerging technologies, the CUC will need to improve their workforce and respective skillsets to meet these new demands, particularly in capabilities around SCADA and implementing it for both the existing power network and any new assets.

Based on workshops and particularly the stakeholder workshop, the CNMI prioritizes consistent base load, levelized cost of energy and renewable penetration.

Next steps and proposed future works

It is recommended that the CUC progress with a serious consideration of integrating renewables into the future power supply options for Saipan, Tinian and Rota. Each stream in this IRP demonstrates this. The next steps and proposed future works for the IRP are as followings:

- Progress with more detailed feasibility studies to develop a better understanding of expected costs development timeline and optimal financial, technical and environmental impact of large scale or staged renewables on each island, using the optimal generation mix proposed for each island as a guide and starting point.
- Develop a staging plan for renewables based on current constraints with funding, local resources, contractor mobilization and land availability.
- Develop an infrastructure upgrade plan that aims to develop the existing infrastructure to be able to interface modern systems that would be installed from both a network reliability and SCADA perspective.
- Undergo internal development and training to build capability to work with modern technologies and systems for renewable systems and power system operation.
- Assess and identify the risk profile for the CUC in adopting different contracting strategies for such assets when development is moving forward (such as owning the assets vs undergoing some form of power purchasing agreement).

Appendix A

HOMER Assumptions Register

Techno Economic Modelling Input & Assumptions

Client	**Commonwealth Utilities Corporation**
Project	**CNMI CUC INTEGRATED RESOURCE PLAN**
Job No.	**12582615**

1	IFU	HL	DH	CM	21/06/2024
0	IFU	HL	DH	CM	17/06/2024
Rev	**Description**	**By**	**Chk'd**	**App'd**	**Date**

Template Version: 3.20

Assumptions Register HOMER Simulations

PROJECT NAME	**CNMI CUC INTEGRATED RESOURCE PLAN**
PROJECT NUMBER	**12582615**

Economics

Parameters	Units	Value(s)	Source	Comments and/or References
Nominal Discount Rate	%	8	Default Modelling parameter	
Expected Inflation Rate	%	2	Default Modelling parameter	
Project Life Span	Years	20	Default Modelling parameter	
Fixed Capital Cost	$	N/A		
Currency	USD	-		

PV

Parameters	Units	Value(s)	Source	Comments and/or References
PV System CAPEX (AC)	$/kW	1592	GHD Database / Knowledgebase	Market data with internal database benchmarks
PV System OPEX (AC)	$/kW/year	17	GHD Database / Knowledgebase	Internal Australian benchmark cost for OPEX converted to USD for 2024

BESS

Parameters	Units	Value(s)	Source	Comments and/or References
8 hour (0.125C) CAPEX	$/kWh	484	GHD Database / Knowledgebase	Scaled from 4 hour BESS CAPEX based on internal adjustment factors used for different durations of BESS
4 hour (0.25C) CAPEX	$/kWh	546	GHD Database / Knowledgebase	**Using NREL data and adjusted based on internal benchmarks and data**
2 hour (0.5C) CAPEX	$/kWh	683	GHD Database / Knowledgebase	Scaled from 4 hour BESS CAPEX based on internal adjustment factors used for different durations of BESS
1 hour (1C) CAPEX	$/kWh	1006	GHD Database / Knowledgebase	Scaled from 4 hour BESS CAPEX based on internal adjustment factors used for different durations of BESS
BESS OPEX	$/kWh/year	11.70	GHD Database / Knowledgebase	Internal Australian benchmark cost for OPEX converted to USD for 2024.

Diesel Generators

Parameters	Units	Value(s)	Source	Comments and/or References
Heat Rate for Diesel Gen (NEW)	L/MWh	236-248	GHD Database / Knowledgebase	Based on engine sizes among: 2.5, 4.5, 8 and 10 MW. Existing plant has uplift in consumption rate due to age (+10%)
Operation & Maintenance - Variable	$/MWh	9.95	GHD Database / Knowledgebase	Based on engine sizes among: 2.5, 4.5, 8 and 10 MW, +15% uplift added for owner's cost allowance
Operation & Maintenance - Fixed	$/Engine	1,985,000	GHD Database / Knowledgebase	Based on engine sizes among: 2.5, 4.5, 8 and 10 MW, +15% uplift added for owner's cost allowance
CAPEX	$/MW	1,665,000	GHD Database / Knowledgebase	+15% uplift added for owner's cost allowance
Lifetime Run Hours	Hours	150,000	Default Modelling parameter Client to confirm	Replacement required after this number of operating hours
Minimum Load ratio	%	30	Default Modelling parameter Client to confirm	
Minimum Runtime	Minutes	30	Default Modelling parameter Client to confirm	
CAPEX - replacement	$/MW	1,665,000	GHD Database / Knowledgebase	+15% uplift added for owner's cost allowance

Fuel

Parameters	Units	Value(s)	Source	Comments and/or References
Diesel	$/L	1.09	Client provided	Average calculated based on financial audit data and RFI information
Carbon Content	%	88	Default Modelling parameter	

Equipment Life and replacement costs

Parameters	Units	Value(s)	Source	Comments and/or References
Life span of **solar PV**	years	25		
Lifespan of BESS	years	20		
Replacement costs in current Models	Y/N	Y		

Technical Parameters

Parameters	Units	Value(s)	Source	Comments and/or References
PV Derating factor	%	N/A	Default Modelling parameter	
PV DC/AC ratio	-	1.2	Default Modelling parameter	
PV Inverter Efficiency	%	98	Default Modelling parameter	
Storage Inverter Efficiency	%	98	Default Modelling parameter	
Storage Round Trip Efficiency	%	85	Default Modelling parameter	

Appendix B

MCA Results

Table 64 Saipan – Base case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	60	60
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	48
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	192
Total diesel (Existing)	Total existing capacity of diesel generation	MW	62.1	62.1	62.1
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	0.00	23.21	3.31
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	44.08	67.67
Financial Information					
PV CAPEX		$M	0	96	96
BESS CAPEX		$M	0	0	102
Diesel CAPEX (New)		$M	-	-	-
Total CAPEX		$M	0	96	198
NPC	Net present cost	$M	810	665	658
LCOE	Levelised cost of energy	$/MWh	418.2	343.7	339.8
Sustainability					
Average emissions per year		MT-CO2/yr	119,217	66,999	39,469
Emissions abatement	Total emissions reduced over project life	MT-CO2	0	1,044,344	1,594,960
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-497	-833

Table 65 Saipan – Low case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	40	60
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	45
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	180
Total diesel (Existing)	Total existing capacity of diesel generation	MW	62.1	62.1	62.1
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	0.00	16.95	10.00
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	42.07	77.24
Financial Information					
PV CAPEX		$M	0	64	96
BESS CAPEX		$M	0	0	97
Diesel CAPEX (New)		$M	-	-	-
Total CAPEX		$M	0	64	193
NPC	Net present cost	$M	709	585	580
LCOE	Levelised cost of energy	$/MWh	447.0	369.2	366.0
Sustainability					
Average emissions per year		MT-CO2/yr	94,351	54,811	21,604
Emissions abatement	Total emissions reduced over project life	MT-CO2	1	790,804	1,454,944
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-534	-1,343

Table 66 Saipan – High case load scenario

Definition	Units	Option 1	Option 2	Option 3	Option 4

System parameters and outputs			Business as usual (BaU)	Solar	Solar + BESS (A)	Solar + BESS (B)
System Configuration						
PV installed capacity	Total installed AC capacity of solar PV	MW	0	60	80	60
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	64	48
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	256	192
Total diesel (Existing)	Total existing capacity of diesel generation	MW	62.1	62.1	62.1	62.1
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	10	10	-	10
System performance						
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0	0
Excess electricity		%	0.00	18.46	6.98	1.79
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	42.63	75.52	61.56
Financial Information						
PV CAPEX		$M	0	96	127	96
BESS CAPEX		$M	17	17	129	97
Diesel CAPEX (New)		$M	17	17	-	17
Total CAPEX		$M	17	112	257	215
NPC	Net present cost	$M	896	730	700	735
LCOE	Levelised cost of energy	$/MWh	410.0	333.9	320.4	336.3
Sustainability						
Average emissions per year		MT-CO2/yr	135,873	78,484	35,040	54,069
Emissions abatement	Total emissions reduced over project life	MT-CO2	0	1,147,771	2,016,650	1,636,078
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-465	-999	-680

Table 67 Tinian – Base case load scenario

System parameters and outputs	Definition	Units	Option 1	Option 2	Option 3

			Business as usual (BaU)	Solar	Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	8	10
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	8
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	32
Total diesel (Existing)	Total existing capacity of diesel generation	MW	17.5	17.5	17.5
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	1.27	24.40	10.31
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	41.44	77.49
Financial Information					
PV CAPEX		$M	0	13	16
BESS CAPEX		$M	0	0	15
Diesel CAPEX (New)		$M	-	-	-
Total CAPEX		$M	0	13	31
NPC	Net present cost	$M	195	175	170
LCOE	Levelized cost of energy	$/MWh	769.0	692.7	670.4
Sustainability					
Average emissions per year		MT-CO2/yr	17,252	10,163	4,335
Emissions abatement	Total emissions reduced over project life	MT-CO2	3	141,769	258,338
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-863	-1,958

Table 68 Tinian – Low case load scenario

System parameters and outputs	Definition	Units	Option 1	Option 2	Option 3

			Business as usual (BaU)	Solar	Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	10	4
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	3
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	12
Total diesel (Existing)	Total existing capacity of diesel generation	MW	17.5	17.5	17.5
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	8.56	64.76	9.44
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	40.25	73.62
Financial Information					
PV CAPEX		$M	0	16	6
BESS CAPEX		$M	0	0	7
Diesel CAPEX (New)		$M	-	-	-
Total CAPEX		$M	0	16	13
NPC	Net present cost	$M	156	155	140
LCOE	Levelized cost of energy	$/MWh	1,410.0	1,397.2	1,267.2
Sustainability					
Average emissions per year		MT-CO2/yr	8,368	4,647	2,123
Emissions abatement	Total emissions reduced over project life	MT-CO2	6	74,414	124,896
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-1,666	-3,308

Table 69 Tinian – High case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS (A)	Option 4 Solar + BESS (B)
System Configuration						

PV installed capacity	Total installed AC capacity of solar PV	MW	0	10	12	10
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	9.6	8
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	38.4	32
Total diesel (Existing)	Total existing capacity of diesel generation	MW	17.5	17.5	17.5	17.5
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-	-
System performance						
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0	0
Excess electricity		%	0.40	20.48	7.45	4.03
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	41.49	71.51	63.67
Financial Information						
PV CAPEX		$M	0	16	19	16
BESS CAPEX		$M	0	0	18	15
Diesel CAPEX (New)		$M	17	17	-	-
Total CAPEX		$M	0	16	37	31
NPC	Net present cost	$M	221	194	190	192
LCOE	Levelized cost of energy	$/MWh	642.0	564.8	551.4	556.8
Sustainability						
Average emissions per year		MT-CO2/yr	23,278	13,790	7,483	9,423
Emissions abatement	Total emissions reduced over project life	MT-CO2	2	189,758	315,911	277,105
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-705	-1,268	-1,017

Table 70 Rota (Iteration 1) – Base case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS
System Configuration					

PV installed capacity	Total installed AC capacity of solar PV	MW	0	6	6
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	2
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	8
Total diesel (Existing)	Total existing capacity of diesel generation	MW	5.6	5.6	5.6
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	11.02	41.61	15.68
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	30.49	76.72
Financial Information					
PV CAPEX		$M	0	10	10
BESS CAPEX		$M	0	-5	-1
Diesel CAPEX (New)		$M	-	-	-
Total CAPEX		$M	0	5	9
NPC	Net present cost	$M	29	23	17
LCOE	Levelized cost of energy	$/MWh	423.2	337.9	242.7
Sustainability					
Average emissions per year		MT-CO2/yr	5,849	3,686	1,283
Emissions abatement	Total emissions reduced over project life	MT-CO2	9	43,256	91,323
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-315	-651

Table 71 Rota (Iteration 1) – Low case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	6	6
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	2
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	8
Total diesel (Existing)	Total existing capacity of diesel generation	MW	5.6	5.6	5.6
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	11.21	42.00	15.98
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	30.36	77.23
Financial Information					
PV CAPEX		$M	0	10	10
BESS CAPEX		$M	0	-5	-1
Diesel CAPEX (New)		$M	-	-	-
Total CAPEX		$M	0	5	9
NPC	Net present cost	$M	29	23	17
LCOE	Levelized cost of energy	$/MWh	424.8	339.3	242.3
Sustainability					
Average emissions per year		MT-CO2/yr	5,815	3,662	1,244
Emissions abatement	Total emissions reduced over project life	MT-CO2	9	43,051	91,412
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-316	-664

Table 72 Rota (Iteration 2) – High case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	6	6
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	2
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	8
Total diesel (Existing)	Total existing capacity of diesel generation	MW	5.6	5.6	5.6
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	10.55	40.62	14.82
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	30.84	75.61
Financial Information					
PV CAPEX		$M	0	10	10
BESS CAPEX		$M	0	-5	-1
Diesel CAPEX (New)		$M	17	17	-
Total CAPEX		$M	0	5	9
NPC	Net present cost	$M	29	24	17
LCOE	Levelized cost of energy	$/MWh	419.5	334.4	243.1
Sustainability					
Average emissions per year		MT-CO2/yr	5,939	3,749	1,375
Emissions abatement	Total emissions reduced over project life	MT-CO2	8	43,813	91,286
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-314	-622

Table 73 Rota (Iteration 2) – Base case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	4	3
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	2
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	2
Total diesel (Existing)	Total existing capacity of diesel generation	MW	5.6	5.6	5.6
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	11.02	30.21	4.32
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	24.55	44.35
Financial Information					
PV CAPEX		$M	0	6	5
BESS CAPEX		$M	0	-3	0
Diesel CAPEX (New)		$M	-	-	-
Total CAPEX		$M	0	3	4
NPC	Net present cost	$M	98	92	88
LCOE	Levelized cost of energy	$/MWh	1,429.2	1,344.1	1,289.0
Sustainability					
Average emissions per year		MT-CO2/yr	5,849	4,013	2,962
Emissions abatement	Total emissions reduced over project life	MT-CO2	9	36,714	57,752
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-1,149	-1,494

Table 74 Rota (Iteration 2) – Low case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	4	3
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	2
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	2
Total diesel (Existing)	Total existing capacity of diesel generation	MW	5.6	5.6	5.6
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	11.21	30.62	4.56
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	24.39	44.55
Financial Information					
PV CAPEX		$M	0	6	5
BESS CAPEX		$M	0	-3	0
Diesel CAPEX (New)		$M	-	-	-
Total CAPEX		$M	0	3	4
NPC	Net present cost	$M	98	92	88
LCOE	Levelized cost of energy	$/MWh	1,440.0	1,354.7	1,298.5
Sustainability					
Average emissions per year		MT-CO2/yr	5,815	3,987	2,928
Emissions abatement	Total emissions reduced over project life	MT-CO2	9	36,548	57,736
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-1,156	-1,508

Table 75 Rota (Iteration 2) – High case load scenario

System parameters and outputs	Definition	Units	Option 1 Business as usual (BaU)	Option 2 Solar	Option 3 Solar + BESS
System Configuration					
PV installed capacity	Total installed AC capacity of solar PV	MW	0	4	3
BESS power capacity	Total installed AC power capacity of the BESS	MW	0	0	2
BESS energy capacity	Total installed energy capacity of the BESS	MWh	0	0	2
Total diesel (Existing)	Total existing capacity of diesel generation	MW	5.6	5.6	5.6
Total diesel (New)	Total capacity of diesel installed in addition to existing diesel	MW	-	-	-
System performance					
Unmet load	Average unserved demand due to shortfall in production	kWh/year	0	0	0
Excess electricity		%	10.55	29.21	3.79
Renewable fraction	Fraction of the renewable energy delivered to the load.	%	0.00	24.90	43.76
Financial Information					
PV CAPEX		$M	0	6	5
BESS CAPEX		$M	0	-3	0
Diesel CAPEX (New)		$M	17	17	-
Total CAPEX		$M	0	3	4
NPC	Net present cost	$M	98	93	89
LCOE	Levelized cost of energy	$/MWh	1,400.0	1,315.6	1,263.0
Sustainability					
Average emissions per year		MT-CO2/yr	5,939	4,083	3,055
Emissions abatement	Total emissions reduced over project life	MT-CO2	8	37,128	57,687
Marginal abatement cost (MAC)	NPV / total MT of CO2 abated	$/MT-CO2	0	-1,133	-1,454

Appendix C

CNMI Demand Forecast

Title:	**CNMI Demand and Energy Forecast**
Prepared By:	**GHD**
Project Number:	**12582615**
Date:	**3-May-24**

FINAL DRAFT

Global Inputs

General Assumptions

General

		Saipan	Rota	Tinian
Model Start Date	Date	31-Dec-19	31-May-23	31-May-23
Assessment period Start Date	Date	01-Jan-24	01-Jan-24	01-Jan-24
Assesment period	#	20	20	20
Assessment period End Date	Date	31-Dec-43	31-Dec-43	31-Dec-43

MW to kW Conversion Factor	#	1,000

Population

Saipan	#	52,457
Tinian	#	2,509
Rota	#	2,323
Saipan (% of total)	%	92%
Tinian (% of total)	%	4%
Rota (% of total)	%	4%

Electricity Consumption by Sector

		Saipan	Rota	Tinian	
Commercial	%	53.33%	25.00%	25.00%	Source: US Department of Energy (Saipan only)
Residential	%	29.33%	70.00%	70.00%	Source: US Department of Energy (Saipan only)
Governmnet	%	17.33%	5.00%	5.00%	Source: US Department of Energy (Saipan only)

Electricity Demand Growth by Sector

		Saipan	Rota	Tinian
Commercial	%	Half of population growth	Half of population growth	Half of population growth
Residential	%	Population growth	Population growth	Population growth
Government	%	Half of population growth	Half of population growth	Half of population growth

Scenario Analysis (Saipan, Rota and Tinian)

		Low Case	Base Case	High Case
Commercial	%	25.00%	50.00%	100.00%
Residential	%	50.00%	100.00%	200.00%
Government	%	25.00%	50.00%	100.00%

Starting Peak Demand (kW)

Saipan	kW	38,200	December 2019 Peak Demand (kW)
Tinian	kW	2,700	May 2023 Peak Demand (kW)
Rota	kW	1,750	May 2023 Peak Demand (kW)

Expected Growth Projects (Expected Completion Dates)

	Completion Date
Saipan	Refer "Expected Projects" tab
Tinian	Refer "Expected Projects" tab
Rota	N/A

Linear Inputs

Linear Assumptions

Population

Year		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Growth Rate (annual)	%	-0.18%	-0.25%	0.53%	0.46%	0.46%	0.46%	0.39%	0.39%	0.36%	0.30%	0.29%	0.24%	0.21%	0.17%	0.14%	0.10%
Growth Rate (monthly)	%	-0.02%	-0.02%	0.04%	0.04%	0.04%	0.04%	0.03%	0.03%	0.03%	0.02%	0.02%	0.02%	0.02%	0.01%	0.01%	0.01%

Year		2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Growth Rate (annual)	%	0.08%	0.01%	-0.01%	-0.05%	-0.10%	-0.14%	-0.21%	-0.25%	-0.28%	-0.34%	-0.36%	-0.41%	-0.45%	-0.46%	-0.49%
Growth Rate (monthly)	%	0.01%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.03%	-0.03%	-0.03%	-0.04%	-0.04%	-0.04%

Month on Month Energy Demand Δ

Month (Counter)		1	2	3	4	5	6	7	8	9	10	11	12
Saipan	%	-16%	5.9%	4.1%	9.9%	6.2%	0.7%	2.4%	-3.1%	3.1%	-3.3%	1.5%	-8.6%
Tinian	%	-3.8%	4.0%	-3.8%	12.0%	-3.6%	-7.4%	-14.0%	39.5%	-13.3%	-1.9%	2.0%	0.0%
Rota	%	2.3%	6.3%	-10.6%	7.6%	7.2%	-2.9%	-9.5%	14.4%	-0.8%	0.2%	0.1%	-11.0%

Peak Load

Date		31-Jan-19	28-Feb-19	31-Mar-19	30-Apr-19	31-May-19	30-Jun-19	31-Jul-19	31-Aug-19	30-Sep-19	31-Oct-19	30-Nov-19	31-Dec-19
Saipan	kw	32,100	34,000	35,400	38,900	41,300	41,600	42,600	41,300	42,600	41,200	41,800	38,200

Date		01-Jun-22	01-Jul-22	01-Aug-22	01-Sep-22	01-Oct-22	01-Nov-22	01-Dec-22	01-Jan-23	01-Feb-23	01-Mar-23	01-Apr-23	01-May-23
Tinian	kw	2,500	2,150	3,000	2,600	2,550	2,600	2,600	2,500	2,600	2,500	2,800	2,700
Rota	kw	1,700	1,538	1,760	1,746	1,750	1,752	1,560	1,596	1,697	1,517	1,632	1,750

CNMI Demand Forecast (Base Case)

Period start	1-Jan-23	1-Jan-24	1-Jan-25	1-Jan-26	1-Jan-27	1-Jan-28	1-Jan-29	1-Jan-30	1-Jan-31	1-Jan-32	1-Jan-33	1-Jan-34	1-Jan-35	1-Jan-36	1-Jan-37	1-Jan-38	1-Jan-39	1-Jan-40	1-Jan-41	1-Jan-42	1-Jan-43
Period end	31-Dec-23	31-Dec-24	31-Dec-25	31-Dec-26	31-Dec-27	31-Dec-28	31-Dec-29	31-Dec-30	31-Dec-31	31-Dec-32	31-Dec-33	31-Dec-34	31-Dec-35	31-Dec-36	31-Dec-37	31-Dec-38	31-Dec-39	31-Dec-40	31-Dec-41	31-Dec-42	31-Dec-43
Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Counter	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Actual	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Forecast	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Population Forecast

Saipan	53,257	53,502	53,748	53,958	54,168	54,363	54,526	54,684	54,816	54,931	55,024	55,101	55,156	55,200	55,206	55,200	55,173	55,118	55,040	54,925	54,787
Tinian	2,509	2,520	2,532	2,542	2,552	2,561	2,568	2,576	2,582	2,588	2,592	2,596	2,598	2,600	2,600	2,600	2,599	2,596	2,593	2,587	2,581
Rota	2,334	2,345	2,354	2,363	2,372	2,379	2,386	2,391	2,396	2,400	2,404	2,406	2,408	2,408	2,408	2,407	2,405	2,401	2,396	2,390	2,383
Northern Mariana Islands (Total)	**58,100**	**58,367**	**58,634**	**58,862**	**59,091**	**59,303**	**59,480**	**59,652**	**59,794**	**59,919**	**60,020**	**60,103**	**60,162**	**60,209**	**60,214**	**60,207**	**60,176**	**60,115**	**60,029**	**59,902**	**59,752**

Population Growth Rates

Saipan		0.46%	0.46%	0.39%	0.39%	0.36%	0.30%	0.29%	0.24%	0.21%	0.17%	0.14%	0.10%	0.08%	0.01%	-0.01%	-0.05%	-0.10%	-0.14%	-0.21%	-0.25%
Tinian		0.46%	0.46%	0.39%	0.39%	0.36%	0.30%	0.29%	0.24%	0.21%	0.17%	0.14%	0.10%	0.08%	0.01%	-0.01%	-0.05%	-0.10%	-0.14%	-0.21%	-0.25%
Rota		0.46%	0.39%	0.39%	0.36%	0.30%	0.29%	0.24%	0.21%	0.17%	0.14%	0.10%	0.08%	0.01%	-0.01%	-0.05%	-0.10%	-0.14%	-0.21%	-0.25%	-0.28%

Saipan

Forecasted Annual Peak Energy Use (kW) - Base Case

Commercial	22,770	22,823	22,875	27,938	28,905	29,317	32,305	32,352	38,370	38,412	38,486	38,514	38,536	38,552	38,557	38,557	38,550	38,535	38,511	38,476	38,431
Residential	12,551	12,609	12,667	12,719	12,768	12,815	12,856	12,893	12,926	12,954	12,977	12,996	13,011	13,022	13,025	13,025	13,021	13,010	12,994	12,971	12,940
Government	7,400	7,417	7,434	7,450	7,464	7,478	7,490	7,500	7,510	7,518	7,525	7,530	7,535	7,538	7,539	7,539	7,537	7,534	7,530	7,523	7,514
Total	**42,722**	**42,849**	**42,977**	**48,106**	**49,137**	**49,610**	**52,650**	**52,746**	**58,806**	**58,884**	**58,988**	**59,041**	**59,081**	**59,111**	**59,121**	**59,120**	**59,108**	**59,080**	**59,035**	**58,970**	**58,886**

Forecasted Annual Peak Energy Use (kW) - High Case

Commercial	22,821	22,926	25,827	31,959	33,180	33,733	40,166	40,284	47,563	47,667	47,800	47,871	47,923	47,964	47,977	47,976	47,960	47,922	47,863	47,776	47,665
Residential	12,607	12,723	12,841	12,945	13,047	13,143	13,225	13,303	13,370	13,428	13,477	13,517	13,546	13,569	13,577	13,576	13,567	13,545	13,512	13,463	13,400
Government	7,417	7,451	7,485	7,516	7,545	7,573	7,597	7,619	7,638	7,655	7,668	7,680	7,688	7,695	7,697	7,697	7,694	7,688	7,678	7,664	7,647
EV Uptake	-	-	3	8	16	27	41	57	76	98	123	150	180	214	249	288	329	373	420	469	521
Total	**42,844**	**43,100**	**46,155**	**52,428**	**53,788**	**54,475**	**61,029**	**61,262**	**68,648**	**68,848**	**69,068**	**69,217**	**69,338**	**69,442**	**69,500**	**69,536**	**69,550**	**69,528**	**69,473**	**69,373**	**69,233**

Forecasted Annual Peak Energy Use (kW) - Low Case

Commercial	22,745	22,771	22,797	22,821	22,843	22,864	22,882	22,898	22,913	22,925	22,936	22,944	22,950	22,955	22,957	22,957	22,955	22,950	22,943	22,933	22,919
Residential	12,524	12,552	12,581	12,607	12,631	12,655	12,675	12,693	12,709	12,723	12,734	12,744	12,751	12,756	12,758	12,758	12,756	12,751	12,743	12,731	12,716
Government	7,392	7,401	7,409	7,417	7,424	7,431	7,437	7,442	7,447	7,451	7,454	7,457	7,459	7,460	7,461	7,461	7,460	7,459	7,457	7,453	7,449
Total	**42,661**	**42,724**	**42,788**	**42,844**	**42,898**	**42,949**	**42,993**	**43,034**	**43,069**	**43,099**	**43,124**	**43,145**	**43,160**	**43,172**	**43,176**	**43,175**	**43,171**	**43,160**	**43,142**	**43,117**	**43,084**

Tinian

Forecasted Annual Peak Energy Use (kW) - Base Case

Commercial	750	752	754	755	757	758	760	761	762	762	763	764	764	764	765	765	764	764	764	763	762
Residential	2,102	2,112	2,122	2,131	2,139	2,147	2,154	2,160	2,166	2,170	2,174	2,178	2,180	2,182	2,183	2,183	2,182	2,180	2,177	2,173	2,168
Government	150	150	872	2,008	2,733	3,530	5,325	5,333	5,340	5,346	5,351	5,355	5,358	5,360	5,361	5,361	5,360	5,358	5,354	5,349	5,343
Total	**3,003**	**3,015**	**3,747**	**4,894**	**5,629**	**6,435**	**8,239**	**8,254**	**8,267**	**8,279**	**8,288**	**8,296**	**8,302**	**8,307**	**8,308**	**8,308**	**8,306**	**8,302**	**8,295**	**8,285**	**8,273**

Forecasted Annual Peak Energy Use (kW) - High Case

Commercial	751	754	758	761	764	767	769	771	773	775	777	778	779	779	780	779	779	779	778	776	774
Residential	2,105	2,124	2,144	2,162	2,178	2,195	2,209	2,222	2,233	2,243	2,251	2,258	2,263	2,267	2,268	2,268	2,267	2,263	2,257	2,249	2,238
Government	150	151	1,355	3,185	4,400	5,726	8,551	8,576	8,598	8,617	8,633	8,646	8,656	8,663	8,666	8,666	8,663	8,655	8,644	8,628	8,608
EV Uptake	-	-	0	0	1	1	2	3	3	4	5	7	8	9	11	13	15	17	19	21	23
Total	**3,006**	**3,029**	**4,256**	**6,107**	**7,343**	**8,688**	**11,531**	**11,572**	**11,608**	**11,639**	**11,666**	**11,688**	**11,705**	**11,719**	**11,725**	**11,726**	**11,723**	**11,713**	**11,698**	**11,674**	**11,643**

Forecasted Annual Peak Energy Use (kW) - Low Case

Commercial	750	751	752	753	753	754	755	755	756	756	757	757	757	757	757	757	757	757	757	756	756
Residential	2,101	2,106	2,111	2,115	2,119	2,123	2,127	2,130	2,133	2,135	2,137	2,138	2,140	2,141	2,141	2,141	2,140	2,140	2,138	2,136	2,134
Government	150	150	150	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151
Total	**3,001**	**3,007**	**3,013**	**3,018**	**3,023**	**3,028**	**3,032**	**3,036**	**3,039**	**3,042**	**3,045**	**3,047**	**3,048**	**3,049**	**3,050**	**3,050**	**3,049**	**3,048**	**3,046**	**3,044**	**3,041**

Rota

Forecasted Annual Peak Energy Use (kW) - Base Case

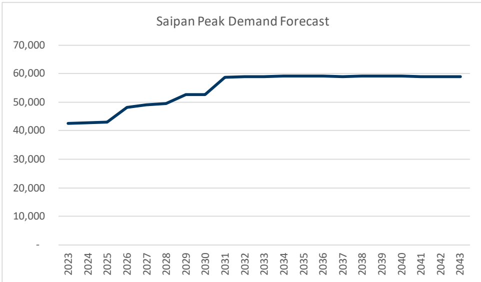
Commercial	440	441	442	443	444	445	446	446	447	447	448	448	448	448	449	449	448	448	448	448	447
Residential	1,233	1,239	1,245	1,250	1,255	1,259	1,263	1,267	1,270	1,273	1,276	1,277	1,279	1,280	1,280	1,280	1,280	1,279	1,277	1,275	1,272
Government	88	88	88	89	89	89	89	89	89	89	90	90	90	90	90	90	90	90	90	90	89
Total	**1,762**	**1,769**	**1,776**	**1,782**	**1,788**	**1,793**	**1,798**	**1,803**	**1,807**	**1,810**	**1,813**	**1,815**	**1,817**	**1,818**	**1,819**	**1,819**	**1,818**	**1,817**	**1,815**	**1,812**	**1,808**

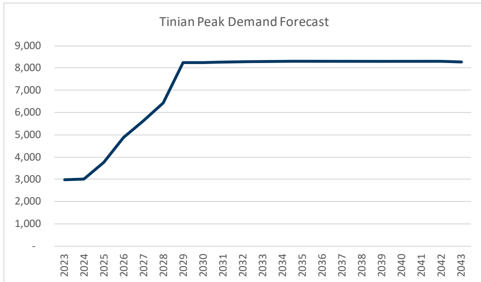
Forecasted Annual Peak Energy Use (kW) - High Case

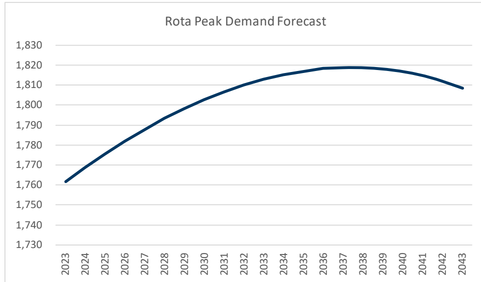
Commercial	441	443	445	446	448	450	451	453	454	455	456	456	457	457	457	457	457	457	456	455	454
Residential	1,235	1,246	1,258	1,268	1,278	1,288	1,296	1,303	1,310	1,316	1,321	1,325	1,328	1,330	1,331	1,331	1,330	1,328	1,324	1,319	1,313
Government	88	89	89	89	90	90	90	91	91	91	91	91	91	91	91	91	91	91	91	91	91
EV Uptake	-	-	0	0	1	1	2	3	4	5	6	7	9	10	12	14	16	18	20	22	25
Total	**1,763**	**1,777**	**1,791**	**1,804**	**1,817**	**1,829**	**1,839**	**1,849**	**1,858**	**1,866**	**1,873**	**1,879**	**1,884**	**1,889**	**1,892**	**1,893**	**1,894**	**1,893**	**1,892**	**1,888**	**1,883**

Forecasted Annual Peak Energy Use (kW) - Low Case

Commercial	440	441	441	442	442	442	443	443	443	444	444	444	444	444	444	444	444	444	444	444	444
Residential	1,233	1,236	1,238	1,241	1,243	1,246	1,248	1,249	1,251	1,252	1,254	1,255	1,255	1,256	1,256	1,256	1,256	1,255	1,254	1,253	1,252
Government	88	88	88	88	88	88	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89
Total	**1,761**	**1,764**	**1,768**	**1,771**	**1,774**	**1,777**	**1,779**	**1,781**	**1,783**	**1,785**	**1,786**	**1,787**	**1,788**	**1,789**	**1,789**	**1,789**	**1,789**	**1,788**	**1,787**	**1,786**	**1,784**



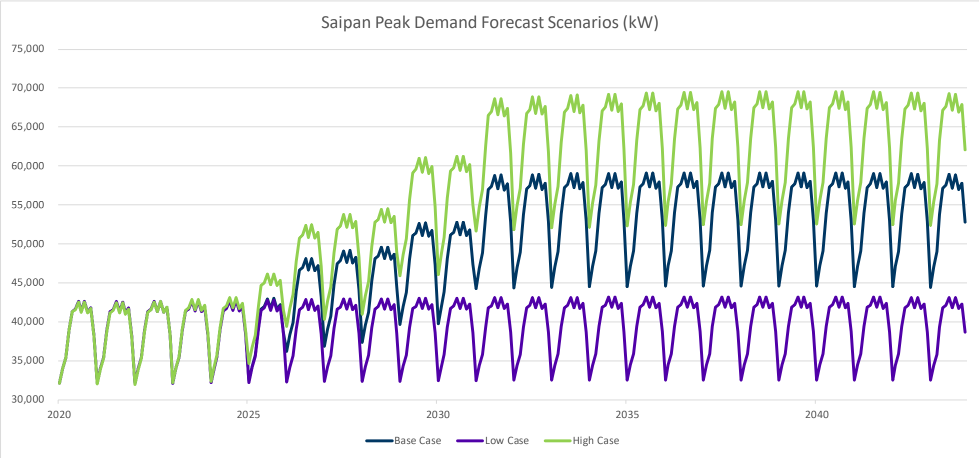




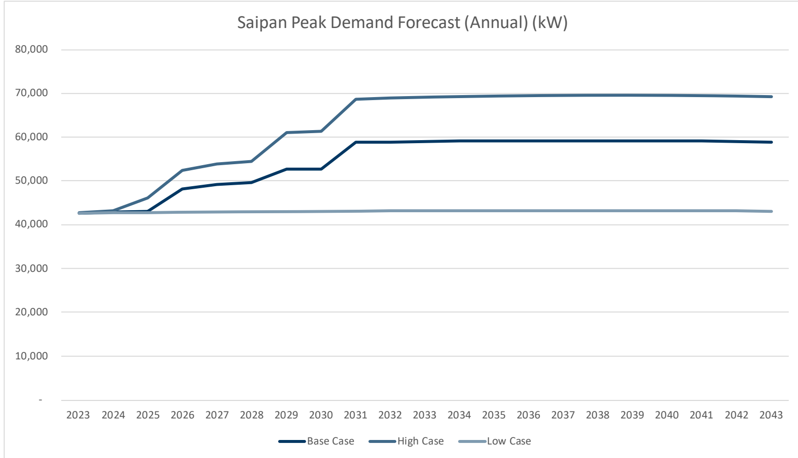
CNMI Demand Forecast - Summary Graphs

Saipan

Monthly

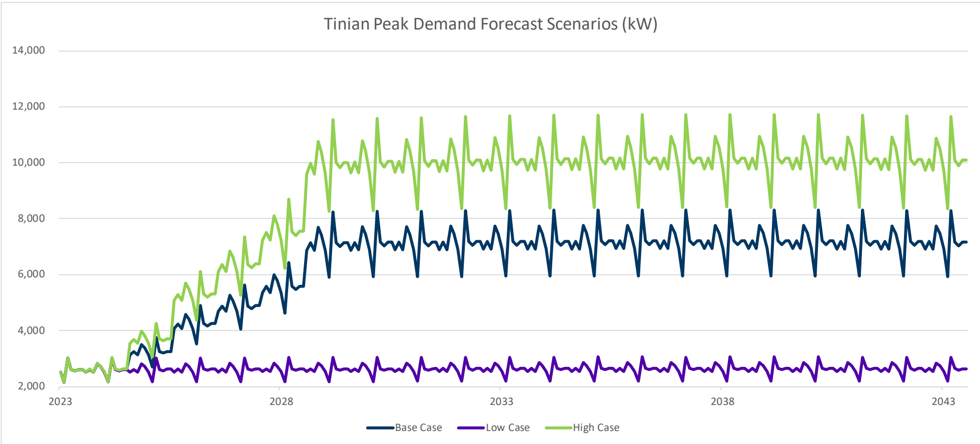


Annual



Tinian

Monthly



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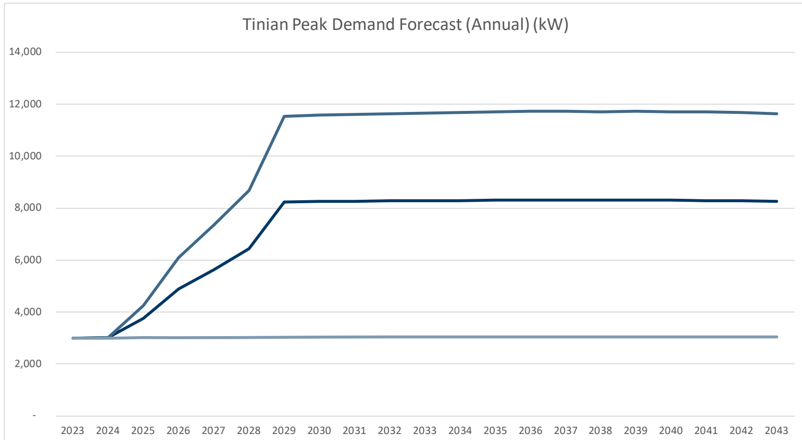
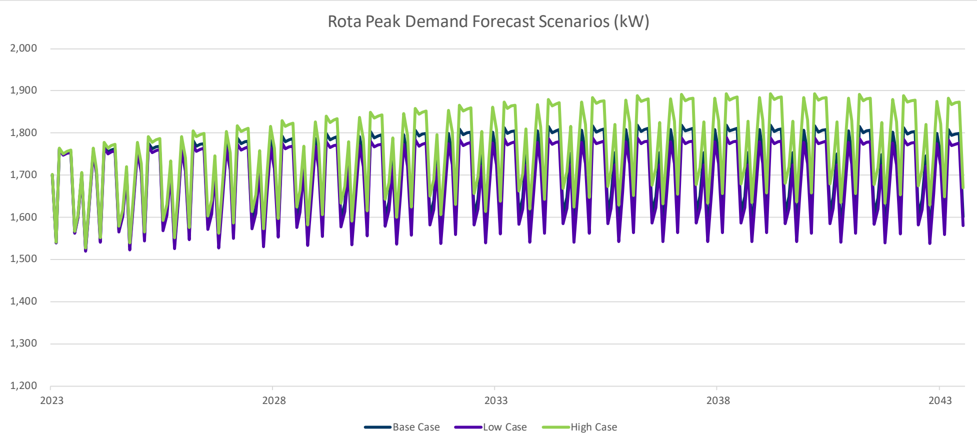


Rota

Monthly



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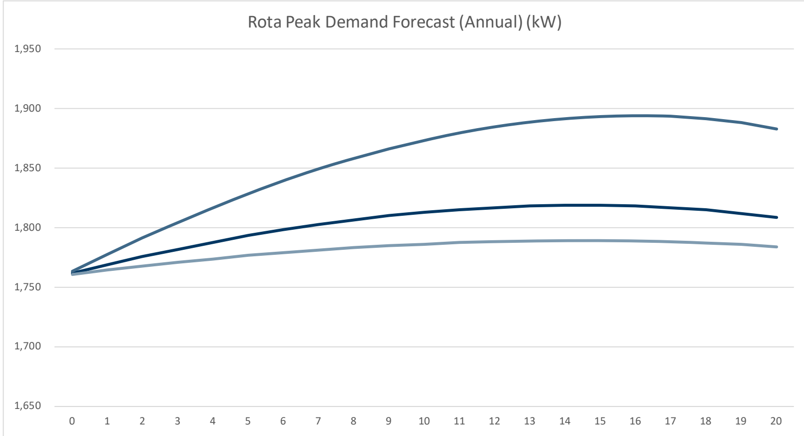

List of Expected Growth Projects in Saipan and Tinian (none confirmed for Rota)

Saipan

Start date 1/01/2024

Name of Project	Service	Feeder Location	Load Demand (MW)	Diversity factor (Base case)	Diversity factor (High case)	Load Demand (kW) - Base Case	Load Demand (kW) - High Case	Years till online from 2024	Expected Date
Sapian Globe Hotel	Hotel and Resort	Feeder 7	4.2	0.5	0.6	2100	2520	5	1/01/2029
Forson Dormitories	Warehouse and Dormitory	Feeder 7	0.06	0.5	0.6	30	36	9	1/01/2033
Imperial Pacific Resort Hotel	Casino	Feeder 2	9	0.5	0.6	4500	5400	7	1/01/2031
Honest Profit Saipan Resort Hotel	Hotel and Resort	Kiya 2	7.55	0.5	0.6	3775	4530	2	1/01/2026
Ocean Vista Resort	Hotel and Resort	Feeder 4	1.17	0.5	0.6	585	702	3	1/01/2027
H.S. Lee Commerial Building	Hotel	Feeder 2	0.27	0.5	0.6	135	162	3.5	1/07/2027
Villora Condotel Residence	Condominium and Villa	Feeder 7	0.54	0.5	0.6	270	324	4	1/01/2028
Beach Road Ocean Resort Complex	Hotel and Resort	Kiya 3	0.23	0.5	0.6	115	138	5	1/01/2029
Hyatt Hotel (currently off-grid)	Hotel and Resort	N/A	0.869	0	0.5	0	2100	5	1/01/2029
Aqua hotel	Hotel and Resort	N/A	0.248	0	0.5	0	2100	1	1/01/2025
		TOTAL (MW)	**24**			**11,510**	**18,012**		

Tinian

Name of Project	Service	Feeder Location	Load Demand (MW)	Diversity factor (Base case)	Diversity factor (High case)	Load Demand (kW) (Base Case)	Load Demand (kW) (High Case)	Years till online from 2024	Expected Date
Camp Tinian	Military	Feeder 4	0.689	0.5	0.75	344.5	516.75	2	1/01/2026
Divert Airfield	Military	Feeder 4	1.78	0.5	0.75	890	1335	5	1/01/2029
Tinian Diamond Hotel and Casino	Casino	Feeder 2	0.119	0.5	0.75	59.5	89.25	4	1/01/2028
Confidential Project - Phase 1	Military	-	1.2	0.5	0.83	600	1000	1	1/01/2025
Confidential Project - Phase 2	Military	-	1.2	0.5	0.83	600	1000	2	1/01/2026
Confidential Project - Phase 3	Military	-	1.2	0.5	0.83	600	1000	3	1/01/2027
Confidential Project - Phase 4	Military	-	1.2	0.5	0.83	600	1000	4	1/01/2028
Confidential Project - Phase 5	Military	-	1.2	0.5	0.83	600	1000	5	1/01/2029
		TOTAL (kW)				**4,294**	**6,941**		

Off-grid Hotels - Supporting Calculations		
Item	Hyatt Hotel	Aqua Hotel
Number of rooms	319	91
Average number of people per room	2	2
50% for additional usage	1.5	1.5
25% for support facilities	1.25	1.25
Average usage saipan residential	0.73	0.73
TOTAL (kW)	869.42	248.02

2018 - 2020 Expected Added Loads

#	Expected Date	Name of Project	Load Demand (MW)
1	Jun-18	Ocean View Resort	0.26
2	Jul-18	Economic Multiplier	
3	Jun-20	Federal Court	0.95
4	Jun-19	ISA Villas	0.21
5	Mar-19	Honest Profit	2.80
6	Mar-19	Royal View Hotel	0.25
7	Apr-19	Himawari Hotel	0.50
8	May-19	Economic Multiplier	
9	Oct-19	Zen Homes	0.40
10	Oct-19	Gualo Rai Park	0.50
11	Feb-19	Saipan Vegas	0.20
12	Dec-19	Art Ridge Vill. Homes	0.60
13	Jan-20	Capital Wonderland Resort	0.80
14	Apr-20	Economic Multiplier	
15	Jun-20	Saipan Garden Resort	3.00
16	Aug-20	BSI	4.00
17	Dec-20	Saipan Globe San Roque	0.50
18	Dec-20	BSI	4.00
		TOTAL (kW)	**18.97**

Appendix D

Power Systems Modelling

D-1 Saipan

The following table shows the proposed PV and BESS output, as well as existing synchronous generators for each of the scenario.

Table D. 1 Generators/ BESS output – Saipan

Name	Type	Output Active Power (MW)			
		Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b
GenPP1_DE1	Existing synchronous generator	Offline			
GenPP1_DE2	Existing synchronous generator	Offline			
GenPP1_DE3	Existing synchronous generator	Offline			
GenPP1_DE5	Existing synchronous generator	Offline			
GenPP1_DE6	Existing synchronous generator	Offline			
GenPP1_DE7	Existing synchronous generator	Offline			
GenPP2_G2	Existing synchronous generator	Offline			
GenPP2_G3	Existing synchronous generator	Offline			
GenPP2_G4	Existing synchronous generator	Offline			
GenPP2_G5	Existing synchronous generator	Offline			
GenPP4_G6	Existing synchronous generator	Offline			
GenPP4_G7	Existing synchronous generator	Offline			
GenPP4_G8	Existing synchronous generator	Offline			
GenPP4_G9	Existing synchronous generator	Offline			
GenPP4_G2	Existing synchronous generator	Offline			
GenPP4_G3	Existing synchronous generator	Offline			
GenPP4_G4	Existing synchronous generator	Offline			
GenPP4_G5	Existing synchronous generator	Offline			
GenPP4_G10	Existing synchronous generator	Offline			
Gen_Aggreko	Existing synchronous generator	Offline			
Small static generators (non-exhaustive)	Existing small generators	3.74	0	3.74	0
Naftan_PV and Naftan_BESS	PV and BESS	15	15	0	0
As Gonno_PV and As Gonno_BESS	PV and BESS	5	5	0.27	3.03
Kalabera_PV and Kalabera_BESS	PV and BESS	31.8	34.6	0	0

The following table lists the line and transformer loadings which are impacted by the proposed PV and BESS connection under the modelled scenarios.

Table D. 2 Thermal study results – Saipan

Name	Type	Loading (%)			
		Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b
Naftan_line	Line	90.6	90.6	3.5	3.9
PLIN_717	Line	1.5	1.5	1.1	1.0
PLIN_703_split_12	Line	90.8	90.8	4.1	4.6
Stat_5-POL_4218_K1	Line	123.4	120.8	6.3	6.1
As Gonno_line	Line	36.6	36.5	3.9	18.0
Line(2)	Line	36.6	36.5	3.9	18.0
Kalabera_line_1	Line	48.7	52.7	13.1	11.7
Kalabera_line_2	Line	82.4	86	7.7	11.7
Sub1_MV_N_Feeder4	Line	57.8	64.3	6.4	3.1
STAT_1-N_Feeder7	Line	54.7	55.9	2.8	3.0
Sub1_MV_N_Feeder1	Line	73.9	76.3	2.8	4.0
Sub1_MV_N_Feeder2	Line	117.9	115.8	7.9	6.1
TR_1_PP1	Transformer	59.3	61.3	3.7	4.9
TR_2_PP1	Transformer	40.6	42.3	2.1	1.3

The following table lists the voltage at the PoC and nearby busbars, including the 13.8 kV and 34.5 kV.

Table D. 3 Voltage study results – Saipan

Terminal/ Busbar Name	Nominal Line-to-Line Voltage (kV)	Magnitude (p.u.)			
		Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b
Terminal_Naftan	13.8	1.00	1.00	1.00	1.00
CUT_2724/ POL_2724 (PoC)	13.8	0.98	0.99	1.00	1.00
Terminal_As Gonno	13.8	1.00	1.00	1.00	1.00
Site 4/ BB (PoC)	13.8	0.99	0.99	1.00	1.00
Terminal_Kalabera	34.5	1.03	1.03	1.03	1.03
STAT_1/HV_BB1 (PoC)	34.5	1.01	1.00	1.03	1.03
STAT_1/HV_BB2 (PoC)	34.5	0.99	0.99	1.03	1.03
STAT1_MV_BB1	13.8	1.00	1.00	1.03	1.03

D-2 Tinian

The following table shows the proposed PV and BESS output, as well as existing synchronous generators for each of the scenario.

Table D. 4 Generators/ BESS output – Tinian

Name	Type	Output Active Power (MW)	
		Maximum Load Scenario	Minimum Load Scenario
DE#1	Existing synchronous generator	Offline	
DE#2	Existing synchronous generator	Offline	
DE#3	Existing synchronous generator	Offline	
DE#4	Existing synchronous generator	Offline	
DE#5	Existing synchronous generator	Offline	
DE#6	Existing synchronous generator	Offline	
Marpo Heights_PV and Marpo Heights_BESS	PV and BESS	8.6	2.5

The following table lists the line and transformer loadings which are impacted by the proposed PV and BESS connection under the modelled scenarios.

Table D. 5 Thermal study results – Tinian

Name	Type	Loading (%)	
		Maximum Load Scenario	Minimum Load Scenario
Line_Marpo Heights	Line	51.3	16.4
Line(183)	Line	42.0	13.4
Line(184)	Line	13.0	3.7
Line(185)	Line	6.0	1.7
Line(185)_a	Line	3.4	1.0
Line(186)	Line	1.1	0.3
St_Up_Tx 4.16/13.8kV	Transformer	86.0	27.0
St_Up_Tx 4.16/13.8kV (2)	Transformer	68.2	19.5

The following table lists the voltage at the PoC and nearby busbars.

Table D. 6 Voltage study results – Tinian

Terminal/ Busbar Name	Nominal Line-to-Line Voltage (kV)	Magnitude (p.u.)	
		Maximum Load Scenario	Minimum Load Scenario
Terminal_Marpo Heights	13.8	1.00	1.00
207 (PoC)	13.8	0.99	0.99
Robert E Kamosa Transmitting Station	13.8	0.98	0.99
Power Station 4.16 kV	4.16	1.00	0.98

D-3 Rota

The following table lists the line and transformer loadings which are impacted by the proposed PV and BESS connection under the modelled scenarios.

Table D. 7 Thermal study results – Rota

Name	Type	Loading (%)	
		Maximum Load Scenario	Minimum Loading Scenario
Line(154)_e	Line	27.3	2.1
OH_fdr	Line	27.4	2.2
St_Up_Tx 0.6/13.8kV	Transformer	59.5	4.7

The following table lists the voltage at the PoC and nearby terminals/busbars.

Table D. 8 Voltage study results – Rota

Terminal/ Busbar Name	Nominal Line-to-Line Voltage (kV)	Magnitude (p.u.)	
		Maximum Load Scenario	Minimum Load Scenario
Terminal(94)	13.8	0.989	1.000
fdr2_term6 (PoC)	13.8	0.992	1.00
Step_up Tx Bus	13.8	0.993	1.000
RE Bus 1	0.6	1.000	1.000

Appendix E

Stakeholder Engagement Workshop Mural Board

CUC Integrated Resource Plan Workshop

Love

Beautiful environment

Ocean

Fruit trees

Mountain life

Cultural identity

Cultural diversity

Humility

resilience

safe and family-friendly

Nice people

Wish

Safety

improvements

Responsible

Better economy

Opportunities

Sustainability

Solar incentive

Renewable power

Clean Air

Less diesel

Cohesiveness

We were more unified

Wonder

sustainable economy

how they afford life

if we will ever improve

advancement

more discretionary spending

economy

if economy will recover

Economic Support

why is it so expensive

compassionate

who is most vulnerable

Compassion

healthy

people

when advancements begin

safer

what it will look like

safety

safety

what will be out future

where we are going

Power plant

will the rates come down

cleanliness

if we can clean it up

accountable

clean and Disney like

support

committed

casino still standing

military

condition

A Loveable approach to infrastructure

A Loveable approach to infrastructure

Here are the verbal questions/comments posed during the q&a session at the end.

What are the economies of scale with solar? How many KW should we aim for for the utility to aim for?

Have we looked at solar and agriculture mixed together for this?

CUC is worried about competitiveness of bids, with the risk associated for longer term contracts/ performance based ...

Catastrophic battery failure - risk

CUC shared the biggest struggle is finding the funding

rate payers buy in, are we paying for this upgrade?

How to ensure the successful bid is accountable in the longrun?

Have we looked at goats to maintain the solar farm areas?

How large a workforce will be required to operate? 10-15 people

Typhoon/Cyclone resilience considered.

Have wild dogs been considered when planning security measures on the solar farms?

Same respondent:

Suggestion: Run the CUC like a business. Perception that there is nepotism or other practices resulting in poor performance of the CUC.

Perception that CUC is engaged in cronyism

Frustration that the energy shift studies have taken so long 22+ years ghd.com

The Power of Commitment