CNMI Strategic Energy Plan

CNMI Office of The Governor, Energy Task Force

April 21, 2023

→ **The Power of Commitment**

GHD [380]

Del Sol Building Beach Road Garapan PMB, Box 10000

Saipan MP, Northern Marina Islands 96950, United States

T [+1 670 234 0483] | **F** [+1 670 234 0483] | **E** saipan@ghd.com | **ghd.com**

Printed date	08 August 2022
Last saved date	08 August 2022
File name	https://projectsportal.ghd.com/sites/pp18_02/cnmisenergypolicy/ProjectDocs/CNMI Strategic Energy Plan Update.docx
Author	Arsh Rattan, Dennis Stanley, Henry Le, Johannes Rickermann, Matt Kennedy, Jordan King
Project manager	Matt Kennedy
Client name	CNMI Office of The Governor, Energy Task Force
Project name	CNMI Strategic Energy Plan Update
Document title	CNMI Strategic Energy Plan | Draft
Revision version	Rev [02]
Project number	11220949

Document status

Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
00	01	MK/JR/DS/AR/HL	Matt Kennedy		Matt Kennedy		3/1/2022
00	02	MK/JR/DS/AR/HL	Matt Kennedy		Matt Kennedy		8/17/2022
00	03	MK/JR/DS/AR/HL	Matt Kennedy		Matt Kennedy		4/21/2023

This update of the CNMI Strategic Energy Plan was prepared and facilitated by GHD Inc. under the guidance of the CNMI Office of Grants Management and the CNMI Governor's Energy Task Force.

ACKNOWLEDGMENTS

CNMI Office of Grants Management (OGM) and GHD thanks the U.S. Department of the Interior's Office of Insular Affairs (OIA) for providing funding for this effort. In particular, OGM would like to thank the Secretary of the U.S. Department of the Interior Honorable Deb Haaland, OIA Director Mr. Nikolao Pula, OIA Deputy Assistant Secretary Mr. Keone Nakoa, OIA Program Manager Ms. Krystina Borja Alfano, OIA CNMI Desk Officer Mr. Francisco Taitano, OIA CNMI Field Representative Mr. Harry C. Blanco for their financial assistance and leadership in this Strategic Energy Plan update for the CNMI.

OGM would also like to thank and acknowledge all the members of the CNMI Governor's Energy Task Force for their dedication to the ongoing energy transformation efforts in the CNMI: Arnold Palacios, Thelma Inos, Gary Camacho, Epi Cabrera, Frankie Angel, A. Kodep Ogumoro-Uludong, Erin Derrington, Anne Crocket, Adrian Reyes, Marianne Teregeyo, Deveney M Dela Cruz, Mariano Iglecias, Elizabeth Balajadia, Vincent Attao, Megan Cruz, Mendiola Deron, Paul Reyes, and William Castro.

In addition, the following GHD staff are acknowledged for their roles in the development, review, and finalization of this strategic energy plan update: Matt Kennedy, PE, Johannes Rickermann, Dennis Stanley, Arsh Rattan, Henry Lee, Jordan King, and Andre Tenorio, PE.

Executive summary

This Strategic Energy Plan (SEP) update provides a road map for the Commonwealth of the Northern Mariana Islands (CNMI) to implement cost-effective energy management solutions, including efficiency/optimization upgrades, demand side management, and use of renewable and future energy solutions. Except for a few small renewable energy systems consisting mostly of residential rooftop solar, the CNMI is dependent on fossil fuels for meeting its energy generation needs. As a result, the CNMI is highly exposed to volatility in fuel pricing and availability that impacts security, the environment and economic viability. The isolated location of the CNMI makes fossil fuel importation and new project development a challenge, underscoring the need for a reduction in fossil fuel dependency by tapping indigenous energy resources.

The CNMI government retained GHD to provide an update to the SEP originally developed in 2013. GHD has documented existing technologies and energy use, evaluated demand management strategies and renewable energy sources, and estimated the cost of applying these measures. GHD has compared the cost of energy production during the last years with the cost of providing energy through renewable sources.

GHD applied a provisional multi criteria analysis methodology to arrive at the best mix of feasible and cost-effective options. Through the analysis and evaluation, the following energy and demand management options are recommended to be considered in detail:

- Expand use of residential and commercial rooftop solar PV systems.
- Pursuit of utility size solar PV systems.
- Integrate Battery Energy Storage systems to provide grid support for high penetration intermittent energy resources.
- Further investigation of onshore typhoon rated wind applications.
- Further investigation of Pumped Hydro Energy Storage (PHES) systems for longer term storage of intermittent energy resources.
- Expand use of solar hot water systems as a demand reduction measure.
- Rollout smart metering systems combined with a time-of-day tariff.
- Continue developing a public transportation system, and incentivize more fuel-efficient and electric vehicles (EVs)
- Invest in infrastructure to promote and support expanded use of EVs.
- Address water system losses to reduce energy required for pumping.
- Further investigation of emerging technologies for future adaptive integration, including hydrogen and offshore wind

In the policy and regulatory realm, the CNMI has tools at its disposal to reach its sustainable energy goals and decrease dependence on fossil fuels. Continued implementation of prioritized strategies such as renewable energy incentive schemes, public-private partnerships and demand-side management initiatives are available. Preferred technology options could be incentivized by capital subsidies, feed in tariffs or administrative rules.

Many of these recommendations require further study and analysis to confirm feasibility with consideration of technical viability, capital cost, operation and maintenance cost, and community acceptance. The CNMI government should use this plan to pursue available funding through the U.S. federal government and other sources, including public-private partnerships (PPP), to confirm viability and fund implementation of programs and high penetration renewable energy systems.

Community outreach and public education should be integral to the pursuit and implementation of any of the recommended energy and demand management options. Public literacy of energy issues is critical to achieve buy-in and effective implementation of energy options and strategies.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.4 and the assumptions and qualifications contained throughout the Report.

Contents

Table index

Figure index

Appendices

Acronyms

AEMO	Australian Energy Market Operator
AMI	Advanced Metering Infrastructure
aMSL	Above mean sea level
BES	Battery energy storage
BOE	Barrels of oil equivalent
BTU	British thermal unit
CAPEX	Capital Expenditure
CHCC	Commonwealth Healthcare Corporation
CHPP	Combined Heat and Power Partnership
CNMI	Commonwealth of the Northern Mariana Islands
COTA	Commonwealth Office of Transit Authority
CO2/CO_2	Carbon Dioxide
CUC	Commonwealth Utilities Corporation
DER	Distributed Energy Resource
DOI	U.S. Department of the Interior
DOW	U.S. Department of Energy
DPW	Department of Public Works
DR	Demand Response
DSM	Demand Side Management
EE	Energy Efficiency
EPA	Environmental Protection Agency
ETF	Energy Task Force
EV	Electric Vehicle
FEMA	Federal Emergency Management Agency
FERC	U.S. Federal Energy Regulatory Commission
FiT	Feed-in tariffs
FSL	Full supply level
ft	Foot or feet
ft/s	Feet per second
GDP	Gross Domestic Product
GHI	Global Horizontal Irradiance
GPA	Guam Power Authority
GSHP	Ground Source Heat Pump
H2S	Hydrogen Sulfide
HMGP	Hazard Mitigation Grant Program
HOMER	Hybrid Optimization of Multiple Energy Resources
HV	High voltage
IDSM	Integrated Demand Side Management
IPP	Independent power purchase/producer
IRP	Integrated Resource Plan
ITC	ITC Investment Tax Credit
km/h	Kilometers per hour
kV	Kilovolt
kW	Kilowatt
kWhr	Kilowatt-hour
LCOE	Levelized cost of energy
LED	Light emitting diode
LNG	Liquified natural gas
m	meter
m/s	Meters per second
MGD	Million gallons per day
mph	Miles per hour
MW	Megawatt/megawatt
MWhr	Megawatt-hour

MSL	Mean sea level
MSW	Municipal Solid Waste
NGBS	National Green Building Standard
NMHC	Northern Marianas Housing Corporation
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
OGM	Office of Grants Management
OIA	Office of Insular Affairs
OPEX	Operational Expenditure
PA	Public Assistance
PHES	Pumped hydro energy storage system
PPP	Public-private partnership
PSS	Public School System
PV	Photovoltaic
RDF	Refuse Derived Fuel
RNG	Renewable Natural Gas
RO	Reverse Osmosis
RPS	Renewable Portfolio Standard
SAT	Single Axis Tracking
SEP	Strategic Energy Plan
TBR	Time-based rates
ToU	Time of use
U.S.	United States
USD	United States Dollar
V2G	Vehicle-to-Grid
WTG	Wind Turbine Generator
WWTP	Wastewater Treatment Plant

1. Introduction

1.1 Background

The Commonwealth of the Northern Mariana Islands (CNMI) is an unincorporated territory and commonwealth of the United States (U.S.) that is geographically isolated from the mainland United States. It is an archipelago that consists of 14 islands located north of the U.S. territory of Guam in the North Pacific Ocean (roughly 15º N, 145º E). This isolated location makes fossil fuel importation and new project development a challenge, underscoring the need for a reduction in fossil fuel use by tapping indigenous energy resources.

Except for a few small renewable energy systems consisting mostly of residential rooftop solar, the CNMI is dependent on fossil fuels for meeting its energy generation needs. There are no natural oil reserves in the islands, forcing the CNMI to import all its fuel oil at relatively high shipping rates and fuel prices. The primary electric power plants in the CNMI are powered by diesel fuel which is shipped from Singapore.

As a result of the economic impacts of fluctuating energy prices — including the record high price for oil in 2008 and again in 2022 — and continued global economic instability caused by the COVID-19 pandemic and geopolitical events, the CNMI recognizes the need to address energy consumption and the associated costs of energy. The cost of oil and petroleum-based fuels are expected to increase over time and could also increase in volatility due to uncertainty in markets, supply chains and geopolitics. Energy security is also a priority and by reducing the need for imported fossil fuels and investing in indigenous resources, the CNMI can develop an energy future that is more economically sustainable and resilient.

The Commonwealth's population increased dramatically during the 1980s and 1990s and has remained stable over the past two decades. The population is likely to decrease as new immigrant worker laws take effect. This population stagnation, combined with a significant reduction in tourist visitors due to the COVID-19 pandemic has resulted in a smaller electric utility customer base and reduced demand, which may require additional electricity rate increases to cover electricity production and other fixed utility operating costs.

The CNMI has few non-renewable resources. Relying heavily on fossil fuel imports, the CNMI is subject to substantial volatility in fuel pricing and availability that impacts security, the environment and economic viability. However, the unique situation of the CNMI also offers many ecological advantages as the Commonwealth has viable sources of alternative energy which can be cost-effective compared to current electricity generation. These resources can provide long-term energy-price stability and offer other environmental and health benefits resulting in reduced air emissions and waste reduction.

Renewable energy standards assist with reducing dependence on fossil fuels and contribute to a reduction of carbon dioxide in the atmosphere. The standards define renewable energy penetration targets as a percentage of the energy demand total. Standards range from 20% at the lower end to up to 99% (Norway). A set standard can assist with future funding opportunities and encourage investment into renewable energy.

1.2 The Energy Planning Process

In March of 2010, the U.S. Department of the Interior (DOI) Office of Insular Affairs (OIA) sponsored a regional energy meeting in Golden, Colorado, that included the CNMI, American Samoa, and Guam. CNMI delegates from the Governor's Office, the Commonwealth Utilities Corporation (CUC) and the Northern Marianas College (NMC) met with representatives from the U.S. Department of Energy (DOE) and senior principals from DOE's National Renewable Energy Laboratory (NREL) to discuss ways to improve energy efficiency and increase the deployment of renewable energy technologies in the Pacific. As a result of this meeting, the CNMI Governor established an energy task force to help coordinate energy policy and promote long-term planning.

In the summer of 2010, OIA funded NREL to conduct an initial technical energy assessment for CNMI that detailed energy consumption and production data and established an energy baseline. This assessment was used to conduct an energy analysis that estimated the energy efficiency and renewable energy potential for the CNMI.

The *Commonwealth of the Northern Mariana Islands Initial Technical Assessment Report* was published in July 2011 and was used by the CNMI Energy Task Force (ETF) as the starting point for developing the July 2013 Strategic Energy Plan (SEP).

During the summer of 2021, the ETF was reformed to provide guidance, input and assistance in the development of this update to the SEP.

1.3 Purpose of this Report

This report updates the July 2013 SEP and provides a road map for further cost-effective energy management solutions, including efficiency/optimization upgrades, demand side management, and use of renewable and future energy solutions. The report provides a reference to the Commonwealth Utilities Corporation (CUC) short-, medium- and long-term goals, with the aim of reducing cost and progressing towards a low carbon transition. The report includes the following elements:

- Overview of the current state of alternative energy used in the CNMI.
- Demand Reduction Scenarios.
- Realistic cost of energy comparison based on data collection.
- Benefit-cost analysis using current figures to determine viability of all renewable energy options.
- New policy and framework that may be used or introduced into legislation.
- Energy efficient strategies for government, private sector, and community.
- Viable alternative energy options for each senatorial district based on compiled data.
- Alternative energy recommendations based on finding/data collection.
- A step-by-step plan to initiate and incorporate alternative energy for the CNMI.
- Potential challenges/factors for all renewable energy strategies and provide recommended expertise.

1.4 Scope and Limitations

This report: has been prepared by GHD for the CNMI OGM and should only be used and relied on by the OGM and other approved CNMI agencies for the purpose agreed between GHD and OGM as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than OGM 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.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information 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 after the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on available information and assumptions made by GHD described in this report (refer section(s) 1.5 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

1.5 Assumptions

The assessment made in this report is based on the information provided by OGM, DPW and CUC to GHD. Additional information has been requested, and not received at the date of this draft report. This assessment may be revised on the receipt of the requested information.

2. Methodology

The 2013 SEP performed a simple “wedge” analysis, where a base case assumed no reduction in fossil fuel use and low- and high-impact scenarios assumed a 20% and 53% fossil fuel reduction, respectively, compared with the base case. A 16-year planning period was assumed with no annual growth in energy consumption. The intent of this approach was to take a high-level view of the potential fossil fuel reduction from various commercially available technologies. Energy was reported in barrels of oil equivalent (BOE). Each scenario assumed some reduction in energy use through efficiency in generation and consumption, as well as an increase in use of various sustainable energy sources, including wind, solar, geothermal and energy from waste. The qualitative analysis showed a conceptual trend in the energy mix over time but provided no details and quantification of actual costs or feasibility of implementing market-based strategies aimed at increasing the sustainable portion of the CNMI’s energy portfolio.

In this SEP update a multi-criteria analysis (MCA) is used as the technical approach for quantifying and evaluating alternative energy options. The MCA is an objective and systematic methodology that is used to evaluate projects and options beyond a cost appraisal. It is used to evaluate variables such as project sustainability, time savings and social and environmental impacts. It is an appraisal technique that addresses the multi-criteria nature of projects and provides a mechanism to mitigate the risks associated with each criterion. The MCA methodology shown in Table 1 below was used to structure and combine the different assessments considered for decision-making.

Table 1. MCA Methodology for Energy Assessment

Step	Description
Drivers for Change	Identify key drivers for roadmap and opportunity identification.
Existing Technologies	Identify key areas to prioritize for emission reduction opportunities.
Energy Analysis	Reviewing the load requirements: Consideration of daily, seasonal variation and applicable future load growth including future load development initiatives.
Energy Options and Strategies	GHD will consider options across the load demands, ranging from solar PV and Battery storage, Solar thermal water heating, Wind generation, Geothermal potential and Ground Source Heat Pumps, and pumped hydro storage with consideration of water security.
Conclusions and recommendations	Identify priorities require future detailed assessment

There are many energy efficient and renewable energy technologies available on the market today. Included within the MCA were mature technologies that are commercially feasible. There are other technologies that the CNMI may investigate for future study, some of which are included in the Energy Options and Strategy section of this report, but for the basis of this strategic plan, technologies included here meet the following criteria:

- Commercially feasible
  - Tested and demonstrated
  - Carry warranty
  - After sales service support and availability of spare parts
- Ready for immediate deployment
- Demonstrated to be a sound investment
- Financing available from private sector organizations.

There are several power generation options available to the CNMI including engine generators that use diesel, heavy fuel oil, liquefied natural gas, and nuclear technologies, as well as renewable energy technologies such as solar, wind, wave, biomass, waste-to-energy, and geothermal energy. Each of these technologies has its own operational characteristics, initial and ongoing operational costs, implementation time horizon, and near- and long-term environmental impacts. Diesel is currently the primary energy source and is expected to remain a key component of the CNMI’s energy portfolio, but its use may be balanced with renewable sources to reduce the carbon footprint and reduce reliance on fossil fuels. Most large-scale power generation options require a large capital investment. For these reasons, any shortlisted technology should be identified through a process of strategic energy analysis to recommend the most appropriate choices are made for the current and future energy needs of the CNMI. Increased power generation is not the only option available to address the CNMI’s energy needs. Demand management, energy conservation and energy efficiency are cost-effective methods to potentially reduce the need for increased investment in electricity generation.

For the purposes of this SEP update, commercial clean energy technologies considered include energy conservation and efficiency measures and the following energy options:

- Current and potential future scope of domestic solar photovoltaic (PV) along with storage options.
- Potential for solar thermal water heating.
- Biological and thermal energy production from waste infrastructure that would allow for effective management of solid waste and wastewater produced locally.
- Demand Side Management (DSM) to reduce diesel consumption.
- Installation of commercial scale renewables, which includes commercial scale solar/battery systems (microgrids) serving remote communities.
- Onshore and offshore wind energy generation potential.
- Geothermal energy potential.
- Ground source heat pumps for public buildings/offices.

GHD did not assess opportunities associated with other emerging renewable energy technologies such as ocean thermal energy conversion, marine hydrokinetic energy, or nonrenewable technologies such as nuclear, coal, and natural gas. The nonrenewable technologies of particular interest to the Energy Task Force (ETF) have been included in this plan and should be investigated further by the ETF as recommended in later sections.

This plan discusses renewable energy and energy efficiency technology potential as well as current barriers and opportunities. Further investigation is needed to quantify the impacts of specific technologies, programs, and/or projects. Environmental, regulatory, legislative, and detailed financial considerations must also be addressed during the project development process. Technologies and markets are constantly changing and evolving. Continual reevaluation of options and strategies is necessary. All prices listed for each technology assessed are in USD and are derived from market estimates, quotations and GHD’s experience in similarly scoped projects.

3. Drivers for Change

The Commonwealth of the Northern Mariana Islands (CNMI) consist of 14 islands in the northwest Pacific Ocean. The three most populated islands with energy generation and distribution systems are Saipan, Tinian, and Rota. Power systems on Saipan and Rota are owned and managed by the Commonwealth Utilities Corporation (CUC). The Tinian power plant was financed, designed, procured, constructed, and then operated and maintained by the Pernix Group, a private company, on behalf of the CUC up until March 2022 when the contract ended. Due to its location, the CNMI is almost fully dependent on fossil fuels to meet current energy needs. This leads to the high cost of energy ($0.18 – $0.20 per kilowatt hour) and an increase in carbon emissions. To tackle these issues and explore other alternative technologies in areas of generation and energy production, a Strategic Energy Plan (SEP) was developed in 2013 by the National Renewable Energy Laboratory (NREL) under the direction of the U.S. Department of the Interior (DOI) Office of Insular Affairs (OIA).

Existing policy supporting energy sustainability in the CNMI includes requirements for the use of renewable energy, energy efficiency and for other energy and cost-saving measures. An amendment to Public Law 15-23 allows customer-generator or private power producers to produce and sell electricity produced by renewable energy to the CUC on a large-scale basis and to provide incentives to produce renewable energy in the Commonwealth. The intent of this legislation is to integrate the use of renewable energy into the CUC power system as soon as feasible to alleviate the cost of purchasing fuel each month for its diesel generators.

The CNMI's current SEP needs to be updated to investigate options to reduce fossil fuel dependency by developing other sustainable sources of energy in the market that could be integrated into the current energy portfolio. The intent of the SEP is that it be a living document. In response to a Request for Proposals issued by the Office of Grants Management (OGM), GHD assisted the CNMI government by providing professional and technical services to update the 2013 SEP. The CNMI is currently investigating new low-cost and energy-efficient technologies available in the market, which should also support its obligations under national conventions related to reducing its carbon footprint. These technologies will include new sources of power generation and other energy solutions suitable for the senatorial districts of Saipan, Tinian, and Rota. Some may also be applicable to northern island homesteads.

The value of the CNMI SEP is that it is a dynamic living document providing an energy transformation roadmap. Accordingly, the main objective of an updated SEP is to assess the effectiveness of energy strategies applied since the development of the SEP in 2013 and to provide a strategic roadmap for how the CNMI's energy needs can be met in the future. The updated SEP also includes scenarios with cost-benefit analyses comparing the alternative sources of energy against current diesel-powered generation. Demand Reduction Strategies are also identified.

3.1 CNMI Energy Task Force

During the Summer of 2021, the CNMI Energy Task Force (ETF) was reformed. GHD worked with the ETF, DPW Energy Division and the CUC to develop this SEP update and provide solutions related to CNMI's energy needs.

VISION

To create a sustainable energy future for the CNMI.

MISSION

The CNMI ETF is charged with development, update, and oversight of a strategic energy plan for the CNMI with the overarching goals of reducing dependence on imported fossil fuel and establishing a sustainable energy future for the Commonwealth in the interest of improving quality of life and promoting economic prosperity. It is anticipated that this strategy will be a living document, evolving as potential energy strategies are tested, and therefore beyond development of the initial SEP. The role of the ETF will be to assess the efficacy of energy strategies implemented and to evaluate and recommend new approaches as appropriate.

3.2 Power system risk mitigation

The CNMI is exposed to external threats and risks impacting its power infrastructure. External risks like tsunamis and earthquakes are elevated due to its location close to the subduction zone of the pacific plate. External risks like typhoon, flooding, wildfires, and rising sea levels are increasing due to human acceleration of climate change. It is expected that the severity and impact of events due to climate change will increase further within the next decade. Severe weather events and economic and political disturbances might impact the security of fuel supplies.

Emergency response plans for each island should detail an adaptive response depending on the severity of the emergency, and provide guidance on resources, tools, and parts requirements to act out the planned responses.

It is prudent to harden the power supply infrastructure to mitigate the effect of risk events. The Smart, Safe Growth Guidance Manual provides guidance on how to plan for resilient infrastructure within a budget constraint, and it provides useful measures to apply in the power system planning and operation space.

Undergrounding of strategic overhead powerlines is costly, but it mitigates the destructive effect of typhoons on an essential piece of infrastructure and reduces bushfire risk and exposure. Where undergrounding is not feasible or cost-effective, strengthening or replacement of strategic poles and structures could be considered.

Buildings and structures for power systems should be rated to withstand the forces of typhoons and earthquakes and designed to minimize exposure to flying debris. Power stations and substations should be built in elevated locations to reduce the impact of sea level rise, storm surge, and flooding events.

Evaluate the practicality of utilizing backup diesel generators for major public facilities, buildings and shopping centers and integrating them into the emergency response plans should a power plant catastrophically fail.

To reduce the dependency on external fuel supplies and contribute to the mitigation of global warming locally, available renewable energy should be extended.

There are economic tools available to make a financial cost / risk assessment, like the concept of the value of lost load, but these concepts do not fully comprehend the social impact of the severe natural events mentioned above.

It is recommended to undertake the following steps to improve the strategic position for CNMI’s power infrastructure.

– Review existing standards and codes of practice to ensure typhoon risks, flooding, wildfires, and earthquake risks are carefully considered in the design of future infrastructure. Amend codes of practice where required.
– Analyze the power infrastructure to identify weaknesses in design or installation. Perform a cost / risk assessment to prioritize high impact / low-cost solutions over low impact / high-cost solutions to the benefit from investment.
– Systematically harden the infrastructure through strategic funding and during the repair and replacement process.
– Invest in renewable energy to reduce reliance on external fuel supplies.

3.3 Inequity of access to power infrastructure across Islands

Access to major power system infrastructure is currently only available on Saipan, Tinian, and Rota. People living on other island do not have equal access to public power infrastructure. With the maturing of renewable energy solutions, the development of small stand-alone power systems has become economically viable when compared to traditional diesel only fueled small power island systems. Utilities in the U.S. and Australia are implementing standalone power systems even in fringe of grid situations to improve power system reliability issues caused by long distribution powerlines.

Consideration should be given to provide power infrastructure to smaller island communities currently not being serviced. It is recommended to perform a feasibility study to implement a scalable pilot system, which can then be rolled out to low population and remote communities, removing some of the inequality of power supply across the islands.

4. Existing Technologies

4.1 General

Currently, the power supply for each of the main islands of Saipan, Tinian, and Rota is produced using ultra-low Sulphur diesel fuel with annual consumption of 19 million gallons[1]. There are a quite a few small renewable energy systems, small scale solar PV (5.08 MW capacity in total) and wind (0.144 MW total) installed at residential, public facilities and schools[2] on Saipan. In 2021 the Public School System (PSS) began a project to install solar PV at its public school facilities as part of a long-term goal under Public Law 18-75 to reduce the utility costs PSS owes to the CUC and ensure the PSS remains financially stable and to mitigate learning loss following natural disasters. No significant renewable energy installations have been installed on Tinian (50 kW) and Rota (26.5 kW) at present, however there are plans being developed for utility scale solar plants for Tinian and Rota. 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 shown in Table 2 below:

Table 2. CNMI Power Generation Summary – Dec 2020

Location	Generation Capacity MW	Peak Demand MW	Fuel Storage capacity Days	50% loss impact
Saipan	40.3	30.6	7	2-3 weeks without power
Tinian	20	2.2	5	30 days without power
Rota	5.6	1.5	5	30 days without power

The primary load for CNMI is from the commercial sector and some small industrial activities (excluding government), accounting for more than half the electricity used in the Commonwealth. The residential sector accounts for between 25% and 30% of electricity consumption in the CNMI[3]. The CNMI had a 20% target of renewable energy generation in 2016 which has not yet been met[4]. As of Dec 2021, there is a total 5.08 MW of grid connected PV solar across Saipan, Rota and Tinian. A majority of the solar (98%) is installed on Saipan. Figure 1 shows the energy consumption by sector and energy generation mix in 2010.

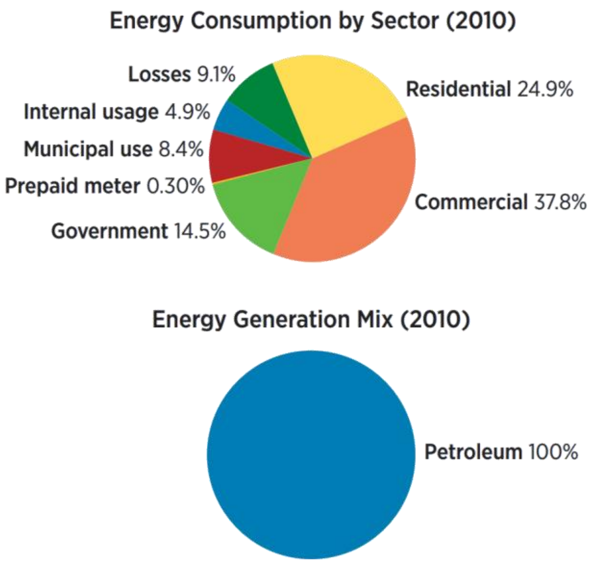


Figure 1. Energy Consumption by Sector and Generation distribution for CNMI - National Renewable Energy Laboratory

There remains a significant opportunity for renewable generation for the CNMI to reduce dependance on fuel imports and mitigate the 50% capacity loss impact for the islands.

---

[1] O&M and fuel cost CUC 2020/2021
[2] CUC Response to RFI – Netmetering customers Phase 1 and phase 2
[3] U.S Energy Information Administration, Northern Mariana Islands Profile, Territory Profile and Energy Estimates. https://www.eia.gov/state/analysis.php?sid=CQ
[4] Commonwealth of the Northern Mariana Islands, House of Representatives, H. B. No. 18-165, SD1 (July 22, 2014). https://cnmileg.net/documents/files/PL%2018-62%20(HB%2018-165%20SD1%20Renewable%20Energy%20Portfolio%20Amendment).pdf

4.2 Disaster Resiliency

Natural disasters, particularly typhoons, pose a significant risk to CNMI power generation, distribution, and service. Following the most recent Category 5 Typhoon Yutu in October 2018, CUC power was offline in many areas for months, and some residents and businesses did not have services reactivated until months after the primary grid was re-energized. As shown in Figure 2, most power is distributed overhead, and many power poles were knocked down during periods of high wind.

Figure 2. Damaged power poles during Typhoon Yutu along Middle Road / Chalan Pale Arnold (Route 30)

Following the most recent typhoon disasters, the CNMI government, private businesses and residents have been building energy system resiliency and installing source of emergency power, specifically small back-up engine generators, that can be activated following a power outage using manual or automatic transfer switches. These systems are part of a larger program in the CNMI to improve disaster resilience and mitigate loss of building and infrastructure use during periods of prolonged power outages. Critical public facilities which have or are planning investments in emergency power generation include Commonwealth Health Care Corporation (CHCC) hospitals, CUC facilities including water wells, water pump stations and sanitary sewer lift stations, and PSS facilities.

Additionally, CUC is planning a Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program (HMGP) funded project to install a permanent underground power line between Power Plant 1 on Saipan and the CHCC hospital to reduce the risk of outage from downed power lines. Sanitary sewer lift stations on Saipan are also planned to have overhead power services installed underground, as overhead services are typically the weak link that fails first during periods of high wind.

These important investments are intended to support the community during and after natural disasters and allow life and commerce to recover more quickly following such an event. Many of these emergency power systems are being funded through the FEMA HMGP, a funding sources that the CNMI government should continue to pursue for energy resiliency projects. These systems should be designed and installed to integrate with the existing electrical grids on each island, and to support future deployment of renewable energy systems. Future investment in energy resiliency is recommended in energy system resiliency, including continued undergrounding of critical segments of power distribution lines, use of concrete power poles rather than wood and installation of automatic distribution circuit disruptors.

4.3 Network Connection and Physical Constraints

A key constraint for renewable energy generation will be integration into the existing power distribution network and power balancing. The power distribution network diagram for Saipan, Tinian and Rota are included in Appendix B. Feeders are color matched for each network. As shown in the Appendix B figures, Saipan has the most diverse distribution network of the islands based on the data provided by CUC. There is limited or no electrical infrastructure in areas ideal for commercial scale renewable generation, particularly wind. Solar PV installations can be installed in or near populated areas, whereas horizontal axis wind turbines should be installed in more remote locations to minimize the impact of the noise generated and the visual impact on the landscape. Installation in these locations would require additional study and investment in electrical distribution infrastructure.

Distributed energy resources (DER) are small-scale electricity supply or demand resources that are interconnected to the electric grid. They are power generation resources and are usually located close to load centers and can be used individually or in aggregate to provide value to the grid. To keep the power network reliable when achieving a significant amount of DER, DER control systems should be considered allowing to manage DER power input into the network and avoiding underloading fossil-fueled fired power generation. Energy storage systems should be considered to stabilize the network and potentially allow for shifting renewable energy from high supply / low demand to high demand / low supply times.

Larger renewable power facilities will require power system studies to be undertaken to identify network constraints and ensure power system stability and system protection is adequate.

4.3.1 Renewables

The environmental and economic impacts of additional rooftop solar PV and ground mounted solar PV are described in Section 6.1. As mentioned, there are currently some public small scale solar PV installations around the CNMI. According to the CUC and DPW Energy Division, there are only independent extra-small-scale and demonstration wind installations in the CNMI. For the purposes of this report, existing wind installations are not considered.

Key factors influencing the amount of rooftop solar PV installed at the residential level is dependent on the population density, affordability, and utility approvals. At the time of writing this report, there is a 26% federal Investment Tax Credit (ITC[5])[6] offered for rooftop solar PV systems including battery storage. This nominal rate will be used for all cost estimate calculations, however it is subject to change. The Net Energy Metering program also incentivizes renewable energy installation at the residential scale by allowing solar PV energy generation to back feed the grid during times of overproduction and receive credit for electricity consumption when there is no solar resource available. At the time of this SEP update, there is no peak and off-peak tariff structure for solar. The islands also have abundant flat lands for ground mounted solar PV. Foundation suitability for cyclonic conditions will be site specific and therefore has not been considered. Section 5.5 models potential savings that PV capacities by percentage of total generation. For Saipan, this entails a scale of larger than 10 MW of solar PV and starting from less than 1 MW for Rota and Tinian.

On Tinian, deployment of significant renewables has been restricted as the power plant is beholden to a power purchase agreement, which expired in March 2022. The end of this power purchase agreement opens the possibility for development of renewable energy systems on Tinian.

4.4 Energy Usage

4.4.1 Current Energy Usage

Seasonal Variation

The two key seasonal changes in climate that would typically affect energy usage is the drier season between December and June and the humid, rainy season between July and November. Temperature data shows the temperature is consistent year-round. Figure 3 shows the average trend in monthly peak energy loads for Saipan, with the peak consumption occurring between July and November. This is likely attributed to the population spending more time indoors during the rainy season and compounded by the hotter apparent temperature. Load profile data was not available for Rota (aggregate data only) or Tinian at the time of writing this report. However, it is assumed that both islands follow a similar profile at a reduced scale due to the smaller residential and industrial sector compared to Saipan.

[5] ICT was enacted in 2006 as a federal policy mechanism to support solar energy growth see Guide to the Federal Investment Tax Credit for Commercial Solar PV.pdf (energy.gov)
[6] A tax incentive for investment that allows individuals or businesses a percentage deduction off their taxes of the investment costs. This is a dollar for dollar tax offset for solar installations completed before 2024. See additional tax incentives at www.dsireusa.org. – Aug 2022

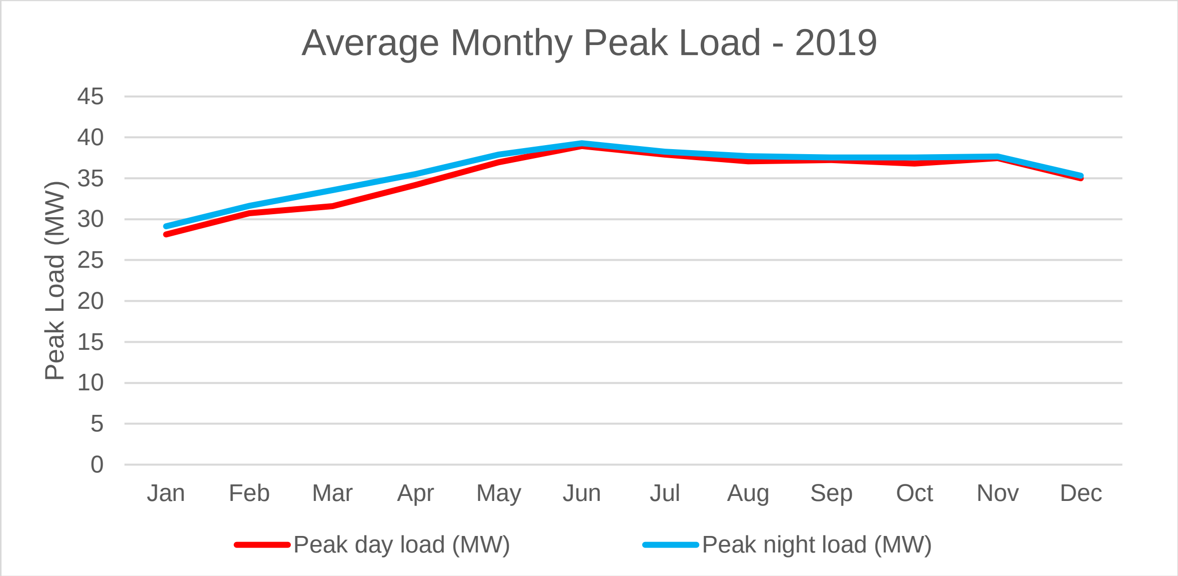


Figure 3. Average Monthly Peak Load Data for Saipan – Provided by CUC

Daily load profile

No hourly data was available as of writing this report. However, peak load data for 2019 was provided. The daily peak consumption for Saipan in March and June during daytime and nighttime was available and is shown in Figure 4 and Figure 5, as an example:

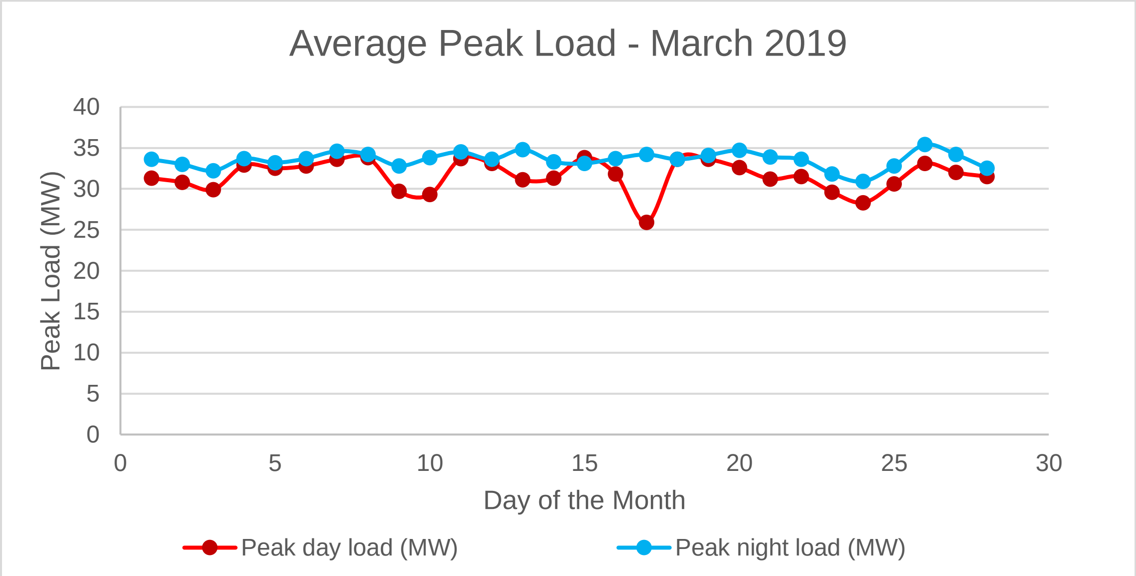


Figure 4. Daily Peak loads for March in Saipan – Provided by CUC

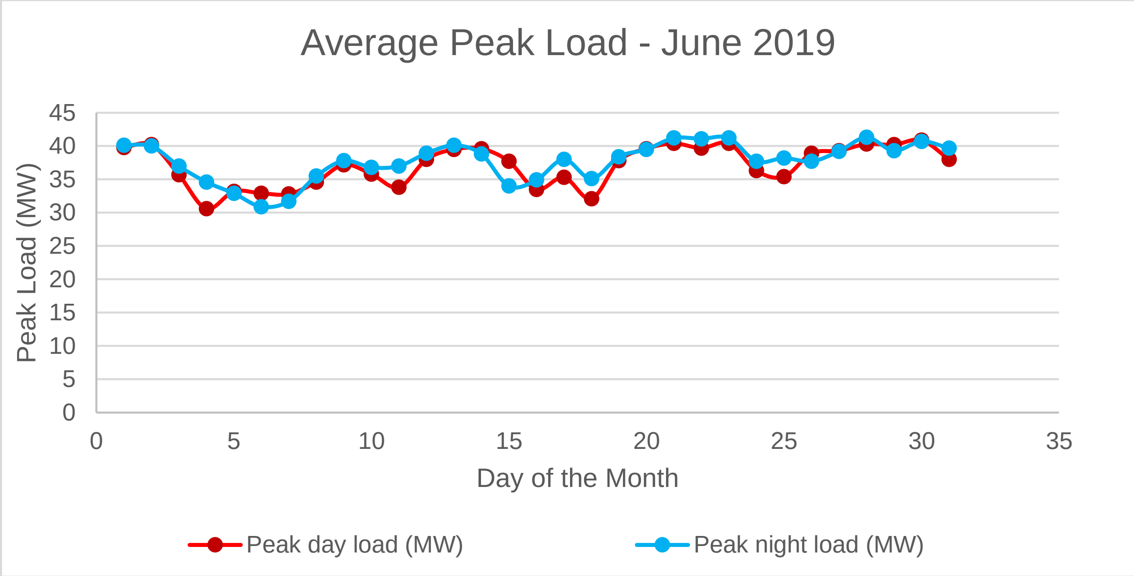


Figure 5. Daily Peak loads for June in Saipan – Provided by CUC

As shown in the figures above, there is a low variation in peaks between night and day energy use. While no hourly load profile was available, the data provides an early indication of a diurnal (two peaks) pattern in daily consumption. On average the daytime peak tends to be at approximately 3 PM every day and the evening peak at approximately 7 PM. The peak load times for each month is shown in Figure 6 below.

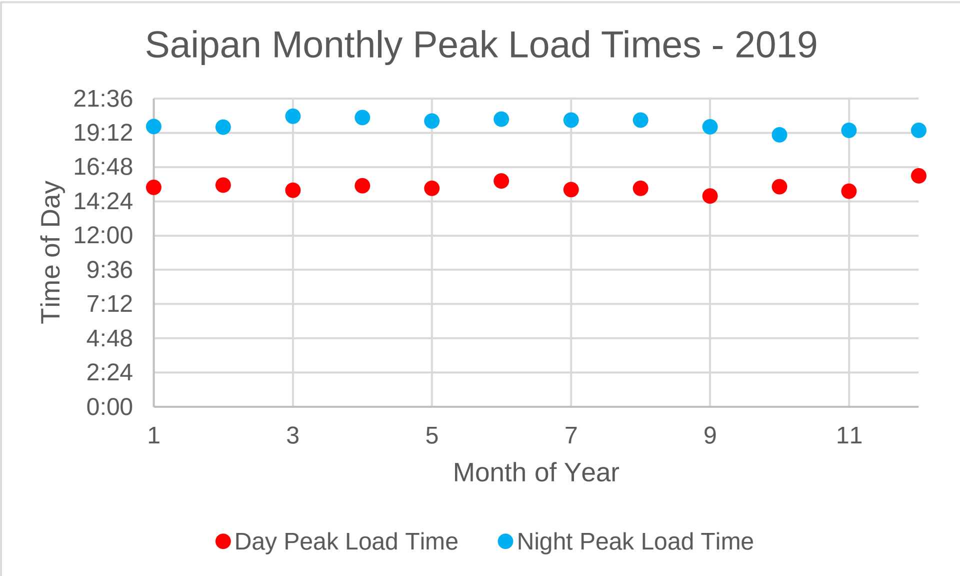


Figure 6. Monthly Peak Load Times – Data provided by CUC

4.4.2 Growth and Future Energy Usage

Load Growth

If the population in the CNMI increases, so will the consumption and load of the residential sector. A load growth factor should be factored into energy growth projections for long-term financial assessments of large-scale renewable generation.

Load Reduction

As the CNMI embraces more sustainable generation solutions, developments in the commercial and residential sector can be significantly more efficient than the existing infrastructure. Large scale developments in the CNMI, particularly for brownfield projects, can potentially reduce load requirements.

Future Projects

The CUC is planning to implement a number of energy projects in the near future. Below is a summary of the planned and ongoing projects:

- Power distribution model for Saipan
- Installation of SMART Meters
- LID Street Light Project, Saipan, Tinian, Rota
- Underground Power from Power Plant #1 to CHCC, Saipan
- Underground Power from Power Plant #1, Tinian
- Tree Trimming and Vegetation Clearing, Saipan
- Wood Power Pole Replacement, Saipan, Tinian, Rota
- Diesel Engine Generator Improvements
- New 80 MW Power Plant
- Solar Farm, Saipan
- 1.5 MW Solar Farm, Tinian
- 1.0 MW Solar Farm, Rota
- CUC Electric Vehicle Fleet

5. Energy Analysis

This section covers details about the current demand and energy consumption, cost of energy production, both energy efficiency and demand side energy measures currently in use on the islands and identifies future demand side management opportunities. A scenario modeling section also compares the energy production costs between fossil fuel (diesel oil) and a residential PV system.

5.1 Current demand and energy consumption of existing electrified areas

Some of the key facts related to CUC's power generation and distribution as of December 2020 are summarized in Table 3 below.

Table 3. Key energy system details – Dec 2020[7]– Saipan power station capacity

Energy System Detail	Saipan	Tinian	Rota
Generation units	13	6	3
Power Generation Facilities	Power Plant #1 – 40 MW Power Plant #2 – 6 MW Power Plant #4 – 10.9 MW	Power Plant #1 – 20 MW	Power Plant #1 – 7.5 MW
Peak demand	30.6 MW	2.2 MW	1.5 MW
Sub-Transmission line voltage	34.5 kV	-	-
Distribution voltage	13.8 kV	13.8 kV and 4.16 kV	13.8 kV
Fuel type	Ultra-low sulfur diesel fuel oil	Ultra-low sulfur diesel fuel oil	Ultra-low sulfur diesel fuel oil
Electric Customers	13,555	867	1024

The future load growth will be driven by combination of commercial, residential and government customers. Other commercial developments such as casinos and hotels due to tourism activities will also add to the existing demand. The overall net demand may reduce in the future due to a range of factors such as increased uptake of rooftop PV systems, demand side management which will reduce the energy consumption by influencing customer behavior, and use of energy efficient appliances.

At the time of this SEP update, some diesel engine generators out of service. Typical replacement cost for reciprocating engines is $1 USDM per MW[8]. Installation costs serve as a rough baseline for repair costs at 40% of the CAPEX for a new system (Excluding equipment costs which may be necessary, increasing price).

5.2 Cost of Energy Production from Diesel Engines

To evaluate the current cost of energy production on Saipan, the relevant information[9] provided by CUC was analyzed. The cost of energy production consists of different components, which are unit cost of fuel, total fuel costs, Operation and Maintenance (O&M) costs and load factor[10]. This calculation was performed based on fuel consumption data for 12 months (June 2020 to May 2021). The calculated fuel cost was $0.13/kWh and does not account for any additional charges. This factor has also influenced the cost of energy production on Saipan and should be treated as an exception. The average cost of energy production will most likely be in the range of $0.18 - $0.20/kWh. During the COVID-19 pandemic, the global fuel consumption pattern changed and as a result fuel costs came down. Since the pandemic fuel prices have increased as demand has increased. Increases and variability in fuel pricing is likely to continue in the foreseeable future with reducing oil supplies, reduced production facilities in the US, and global geopolitical impacts.

[7] Commonwealth Utilities Corporation – CUC Power System Profile
[8] AEMO 2020 Costs and Technical Parameter Review. https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2021/aurecon-cost-and-technical-parameters-review-2020.pdf?la=en
[9] CNMI Initial Technical Assessment Report - July 2011
[10] Load factor is a ratio of average demand and maximum demand

5.3 Demand Side Management

Demand side management (DSM) involves the planning, implementing, and monitoring activities of electric utilities that are designed to encourage consumers to modify their level and pattern of electricity usage, typically reducing energy use. The DSM options including energy efficiency (EE), demand response (DR), conservation, and other behavioral programs, will be considered in parallel with traditional supply-side resource options in an integrated and holistic fashion.

However, in recent years, the concept of DSM has expanded beyond EE and DR to include customer-sited distributed energy resource (DER) technologies, particularly rooftop PV. The availability and decreasing cost of DER technologies has changed the types of DSM opportunities available to customers, and the potential solutions for program administrators responsible for implementing DSM programs.

The Integrated demand side management (IDSM) at a conceptual level is a strategic approach to designing and delivering a portfolio of DSM programs to customers that provides benefits to both participating customers (i.e., lower bills) and non-participants (i.e., resource benefits). Integrated demand side management (IDSM) programs typically deliver customer centric strategies with the goal of increasing the amount of DSM in the field but doing so in a way that integrates various measures and technologies to improve their collective performance and/or penetration.

IDSM takes a wider approach to integrate other factors related to DSM rather than focusing on just EE and DR[11] as shown in Figure 7 below.

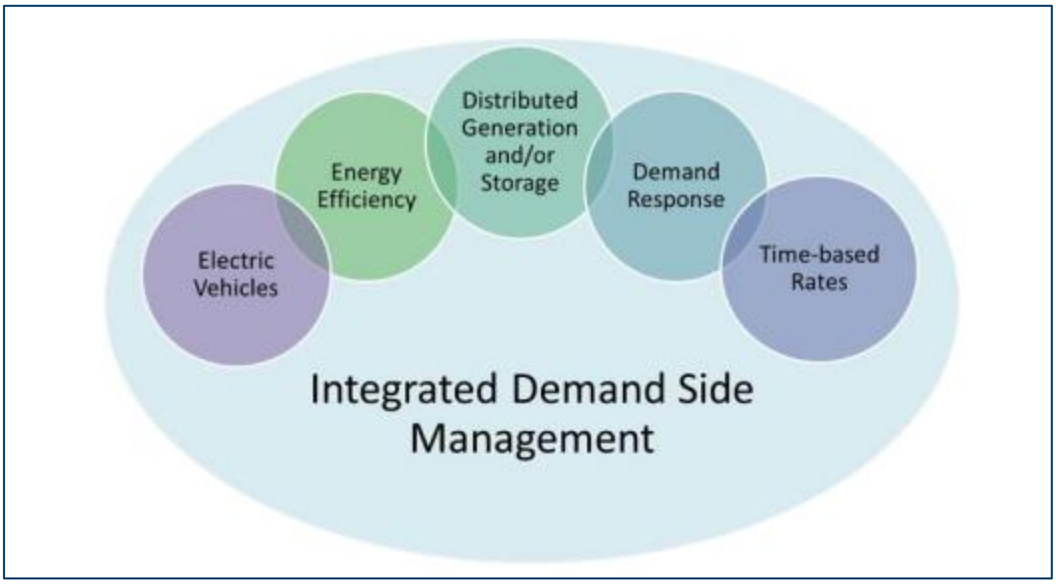


Figure 7. IDSM Components

The IDSM components shown in Figure 7 above are discussed in the following sections.

5.3.1 Energy Efficiency

The CNMI is already using some energy efficiency measures mentioned in the table below as part of DSM to reduce its peak demand. The energy efficiency measures are more cost effective than other renewable energy options covered under Section 6 of this report. Some of the energy efficiency measures that were recommended as part of CUC's 2015 Integrated Resource Plan (IRP) report are summarized in Table 4 below.

Table 4. Energy efficiency measures

Energy efficiency category	Energy efficiency measure	Description
Residential Sector Programs	Residential LED lighting – A point-of-sale rebate or cost buy-down for LED (light emitting diode) screw in retrofit bulbs, delivered by local hardware retailers, will improve the efficient lighting market and sales for the retailers, make the experience easy for the customer, and generate customer interest in other efficiency	A residential program focusses on easy, self-installation of water and lighting measures distributed via a free kit.

[11] Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities: A Scoping Study

Energy efficiency category	Energy efficiency measure	Description
	opportunities. Promotion of the offering can be largely housed at the retail site, minimizing advertising costs.	
	Energy Savings Kit – A free kit containing a low flow shower head and faucet aerator to be offered at retail sites, public events in which CUC could participate, or distributed by a third party contractor.	
	Energy awareness program. Public education and conservation outreach and outreach program to educate residents about energy efficiency and how to conserve energy.	DPW Energy Division gives out free portable propane stoves and LED lights. About a $50 value. Verified with ID and power bill. Most recently done in December 2021. More than 600 people participated. It is an annual program.
	Income based Weatherization Assistance Program (WAP).	Give away refrigerators and aircon, up to 10k BTU. Also replace incandescent lights with LEDs.
	Cool roof program	Started in 2011 as a rebate program. Part of education and conservation public outreach. Currently buy one get one free. Purchase roof primer and get elastomeric product. Keep homes cooler.
	EnergyStar rebate program. State Energy Program.	Submit application and receive a voucher. Voucher presented to vendor at the time of purchase Vendor gives discount to customer, delivers/installs appliance and then voucher returned to Energy Division to pay back the vendor. Making sure inefficient appliances are replaced with efficient appliances.
Commercial Sector Programs	Efficient Refrigeration Direct Install – The utility will cover 75% of project cost up to a project cap, for selection, procurement, and installation of various refrigeration measures, including: – Insulated night covers for open coolers – LED strip lighting to replace standard fluorescent strips in coolers and freezers – Electronically commutated motors (ECM) to replace standard evaporator fan motors in reach-in cases. – Anti-sweat heater controls on glass door cooler/freezers. – Strip curtains to limit cold air exfiltration/warm air infiltration to walk-in coolers/freezers.	A commercial program addresses significant energy end uses for hard to reach small and medium sized businesses—lighting and refrigeration measures.
Commercial Lighting	Efficient Lighting Direct Install – The utility will cover 75% of project cost up to a project cap, for selection, procurement and installation of various lighting measures, including: – LED bulbs replacing halogen down-lighting. – LED linear tubes replacing standard fluorescent tubes. – Super T8 tubes replacing standard fluorescent tubes.	

Both residential and commercial energy efficiency measures are easy to implement as compared to other renewable energy options and should be prioritized to reduce current and future demand for electricity.

Some of the energy efficiency measures were recommended in CUC's 2015 IRP, and further analysis is needed to determine their effectiveness. Due to lack of available data related to these initiatives, efficiencies around these energy efficiency measures are not addressed in this report.

5.3.2 Demand Response

Demand response (DR) is the opportunity for consumers to play a role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to a time-based rate structure or other forms of financial incentives. There was no evidence of DR being used or implemented on any of the three islands. This approach may be highly effective when other renewable energy options are implemented along with energy storage devices such as batteries.

5.4 Demand Side Management Opportunities

As stated earlier, DSM can be achieved by combination of different approaches. Some of these may include use of smart meters, adopting time of use (ToU) tariffs, building energy audits and cool roof programs as described in the section below.

5.4.1 Smart Meters[12]

A smart meter is a device with a digital two-way communication system that monitors and reports when and how much electricity is used. It records energy usage in minimum 15-minute intervals and transmits the information to the energy retailer daily. It also allows energy usage to be monitored remotely on a continuous basis.

5.4.1.1 Advantages

Some of the advantages associated with smart meters are:

Lower fees and charges

- Smart meters send information to the retailer digitally, it does not need a meter reader which eliminates the cost of manually reading meters.
- Connections and disconnections are cheaper. A smart meter can be turned on and off remotely when a customer is moving in and out without the need for a technician to visit customer's premises.

Accurate and reliable

- Smart meters are more accurate in calculating energy charges as there is no estimation of power usage.
- They provide detailed, real-time information about how much electricity is consumed and may assist the customer how to save money on their bills. Many electricity retailers have online platforms and apps that show usage in graphs and charts. The user/customer can be provided access to their energy usage through the online platform, allowing them to see their usage in real time. This access raises awareness of energy use and is a tool in DSM.
- Smart meters can quickly identify electricity supply outages and notify your electricity distributor. This means faster repairs and improved reliability.

Flexible pricing and monthly billing options

- With a smart meter, a time of use plan can be provided which has different electricity prices for different times of the day. For example, you can save money if you use less energy in peak periods. This type of pricing structure can be used to encourage consumers to modify their level and pattern of electricity usage.
- Traditional meters are read every three months. This limits options for monthly billing.

Going solar

- Smart meters are ideal for installations with small PV systems and batteries.
- Incentives can be established allowing customers to earn some credits towards their electricity bills.
- Smart meters can allow customers to independently decide when to export excess electricity to the grid and when to use it internally.

[12] Smart meters | NSW Government

One of the challenges in implementing a smart metering solution is the initial cost and availability of bandwidth in the wireless mobile network, which is a key requirement for operation of smart meters. The cost challenge can be addressed by a change in existing policy to provide a subsidy for the installation.

5.4.2 Battery

To encourage the adoption of storage devices such as Lithium-ion and other types of batteries, new incentives should be offered to consumers on the islands. Integrating battery energy storage (BES) with the existing distribution system can offer flexibility for both customers and the grid during times of critical need and can absorb power from the grid when prices are lower, providing an effective mechanism for storing excess energy[13]. This approach is covered in detail under Section 6.10 of the report.

5.4.3 Time of Use Tariffs

The DR refers to the possibility of changing energy loads during specific time intervals by exposing consumers to the correct cost-reflective price signals. The U.S. Federal Energy Regulatory Commission (FERC)[14] defines demand response as "changes in the electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when the system reliability is jeopardized".

ToU tariffs enable customers to adjust their electricity consumption voluntarily (either through automation or manually) to reduce energy expenses. Time-based rate programs require advanced metering infrastructure (AMI). Consumers are free to decide how and when to react to price signals and to adjust consumption during specific time intervals. With consumers' higher responsiveness to price signals, the whole power system, as well as consumers themselves, can benefit.

ToU tariffs offer flexibility to customers to monitor their peak demand and use energy when it is most economical to do so. This approach will be most suited to power consumers who can adjust their usage based on the price point available to them at the time of usage. ToU have been implemented around the world to achieve reduction in maximum demand[15].

5.4.4 Energy Audit Program

An energy audit is an inspection survey and an analysis of energy flows for energy conservation in a building. The energy requirements for buildings, including heating, cooling, lighting and appliances, account for 28% of all carbon emissions[16]. An energy audit training program for government and private companies with technical background could better inform and accelerate change in design and influence energy usage in buildings.

The energy audit program could identify common measures to improve energy efficiency, which then could form part of a program to implement or subsidize these measures. A free audit program could encourage property owners to implement cost effective changes[17].

5.4.5 Cool Roof Program

A cool roof utilizes highly reflective paint or roof coatings to reduce the amount of heat absorbed by the building. A cool roof program could be mandated in the building code or be subsidized. Roofs prone to organic build-up would require cleaning, as mosses and algae absorb significantly more heat than a reflective roof coating[18]. CNMI have implemented such a program, refer table 4.

The CNMI has adopted the 2014 CNMI Tropical Energy Code, which includes provisions that replacement roofs for residential and commercial buildings comply with cool roofs requirements, including an aged reflectance of at least 0.55 and a minimum thermal emittance of 0.75 or a minimum aged SRI of at least 64. Insulation requirements are also specified.

[13] Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities: A Scoping Study
[14] Time-of-use tariffs – Innovation Landscape Brief (irena.org)
[15] Page 13 - Time-of-use tariffs – Innovation Landscape Brief (irena.org)

[16] International Energy Agency - 2019 Global Status Report for Buildings and Construction
[17] CNMI Strategic Energy Plan 2013, Page 16
[18] CNMI Strategic Energy Plan 2013, Page 16

As an alternative or in addition to paints and coatings, a roof insulation program could assist in reducing energy usage and cost of air-conditioning significantly. Some countries mandate roof insulation to reduce energy consumption[19]

Another alternative is to utilize roof vegetation (green roofs) to reduce heat radiation onto the roof. Although this method was utilized for centuries in cold climate countries (Scandinavia) to insulate houses to keep them warm, this method works as well in warm climates provided sufficient water resources are available. The initial capital cost of a green roof and the requirement for water infrastructure make this a costly solution. Regulation could stipulate a maximum heat transfer rating for roofs.

5.4.6 Energy efficient house

Energy efficient houses can reduce energy usage by up to 80% utilizing insulated walls and foundations, two or three glazed-windows, passive cooling elements like trees and window shades and a design for passive ventilation supported by ceiling fans and refrigerant air-conditioning to enable de-humidifying the airflow.

Highly energy efficient houses have been estimated to cost up to 50% more than a standard house when built in small numbers, but economies of scale could bring the price difference down significantly, estimated by half.

The National Green Building Standard (NGBS), approved by the American National Standard Institute (ANSI), provides guidelines for environmentally friendly and energy efficient buildings. Some Municipalities have adopted NGPS as mandatory code for residential buildings and others provide tax incentives for NGBS certified buildings[20].

For new housing developments energy efficient houses could be enforced by regulation and be subsidized by CNMI or the federal government. The 2014 CNMI Tropical Energy Code provides the minimum requirements for energy efficiency design of residential and non-residential buildings in the CNMI, addressing the building envelope, air conditioning and ventilation, water heating and lighting.

5.4.7 Electric Vehicles

Electric Vehicle (EV) programs could provide incentives or rebates for deployment of EVs, EV chargers, grid-integrated EV smart chargers or offer special time-based rates (TBR) to encourage specific charging behavior patterns that can minimize the load impact to the distribution system. Both smart chargers and TBR[21] encourage consumers to use devices during off peak, which will reduce the maximum demand on the distribution network during peak load. An EV program would also reduce dependency on fossil fuels in transportation and be a step towards an electrified transportation system consisting of personal vehicles and public transport buses. Programs to deploy a fleet of electric buses by the Commonwealth Office of Transit Authority (COTA) could be a key leadership tactic to transitioning toward the use of EVs and away from gasoline powered vehicles.

5.5 Scenario Modeling

A scenario model was developed to compare the cost of energy production on Saipan. The model included cost comparison of energy production with fossil fuels and energy production using residential PV systems over a period of 30 years. This model was developed based on several assumptions including the load factor for Saipan, maximum generation, annual generation, total marginal cost, annual fuel cost and O&M cost. The model also considers the capital cost of installation for a PV system and its associated O&M cost.

This scenario modelling covers different situations which include

– Base case where fossil fuels will be supplying the total load (100%).
– Cost incurred based on fossil fuel supplying (75% of total load) and rest by PV system (25%).
– Cost incurred based on fossil fuel supplying (50% of total load) and rest by PV system (50%).
– Cost incurred based on PV system supplying the total load (100%).

A gradual step change starting from 25% PV adoption to 100% PV adoption indicates that the cost of energy production using PV system is significantly less than the cost of energy production using fossil fuels. Figure 8 below shows energy production cost comparison from fossil fuels and increasing size of PV system side by side.

[19] European Regulation 2012/27/EU
[20] https://www.homeinnovation.com/services/certification/green_homes/resources/ngbs_incentives_summary?p=1&
[21] Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities: A Scoping Study

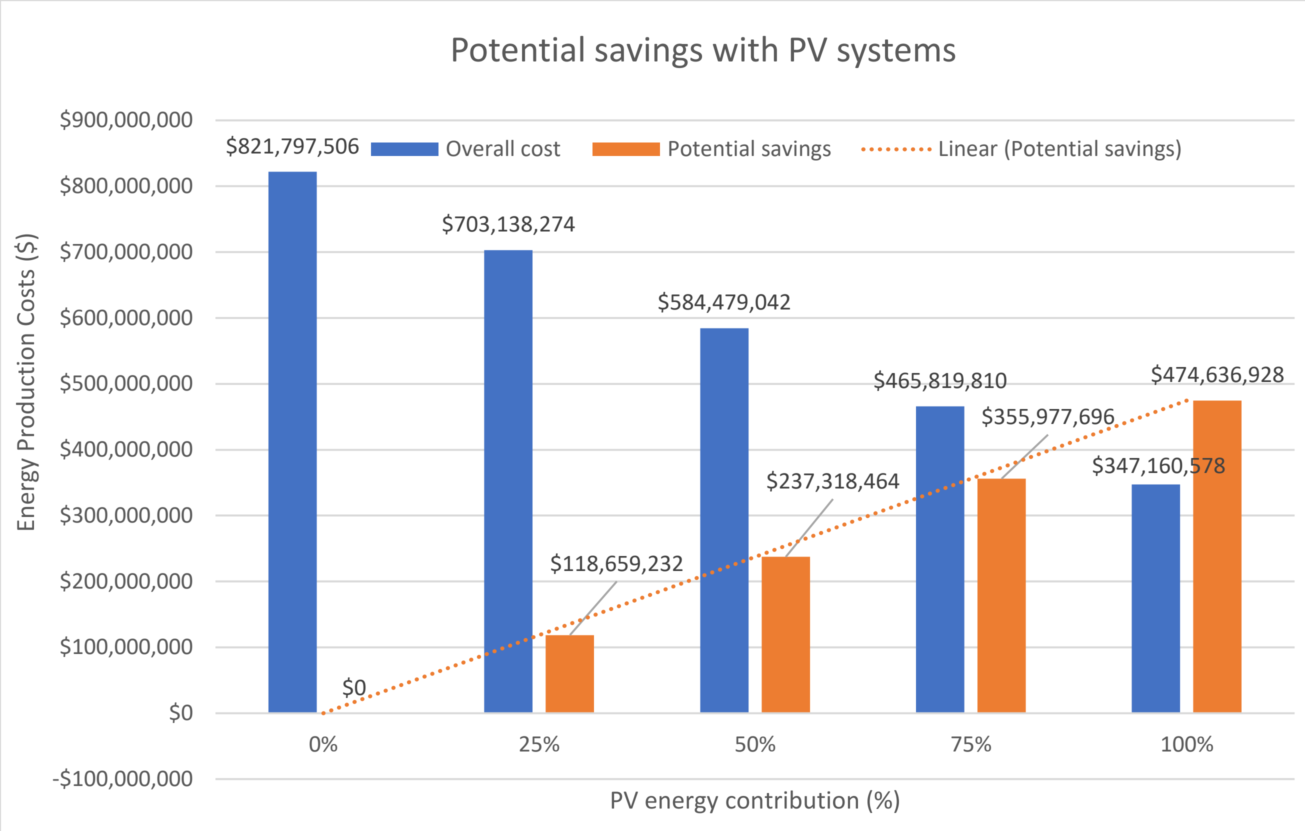


Figure 8. Potential savings with PV systems

A trendline indicates the potential savings as the PV penetration increases from 25% to 100% over a period of 30 years. This model clearly highlights the savings which can be achieved by deploying residential PV systems to supply consumers on Saipan and could be extended to Tinian and Rota for similar and proportional savings. The next section will cover details related to different types of PV systems, battery storage, output yields and related costs.

6. Energy Options and Strategies

6.1 Overview

A summary of the cost for installation and O&M costs for the technologies considered are summarized in Table 5. Where practicable, a nominal capacity of 1 MW for energy generation and 1 MWh energy storage is costed for comparative purposes.

Table 5. Technologies Cost Summary

Technology	System Size	Unit	Value ($ USD)	Annual O&M Cost per MW ($)	Potential Alternative Technologies (Not discussed in report)
Solar	1 MW	$/MW	1,487,160	14,040	Floating solar
Solar Thermal Water Heating	1 Residential Unit	$	3,120	N/A	PV water heating, Natural/Hydrogen gas heating
Waste Energy Plant	1 MW	$/MW	7,460,000	92,580	
Wind onshore / offshore	1 MW	$/MW	2,991,200 / 9,286,730	26,280 / 165,564	Small scale vertical axis wind
Geothermal Flash Steam / Binary Cycle	1 MW	$/MW	10,950,000 / 21,349,000	2,737,500 / 5,337,250	Pumped geothermal water
Ground source heat pumps	1 Residential Unit	$	19,500	N/A	Heat conductive concrete
Pumped Hydro Energy Storage Systems	1 MW	$/MWh	1.6 – 2 million / 3-5 million	25000	BESS
Battery Energy Storage Systems	1 MW / 1 MWh	$/MWh	500,000	115,000	PHES, Vanadium flow batteries
Diesel generators	1 MW	$/MW	1,200,000	1,272,000	LNG

6.2 Alternate fuel sources or supply options

All diesel fuel for power production in the CNMI is shipped from Singapore. Due to the high cost of diesel fuel, it would be wise to obtain alternate quotes and investigate alternate supply options. This could include cooperating with Guam on diesel purchase, investigating other diesel suppliers and alternate supply ports. As prices fluctuate over time it could be advantageous to lock in prices for a longer period or hedge prices to gain access to favorable pricing.

Liquified natural gas (LNG) is a possible alternative, prices for LNG have been significantly lower than diesel in the distant past.

LNG would come however with a very large switching cost. All diesel generators would have to be replaced with costly gas generators ($50 million). A new onsite storage facility would have to be built to store and handle the LNG, and large ships providing LNG require a deep harbor or alternatively a long unloading jetty or dock.

LNG is not carbon neutral, although its carbon emissions are lower compared to diesel fuel. The LNG market has proven to be very volatile lately, with prices at times exceeding the price of diesel fuel[22]

Compared to diesel generators gas generators are less robust in high penetration renewable power systems due to the much lower energy density of the fuel and the possible strong load swings.

[22] Global quarterly fuel price changes, 2010-2020 – Charts – Data & Statistics - IEA
LNG netback price series | ACCC

6.3 Solar PV and Battery Storage

The following solar technologies are considered:

- Rooftop Solar
- Fixed Tilt ground mounted solar
- Single axis tracking (SAT) ground mount solar

Rooftop is a common mode for solar installations in the industrial and residential sectors. Solar PV modules are mounted on existing rooftop space. They can also be installed as a part of a shade canopy system for a parking lot. It is an effective method for harvesting solar energy in areas that are already developed. The rooftop solar market is mature and can be deployed at the residential scale (per household) or scaled up to supplement power supply for industrial processes. PV can be added to government buildings to help offset building energy demands, or to new or existing parking lot shade canopies.

Figure 9. Solar PV Modules Installed on Residential Rooftops

Ground mounted systems require a dedicated flat land area with minimal shading. Ground mount systems allow for larger installed capacities with more PV modules installed.

Single axis tracking (SAT) is an additional capability where motors allow the PV modules to tilt, tracking the sun to maximize solar exposure and generate maximum energy. Figure 10 shows an example of an SAT ground mounted PV system.

Figure 10. Example of a Ground Mounted SAT System

6.3.1 Modelling and Analysis Methodology

A HOMER Energy model was developed to calculate an approximate total energy from solar to take a quantitative approach when assessing installed solar. HOMER Pro is the global standard software package for optimizing microgrid and grid connected design. HOMER modeling uses weather data obtained from NASA surface meteorology and solar energy database over a 22-year period from July 1983 to June 2005.

HOMER Pro simulates the operation of a system by making energy balance calculations in each time step (interval) of the analysis 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.

For each island (Saipan, Tinian, and Rota), a preliminary assessment was performed to determine land availability for SAT and fixed tilt ground mounted utility size solar and household density for rooftop solar. Based on the density of households, an estimate of 500 kW of solar is allocated to the residential sector for each island. Based on land availability not too isolated from populated areas, a preliminary installation of a 1.5 MW solar array is modeled for Saipan. Reduced capacities of 1 MW are modeled for Rota and Tinian as their network capacities and consumption are significantly smaller compared to Saipan. These values are nominal only to give an indicative solar yield and cost. 1.5 MW corresponds to approximately 2 hectares or 5 acres of land.

The web-based software package PVSketch was used to validate solar sizing for ground mount and rooftop mounted solar. Table 6 shows a summary of the solar capacities modelled in HOMER for each island.

Table 6. Preliminary Solar PV System Sizing

Island	Solar capacity [kW]	Description
Saipan	1500	SAT / fixed tilt ground mounted
	500	Rooftop mounted
Tinian	1000	SAT / fixed tilt ground mounted
	500	Rooftop mounted
Rota	1000	SAT / fixed tilt ground mounted
	500	Rooftop mounted

6.3.2 Modelling and Yield Results

A summary of the solar PV yield for each of the islands from the HOMER model is shown in Table 7. Also included in the results is the potential reduction in CO2 emissions compared to the scenario where each island has no solar installation. The emissions intensity used in the model is the default value of 632 g/kWh energy from the grid.

Table 7. Solar PV Yield Results[23]

Island	Description	Solar capacity kW	Generation (kWh/Yr)	Mean output (kW)	Capacity Factor* (%)	CO_2 Emissions Reduction (Metric Tonnes/yr)
Saipan	SAT ground mounted	1500	3,175,043	362	24.10%	2,007
	Rooftop mounted	500	955,839	109	21.80%	604
Tinian	SAT ground mounted	1000	2,115,039	241	24.10%	1,337
	Rooftop mounted	500	954,963	109	21.80%	604
Rota	SAT ground mounted	1000	2,088,782	238	23.80%	1,320
	Rooftop mounted	500	943,519	108	21.60%	596

** Capacity factor is defined as the ratio between the mean output of the solar PV and the maximum installed capacity expressed as a percentage. It provides a measure of how much energy can be expected to be generated from a specific technology in a defined location.*

Across the three islands, there is little variation for rooftop and SAT PV. As such, the performance of a solar installation on any one island is likely to have a similar performance to an equivalent installation is deployed on the other islands.

[23] A rough estimate of 500kW per island is assumed to be adopted by the residential market sector.

A decline in capacity factor can be seen in the southernmost island Rota, meaning that the effectiveness of solar is reduced by a small amount (0.3%) in Rota compared to Saipan and Tinian. While Rota is closer to the equator compared to the other islands, NASA data shows that there is a slight decline in clearness index. Clearness index is a measure of clearness, between 1 and 0, of the atmosphere with a high value under clear, sunny conditions, and a low value under cloudy conditions.

Availability of land and proximity to power distribution are key factors in implementing large ground mounted solar PV systems. Land availability is limited in the CNMI and locating a large solar PV system array near the existing power grid is key to integrating it with the existing energy grid. If located in a remote location where land is more available, the cost of installing additional distribution infrastructure must be factored into the project. Commercial scale PV and SAT systems open opportunities for public-private partnerships (PPP), lease-buyout and long-term lease to finance and operate the system. For example, on Guam the U.S. Navy has leased land to the Guam Power Authority (GPA) for the construction of a system of photovoltaic solar panels in eight locations to generate about 40 megawatts of power. The project is part of a long-term design-build-operate power sales contract between a private energy corporation and GPA.

6.3.3 Costing Estimates

In the CNMI, there is a Business Energy Investment Tax Credit available allowing a 26% discount on solar installations for homeowners and businesses[24]. It is assumed that the SAT or fixed tilt ground mounted solar PV is eligible for this discount.

The base CAPEX (capital expenditure, or initial cost) for small-scale (<10kW), residential rooftop solar is $2,220 USD/kW and the OPEX (operational expenditure) is $11.70 USD/kW per year[25]. Key factors that determine cost in the CNMI include the remote location and lack of competition, there is only one PV vendor is present in the CNMI. With increased demand for rooftop solar systems and potential government capital subsidies, new vendors may enter the local market and cause price adjustments for the region.

For larger scale, dedicated rooftop solar systems (>10kW) the baseline CAPEX reduces to $1,020[26] and the OPEX is $11.70 USD/kW per year. Small-scale solar has a higher CAPEX to offset additional costs when participating in the retail environment. Larger SAT ground mounted solar has an additional capital cost of 21.5% compared to larger scale rooftop solar. Fixed tilt on the other hand is 14.7% additional capital cost compared to rooftop solar due to the requirement of ground clearing and foundations.

Cyclonic wind speeds in Australia are comparable to the recent category 5 Typhoon Yutu that passed through the CNMI in 2018. Certifications for wind speeds are typically ingrained in the Australian solar market and a distinct cost for inclusion of appropriately rated mounting systems. A contingency buffer of 20% is included in the cost estimate to account for this. A summary of costings is shown in Table 8. Australia has had deployment of large scale solar with SAT systems in regions categorized as “Cyclonic” according to Australian standards (Region C). Fixed tilt ground mount systems would be less susceptible to high wind speeds as there are fewer moving parts at the cost of a decrease in yield (15%-20%). They can be rated up to cyclonic Region D windspeeds (197 mph). Australia also has established mounting guidelines for rooftop solar in Region C areas. For the context of this report, Australian guidelines are used.

Table 8. Cost Estimates for Solar PV – Installation Cost Included

Island	Description	Solar capacity kW	Cost Estimate ($ USD)	Operation and Maintenance ($USD/year)
Saipan	SAT ground mounted	1500	$2,230,740	$21,060
	Fixed tilt ground mounted	1500	$2,105,892	$21,060
	Rooftop mounted	500	$1,332,000	$5,850
Tinian	SAT ground mounted	1000	$1,487,160	$14,040
	Fixed tilt ground mounted	1000	$1,403,928	$14,040
	Rooftop mounted	500	$1,332,000	$5,850
Rota	SAT ground mounted	1000	$1,487,160	$14,040

[24] US Department of Energy. https://www.energy.gov/sites/default/files/2021/02/f82/Guide%20to%20the%20Federal%20Investment%20Tax%20Credit%20for%20Commercial%20Solar%20PV%20-%202021.pdf
[25] Based on CNMI Local Vendor quotation.
[26] Based on Australian Market pricing using similarly scoped projects completed by GHD.

Island	Description	Solar capacity kW	Cost Estimate ($ USD)	Operation and Maintenance ($USD/year)
	Fixed tilt ground mounted	1000	$1,403,928	$14,040
	Rooftop mounted	500	$1,332,000	$5,850

The lifetime in the system modeled is 25 years, which is the typical lifetime for PV modules. PV systems require minimal maintenance over their lifespan hence the marginal operation and maintenance cost. It is expected that capital cost for larger solar farms (e.g., 10MW +) will further reduce due to economies of scale.

For the residential and business sector, the CAPEX for BES systems is $2,200 USD/kWh[27]. BES systems do not serve as a form of renewable generation, but they can be effective when providing spinning reserve or leveraging peak and off-peak tariffs during peak shifting operation. OPEX for battery storage systems are estimated to approximately $115 USD/kWh per year. The sustainability of a BES system is dependent on the electricity source charging it, with most of the CNMI's energy being from diesel, a green BES system would need to be deployed together with renewable generation to achieve a high renewable energy penetration.

Capital cost of BES is significantly more expensive than capital cost of current diesel technology, however cost of BES systems is projected to decline over time. Capital cost of utility size BES systems (10 MW/10 MWh) are significantly lower (~$500 US / kWh) compared to residential systems.

A key long-term cost consideration is the affect individual PV systems have on CUC revenue. CUC requires revenue to operate and maintain the energy systems on each island (generation, transmission/distribution, and service). While reducing demands for petroleum generated energy is a key strategic goal of the CNMI, increasing individual residential and business PV generation has the potential to negatively impact CUC revenue used to maintain the grid. This is limited in part by current legislation (see Section 8, Public Law 18-62 and 18-75), but careful consideration should be made regarding potential erosion of CUC rate base.

6.4 Solar Thermal Water Heating

Solar thermal water heating involves the use of solar collectors (typically flat plate or evacuated tube) for residential or commercial properties to heat water that is then thermo-siphoned out of an accompanying storage tank. The residential sector in the CNMI accounts for about 30% of all electricity consumption, with the rest being consumed by government and utility.

Water heating takes up a significant proportion of residential consumption at approximately 29%[28]. Water heating accounts for 17.9% of residential energy use in Hawaii, which is of comparable climate to the CNMI[29].

According to the CNMI department of commerce 23.1 % of households on the islands have hot water systems. This equates to approximately 1.2% of all energy use in the CNMI is for water heating[30]. With solar hot water systems an increase in hot water supply would not result in a significant increase in electrical demand.

Solar thermal water heating is dependent on solar irradiance to preheat water that is circulated to a tank.

6.4.1 Analysis

A preliminary assessment of the existing solar thermal market in Australia shows that solar thermal water heating technology can be effectively utilized provided appropriate levels of solar irradiance is present. The solar contribution to water heating is assessed against global horizontal irradiance for key locations around Australia in Table 9. The table also shows predicted contributions at residential locations in CNMI.

Table 9. Solar Contribution of Solar Thermal Water Heating and GHI

Location	GHI	Solar Contribution (%)
Perth, WA	1957	77.50
Darwin, NT	2096	92.50
Cairns, QLD	1951	82.50

[27] Based on local vendor quotation, price inclusive of ITC credit
[28] U.S. Department of Energy, Energy Transitions Initiative, Commonwealth of the Northern Mariana Islands Energy Snapshot (June 2020), p. 1
[29] News, U., 2022. Refrigerators, electric devices top energy use in Hawaiʻi households | University of Hawaiʻi System News. [online] University of Hawaiʻi System News. Available at: https://www.hawaii.edu/news/2021/10/01/energy-use-in-hawaii-households/
[30] LFP Housing Characteristics 2017 By Hot and Cold Water in Unit and Hot Water Energy Type - Department of Commerce – Commonwealth of the Northern Mariana Islands (CNMI) (cnmicommerce.com)

Location	GHI	Solar Contribution (%)
Brisbane, QLD	1787	77.50
Sydney, NSW	1620	67.50
Canberra, ACT	1749	62.50
Melbourne, VIC	1507	60.00
Hobart, TAS	1356	52.50
Adelaide, SA	1760	67.50
Saipan	**2090**	**87.93**
Tinian	**2111**	**88.97**
Rota	**2045**	**85.68**

The average GHI (Global Horizontal Irradiance) for the CNMI is on the higher end compared to ideal locations in Australia for potential solar contribution to solar thermal heating.

Figure 11 shows that the annual radiation and clearness index for Saipan is consistent year-round. Clearness index is measure of clearness of the atmosphere. It is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the Earth and is on a scale between 0 and 1. The clearness index remains stable year-round in the CNMI.

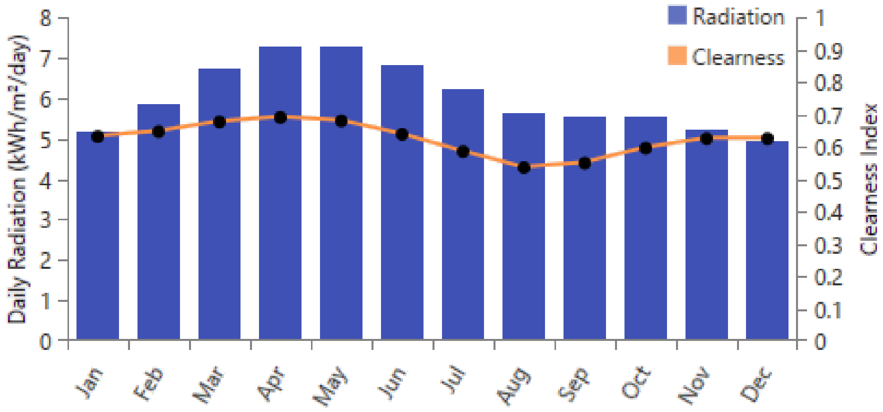


Figure 11. Saipan Annual Radiation and Cleanness Index[31]

6.4.2 Cost Estimates

Assuming an average household consumption equivalent to residential Australia at approximately 40 kWh per day[32] (1.67 kW/h), the contribution of a household solar thermal system in kW can be estimated. It should be noted that typical household consumption varies with climate and culture. Using a typical system cost for a solar water heating system of approximately $3,120 USD[33] for one household, a baseline cost can be established.

Energy contribution in kW

Mean solar contribution of a solar thermal heating system in CNMI is estimated to 87.53% (average of Solar Contribution for Saipan, Tinian and Rota from Table 9).

Using 17.9% of residential energy, the estimated energy used for water heating is therefore:

$$0.179 \times 40 = 7.16\ kWh$$

For a single household, 10 kWh of energy per day is required for heating, of which 87.53% can be contributed via solar thermal heating:

$$0.8753 \times 7.16 = 6.27\ kWh$$

Savings in energy cost can be estimated with a cost of $0.20/kWh saved, they amount to

[31] HOMER visualization of NASA data
[32] Australian Energy Market Commission
[33] SolarQuotes. 20% contingency included as technology is not common on CNMI. https://www.solarquotes.com.au/hot-water/price/

$1.75 per day and $638 per year. This equates to a payback period of approximately 5 years.

An alternative water heating technology is a heat pump system, with a lower capital cost at approximately $2,500 USD[34]. Heat pump water systems use the same principal as reverse cycle air conditioners and are significantly more efficient than solar thermal systems (between 300% and 400%). The approximate CAPEX for a heat pump system is approximately $2,000 USD/kW. Heat pump systems could also leverage changes in peak and off-peak tariffs by diverting other sources of renewable generation (such as solar) during excess periods. Heat pumps consume electrical energy, with an assumed efficiency of 330% and 10 kWh per day heating requirement it would consume 3 kWh / day, amounting to operating cost of ~ $220 USD per year. The payback period would be about 5 years.

6.5 Energy from Waste

6.5.1 Solid Waste

Solid waste incineration is a proven technology utilized in Europe for more than 30 years. It can be utilized as baseload power plant, replacing diesel fueled power generation. Waste incineration can assist with reducing the size of landfills. However, the technology produces significant carbon emissions, particularly if compared to a circular economic reuse strategy. Community acceptance could also be a potential issue. Initial capital cost are high, earlier reports estimate $54 million USD in capital cost for a 2.6 MW plant. Table 10 summarizes the expected range of potential energy from waste to energy for low and high efficiency systems.

Biomass technologies can be used directly to produce heat or electricity. Biomass solutions are available in different forms, allowing for opportunities to minimize cost. An example of such is biofuels (such as biodiesel), which can be consumed using the same equipment as diesel, allowing this fuel source to be adopted at minimal cost.

Typical resources for energy production via biomass utilize general solid waste and municipal solid waste (MSW). Waste generated by the populations on each island can potentially be used for energy production. As of 2017[35], it is estimated that the Marpi Landfill on Saipan alone receives approximately 24,700 tons of MSW per year with approximately 74% of the mass being combustible. A 2011 technical assessment by NREL outlines two efficiency scenarios for the energy density of MSW[36]:

Table 10. Waste to Energy Potential – Assuming 104 Tons Per Day with 15% Parasitic Load

Description	Energy Yield (kWh / ton)	Net Power Generation (MW)
Low Efficiency	600	2.6
High Efficiency	900	4.6

The Low efficiency scenario is based on typical existing metrics as of 2011. The High efficiency scenario refers to projected improvements and advancements proclaimed by manufacturers of solid waste energy plants at the time.

Energy via MSW or other sources such as green waste, wastewater treatment sludge will have a higher capacity factor then renewables as the generation profile is not as volatile.

6.5.2 Cost Estimates

Approximate cost information has only been made available for energy from MSW in the 2011 technical assessment report by NREL. Using the low efficiency scenario described above, the approximate CAPEX for energy production via MSW is $25,090[37] USD per kW. The preliminary economic analysis in the assessment report looks at various sensitivity scenarios for different electricity sales and tipping fees. As a minimum, the following cost arrangements in Table 11 are required as a minimum to have a positive net present value (NPV).

[34] SolarQuotes. https://www.solarquotes.com.au/hot-water/price/
[35] Landfill Gas Extraction Feasibility Study – EA Engineering - 2019
[36] Commonwealth of the Northern Mariana Islands Initial Technical Assessment Report. https://www.nrel.gov/docs/fy11osti/50906.pdf
[37] Using latest CPI data as of 6th August 2021 to project cost in the present.

Table 11. NREL Economic Analysis Minimum Pricing Structures– Results from 2011

Electricity Sales Price in 2011 $/kWh	Tipping Fee (2011) $ / ton	NPV 2011 $	Description
0.30	60	2,192,065	Assuming no energy investment tax credit (ITC)
0.25	30	2,012,521	NPV including energy ITC factored in

Noting developments in biomass energy production since 2011, an alternative estimate using current data can be determined. Based on Australian Energy Market Operator (AEMO) data, the approximate CAPEX for a biomass energy production plant is valued at approximately $7,460 USD per kW with an operational cost of $140 USD per kW when land development and a 20% contingency margin is considered (excluding engineering, procurement, and construction costs). The O&M cost is $92.60 per kW.

Opportunities and Current Trends

Incineration, which would be the process used in the example above, can also be effectively used with other solid biomass sources, such as forestry products (wood chips, sawdust, etc.), harvest residues (sugar cane, bagasse, etc.), or refuse-derived fuel (RDF) among others. Other processes, also described in the 2011 NREL report, include anaerobic digestion, gasification, and manufacture of biofuels.

Incineration generation plants using forestry products are currently in use in the U.S. and Australia. Western Australia also currently has two operation plants using MSW and RDF as a fuel source. The average unit size for biomass power plants utilizing incineration or combustion technology is 20 to 40 MW. The economic viability of higher generation capacities would be dependent on availability of feedstock within a reasonable transit distance from the plant.

6.5.3 Anaerobic digestion

Anaerobic digestion in wastewater treatment plants (WWTP) is a common method of stabilizing biosolids, which is the solid material produced during the treatment of wastewater. Anaerobic digestion is a process through which bacteria break down organic matter in the absence of oxygen. The process of anaerobic digestion produces biogas and digestate. Digestate is the solid and liquid end products. The liquid is re-treated in the WWTP and the solids are typically disposed of in a landfill. The process takes place in a sealed vessel called a reactor. The reactor contains complex microbial communities that break down (or digest) the waste and produce resultant biogas and digestate. Biogas is composed mostly of methane (CH_4), which is the primary component of natural gas, typically at a concentration of 50 to 75 percent by volume. Other gases include carbon dioxide (CO_2), hydrogen sulfide (H_2S), water vapor, and trace amounts of other gases. The energy in biogas can be used like natural gas to provide heat, generate electricity, and power cooling systems, among other uses. Biogas can be recovered and purified by removing the inert or low-value constituents (CO_2, water, H_2S, etc.) to generate renewable natural gas (RNG). The RNG can be piped to a reciprocating engine, microturbine or fuel cell to produce electricity, offsetting a portion of the WWTP’s energy needs.

A 2011 U.S. EPA funded study by the Combined Heat and Power Partnership (CHPP) evaluated WWTPs in 30 U.S. states representing 437 MW of capacity. The study reported that that influent flow rates of 5 million gallons of average strength wastewater per day (MGD) or greater were typically required to produce biogas in quantities sufficient for economically feasible energy recovery systems (Eastern Research Group, 2011).

There are two CUC owned and operated WWTPs on Saipan that treat municipal wastewater, the Agingan WWTP and the Sadog Tasi WWTP. Currently the islands of Tinian and Rota have no CUC owned wastewater infrastructure; wastewater treatment and disposal is accomplished by use of private septic systems. The Agingan WWTP treats an average flow of about 1.5 MGD of municipal wastewater. The Sadog Tasi WWTP treats about 2.0 MGD of low-strength municipal wastewater. Based on the flows treated, and low-strength of the influent wastewater, anaerobic digestion is not expected to be a financially viable source of renewable energy in the CNMI.

6.5.4 Landfill gas capture and conversion

Many municipal waste facilities have installed gas capture and conversion facilities on their landfill sites. Technologies range from reciprocating engines, gas turbines and microturbines. Capital costs range from $1,400 USD / kW for a small gas turbine (3 MW) up to $5,500 USD / kW for a microturbine. In addition, the cost of gas capture and processing must be added. Maintenance costs range from $380 - $1,830 USD per kW. Technical issues are in the gas processing areas and potential in the inconsistent supply of landfill gas depending on waste composition. Due to the size of the landfills and the remoteness of the locations it is likely that the capital and operation and maintenance costs are substantially higher than current benchmark figures on a per kW capacity basis. Landfill gas capture and conversion could only make a small contribution to a renewable energy production in the CNMI. The Landfill Gas extraction Feasibility Study prepare for the CNMI Office of the Governor Capital Improvements Projects Office estimates an average annual electricity generation of 230 – 353 kW from Landfill Gas from the Marpi Landfill, and even less from the Eloy S. Inos Peace Park (formerly Puerto Rico Dump) landfill. It concludes that landfill gas capture and conversion does not appear economically feasible on Saipan.

6.6 Wind Generation

6.6.1 Modelling and Analysis Methodology

The HOMER model was used to develop preliminary estimates of wind generation and emissions reduction in the CNMI. Modeling in HOMER was performed using a 2-winged turbine designed to be manually lowered in extreme wind speed conditions (Vergnet GEV MP C 275kW turbine). Figure 12 shows an image of a demonstration wind turbine at the CNMI DPW Energy Division office.

Figure 12. Skystream 2.4kW residential wind turbine demonstration system at DPW Energy Division office.

HOMER is not optimized for accurate estimates for wind turbine generation (WTG) so other sources of accurate wind data and assessments from the literature were included for assessment of wind turbine generation technology. Table 12 summarizes HOMER model results for a 2.2 MW wind installation. Due to HOMER's limited capabilities for wind modelling, the results at all 3 islands were identical.

Table 12. Preliminary Wind Generation and Emissions Reduction Using Vergnet Turbine – HOMER

Location	Installed wind (kW)	Generation (kWh/Yr)	Mean output (kW)	Capacity Factor* (%)	CO2 Emissions Reduction (Metric Tonnes/yr)
CNMI	2200	6,344,074	724	33%	3,655,180

Data from the web application Global Wind Atlas was also assessed to determine power metrics at high wind speed locations that are not too close to residential or commercial districts. Global Wind Atlas provides mean wind power density available in at given location. Wind power density is the total power available within the swept area of a turbine, that is, the maximum power available that can be collected within the circle drawn by a turbine's rotors. Results using data from Global Wind Atlas is shown in Table .

Table 13. Wind Speed Data and Mean Wind Power Available (Assuming Hub Height 50m) – Global Wind Atlas[38]

Island	Location Easting	Location Northing	Maximum Wind Speed (ft/s)	Mean Wind Power Density Available (W/ft²)
Saipan	15.155648°	145.787544°	25.29	43.76
Tinian	14.968003°	145.658798°	25.00	44.41
Rota	14.128252°	145.175743°	28.15	54.63
Offshore	-	-	21.33	33.45

In general, the average offshore wind speed is approximately 21.3 ft/s (6.5 m/s) with an available wind power density of 360 W/m², which is lower than what can be achieved with onshore/land installations. However, offshore windspeeds are significantly more consistent than onshore and it is possible in the longer term to net a better generation output if the wind speed fluctuations are significant onshore. Figure 13 compares the power density of onshore and offshore wind installations. Offshore wind installations will require fixed foundations at water depths up to 30 m (100 ft), or could use of emerging technologies like floating foundations.

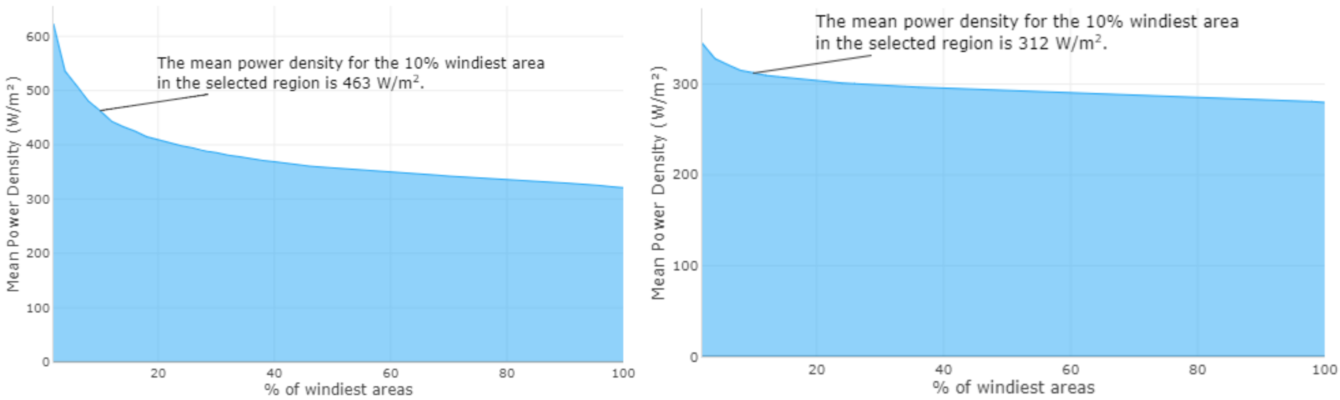


Figure 13. Onshore Power Density Curve (Left, avg = 43.01 W/ft²) and Offshore Power Density curve (Right avg = 28.99 W/ft²)

Extreme Wind Speeds

The CNMI has been struck on multiple occasions to extreme climate conditions. As recently as 2018, typhoon Yutu, a Category 5 typhoon, exposed Saipan to 10-minute sustained wind speeds of 130 mph with 1-minute sustained gusts of up to 180 mph[39].

Current wind turbine standards and technology are not generally designed to withstand Category 5 sustained and gust wind speeds. However, the current market does have WTGs classified for wind class IA (extreme 50-year gust wind speed of 155 mph [250 km/h] and high turbulence) and survival wind ratings greater than 124 mph (200 km/h). There are also options whereby the WTG are designed to be manually lowered in less than an hour in response to extreme weather conditions, allowing for the survival wind rating to rise to 190 mph (306 km/h) in the lowered position[40]. Figure 14 shows an example of a tilt down wind turbine. New certifications for large scale Offshore Wind technologies have recently been established, such as DNV's Typhoon certification (Class T certification) that take into consideration survivability to high sustained wind conditions. GE's 12MW Haliade-X offshore wind turbine is one of the first offshore wind turbine technologies to receive the Class T certification.

[38] Globalwindatlas.info. 2021. Global Wind Atlas. https://globalwindatlas.info/
[39] Carlowicz, M., 2018. Super Typhoon Yutu. https://earthobservatory.nasa.gov/images/144137/super-typhoon-yutu
[40] Vergnet GEV MP C 275 kW.

Figure 14. Tilt down Wind Turbine for Protection Against Extreme Wind Speeds

6.6.2 Cost Estimates[41]

The cost estimates are based on typical installations of WTGs using Australian market rates. No rebates, discounts or credits are included in the costing estimate for WTG. The base CAPEX for WTG in the US is approximately $1450 USD/kW, with an annual OPEX of $43 USD/kW[42]. Offshore WTG installations have an approximate CAPEX of $4100, and an OPEX of $110 USD/kW[41] [43]. An additional contingency factor of 20% was applied to account for large scale WTG being a new market opportunity in the CNMI.

Civil improvements to prepare land for installation of onshore WTG and offshore WTG is an additional cost of 6% and 2% of the CAPEX respectively. A summary of planning level costs is shown in Table 14 below[41].

Table 14. Planning Level Cost Estimate for Wind Generation

	Installed Capacity (kW)	Cost Estimate Onshore ($USD)	Cost Estimate Offshore ($ USD)
Saipan	2200	$4,057,680	$11,473,440
Tinian		$4,057,680	$11,473,440
Rota		$4,057,680	$11,473,440
Total		$12,173,040	$34,420,320

Further cost increases will need to be considered if smaller scale turbines (such as the Vergnet with the additional manual features shown in Figure 12) with lower hub heights are considered. Additional installed capacity may be required due to the decrease in efficiency with less height, which may increase cost. Larger Wind energy developments have a reduced cost per kW capacity (< $1400 / kW) due to economies of scale.[41] [44]

6.7 Geothermal Potential

6.7.1 Overview

Geothermal electricity generation is currently used in 26 countries. It refers to extraction of heat dissipated from the Earth's core radiating outward radially. In general, efficiency of geothermal generation increases with the temperature of a geothermal reservoir. Current technology allows for generation with geothermal reservoir temperatures as low as 135°F[45]. The potential for geothermal power in CNMI is dependent on geothermal reservoir

---

[41] Australian Energy Market Operator 2020 Costs and Technical Parameter Review. https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2021/aurecon-cost-and-technical-parameters-review-2020.pdf?la=en
[42] NREL, Annual Technology Baseline, Land Wind 2021 https://atb.nrel.gov/electricity/2021/land-based_wind
[43] NREL, Annual Technology Baseline, Offshore Wind 2021 https://atb.nrel.gov/electricity/2021/offshore_wind
[44] GenCost 2020-21, CSIRO. https://www.csiro.au/-/media/EF/Files/GenCost2020-21_FinalReport.pdf
[45] Kamil Erkan, Gwen Holdmann, Walter Benoit, David Blackwell, Understanding the Chena Hot Springs, Alaska, geothermal system using temperature and pressure data from exploration boreholes, Geothermics Volume 37, Issue 6, 2008

temperatures. Geothermal power generation technologies could provide consistent, sustainable power generation if a local geothermal resource is confirmed on any of the three islands.

Table 15 summarizes the two key modern technologies considered for geothermal power production.

Table 15. Geothermal Power Technologies

Generation Type	Minimum Reservoir Temperature (°F)	Description
Flash Steam	≥356	High pressure, hot water is pumped into low pressure environment. Resultant flashed steam is used to drive turbines. Cooled water is returned to reservoir via deep wells to be reheated. • Most common generation type in operation • Has fewer components compared to binary cycle and therefore has a reduced CAPEX
Binary Cycle	≥135	Hot water is used to heat a secondary fluid with a very low boiling point. Flash vaporization of the secondary fluid is used to drive turbines. • This generation type is the most common be constructed • More complex than flash steam systems, higher CAPEX • Has an efficiency of approximately 12%[46]

Due to the use of a secondary fluid, which allows for flash vaporization at significantly lower temperature, a lower minimum geothermal reservoir temperature is required for binary cycle geothermal power stations.

6.7.2 Existing Findings for CNMI

There are multiple islands along the Mariana Arc that have active volcanos, meaning there are high temperature geothermal reservoirs available.

In 2008, preliminary data from temperature logs taken from water wells in Saipan at various depths suggests that the temperature increase at depth on Saipan may be sufficiently steep such that electricity generation is feasible. The maximum projected temperature gradient is 257.17 °F/mile which is extrapolated from the temperature logs. The cost of transporting energy across islands would be prohibitive. Hence the desire for establishing feasibility for geothermal power on the three main islands in CNMI.

A study performed in 2009 assessed the geothermal generation opportunities for Saipan and nearby islands, particularly Pagan[47]. While elevated temperatures have been verified at depth on Saipan, the maximum measured temperature was only 92.91°F at a depth of 410 ft. Multiple locations on Pagan have been found to have varying degrees of elevated temperature geothermal systems that are possible suitable for electricity generation, the maximum water temperature measured at Pagan was 111.56 °F. The key limitation for Pagan being transmitting or transport of energy off the island being too expensive, so any development of geothermal power should be for local demand. According to CUC a test drill project demonstrated that the thermal resource on Saipan was not viable to build a geothermal power plant, however further investigations should be undertaken to confirm viability.

6.7.3 Cost Estimates

The pricing structure for the two generation types considered is dependent on the reservoir temperature and is summarized in Table 16.

Table 16. Geothermal Power Generation CAPEX Prices[48]

Generation Type	Operating Temperature CAPEX ($ USD/kW)			
	≥392 °F	302-392 °F	275-338 °F	< 275 °F
Flash Steam	3,000	4,140	7,004	10,950

[46] Ronald DiPippo, Chapter 8 - Binary Cycle Power Plants, Editor(s): Ronald DiPippo, Geothermal Power Plants (Fourth Edition), Butterworth-Heinemann, 2016
[47] Geothermal Resource Assessment of the Commonwealth of the Northern Mariana Islands, 2010. https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/1635.pdf
[48] National Renewable Energy Laboratory. https://atb-archive.nrel.gov/electricity/2019/index.html?t=gt

Generation Type	Operating Temperature CAPEX ($ USD/kW)			
	≥392 °F	302-392 °F	275-338 °F	< 275 °F
Binary Cycle	5,491	29,135	11,027	21,349
Average	3,906	7,720	8,794	16,248

Assuming the base case scenario where the minimal validated temperature for generation at 134.6°F using binary cycle generation is achievable in the CNMI, an indicative cost scenario can be presented. A 25% contingency factor is included to account for a new opportunity in CNMI, land development costs and preliminary planning and development. Table 17 provides a cost comparison of a 5MW geothermal power production facility with the equivalent sizing for solar PV using the pricing structure and capacity factors presented in Section 6.1.

Table 17. Geothermal Power Generation CAPEX Prices[48]

Location	Capacity (MW)	CAPEX + OPEX + Contingency ($ USD/kW)	Cost ($ USD)
Geothermal	5	$26,686.25	$133,431,250
Solar PV (No SAT)	5	$2,678.04	$ 13,390,200

6.8 Ground Source Heat Pumps

Ground source heat pumps (GSHP) are used to heat or cool a building via a heat exchanger embedded into the Earth. A vapor-compression refrigeration cycle can be used in such systems. The Earth is effective as a stable, consistent source of heat or to act as a heat sink and requires minimal additional electricity consumption to maintain desired temperatures. GSHPs can be very advantageous in regions with climatic extremes as a colder environment demonstrates the superior efficiency and sustainability of GSHP.

The capital cost of a GSHP system for a single household is between $15,600 – $23,400 USD and are typically serviced once or twice a year. The capital cost of GSHP is between 200%-250% of the capital cost of typical HVAC systems.

The CNMI is a tropical climate, as shown in Figure 15, and there are minimal temperature fluctuations throughout the year with a minimum temperature of 72.86 °F. There are also no extended periods at low temperature The net benefit high efficiency heating or cooling via GSHP is unlikely to offset the significant cost over traditional HVAC technologies using heat pumps in CNMI’s tropical climate.

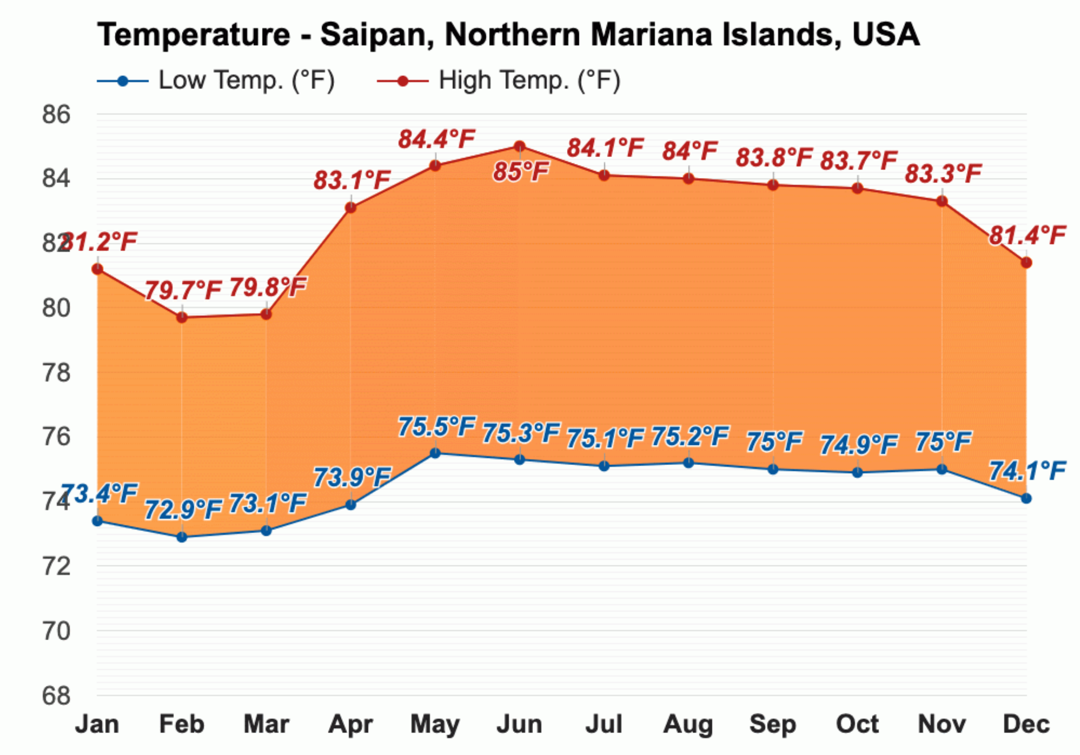


Figure 15. Average climate data in Saipan – Weather Atlas[49]

6.9 Microgrids

A Microgrid includes more than one form of energy resource and can perform as a stand-alone grid. With adding significant sources of solar and possibly wind energy, the CNMI electrical grids will become Microgrids, a system type that CUC is considering and could be implemented into new homesteads. The utilization of rooftop solar PV systems in a coordinated manner is what a distributed energy resource management system can provide. If a high renewable penetration Microgrid is planned, a form of energy storage combined with renewable resource forecasting might be required. A Microgrid control system balances energy sources and can integrate forecasting into the grid balancing computations. It ensures reliability of power supply with at the same time maximizing renewable energy penetration.

6.10 Energy Storage Systems

With increasing energy production of intermittent resources like solar PV and wind, an energy storage system might be advisable to provide reserve capacity. Reserve capacity might be required to provide power when renewable intermittent resources suddenly reduce due to cloud cover or change in wind. An energy storage system can keep the power supply reliable without having to run an excessive amount of diesel reserve capacity.

6.10.1 Battery Energy Storage Systems

Battery Energy Storage Systems are widely used to provide short-term spinning reserve and become increasingly utilized to shift energy from times of abundance into times of lack of renewable energy to maximize the energy used from renewable sources. It is an excellent tool to increase renewable energy penetration beyond the 20% - 30% threshold. Efficiencies of Lithium-ion based systems are > 80%.

The current costs for large standard Lithium-ion battery systems are in the order of $1 million USD per MW / MWhr for remote areas, but costs are predicted to fall.

6.10.2 Hydrogen storage

Hydrogen can be utilized as a long-term energy storage technology to buffer the peaks and troughs of intermittent energy resources. An electrolyzer is splitting water into hydrogen and oxygen, Hydrogen is then stored in high pressure tanks and the oxygen released to atmosphere or captured and stored in pressure tanks for other uses. A

[49] Weather Atlas, Monthly weather forecast and climate - Saipan, Northern Mariana Islands, USA. https://www.weather-us.com/en/northern-mariana-islands-usa/saipan-climate?c,mm,mb,km

fuel cell is utilized to combine hydrogen and oxygen to generate power. Water is generated as a waste product. To save capital cost a regenerative fuel cell can be used in lieu of the electrolyzer. At present the efficiency of energy storage using hydrogen is well below 50% and capital cost are high. It is expected that this technology will become more efficient and cost-effective over time.

6.10.3 Pumped Hydro Energy Storage Systems

6.10.3.1 Overview

Pumped hydro energy storage (PHES) systems constitute most global energy storage systems, meeting >90% of the requirement with almost 200 GW installed worldwide. It is a mature, cost effective and efficient form of storage, with some installations approaching 100 years of operation and 50 years being typical, costs between $1.5M-$2M /MW installed for 8-12-hour storage durations, and a round-trip efficiency of >80%.

Further advantages are the high level of local input in construction, low embodied energy, ability to train local support with high reliability, lack of waste over time and provision of water security for broad uses including firefighting.

The idea behind a PHES system is to store power produced during periods of excess generation, such as with solar PV during the day, as potential energy in reservoirs or tanks at elevation. During periods of higher demand, the water is run through a hydro turbine to generate power and help meet the demands.

6.10.3.2 Key Site Selection Criteria

Key site selection criteria for PHES are:

– Topography: adequate vertical difference between upper and lower storages (typically 300 feet < height <1,500 feet) and in the ratio of distance between them to the head difference (typically <6x); also suitable flat areas for large storage reservoirs, turkey’s nest type dams or valleys with gently upwards sloping floors but steep sides are ideal.
– Geology: competent geology of moderate strength and lower permeability, although weathering and permeability of stable strata can be overcome with liners and grouting; weak and unstable rock is a major challenge, and material unsuitable for concrete aggregate or rockfill is expensive to bring onto the site from elsewhere.
– Hydrology: although PHES are most commonly “closed loop” systems, reusing the same water each cycle, water is needed for the initial fill and replenishment of net evaporative and infiltrative losses; if dams are built in valleys, floods studies determine design parameters.
– Power: proximity to a distribution/transmission network or load, and sources of revenue from that network or load are necessary; the network needs to be able to provide starting power during pumping, and benefit from voltage and frequency stability, system strength and inertia, and black start and reserve capabilities.
– Regulatory/Social license to operate: the scheme must minimize environmental and heritage impacts and be acceptable to the community, while meeting regulations on construction and operations.

6.10.3.3 Saipan

In common with all the North Mariana Islands, Saipan is a marine limestone terrace punctuated by volcanic intrusions, uplifted by tectonic forces that have formed the adjacent Mariana Trench.

The intrusive range along the spine of the island provides relief of over 1,520 feet above sea level, while the populated west coast is low lying, showing areas of swamp (including Lake Susupe), just above high tide. An upper storage might be created in the depression down from the peak (interrupting one of the roads) for a full supply level (FSL) of 1,050 feet above mean sea level (MSL). This provides a potential 935 feet of head for storage just over 1.4 miles apart. The lower storage would need the area to be built up to provide adequate drainage below a liner to interfere with the local water table. Although this requires a greater footprint, it results in a storage with less level variation making it more visually and environmentally acceptable. The water in Lake Susupe is brackish, and reportedly contains edible fish, as well as being home to an endangered species of waterhen so it will be important to engineer the lower storage to not interfere with this valuable natural resource.

The geology of the island spine is no doubt predominantly intrusive volcanics, and these may be deeply weathered and set in a context of karstic limestone and residual marine facies. Construction of a turkey’s nest storage involving by cut slopes and embankments in this material will be complex, but it should be possible to provide a stable basin, although it may need to be fully lined as well.

The prevalence of karst on the slopes may provide some challenges to a surface pipeline which could also have aesthetic constraints, but this type of rock should also make burying the pipeline practical.

There appear to be few water storages of any size on the island, and only a single lake, so it would seem likely that water is generally not in short supply. But dry spells and droughts can occur, and bring with them fire risk, so additional water storages to guard against these risks would add value. The volume of water to fill the system will depend on the capacity adopted. For example, a 400 acre-ft storage could provide 30MW for 12 hours and could be accommodated on the footprints shown in Figure 16 below. The feasibility of this type of system on Saipan requires further study.

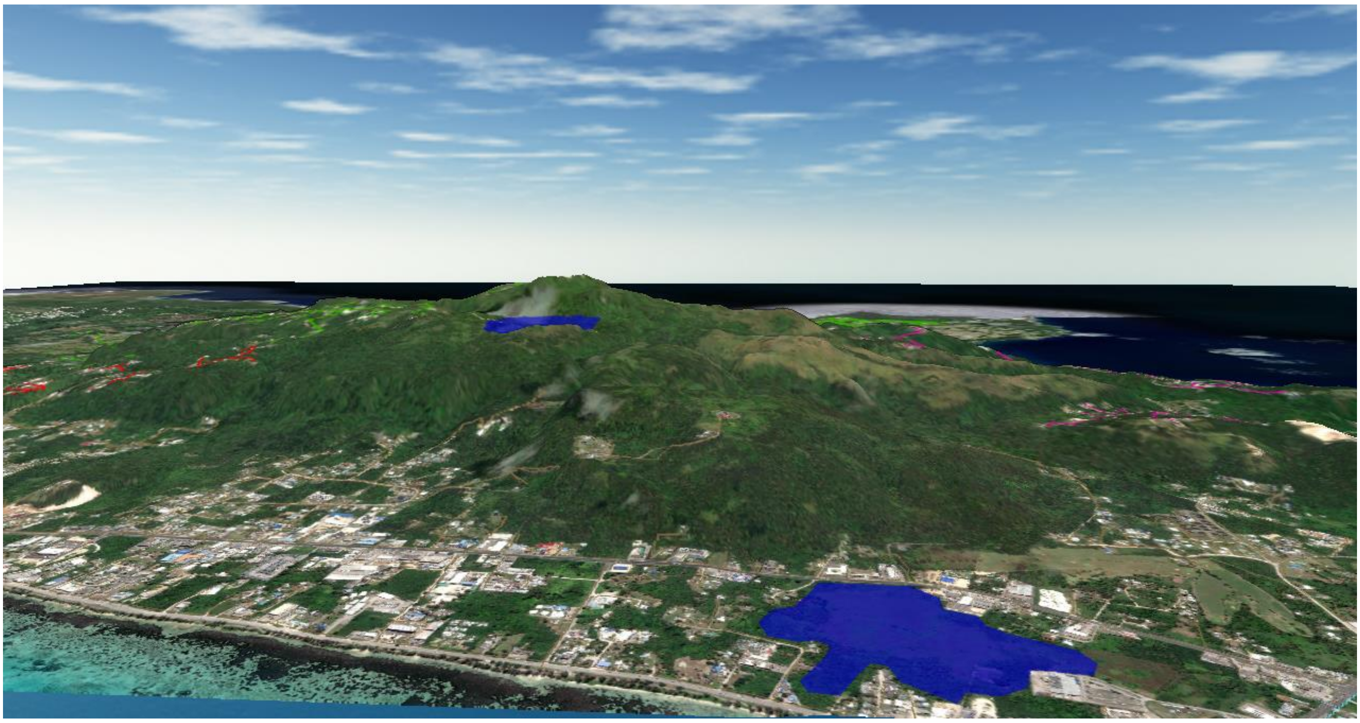


Figure 16. Illustrative concept for Saipan PHES

Clearly careful evaluation of the ability of the network to evacuate this amount of power at this point will need to be undertaken, but the PHES could provide considerable stability and reliability in addition to overnight storage of daily solar generation at a considerably lower cost than diesel generation.

The social and environmental impact of the PHES could be challenging to overcome and critical to endangered species, or on heritage areas of historical or aesthetic value, if not properly investigated and managed. PHES is largely an unknown to most communities and questions such as the areas inundated, how water levels fluctuate, and the water lost during operations all need to be explained and the community engaged with for a successful outcome.

6.10.3.4 Tinian

Tinian is like Saipan, an uplifted marine limestone formation, though with very little of the vulcanism that has formed the elevated spine of Saipan. This has resulted in a limestone terrace 165 feet – 260 feet above MSL. At the southern end there is a plateau at up to 600 feet above MSL, with a cliff into the sea at its southeastern extremity which contains some undercut caves. This topography creates the possibility of a seawater type PHES like that built on Okinawa in 1999, which is shown in Figure 17 below. Although largely a proof of concept, the Okinawa Yanbaru PHES system demonstrated the viability of this type of installation. It was eventually taken from service after a competing coal power station was constructed.

Figure 17 Okinawa Seawater PHES (31.4MW)

Such an installation would have sufficient head and proximity to the sea to meet topographical criteria, and the limestone platform in this region does not appear karstic if an open surface impoundment is used. When used in conjunction with a larger scale solar PV system, power generated during the day could be used to pump seawater into tanks which can then be drained through turbines back into the ocean to meet demands during after dark periods. A concept of such a system on Tinian is shown in Figure 18 on the following page.

Use of seawater in an excavated impoundment would require a liner to prevent infiltration of seawater into the groundwater. An alternative could be to construct a series of above-ground storage tanks on concrete foundations that fill and empty in series. Piping could be run along the cliff to the ocean, or a shaft could readily be sunk down below sea level for the powerhouse cavern, but the permeability of the strata at depth would need to be ascertained to determine whether ingress of water was likely to be a constraint.

The use of seawater overcomes concerns regarding the availability of initial fill or replenishment water and the elevated location obviates issues of flooding, other than into the powerhouse cavern.

The environmental impact of such as system, apart from impacts on the terrestrial and marine ecology during construction, also includes the challenge of not entraining marine life into the system. The issues are both that this sea life may fix itself to water passages but also that the significant rapid pressure and temperature changes would result in the death of most forms of sea life, and these dead organisms would be ejected into the sea during the energy generation cycle. The long term impact of this would need to be ascertained, and as a minimum, intakes would need to be designed to minimize the entrance of marine life into the waterways.

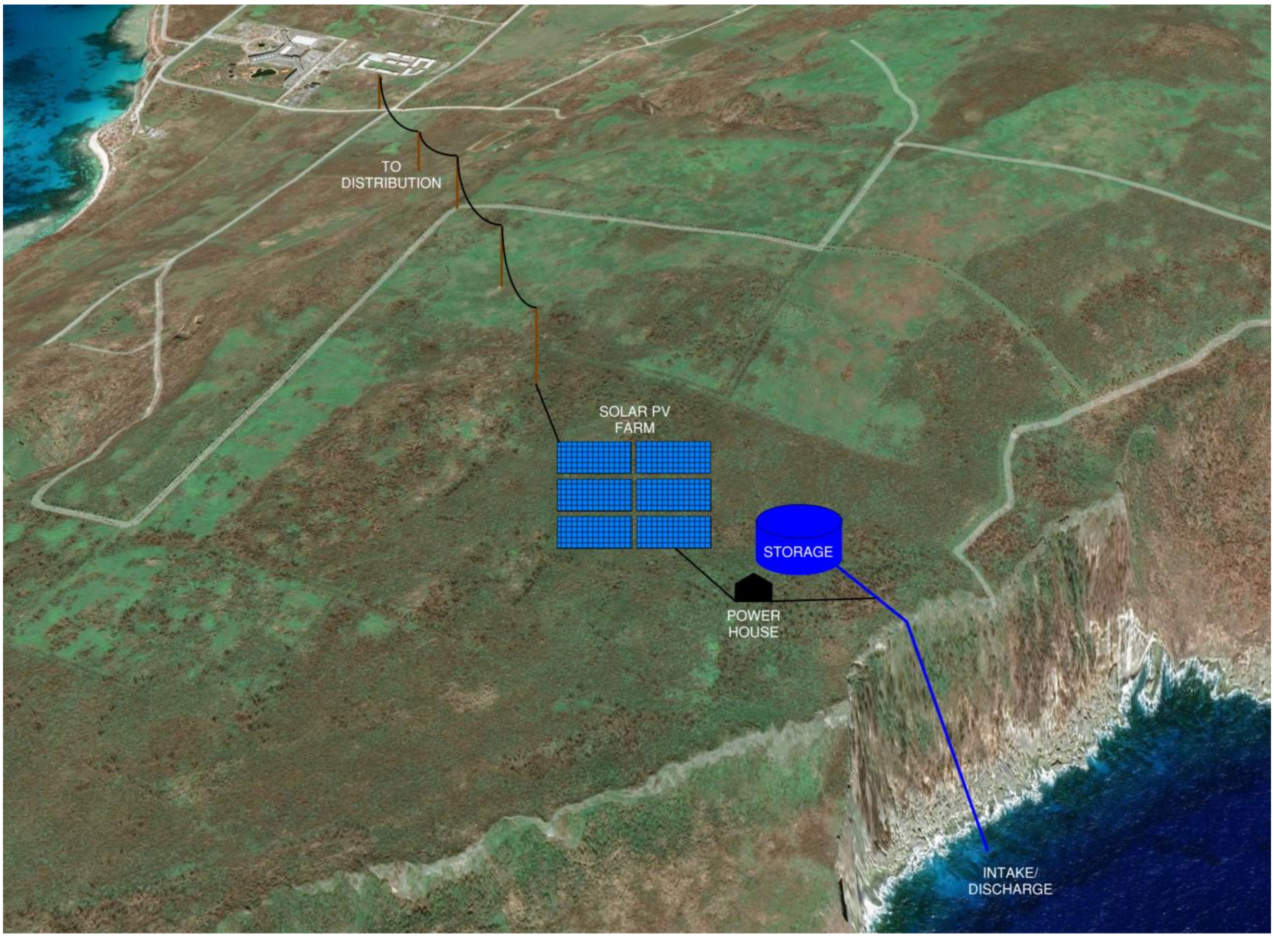


Figure 18 Illustrative concept for seawater PHES in southeastern Tinian

6.10.3.5 Rota

Like Tinian, Rota is a series of marine limestone platforms, but the uplift has been greater, resulting in the highest terrace of Mount Manila at 1,614 feet above MSL. The airport and village of Sinapalu are constructed on a broad terrace at around 560 feet above MSL, providing over 980 feet of elevation only 1.25 miles apart. A narrower terrace partly obscured by colluvium exists to the north of Mount Manila at a lower level. There is ample space on both the Mount Manila terrace and that adjacent to the village for adequate storage.

There is evidence of intrusive volcanics on the southern face of Mount Manila but most of the plateau is limestone exhibiting some karstic formations where weaker material has dissolved then recrystallized. This suggests that a liner would almost certainly be required for any open water impoundments, at least for the upper storage and most likely for the lower storage as well. A shaft would be sunk from the upper storage emerging at the base of the terrace, with a surface silo type powerhouse opening into the lower storage.

Water to fill and replenish the water in the scheme would need to be harvested from available groundwater supplies or from stormwater runoff from the airport. A seawater system like that described for Tininan could also be considered with appropriate siting studies, possibly near the south of the island.

The region suggested would enable a powerhouse to be built very close to existing power lines and the major loads in the village and airport. The area is used for agricultural production in places while the top of Mount Manila appears sparsely vegetated, as is common on exposed limestone terraces.

Figure 19 Illustrative concept for Rota PHES

A feasibility study is recommended for CNMI to evaluate the options and viability of PHES, particularly the use of a seawater-based system on the island of Tinian.

6.11 Underwater Power Cable Between Tinian and Saipan

The islands of Tinian and Saipan are approximately 3.3 miles apart. The cost of transporting diesel fuel to Tinian are high and have been reported at $0.60 USD per gallon (pre-COVID-19). There are also indications for a good wind resource on Tinian. A subsea marine cable has been discussed to provide an electrical connection between the two islands, reduce the number of power stations and avoid the cost in transporting fuel to Tinian.

Subsea marine cables are expensive to purchase and to install. A subsea high-voltage (HV) transmission cable at 33 kV would require step up transformers on each island as well. Cost estimates for cables vary between $20 - $50 USD per foot, and installation cost are estimated at between $25 million and $65 million USD. Any cable failure would incur repair cost in the order of $1 million USD or more, and due to mobilization requirements for a repair ship a significant waiting period would apply. [50]

As the contract for the current power plant operated by a private company through a power purchase agreement expires in March 2022, there is an opportunity to implement renewable energy on Tinian. Cost for a stand-alone system is expected to be much below the cost for a subsea HV cable connection.

6.12 Energy Development in the Northern Islands

On the northern islands of the CNMI archipelago there are currently residents without mains or grid power. Ecotourism or a potential homesteading program to expand agricultural production could lead to population growths and increasing energy needs. This is a unique opportunity to provide renewable power to residents without main grid power[51]. In Australia and parts of the U.S., stand-alone power systems have been designed and implemented to improve reliability for fringe of grid customers and save significant cost for maintenance of long distribution powerlines. These systems consist of a solar-battery system with a backup diesel generator, which are fully automated. The diesel generator starts when solar power and battery power reserves are low. These systems

---

[50] Electricity (strath.ac.uk)

[51] CNMI Strategic Energy Plan 2013 – page 22

have proven to be cost-effective and reliable[52]. It is recommended to consider a feasibility study to implement standalone power systems in the northern islands.

6.13 Transportation Strategies

The cost of vehicle fuel is high in the CNMI. Reducing the energy required for transportation is an important part of the CNMI energy strategy. Potential solutions to reduce transportation cost and energy demand from fossil fuels include:

- Developing public transport system to discourage use of personal transport.
- Utilizing more fuel-efficient vehicles, e.g., by offering discounts for fuel efficient vehicles or mandating a maximum fleet consumption level to manufacturers.
- Restructuring traffic flow to achieve efficient traffic flow (roundabouts, “green wave for traffic lights”, reduced number of stops)
- Utilizing locally produced biodiesel as a renewable resource
- Promote the use of electric vehicles (EV)[53]

Utilizing vehicle batteries as a demand management tool could be part of an integrated energy storage approach.

Integrated planning for a sustainable energy system needs to consider power generation, storage capacity, and the flexibility of demand. EVs can play a pivotal role in increasing demand flexibility, as they can absorb excess energy at times of peak generation and serve as additional energy storage capacity. As the battery capacity of an EV ranges from 10 kWhr to 100 kWhr, the cumulative charging and discharging of an EV fleet in a given energy and transport cluster could have a significant impact on grid balance and performance, particularly on small island power systems with installed generation capacities below 200 MW.

The geographic and economic characteristics of small island territories such as CNMI offer vast advantages for the roll-out of EVs. EVs can be significant off-takers of renewable energy, which will increase economy of scale and further reduce their generation costs as well as enhance electrical grid services and security of supply.

Small island territories such as CNMI are also at an advantage because their modest size means EVs would require less frequent charging than those on the mainland, where vehicles often travel longer distances. The limited road network on CNMI means that massive investment in charging infrastructure–one of the main drawbacks of the technology in larger systems–is not required. In addition, overwhelming the electricity distribution grid can be avoided. Even small-scale renewable energy generation can cover a significant level of EV penetration.

EVs can contribute to enhancing grid stability and energy security. Under appropriate policy incentives, EVs can absorb renewable energy generation surpluses. Vehicle-to-grid (V2G) solutions, whereby EVs are capable of feeding electricity back into the grid, have the potential to bolster the stability of islands’ distribution grids. They can also create significant cost efficiencies by providing balancing and ancillary services to the grid operator.

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. Passenger vehicles are parked for a large majority of the time. Therefore, their charging schedule can be adapted to the needs of the grid and the peak hours of electricity generation from renewable energy resources.

For the CNMI, the use of EVs can make renewable energy generation more economically viable, by absorbing the oversupply of power from intermittent energy resources and, by increasing electricity demand, create economies of scale for renewable energy installations. Under controlled charging schemes, EVs absorb the surpluses of renewable energy generation and thereby reduce the need for expensive curtailment and grid-balancing measures.

The increase in electricity demand would reduce the risk of renewable energy investments, as capital costs could be borne by a broader basis of end users and mitigate off-taker risks. Furthermore, the CNMI could offer discounts or other financial incentives for EV charging at off-peak demand times, applying preferential time-of-use rates.

A feasibility study is recommended for CNMI to evaluate the options and viability of supporting the rollout of EVs and EV charging stations.

---

[52] Off-Grid Power Systems | Solar Battery Storage Systems - Western Power

[53] National Renewable Energy Laboratory https://atb-archive.nrel.gov/electricity/2019/index.html?t=gt

6.14 Water Strategies

Pumping and treating potable water, as well as collecting, pumping, and treating wastewater, requires a lot of energy. Overall fuel use and energy expenses can be reduced by lowering water use and enhancing the efficiency of water pumping systems.

Potable water in the CNMI comes from groundwater sources (wells) and one small surface water source near the airport on Saipan. The monthly rates for residential and commercial customers have a tiered structure. Government customers are charged a significantly larger, flat rate, regardless of how much water they use.

The total energy use for water and wastewater services in the CNMI was not calculated for this report. The CUC estimates that leaks in the piping system cause losses approaching 50% of the potable water produced. Repairing these leaks and investigating ways to enhance pumping efficiency will result in a significant reduction in energy costs, as well as more efficient use of limited potable water resources. Investment in smart water monitoring systems and preventative maintenance can also significantly reduce losses and improve costs.

A leak detection program and investigation of illegal and unmetered connections to the water distribution is recommended. Water conservation and efficiency may also significantly reduce costs for CNMI government customers due to their very high-water rates and reduce overall energy and fuel consumption.

6.15 Public Education and Incentives

To implement various solutions towards energy efficiency and IDSM on the islands range of measures should be implemented including with public education and training. The public education should include educating public about various energy efficiency measures that they can use to reduce their energy consumption and save money. Training the local workforce to be knowledgeable in the design, construction, maintenance of the energy systems discussed and recommended in this report will help create local jobs and bring specialized skills required to develop and operate the energy systems and infrastructure. All the following initiatives could be implemented by CUC, DPW and the local Northern Marianas College (NMC) with government support while offering incentives to consumers to increase their adoption rates.

6.15.1 Time of Use tariffs

Both ToU and TBR should be adopted because a utility will charge a different price to retail customers depending on the time of the day considering off-peak and peak periods. A customer who is aware of the difference in price will take it into account to lower their electricity bills. This approach can be implemented differently depending on customer type (residential and commercial). Overall, ToU will benefit both the customers and the utility by allowing them to manage the demand during peak loads.

6.15.2 Energy Audits

Energy audits are a very effective method to identify how energy consumption can be reduced. A major portion of energy consumption in buildings is related to heating, cooling, and other applications. An audit program can be used by CUC and DPW for both public and private industry to educate them about energy saving opportunities. By following this approach, building code enforcement, including the CNMI Tropical Energy Code, and more efficient building designs could improve energy efficiency.

6.15.3 Cool Roof Program

The existing cool roof program could be expanded, and additional incentives offered on the islands to reduce heat absorption thus reducing the energy consumption. Cool roof requirements in the CNMI Tropical Energy Code should be enforced for new and reconstructed roofs. Requirements for old buildings without roof insulation should enforced to increase energy efficiency. Based on this principle, several regions around the world[54] are implementing similar initiatives to save energy.

---

[54] Grants and funding | energy.gov.au

7. Multi Criteria Analysis

7.1 General Strategy

The Multi criteria approach is utilized to integrate several criteria in an analysis to distinguish between technologies to find the most feasible and cost-effective solution considering all criteria. For this analysis, the CNMI is looking for new low-cost and energy efficient sources of energy, able to be integrated into the current energy portfolio and significantly reducing its carbon footprint.

7.2 Criteria selection

The criteria to assess and compare technologies or other solutions must be in line with the long-term energy strategy of low-cost, low-carbon intensity and renewable energy sources. Capital cost and O&M costs are important criteria to decide on the best technology. Life-cycle cost or levelized cost of energy summarize cost adequately. The levelized cost of energy (LCOE) is a measure of a power source that allows comparison of different methods of electricity generation on a consistent basis. It is an economic assessment of the average total cost to build and operate a power-generating asset over its lifetime divided by the total energy output of the asset over that lifetime.

Scoring of cost criteria is qualitatively assessed as high, medium, and low cost, where high is benchmarked to the current cost of diesel generation.

– High is used for LCOE > $0.15/kWhr
– Medium is LCOE > $0.1/kWhr and LCOE < 0.15/kWhr, and
– Low cost is benchmarked for LCOE < $0.1/kWhr

The shortlisted solutions must assist in CNMI's goal to reducing carbon emissions substantially. So low, medium, and high carbon footprint is another important criterion.

Community acceptance is another important criterion, the proposed solutions will be discussed in a public outreach process and community acceptance determined thereafter. Not all clean and cost-effective solutions are acceptable to the public or the government. For example, there might be visual (solar PV glare issues) or noise issues (wind turbine noise), or environmental issues to be considered.

Baseload / intermittency of the technology should also be considered, as base load technology does not require backup capacity. Intermittency can be mitigated with either an energy storage solution or increased spinning reserve.

Technical feasibility looks at the energy source and its technology to measure if it is a technical and commercially mature technology can be implemented in this environment at the required scale. It is a binary criterion excluding a technology from consideration.

Table 18 on the following page summarizes the multi criteria assessment of the alternative energy options discussed in Section 6 and indicates whether the option should be pursued further in study, analysis and implementation.

Table 18. Multi-criteria assessment summary

	Whole of life cost	Carbon emissions	Community Acceptance	Base load / intermittency	Technically Feasible and proven	Risk mitigation for intermittency	Recommended
Rooftop solar PV	Low	Low	Yes	intermittent	Yes, needs to be cyclone rated	Energy Storage system	Yes
Solar PV utility size	Low	Low	Yes	intermittent	Yes, needs to be cyclone rated	Energy Storage system	Yes
Wind offshore	High	Low	TBD	intermittent	No, lack of shallow water	Energy Storage system	No
Wind onshore	Low	Low	TBD	intermittent	Yes, needs to be cyclone rated	Energy Storage system	Yes
Geothermal	High	Low	TBD	Base load	Yes	Not required	No
Waste incineration	High	High	TBD	Base load	Yes	Not required	No
Waste from sewerage	Low	Low	TBD	Base load	No, sewage flows are too low	Not required	No
Landfill gas capture and conversion	High	Low	TBD	Base load	Yes	Not required	No
Solar Hot water	Low	Low	Yes	Demand management measure	Yes	Not required	Yes
Smart Metering	Medium	Low	TBD	Demand management measure	Yes	Not required	Yes
Ground source heat pump	Medium	Low	TBD	Demand management measure	Yes	Not required	Yes
Battery Energy Storage System	High	Low	Yes	Demand smoothing	Yes	Risk mitigation measure	Yes
Pumped Hydro Energy Storage	Medium	Low	TBD	Demand smoothing	Yes	Risk mitigation measure	Yes
Diesel power generation	High	High	Yes	Base load	Yes	Not required	Listed for comparison

8. Energy Policy Review

8.1 Current Policy Background

The Commonwealth Utilities Corporation (CUC) is a state government corporation that regulates and operates the electric power, water, and wastewater services on the three main islands of Saipan, Tinian, and Rota. The CUC is an autonomous agency of the CNMI government.

8.1.1 Energy snapshot

A snapshot[55] of the existing environment (2020) indicates the following:

– The CNMI meets nearly all its energy needs with imported petroleum products, including diesel fuel used for both electricity generation and transportation. Refined petroleum accounted for 21% of CNMI's import costs in 2018.

– Electricity customers in the CNMI pay a fuel surcharge that varies with the price of diesel fuel. In August 2020, CNMI's fuel surcharge was 37% less than a year earlier because of a decline in world petroleum demand and prices, due, in part, to the global coronavirus pandemic.

– In 2017, Gross Domestic Product (GDP) per capita in CNMI was less than half that of the U.S., but CNMI had one of the fastest growing economies in the world that year, primarily because of increased tourism and new casinos.

– The CNMI had no solar energy capacity in 2010, but by 2020, it had 2 megawatts with plans to add two new solar power plants with a combined capacity of 5 megawatts.

– The CNMI's electric utility, CUC, generates electricity at five diesel-fueled power plants--three on Saipan and one each on Tinian and Rota--and the territory’s entire population has access to electricity except in the islands north of Saipan.

The CNMI has adapted an energy policy framework designed to assist moving towards a future where renewable energy resources provide a better alternative and consequently dependence on fossil fuels is reduced and a future where costs of energy services are affordable and sustainable, thus allowing households equitable access to electricity. The framework objectives aim to establish a future where security and sustainability of energy supply are achieved. The related energy policy legislation is briefly outlined in Section 8.2. In 2010, the ETF was created by executive order to develop a strategic energy plan and oversee the implementation of the plan’s constituent strategies. In 2012, the EFT developed the Strategic Energy Plan, which was adopted in July 2013 with renewable energy and demand side management the focus of the plan. While an overarching CNMI energy policy may not be developed, energy objectives are being achieved through targeted policy strategies as listed in Table 19 and legislation and initiatives discussed in Section 8.2.

Table 19. Existing Energy Policy Initiatives[56][57]

Renewable Energy	Legislation Reference
Renewable Portfolio Standard/Quota (RPS)	Public Law 15-23
Net metering/billing	Public Law 18-62, 18-75
Interconnection Standards	Public Law 18-62, 18-75
Demand Side Management	**Legislation Reference**
Building Code adaption (IBC)	Public Law 15-23
Streetlight LED conversion project	Public Law 15-23
Energy Efficiency- weatherization program	Public Law 15-23
Energy Efficiency- appliance rebate program	Public Law 15-23
Demand Side Management	**Legislation Reference**
Energy Conservation- education program	Public Law 15-23
Energy Conservation – prepaid meter program	Public Law 15-23

[55] US Energy Information Administration 2020
[56] CNMI 2013 Energy Action Plan
[57] Energy Transition Initiative Snap Shot 2015

8.2 Policy Legislation

The CNMI Legislature finds that the people of the CNMI demand and deserve, at the earliest possible time, reliable power at affordable rates delivered by an efficient, well-managed utility service.

The Legislature finds that the CNMI must find ways to conserve energy and explore alternative energy sources. Rising world oil prices have had a profound effect on the Commonwealth most notably with regard to public utilities. The Legislature further finds that the CNMI must reduce its dependence on fossil fuels and move toward the use of renewable energy while setting realistic deadlines for meeting this goal.

A summary of related public laws and application introduced to achieve these objectives is briefly described in the following subsections.

8.2.1 Public Law 15-23: Energy Conservation Act (August 2006)

The primary goals of the Energy Policy and Conservation Act (1975) are to increase energy production and supply, reduce energy demand, and provide energy efficiency. In particular, the Act’s purpose is to incentivize alternative energy and to establish requirements for the use of renewable energy, energy efficiency and for other energy and cost-saving measures.

Public Law 15-23 (2006) introduced the Chapter 6, Energy amendments to provide for adoption of:

- High Performance Buildings Standards Act.
- Renewable Portfolio Standards.

8.2.2 Public Law 15-26: To Amend 2 CMC § 4483 by adding a new subsection (c); and for other purposes (August 2006)

The purpose of this legislation is to amend 2 CMC § 4483 giving the Northern Marianas Housing Corporation (NMHC) the authority to require through regulation that all new home loan applications, on a voluntary basis, incorporate solar thermal technologies and/or a water collection and storage system into their new home developments to provide options to address issues of fuel price increase, uncertainty in CUC’s power generation capability and persistent problems of water availability.

The legislation allows NMHC to either require all new home loan applicants to incorporate solar thermal technologies into their new home developments or develop a separate solar thermal technologies loan program that will provide loans for homeowners to install such technologies into their homes.

8.2.3 Public Law 15-87: To Amend Certain Section of Public Law 15-23 (September 2007)

The purpose of this legislation is to amend Public Law 15-23 to allow customer-generator or private power producers to produce and sell electricity produced by renewable energy to the CUC on a large-scale basis and to provide for incentives to produce renewable energy in the Commonwealth.

The Legislature finds that Public Law 15-23 established incentives for producing electricity using alternative or renewable energy. However, Public Law 15-23 limits the scope in which a customer-generator or a private power producer could produce and sell electricity produced by renewable energy to the CUC or a utility company.

8.2.4 Public Law 16-17: CUC Private Sector Partnership Act of 2008 (October 2008)

The primary purpose of this legislation is to allow and encourage the CUC to engage the private sector to partner with the Commonwealth to secure reliable utility services at affordable rates.

The Legislature finds that the people of the Commonwealth demand and deserve, at the earliest possible time, reliable power at affordable rates delivered by an efficient, well-managed utility service. To achieve this goal, the CUC requires an infusion of funds. A source of funding may be available through CUC's issuance of public utility revenue bonds, federal grants or through private sector investment and other funding sources that are independent of the Commonwealth and federal government.

8.2.5 Public Law 17-34: To Amend Section 3 of Public Law 16-17 (March 2011)

The purpose of the Public Law 17-34 Amendment to Public Law 16-17 is to give the CUC the flexibility needed to partner with the private sector to provide reliable service at efficient rates.

The Legislature finds the Commonwealth and CUC are to implement successful models of public-private sector partnerships. These models range from privatization of management through performance management contracts, as undertaken on Guam, to privatization of an entire utility service regulated by a public utilities commission.

By taking advantage of one or more of these models, the Commonwealth and CUC can draw on outside financing and expertise from the private sector to meet and resolve the power supply challenges.

8.2.6 Public Law 18-62: Renewable Energy (September 2014)

The purpose of the Public Law 18-62 is to amend the standards for the renewable energy portfolio for electrical power producers and to authorize the installation of net energy metering for all eligible residential customer-generators, and for other purposes.

The Legislature finds that renewable energy sources are becoming readily available and more and more residential customers are seeking new options, even if it is at their expense, to help reduce the high costs of utility rates.

8.2.7 Public Law 18-75: Net Metering for PSS and CHCC (February 2015)

The purpose of Public Law 18-75 is to amend renewable legislation to prioritize net metering for health and education renewable energy capacity.

The Commonwealth Legislature finds that the Commonwealth Healthcare Corporation (CHCC) and the Public School System (PSS) continue to struggle to pay very exorbitant utility bills. At the same time, the Legislature finds that the Commonwealth government cannot afford to fully subsidize CHCC and the PSS. The Legislature finds that the only way to reduce utility costs is to utilize renewable energy sources to offset the electricity or other utility required for the operations of CHCC and PSS. Accordingly, the purpose of this legislation is to provide a definition for net metering and to prioritize the interconnection with net metering for health and education renewable energy capacity.

8.2.8 Renewable Energy

8.2.8.1 Renewable Portfolio Standard

The CNMI government enacted a renewable portfolio standard (RPS) in 2006[58] that set a target of 80% of electricity sales from renewable energy by 2014. The RPS was amended in 2014[59], and the target was reduced to 20% of electricity sales from renewable resources by 2016. Although the target was not met, several small-scale solar PV and wind projects have been installed at private residences, public facilities as demonstration projects, and public schools. Not all installations are still functioning.

The RPS also requires government departments to help the CUC and developers locate potential renewable energy sites, assist in planning and permitting, and publish a list of sites for potential renewable energy development every two years.

Several larger solar energy projects are in development, including a new 3-megawatt solar PV plant on Tinian and a new 2-megawatt solar PV plant on Rota.

8.2.8.2 Net Metering Policy

“Net metering" means measuring the difference between the electricity supplied through the electrical grid and the electricity generated by an eligible entity and fed back to the electric grid over a monthly billing period.

The CUC, the only public utility in the CNMI, is required to offer net metering to its commercial and residential retail electricity customers for renewable energy systems and has implemented a net energy metering policy that

[58] Public Law 15-23
[59] Public Law 18-62

permits residential and commercial energy generation systems under 100 kW until 30% of CUC's peak demand has been met. That is, the aggregate capacity limit of all net-metered systems on the island of Saipan, Tinian, or Rota, cannot independently exceed 30% of CUC's system peak demand on the island where the system is located.

A variety of renewable technologies are eligible, and customers receive a credit at the retail rate for excess production. The credit rate drops to 50% of the retail rate for remaining excess generation after the 12-month billing cycle. The net metering program was augmented in 2015 under Public Law 18-75, which obligated the utility to prioritize the interconnection of distributed generation at health and educational facilities due to the impact of high electricity costs on those facilities.

8.2.9 Demand Side Management

As described in Section 5.3, DSM encompasses utility-initiated actions to improve energy efficiency, increase energy conservation, and reduce peak electricity demand. Examples include conservation education, rebates, incentives, utility investments that improve building shell insulation and the efficiency of heating and cooling systems, and rate structures that shift demand from times of peak energy use to off-peak hours.

In 2010 the CNMI took a proactive approach to energy efficient new construction by adopting the International Building Code (IBC) energy codes for residential and commercial buildings and a local CNMI Tropical Energy Code, which provides additional requirements based on both the local climate and expertise[60]. Currently, the 2019 IBC is enforced in the CNMI, and the CNMI Tropical Energy Code was revised in 2014.

The U.S. Department of Energy has provided funding programs[61] to CNMI to support the following DSM Initiatives:

– Weatherization, a program to improve energy efficiency in homes supported by education and training programs.
– Incorporating energy efficiency technologies and practices in buildings, installing energy efficiency retrofits in school buildings, and providing for the development, implementation, and enforcement of energy policies.
– Energy Efficient Appliance Rebate Program, which offers consumer rebates for purchasing certain ENERGY STAR® rated appliances.

The DPW Energy Division is responsible for managing the energy efficiency rebate programs in the CNMI and enforcing building and energy code requirements. They have provided updates[62] to funded DSM programs as noted below.

– **Energy Awareness Campaign:** DPW Energy Division gives out free portable propane stoves and LED lights. One or the other for a $50 value. Verified with ID and power bill. This initiative falls under public education and conservation outreach and outreach program to educate residents about energy efficiency and how to conserve energy. In December 2021 alone more than 600 individuals took up this initiative. Past annual give-away programs included fans, but this has now ceased.
– **Income based Weatherization Assistance Program (WAP**): Offered free refrigerators and air-conditioning units, up to 10k BTU. The program also offered replacement LEDs for incandescent lights.
– **Cool Roof Program:** Objective to keep homes cooler. Commenced in 2011 as a rebate program. Part of education and conservation public outreach. Current offer is purchase one get one free. For example, purchase roof primer and get elastomeric product.
– **EnergyStar rebate program:** A currently active State Energy Program. Not income based. Objective to replace inefficient appliances with efficient appliances. It's a first-come first-serve basis. The typical process involves an announcement on rebate program and the customer applies for and receives a voucher from DPW. The voucher is presented to a vendor at the time of appliance purchase. The vendor gives a discount to the customer and delivers/installs appliance. The voucher is then returned to DPW Energy Division to pay back the vendor.

DPW has also noted that previous energy efficiency programs, such as government building retrofits, have been implemented depending on level of funding available.

While these initiatives should have contributed to reduced peak demand, information on the outcomes of these programs was not available for review.

[60] CNMI SEP2013 NREL
[61] U.S. Department of Energy Northern Mariana Islands Recovery ACT snapshot
[62] DPW response to GHD RFI December 2021

8.3 Future Policy Considerations

8.3.1 Challenges and Opportunities

In the policy and regulatory realm, the CNMI still has tools at its disposal to reach its sustainable energy goals and decrease its dependence on fossil fuels.

Transforming small-island power systems requires appropriate technical planning studies for the integration of various renewables particularly in identifying the technical challenges such as frequency and voltage stability that must be addressed to integrate high shares of solar and wind energy. Consideration must be given to system specificities, available resources, and the need to maintain a secure and reliable power system[63].

Encouraging long-term investment in renewable energy technologies is key to the success of an energy transformation, such as using independent power production (IPP), feed-in tariffs (FiT), and other policies. An IPP is typically a private entity that owns facilities to generate electric power for sale to utilities and end users. A new solar farm in Dandan was recently completed under an IPP agreement. A FiT is a policy mechanism designed to accelerate investment in renewable energy technologies by offering long-term contracts to renewable energy producers. The goal of a FiT is to offer cost-based compensation to renewable energy producers, providing price certainty and long-term contracts that help finance renewable energy investments.

While most developments lean towards low-carbon transition have been focused on renewable energy, energy efficiency holds the complementary potential to drive the CNMI's sustainable energy transition. Moreover, from a policy perspective, encouraging and adapting increased use of energy-efficient technologies reduces electricity demand often at a lower capital cost than investing in new energy infrastructures.

Research indicates[64] that informal aspects such as historical legacy, cultural norms, degree of informal stakeholder interactions and informal networks all play a part in determining whether formal policy structures will be effective in delivering successful outcomes when implemented.

Table 20 identifies policy development that could attract greater investment in renewable energy and DSM solutions.

Table 20. Policy Development Options

Renewable Energy	**Brief Description**
Subsidized rooftop solar	Schemes that incentivize residential roof top solar installation and offer rebates or 0% interest financing.
Incorporating solar at homestead sites	Reserve a portion of homestead lands to be dedicated to solar energy production.
Incorporating microgrids at homestead sites	Microgrids could be used at remote homestead locations. Homes likely must comply with current NEC standards.
Subsidized residential storage (BESS)	Schemes that incentivize installation of residential battery storage to compliment solar panel installation and offer rebates or 0% interest financing.
IPP / FiT fixed tilt solar farms	Independent Power Producer develops and funds the solar farm with a Power Purchase Agreement (contract) in place to purchase the energy output.
IPP / FiT small wind (275kw**)**	Independent Power Producer develops and funds the wind power turbine with a Power Purchase Agreement (contract) in place to purchase the energy output.
Long Term Energy Service Agreements for grid scale solar, wind or storage	Project viability supported by long term Power Purchase Agreements for energy and /or ancillary power system services.
Permitting and siting standards	Availability of clearly documented permitting processes and standards including timelines and information required to gain approval for renewable energy developments and connection to the network.
Demand Side Management	

[63] IRENA report transforming small island power systems
[64] Drivers and inhibitors of renewable energy 2016

Subsidized solar hot water systems	Schemes that incentivize solar hot water system installation by offering rebates or 0% interest financing.
Smart metering peak demand tariffs	Introduction of peak demand tariffs that incentivize customers to reduce power demand during peak hours.
Subsidized PF correction	Schemes that incentivize customers to reduce network losses by offering grants to install power factor correction particularly in commercial or industrial facilities.
Subsidized BMS	Schemes that support funding of smart building systems that enable automatic control of energy efficiency outcomes such as lighting, heating, and cooling.
Energy efficient housing	Schemes like home insulation, cool roof etc.

8.3.2 Network climate resilience

The Northern Mariana Islands are vulnerable to tropical storms and typhoons. Saipan's power generation and distribution system were badly damaged by Typhoon Soudelor in 2015, which led to several months of power outages and disruptions of the public water supply and wastewater treatment systems. More recently, Typhoon Mangkhut devastated Rota in September 2018, and damaged much of that island's energy infrastructure, and then Typhoon Yutu hit Saipan and Tinian in October 2018 causing significant wide-spread damage. In 2019, CNMI revised its economic development strategy to improve the resiliency of its infrastructure against typhoon and earthquake damage. In 2020, the CUC received $36 million in funds from a federal grant, which will allow them to repair and harden infrastructure impacted by recent typhoons. Additional funding through the Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program (HMGP) and Public Assistance (PA) programs to address damage from Typhoon Yutu and mitigate future hazards is still in process to fund resiliency projects on Saipan, Tinian and Rota. The CUC plans to use these funds for power plant upgrades, replacement of wood power poles with concrete power poles, and burial of overhead power lines to avoid damage from future storms[65].

8.4 Public Outreach

Public outreach and public input were performed for the period of December 9, 2022 through March 31, 2023. Newspaper advertisements were posted in Mariana's Variety and Saipan Tribune on December 9, 2022, and for one week online with each newspaper. Public comments and input were obtained through a Social Pinpoint website. Social Pinpoint is a leading digital engagement tool that enables community planning professionals and public agencies to build hybrid participation strategies that drive greater reach, diversity, consultation, and collaboration on a wide range of projects.

A Social Pinpoint site was established for the Strategic Energy Plan update, which enabled the public to review the Draft SEP report, provide specific comments and input, take a survey and voice ideas and concerns. Comments were graphically linked to mapped locations on each island. The site also included a comment form. The project website URL was: http://lrsp.mysocialpinpoint.com/cnmi-sep.

The following sections summarize the public comments received.

8.4.1 Website Visitation

During the approximately 4-month public comment period there were a total of 1,366 visits to the project website by 506 unique users/individuals. The average time each user spent on the website was a little under 1 minute (57 seconds).

A total of eight (8) downloads of the Draft SEP document occurred.

There was a total of 18 comments received.

There was a total of 22 survey responses recorded.

The chart in Figure 20 graphically summarizes the website visitation for the public input period. Following public notice there was a noticeable spike in website traffic and comments. Half of the comments received were in December 2022, and the remaining half were in March 2023.

[65] US Energy Information Administration 2020 update

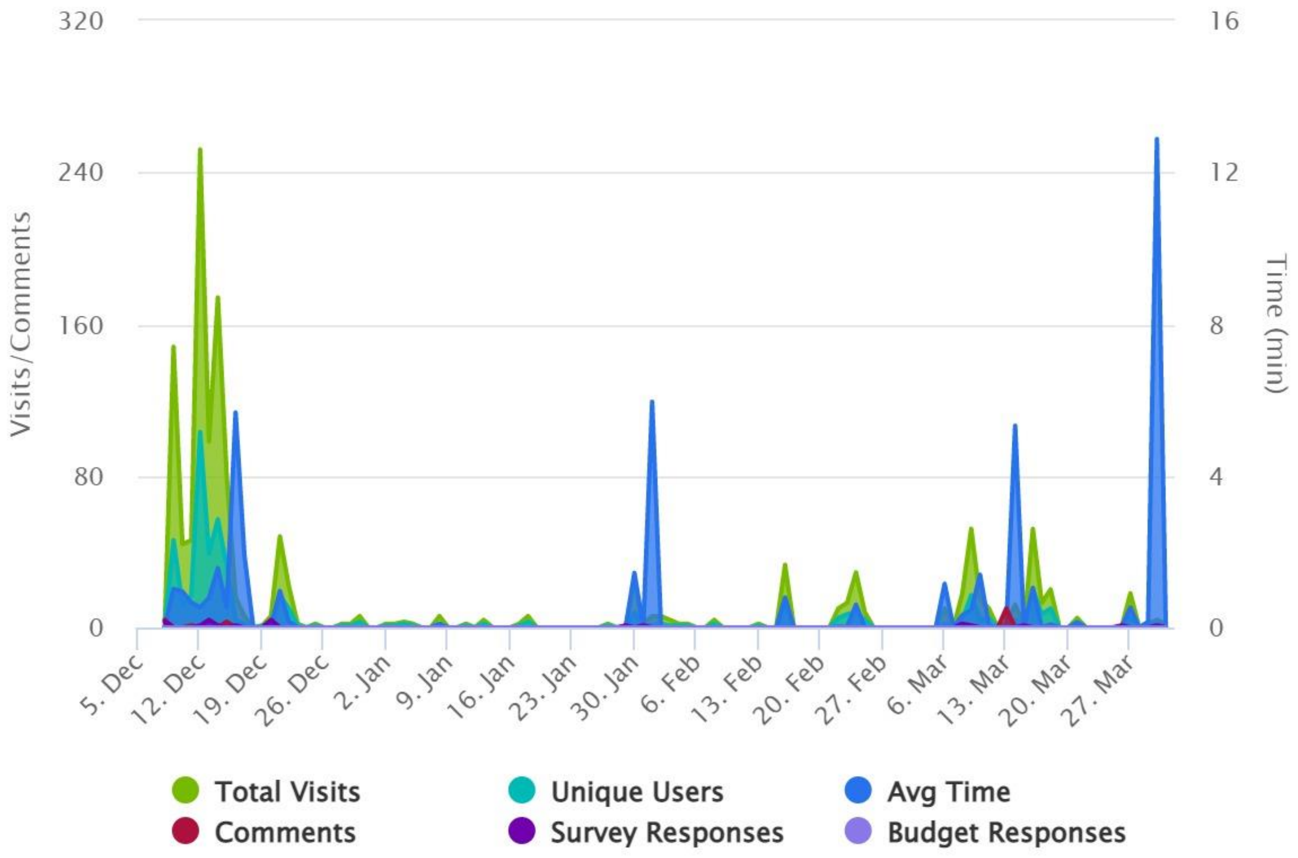


Figure 20 Summary of public engagement by day.

8.4.2 Public Comments

The comments received primarily focused on applications for solar energy, as shown in Figure 21 below.

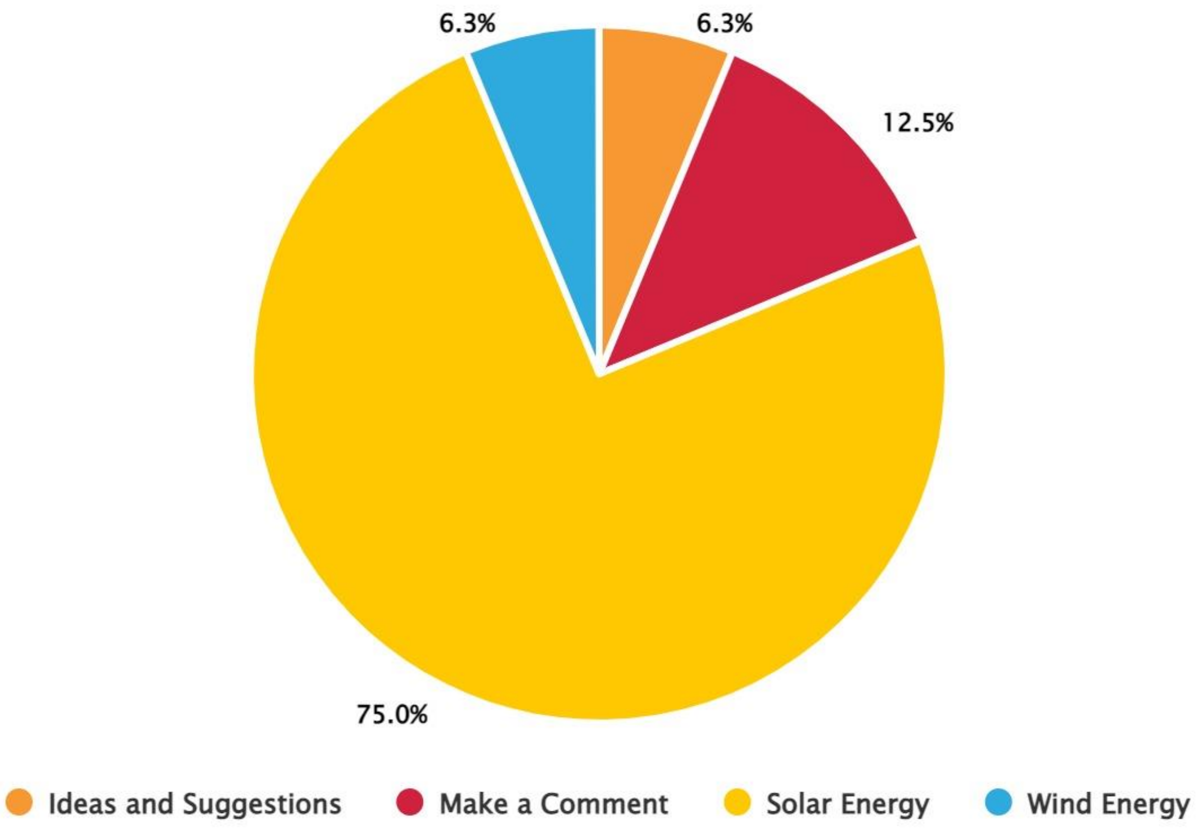


Figure 21 Summary of public comment types.

Eleven of the comments received were geographically linked to the island of Saipan, and the remaining 7 were associated with Tinian. There were no comments associated with Rota. Figure 22 shows the geographic associations of the comments for each island.

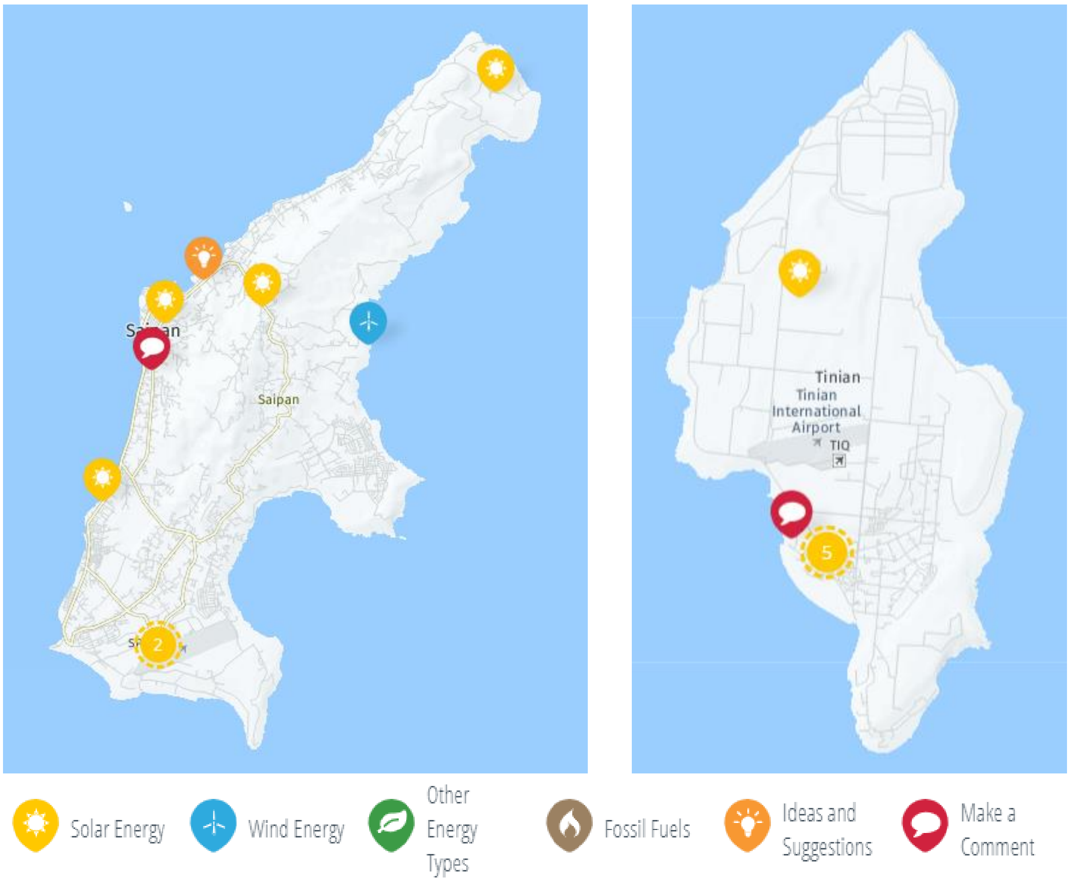


Figure 22 Geographic locations of comments linked to the islands of Saipan and Tinian.

Table 21 below summarizes the comments received on the Draft CNMI Strategic Energy Plan. Fourteen of the eighteen comments received focused on expanding development of solar energy generation at schools, parks and other public facilities as well as residential rooftop. Solar energy comments also included locating solar farms near power plants, and at airports where there are large areas of open space. One comment discussed the possibility of wind energy on Saipan’s east coast, and several comments discussed the implementation of microgrids for government facilities and homestead subdivisions.

8.4.3 Public Opinion Survey

A twelve-question survey was developed as part of the public outreach effort to gauge the public opinion on topics of renewable energy. The survey questions and responses are summarized below:

1. Considering your complete knowledge about renewable energy and its benefits, how likely would you be to recommend your friend or colleague to start using them (0 being low and 10 being high)?

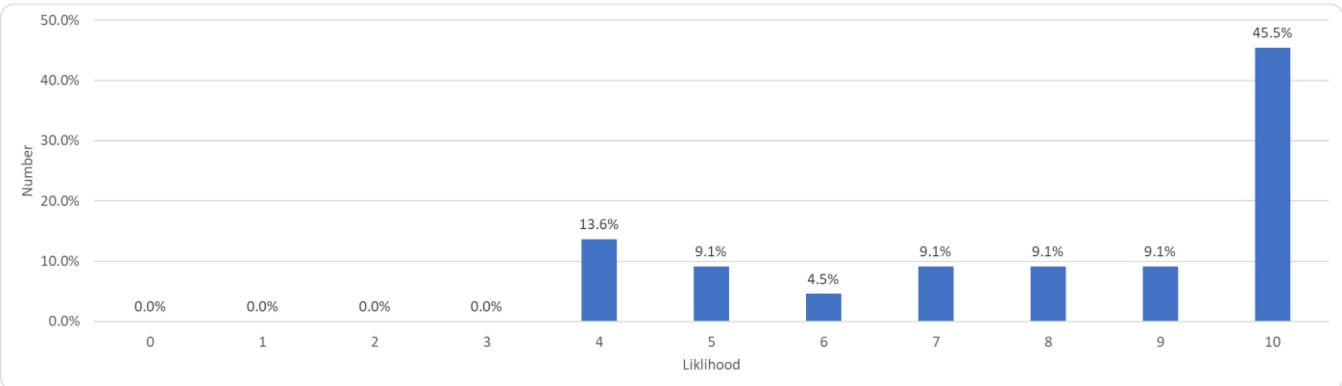
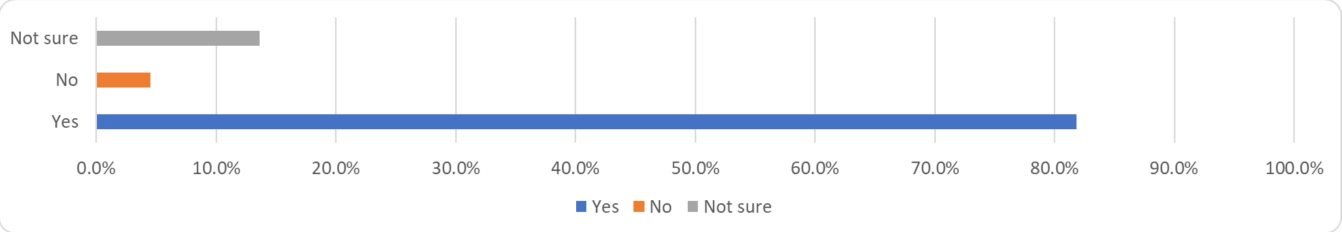


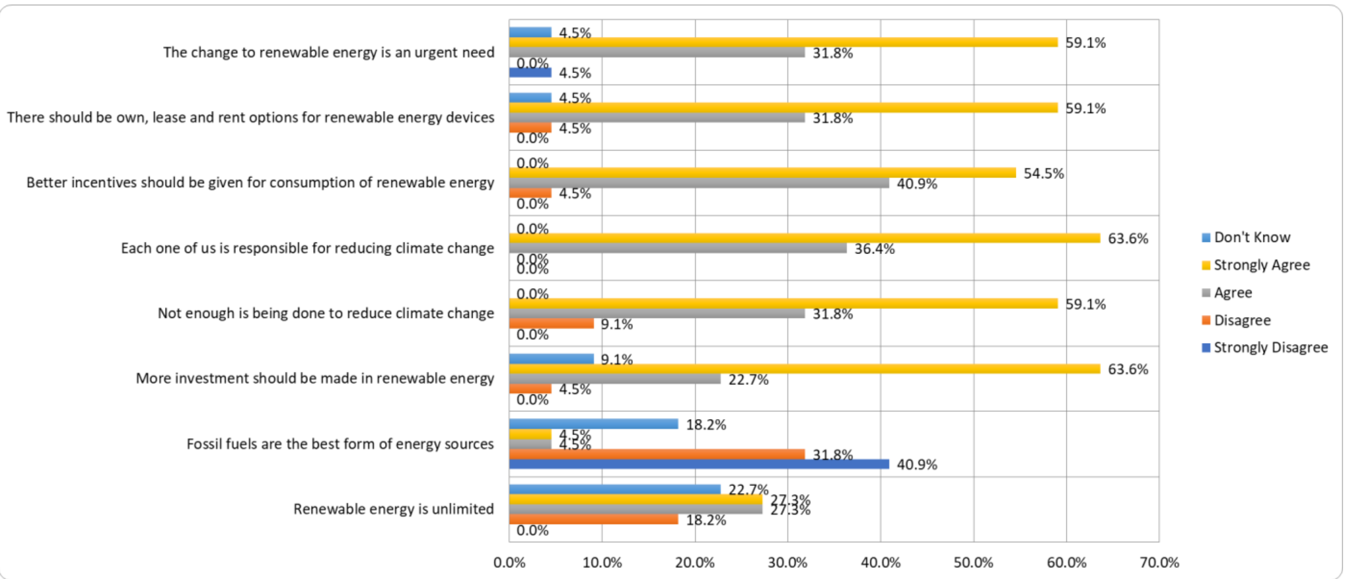
Table 21. Summary of public comments received on Draft CNMI Strategic Energy Plan.

Created on	Latitude	Longitude	Island	Type	Comment
12/8/2022 13:20	14.97456	145.6255	Tinian	Solar Energy	[Tinian Junior/Senior High School] Needs solar energy
12/8/2022 13:21	14.97215	145.6244	Tinian	Solar Energy	Tinian Elementary school needs solar energy too.
12/8/2022 13:22	14.96357	145.6305	Tinian	Solar Energy	[Antonio M. Borja Amphitheater] The Natipu Park has power but need to run under solar energy
12/8/2022 19:55	15.27133	145.8174	Saipan	Solar Energy	[Marpi Landfill] DPW is looking into solar or other renewable options here for the landfill - might be viable at a larger scale / have potential for larger scale generation?
12/11/2022 22:18	15.27133	145.8174	Saipan	Solar Energy	Solar energy at playgrounds. Allow Children to play longer. Beneficial for health, less screen time
12/15/2022 16:21	15.27133	145.8174	Saipan	Solar Energy	I agree, but it may be critical to involve the community and MVA and see whether which options they would support. If it's the "Waste-to-Energy" power plant option, similar the one in Oahu, wind patterns and environmental impacts should be assessed. One of the best actions CNMI can do in the meantime is build the capacity to install and maintain renewable energy facilities.
12/15/2022 16:23	15.20158	145.7809	Saipan	Wind Energy	[East coastline] This coastline might be create for harnessing wind energy. Could this potentially supply energy for nearby residential areas?
12/15/2022 16:33	15.19484	145.7192	Saipan	Make a Comment	[Puerto Rico] Buildings that receive regular sun exposure should look into harnessing solar energy. It would be worthwhile to use federal funding to supply solar grids and financing and technical services to business and residential buildings so they can start switching to solar energy. I think that would also make us more resilient to storms. Solar panels and battery storage in Puerto Rico, for instance, kept electricity running in some households after Hurricane Fiona.
3/13/2023 16:34	15.20772	145.7232	Saipan	Solar Energy	Mirco grid system for Mihaville.
3/13/2023 16:36	15.11749	145.7301	Saipan	Solar Energy	Provide solar panels at the Saipan International Airport.
3/13/2023 16:38	15.15849	145.7053	Saipan	Solar Energy	Microgrid system with MHS, DFEMS, DOC, DPS and Judiciary Branch.
3/13/2023 16:39	15.21232	145.7508	Saipan	Solar Energy	Microgrid system for all government occupied buildings in Capitol Hill.
3/13/2023 16:41	15.2195	145.7341	Saipan	Ideas and Suggestions	Decommission Power Plant No. 4. Relocate engines to lower base.
3/13/2023 16:43	15.12388	145.7125	Saipan	Solar Energy	[San Antonio] Allow and plan for microgrid system for future homestead lots in Koblerville.
3/13/2023 16:51	15.03304	145.6166	Tinian	Solar Energy	Solar farm with partnership with the Federal Government/Military.
3/13/2023 16:53	14.97644	145.6214	Tinian	Solar Energy	Solar panels at the NMC Campus
3/13/2023 16:58	14.97355	145.6146	Tinian	Make a Comment	[Tinian Powerplant] Power Plant and Transfer Station
3/13/2023 16:58	14.97302	145.6164	Tinian	Solar Energy	[Tinian Powerplant] Provide solar panels near Power Plant.

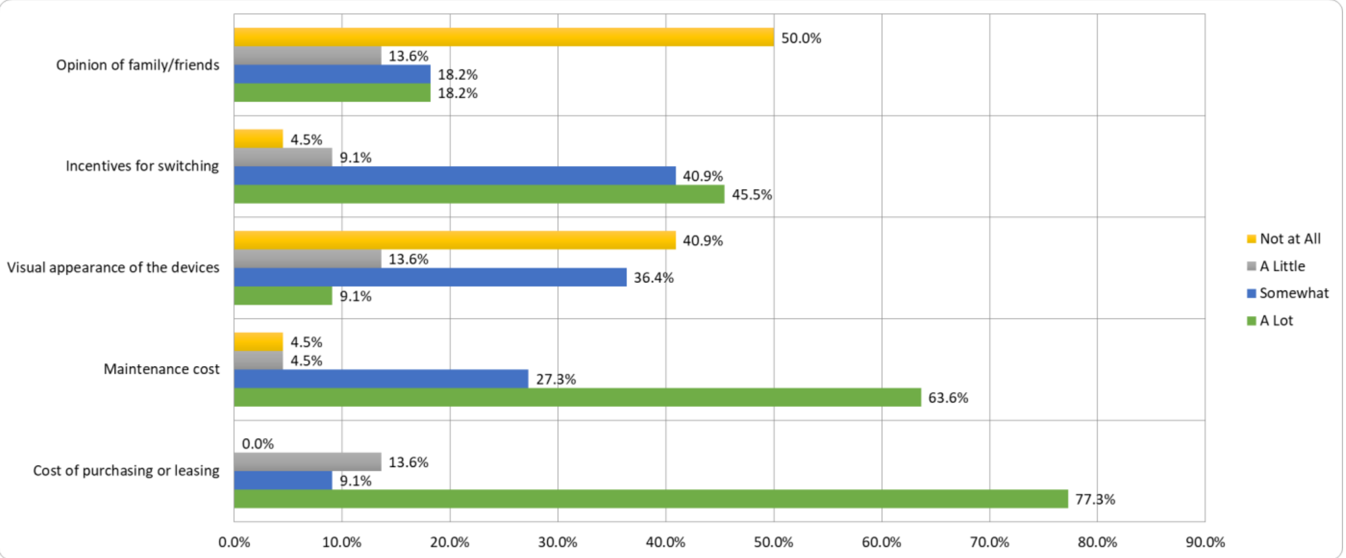
2. Do you know the difference between renewable and non-renewable energy?



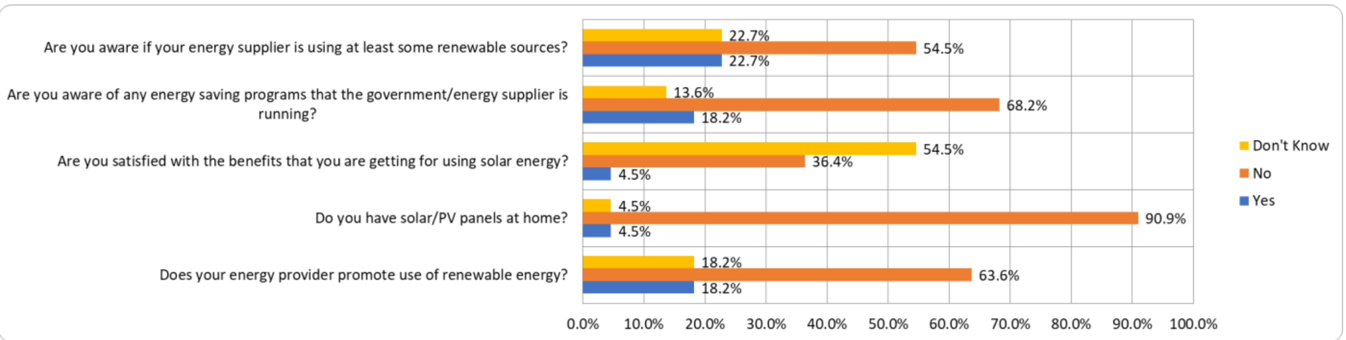
3. Please state your level of agreement to the following (strongly disagree, disagree, agree, strongly agree, don't know):



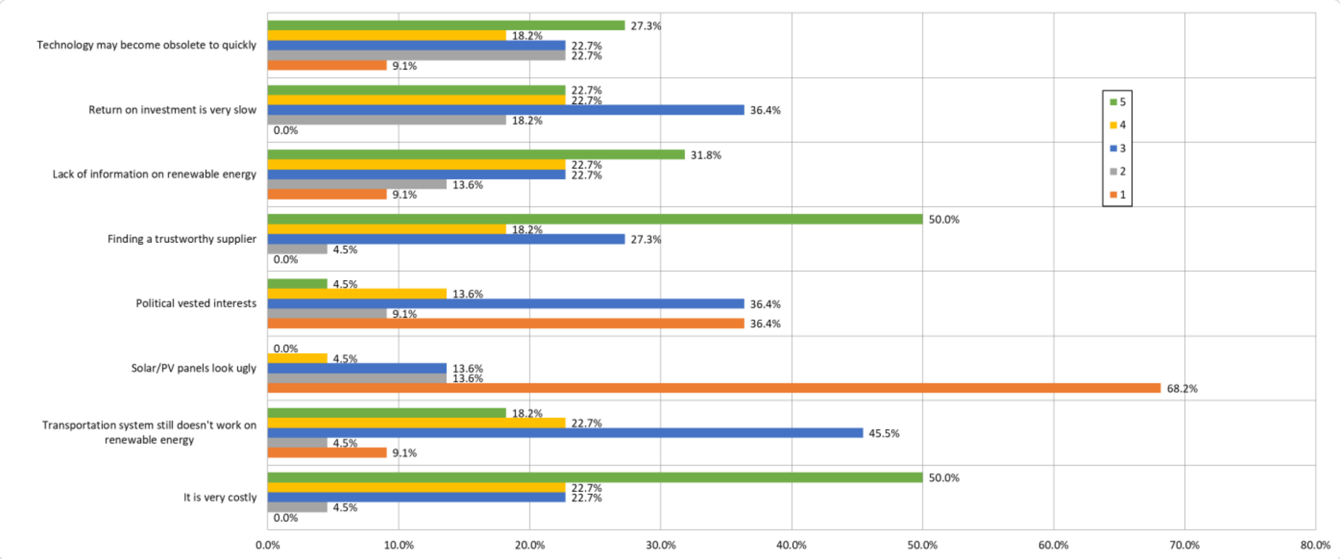
4. How much do the following points influence your decision to install solar on your home (a lot, somewhat, a little, not at all)?



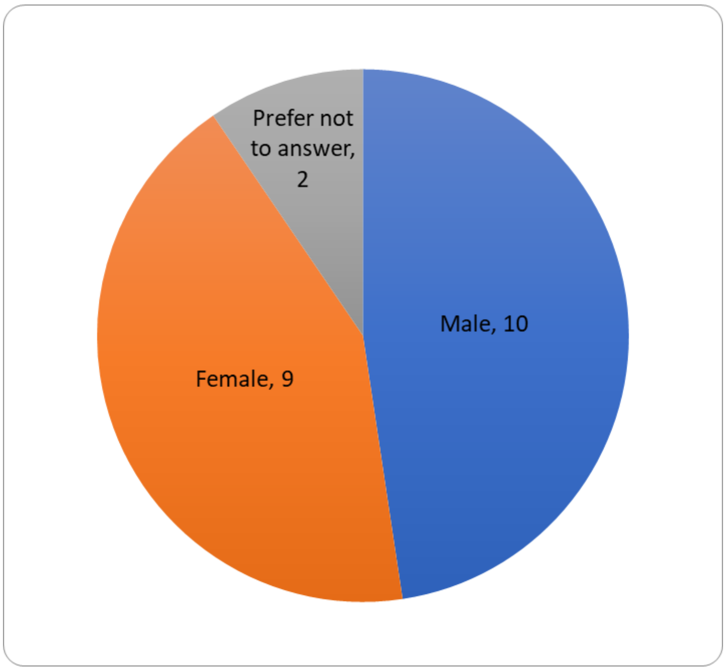
5. Please state your opinion for the following (yes, no, don't know):



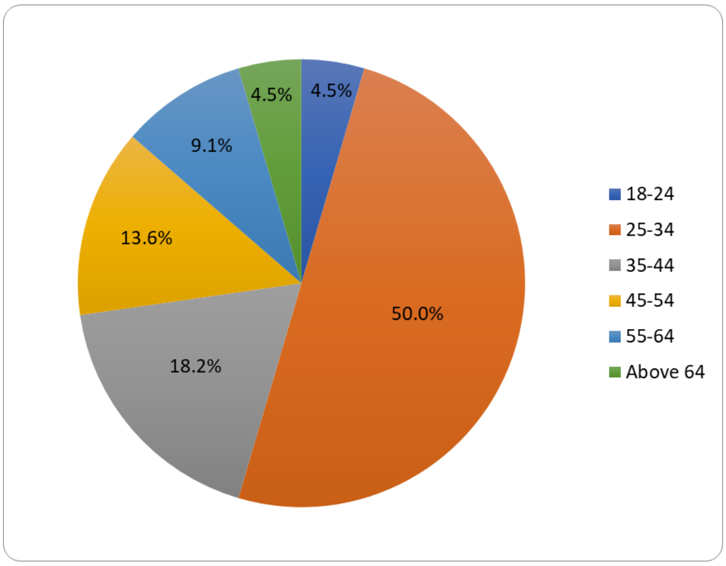
6. To what extent are the following a barrier to switch from fossil fuels to renewable energy to you? (on a scale of 1 to 5, 1 being the lowest)



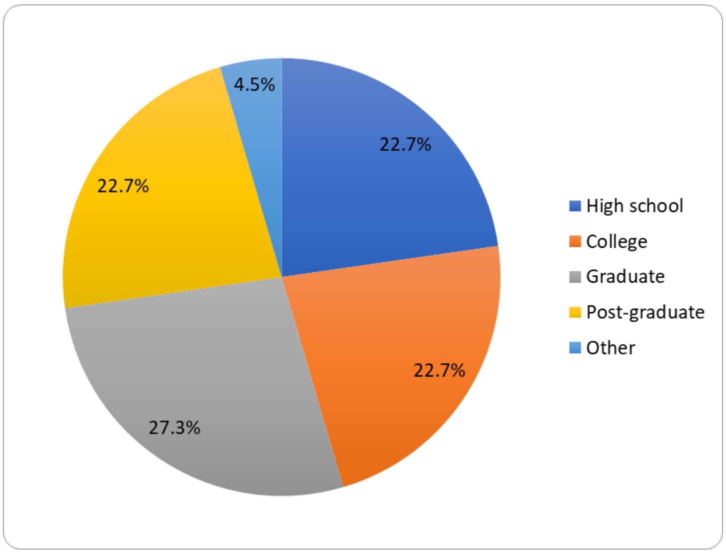
7. What is your gender?



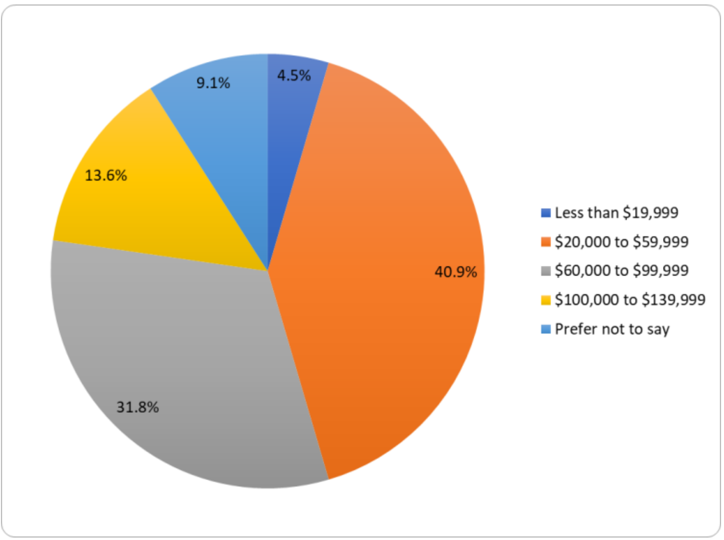
8. How old are you?



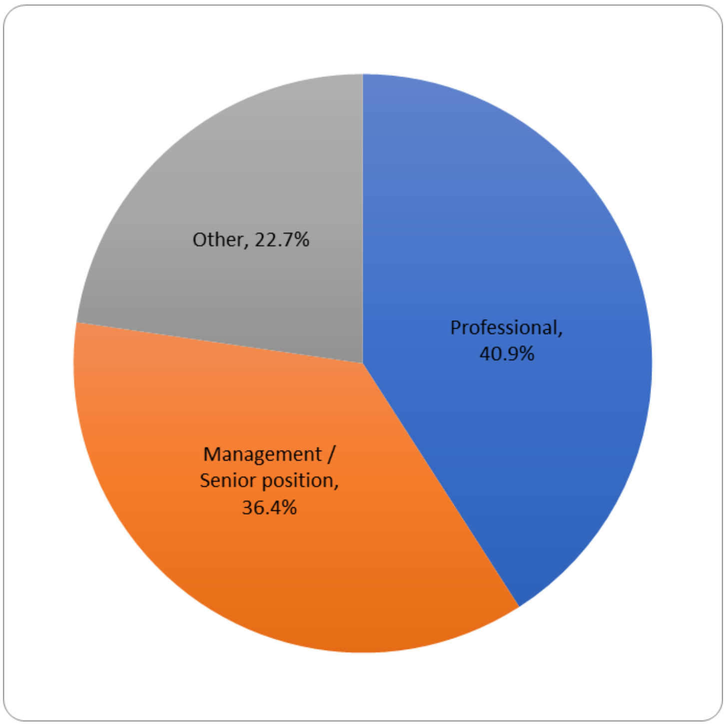
9. What is your highest level of education?



10. What is your total household income?



11. What is your current employment status?



12. Do you have any comments/suggestions to help promote development and use of renewable energy?

- 1) More rebates and vouchers for people to starting changing their appliances to renewable energy.
  2) Should include washer and dryer as an incentive for the vouchers.
  3) Vouchers for electric water heaters.
  4) Vouchers for electric cars.
- Have more outreach efforts to residents promoting renewable energy. Make presentations at organizations, monthly meetings, etc... Require commercial spaces, schools, to produce renewable energy a minimum percentage of their usage. CUC to be compatible or more compatible with renewable energy. CUC to have a renewable energy division.
- The first comment that I have regarding the matter is to have the current laws that we have in the CNMI applied as they are in our Commonwealth Code. Currently, the laws that we have today regarding renewable energy, more specifically solar energy are not enforced as they are codified in CNMI Law. By this I mean that the Government entities involved in implementing and regulating the usage of renewable energy in the CNMI completely ignore what is stated in law. In addition to this, the Commonwealth Utilities Corporation (CUC) the entity which is in charge of these implementations completely ignore the law and believe that regulations regarding this matter is governed by the bylaws that were created and agreed upon by the CUC board and its members. They continually believe that the bylaws of what the CUC board has created trump what is stated in CNMI law today (which it does not). As a result of this, many residents are limited to the a certain amount of renewable energy that they personally generate on their property that may be allowed to have off-set their energy consumption via the CUC's net metering service. This has been very detrimental to myself and many other residents on the island who have chosen to make the switch over to renewable energy as the cost of energy from CUC continually raise all while CUC limits residents from generating as much renewable energy as they possible can to off-set their cost for energy consumption. Secondly, before the CNMI "promotes development and use of renewable energy" they need to settle all matters on this issue because if they do not, matters related to renewable energy in the CNMI will become an even bigger mess and the potential switch over to renewable energy in the CNMI will be more costly and will hurt the residents of the CNMI more than it will help.
- The private sector needs help partly or fully switching over to renewable energy.
- I have several ideas that I would like to share with the CNMI. I have been in this realm for over a decade and feel I can add value to the CNMI's Energy Plan now and in the future.
- Massive multi-media awareness campaign needed.
- Incentives would be a great next step to support much needed RE deployment and support system diversification! Needs of our low-income community members and renters should also be addressed in part to help bring down VERY HIGH utilities costs. We also really need to make sure our vulnerable critical facilities and shelters have back-up power to build our resilience!
- Promote the idea of residential units getting solar power. There is no need for a solar farm on an island with such limited land.
- In order to gain a comprehensive understanding of the technicalities and specifics involved in establishing a diversified renewable energy portfolio in the CNMI, it is recommended that the CNMI Energy Task Force adopt a more proactive approach by visiting other islands and states that share similar characteristics and have effectively integrated renewable energy into their energy portfolios. Such visits will enable the Task Force to acquire valuable insights and knowledge on successful renewable energy projects and technologies, which can be applied to further enhance the CNMI's energy infrastructure and sustainability goals.

9. Conclusions and Recommendations

9.1 Summary

This CNMI Strategic Energy Plan (SEP) report updates the original SEP prepared in July 2013. The intent of the SEP is that it be a living document, which requires periodic updates to investigate options to reduce fossil fuel dependency and re-evaluate sustainable sources of energy in the context changing markets and improving technology that could be integrated into the CNMI's current energy portfolio.

Currently, except for a few small renewable energy systems consisting mostly of residential rooftop solar and recent installations of rooftop solar at Public School System (PSS) facilities, the CNMI is primarily dependent on fossil fuels for meeting its energy generation needs. As a result, the CNMI is exposed to volatility in fuel pricing and availability that impacts security, the environment and economic viability. The isolated location of the CNMI makes fossil fuel importation and new project development a challenge, underscoring the need for a reduction in fossil fuel dependency by tapping indigenous energy resources.

This SEP update includes the following sections summarizing available information, analysis, options, and recommendations:

13. <u>Introduction:</u> background, purpose, and planning process.
14. <u>Methodology:</u> approach to analysis.
15. <u>Drivers for Change:</u> Energy Task Force, vision, mission, risk mitigation and inequity.
16. <u>Existing Technologies:</u> existing system, network constraints, and energy use.
17. <u>Energy Analysis:</u> current demands, cost of production, demand management options and opportunities
18. <u>Energy Options and Strategies:</u> alternate fuel sources, alternative energy sources, storage options, energy reduction strategies and public education.
19. <u>Multi Criteria Analysis:</u> criteria selection and analysis outcome for most feasible and cost-effective solutions.
20. <u>Energy Policy Review:</u> current policy and future policy considerations, and public outreach.
21. <u>Conclusions and Recommendations:</u> general summary, overall conclusions, recommendations, and roadmap.

A road map is provided in Section 9.3 for each island for further cost-effective energy management solutions, including efficiency/optimization upgrades, demand side management, and use of renewable and future energy solutions.

9.2 Conclusions

The CNMI have several alternative energy sources available to reduce dependency on fossil fuels. The extent to which each could be implemented will depend on market conditions, available funding, and further study.

Solar PV power is available on all three islands, and it can be implemented on a larger scale as a mix of rooftop solar and utility size solar very quickly. Power network studies need to confirm the level of solar PV penetration with and without battery storage to inform the site selection and study of the size of the envisaged solar PV plant. At this point in time fixed tilt solar PV is recommended due to its ability to be designed for cyclone 5 regions like the CNMI. Rooftop solar on all three islands can be increased depending on the maximum PV penetration per Feeder, but it likely will need to be controlled at higher penetration levels for system security purposes with a Distributed Energy Management system (DER). Revenue management will remain a key issue to be resolved by the CUC as implementation of solar increases.

The Islands have a promising wind energy resource, but the wind data are coarse. It is recommended to perform wind monitoring on each island at potential sites to determine the actual wind resources and aid the decision-making process. Prospective sites and the recommended tilt down wind-turbine technology should be discussed with the community to gauge community support for a medium to large scale wind power project. Wind power can improve renewable penetration due to its availability outside of peak solar irradiation and reduce the amount of energy storage necessary for a high penetration scenario.

Investment in a Battery Energy Storage System (BESS) system can enable the renewable energy penetration to increase beyond the typical levels of 20-30% power penetration. Capital cost of BESS is currently high, however cost of BESS systems is projected to decline over time as the technology matures.

The islands have a promising elevation structure for a pumped hydro storage scheme. Pumped hydro can be cost effective as a peak shaver compared to battery systems for larger storage durations (e.g., duration ≥ 4 hrs). It is recommended to perform a detailed feasibility study to determine the suitability and possible sizes of pumped hydro systems on the islands, which can inform the sizing study for possible BESS systems.

The possible geothermal resource on Saipan has been studied and tested by others and found not to be viable. Installation of large-scale systems on northern islands is not viable due to the high capital cost and the high cost of connecting the electricity network across islands. Due to the volcanic origins of the CNMI islands, geothermal should be investigated further to better assess the viability as an energy source in the three main islands, as well as homesteads on Pagan.

The maturing technology of standalone power systems opens an opportunity to cost effectively electrify smaller islands which at present do not enjoy utility power resources.

Integrated planning for a sustainable energy system needs to consider power generation, storage capacity, and the flexibility of demand. 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. Programs to electrify government fleet vehicles and the Commonwealth Office of Transit Authority (COTA) buses could be a key leadership tactic to transitioning toward the use of EVs and way from gasoline powered vehicles. The CNMI Office of Grants Management (OGM), Commonwealth Utilities Corporation (CUC) grant program office and Department of Public Works (DPW) should collaborate and pursue federal funding and other partnership opportunities to study the deployment of EVs and related infrastructure.

New energy infrastructure could be government or privately funded, and the technology is suitable for both options. The CNMI Office of Grants Management and Commonwealth Utilities Corporation grant program office should continue to pursue federal funding and other partnership opportunities to study alternative energy power generation options and strategies described in this report.

Demand management options include wider use of solar hot water systems, energy efficient commercial and government buildings, houses and appliances, and continued support of the existing cool roof program can assist to reduce the demand for current and future applications.

These programs are best implemented with supporting education campaigns to ensure the consumer is informed across the need and implementation of the programs.

9.3 Recommended next steps

To visualize the next steps a tabular conceptual roadmap was compiled for each of the three islands. The roadmap is only a rough plan or guideline, bound to change based on CNMI government and agency priorities, and if the results from feasibility studies, public outreach or site selection differ from this pre-feasibility conceptual assessment. Steps far in the future are indicated with red colored text.

9.3.1 Saipan roadmap

Action \ Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Rooftop solar	Amend legislation to allow more rooftop PV	5 MW	7 MW	9 MW	10 MW	Review system stability and legislation				
Utility size solar fixed tilt	Feasibility and site selection	Land agreement, development approvals	Procurement	Site commissioning and network connection	10 MW	Review system stability and solar farm performance	15 MW	20 MW		
Wind onshore	Feasibility and monitoring sites selection,	Grant application for wind monitoring	Review monitoring data and site selection	Land agreement, development approvals	Funding/ procurement	Site commissioning and network connection	2.5 MW	5 MW	Review wind data and energy supply data	
Geothermal	Grant application/ funding	Feasibility study	Detailed site investigation study	Environmental and other approvals	Environmental and other approvals	Funding/ procurement	Detailed system Design	Site works commence	Commissioned	
BESS		feasibility study, compare to pumped hydro	site selection with solar / wind	Funding/ procurement	Site commissioning and network connection	5 MW / 10 MWh	10 MW / 20 MWh	review system stability and BESS sizing		
Pumped hydro	Grant application/ funding	Feasibility study, compare benefits to BESS	Detailed site selection study	Environmental and other approvals	Environmental and other approvals	PHES Design	PHES Design	Site works commence	30 MW / 12 hrs commissioned	
Electric vehicles / buses	Grant application /funding	Feasibility study	Feasibility study	Grant application/ procurement	Charging station design	Charging station construction	Policy amendments for EV supplying grid			
DER control / Microgrid	Grant application /funding	Feasibility for DER control	Policy to enforce DER control	DER and Microgrid control tender	DER control integrated into power system control	Microgrid control integrated into power system			Consider adding hydrocarbon off function	
Smart meters		Business case for high penetration scenario	Draft legislation change	Smart meter with every rooftop solar system	Smart meter program roll out with renewal / replacement	Smart meter program roll out with renewal / replacement	Smart meter program roll out with renewal / replacement	Review system success and economic levers	Smart meter program roll out with renewal / replacement	Smart meter program roll out with renewal / replacement

Action \ Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Solar hot water		Application or grant / subsidies	Grant scheme approved and roll out	Grant scheme approved and roll out	Roll out	Roll out	Roll out	Roll out	Roll out	Roll out
Cool roofs	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies	Ongoing program, education, and subsidies
Energy efficient houses / (NGBC)	Grant application/ funding	Engage consultant for draft legislation	Legislation passed for new housing		Efficiency and performance review	Amend legislation / design requirements	Continue role out	Continue role out	Continue role out	Continue role out
Education	Cool roofs	Solar and DER control	Energy efficient housing	EVs	Solar and DER control	Energy efficient housing	Cool roofs	Solar and DER control	Energy efficient housing	EVs

9.3.2 Tinian roadmap

Action \ Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Rooftop solar	Amend legislation to allow more rooftop PV	100 kW	150 kW	200 kW	Review system stability and legislation					
Utility size solar fixed tilt	Grant application/ funding	Feasibility and site selection	Land agreement, development approvals	Procurement	Site commissioning and network connection	1.5 MW	Review system stability and solar farm performance			
Wind onshore	Grant application/ funding	Feasibility and monitoring sites selection,	grant application for wind monitoring	review monitoring data and site selection	Land agreement, development approvals	Grant application/ funding for design	Design & Procurement	Site commissioning and network connection	550 kW	Review wind data and energy supply data
BES	Grant application/ funding	Feasibility study, compare to pumped hydro	site selection with solar / wind	tender	Site commissioning and network connection	1 MW / 2 MWh	Review system stability and BESS sizing	Review system stability and BESS sizing		

Action \ Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Pumped hydro	Grant application/ funding	Feasibility study, compare to BES	Detailed site selection study	Grant application/ funding for design	Design	Environmental and other approvals	Procurement	Site commissioning	2 MW / 8 hrs	
Electric vehicles / buses			Grant application/ funding	Feasibility study	Feasibility study	Grant application/ procurement	Charging station design	Grant application /funding	Feasibility study	
DER control / Microgrid			Feasibility for DER control	Policy to enforce DER control	DER and Microgrid control tender	DER control integrated into power system control	Microgrid control integrated into power system	Consider adding hydrocarbon off function		
Smart meters			Business case for high penetration scenario	Draft legislation change	Smart meter with every rooftop solar system	Smart meter program roll out with renewal / replacement	Smart meter program roll out with renewal / replacement	Smart meter program roll out with renewal / replacement	Review system success and economic levers	smart meter program roll out with renewal / replacement
Solar hot water			Application or grant / subsidies	Grant scheme approved and roll out	Grant scheme approved and roll out	Roll out	Roll out	Roll out	Roll out	Roll out
Cool roofs	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies
Energy efficient houses / (NGBC)				Continue role out	Continue role out	Continue role out	Continue role out	Continue role out	Continue role out	Continue role out
Education	Cool roofs	solar and DER control	Energy efficient housing	Cool roofs	EVs	Energy efficient housing	Cool roofs	Solar and DER control	Energy efficient housing	

9.3.3 Rota roadmap

Action \ Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Rooftop solar	50 kW	100 kW	150 kW	200 kW	Review system stability and legislation	300 kW				

Action \ Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Utility size solar fixed tilt	Grant application/ funding for feasibility study	Feasibility and monitoring sites selection,	Grant application/ funding for design and construction	Land agreement, development approvals	Procurement	Site commissioning and network connection	3 MW	Review system stability and solar farm performance		
Wind onshore	Grant application/ funding for feasibility study	Feasibility and monitoring sites selection,	Grant application/ funding for wind monitoring	Review monitoring data and site selection	Land agreement, development approvals	Grant application/funding for design and construction	Design and procurement	Site commissioning and network connection	550 kW	Review wind data and energy supply data
BES	Grant application/ funding	Feasibility study, compare to pumped hydro	Procurement	Site commissioning and network connection	2 MW / 3 MWh	Review system stability and BESS sizing	Review system stability and BESS sizing	Review system stability and BESS sizing		
Pumped hydro	Grant application/ funding	Feasibility study, compare to BESS	Detailed site selection study	Environmental and other approvals	Environmental and other approvals	Procurement		Site commissioning	2 MW / 8 hrs	
Electric vehicles / buses						Grant application/ funding	Feasibility study	Charging station design		
DER control / Microgrid		Grant application/ funding	Feasibility for DER control	Policy to enforce DER control	DER and Microgrid control tender	DER control integrated into power system control	Microgrid control integrated into power system	Consider adding hydrocarbon off function		
Smart meters			Business case for high penetration scenario	Smart meter with every rooftop solar system	Smart meter program roll out with renewal / replacement	Smart meter program roll out with renewal / replacement	Smart meter program roll out with renewal / replacement	Review system success and economic levers	Smart meter program roll out with renewal / replacement	
Solar hot water			Application or grant / subsidies	Grant scheme approved and roll out	Grant scheme approved and roll out	Roll out	Roll out	Roll out	Roll out	Roll out
Cool roofs	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies	Ongoing program, education and subsidies
Energy efficient houses / (NGBC)				Continue role out	Continue role out	Continue role out	Continue role out	Continue role out	Continue role out	Continue role out

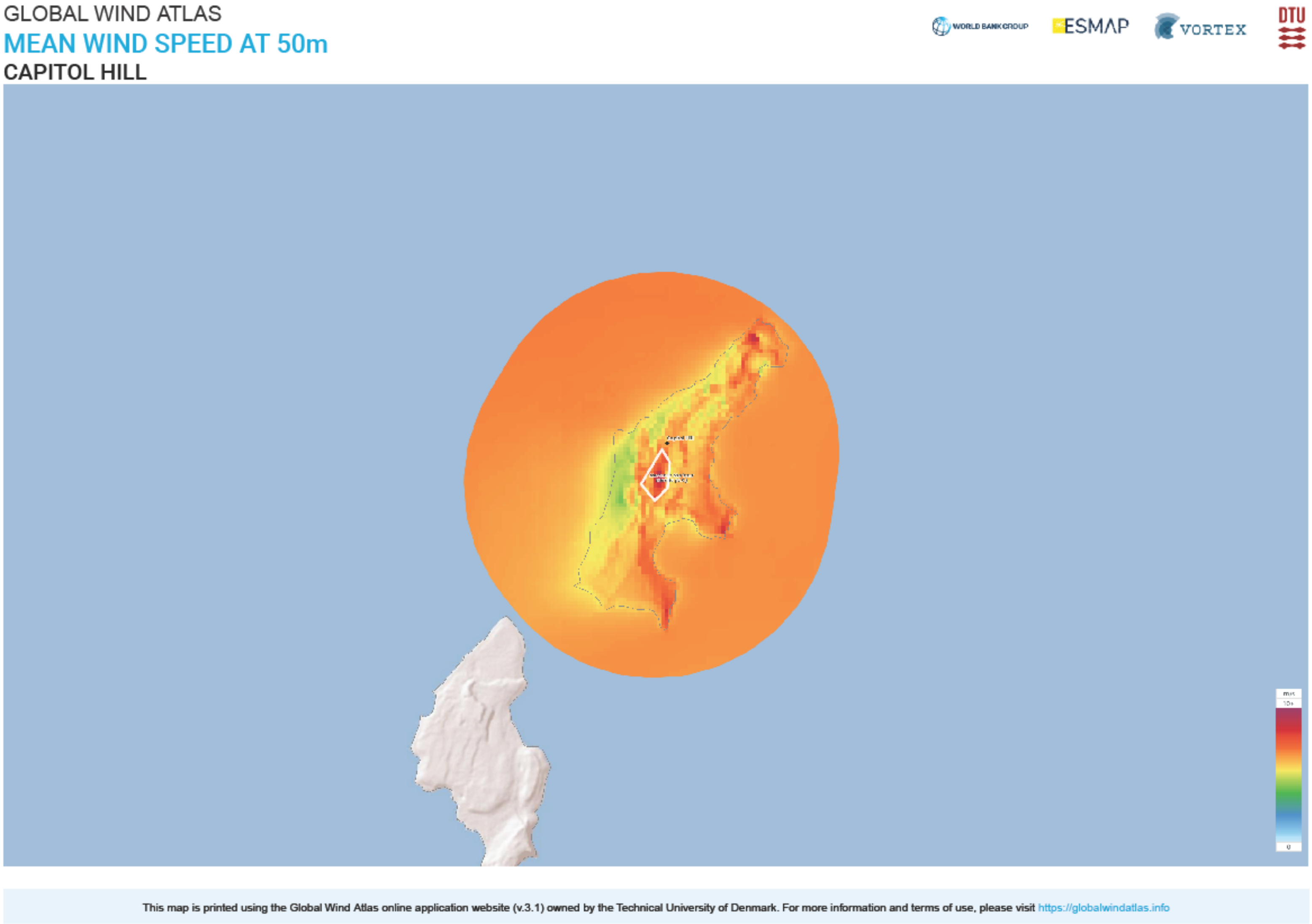
Action \ Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Education	Cool roofs	Solar and DER control	Energy efficient housing	Cool roofs	Solar and DER control	Energy efficient housing	EVs	Solar and DER control	Energy efficient housing	Cool roofs

Appendices

Appendix A

Wind Maps

Saipan

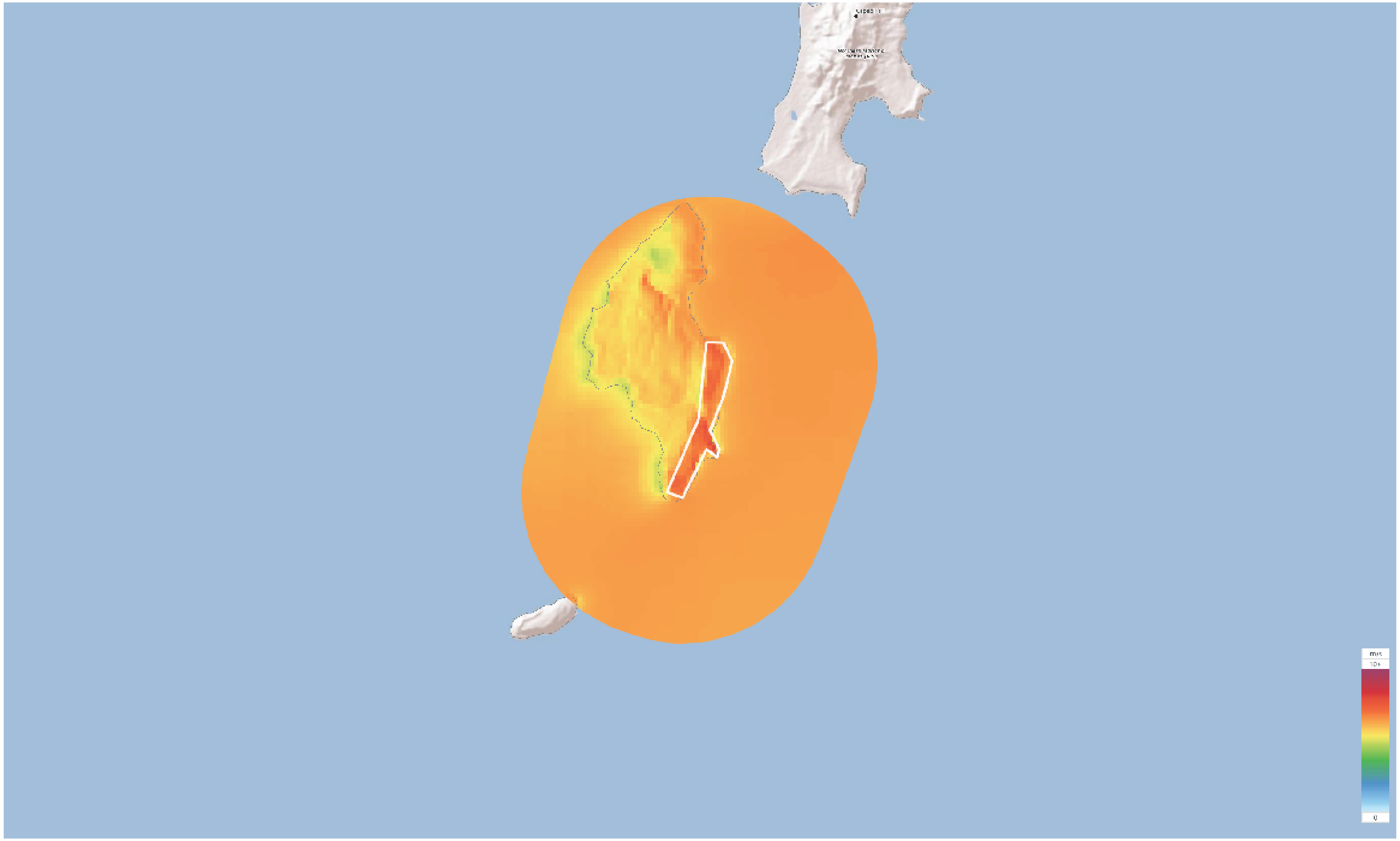

GLOBAL WIND ATLAS
MEAN WIND SPEED AT 50m
CAPITOL HILL
ESMAP
VORTEX
DTU
This map is printed using the Global Wind Atlas online application website (v.3.1) owned by the Technical University of Denmark. For more information and terms of use, please visit https://globalwindatlas.info

Tinian:

GLOBAL WIND ATLAS

MEAN WIND SPEED AT 50m

TINIAN WINDSPEED



This map is printed using the Global Wind Atlas online application website (v.3.1) owned by the Technical University of Denmark. For more information and terms of use, please visit https://globalwindatlas.info

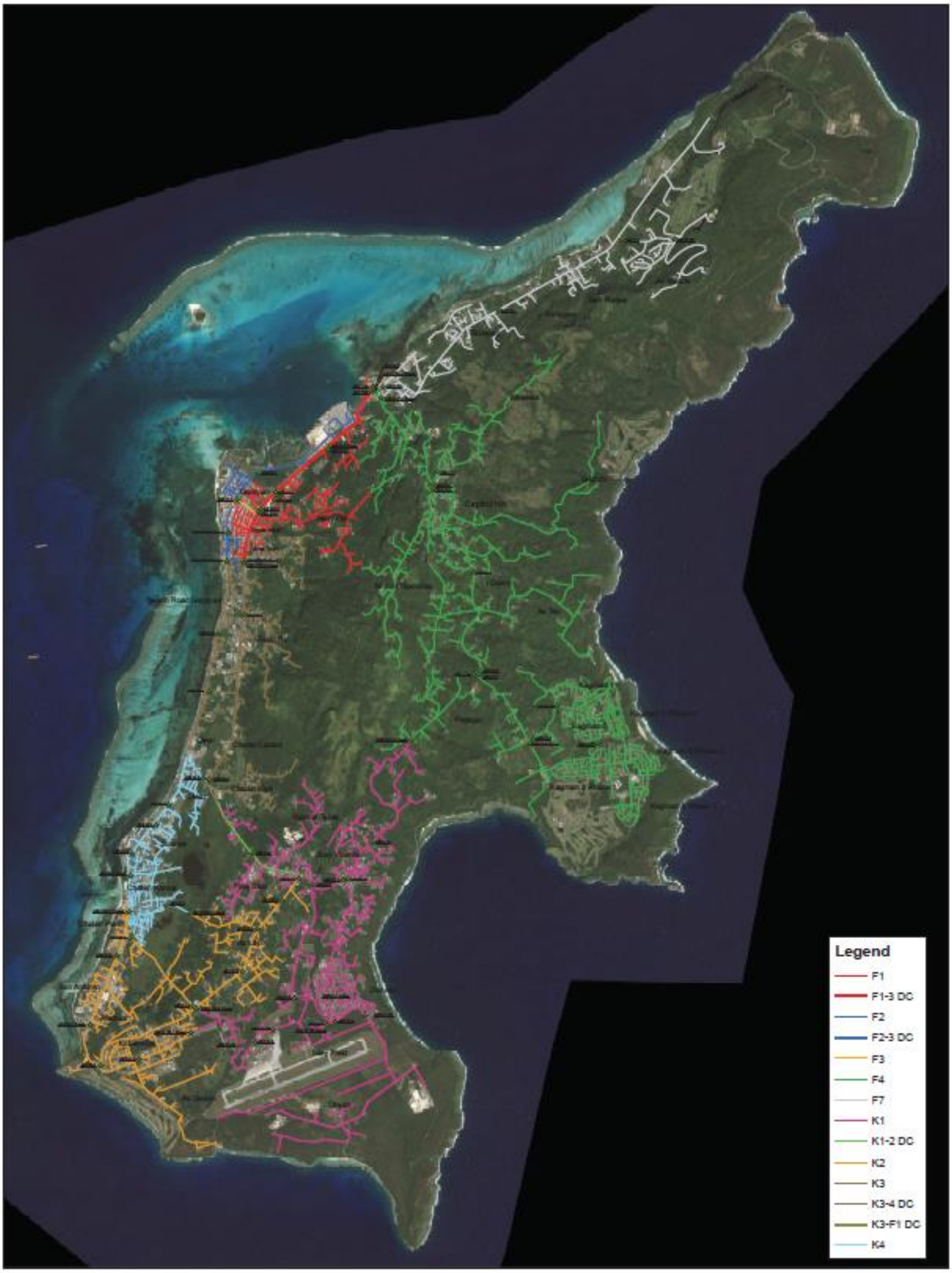
Rota


GLOBAL WIND ATLAS
MEAN WIND SPEED AT 50m
ROTA
WORLD BANK GROUP
ESMAP
VORTEX
DTU
This map is printed using the Global Wind Atlas online application website (v.3.1) owned by the Technical University of Denmark. For more information and terms of use, please visit https://globalwindatlas.info

Appendix B

CNMI Network Diagrams

Saipan: Geographic One-Line Diagram



Rota: Geographic One-Line Diagram

Tinian: Geographic One-Line Diagram

Appendix C

References

1. O&M and fuel cost CUC 2020/2021

2. CUC Response to RFI – Netmetering customers Phase 1 and phase 2

3. U.S Energy Information Administration, Northern Mariana Islands Profile, Territory Profile and Energy Estimates. https://www.eia.gov/state/analysis.php?sid=CQ

4. Commonwealth of the Northern Mariana Islands, House of Representatives, H. B. No. 18-165, SD1 (July 22, 2014). https://cnmileg.net/documents/files/PL%2018-62%20(HB%2018-165%20SD1%20Renewable%20Energy%20Portfolio%20Amendment).pdf

5. ICT was enacted in 2006 as a federal policy mechanism to support solar energy growth see Guide to the Federal Investment Tax Credit for Commercial Solar PV.pdf (energy.gov)

6. A tax incentive for investment that allows individuals or businesses a percentage deduction off their taxes of the investment costs. This is a dollar for dollar tax offset for solar installations completed before 2023

7. Commonwealth Utilities Corporation – CUC Power System Profile

8. AEMO 2020 Costs and Technical Parameter Review. https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2021/aurecon-cost-and-technical-parameters-review-2020.pdf?la=en

9. CNMI Initial Technical Assessment Report - July 2011

10. Load factor is a ratio of average demand and maximum demand

11. Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities: A Scoping Study

12. CUC Response to RFI – Netmetering customers Phase 1 and phase 2

13. Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities: A Scoping Study

14. Time-of-use tariffs – Innovation Landscape Brief (irena.org)

15. Page 13 - Time-of-use tariffs – Innovation Landscape Brief (irena.org)

16. International Energy Agency - 2019 Global Status Report for Buildings and Construction

17. CNMI Strategic Energy Plan 2013, Page 16

18. CNMI Strategic Energy Plan 2013, Page 16

19. European Regulation 2012/27/EU

20. https://www.homeinnovation.com/services/certification/green_homes/resources/ngbs_incentives_summary?p=1&

21. Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities: A Scoping Study

22. Global quarterly fuel price changes, 2010-2020 – Charts – Data & Statistics - IEA LNG netback price series | ACCC

23. A rough estimate of 500kW per island is assumed to be adopted by the residential market sector

24. US Department of Energy. https://www.energy.gov/sites/default/files/2021/02/f82/Guide%20to%20the%20Federal%20Investment%20Tax%20Credit%20for%20Commercial%20Solar%20PV%20-%202021.pdf

25. Based on CNMI Local Vendor quotation.

26. Based on Australian Market pricing using similarly scoped projects completed by GHD.

27. Based on local vendor quotation, price inclusive of ITC credit

28. U.S. Department of Energy, Energy Transitions Initiative, Commonwealth of the Northern Mariana Islands Energy Snapshot (June 2020), p. 1

29. News, U., 2022. Refrigerators, electric devices top energy use in Hawai'i households | University of Hawai'i System News. [online] University of Hawai'i System News. Available at: https://www.hawaii.edu/news/2021/10/01/energy-use-in-hawaii-households/

30. LFP Housing Characteristics 2017 By Hot and Cold Water in Unit and Hot Water Energy Type - Department of Commerce – Commonwealth of the Northern Mariana Islands (CNMI) (cnmicommerce.com)

31. HOMER visualization of NASA data

32. Australian Energy Market Commission

33. SolarQuotes. 20% contingency included as technology is not common on CNMI. https://www.solarquotes.com.au/hot-water/price/

34. SolarQuotes. https://www.solarquotes.com.au/hot-water/price/

35. Landfill Gas Extraction Feasibility Study – EA Engineering – 2019

36. Commonwealth of the Northern Mariana Islands Initial Technical Assessment Report. https://www.nrel.gov/docs/fy11osti/50906.pdf

37. Using latest CPI data as of 6th August 2021 to project cost in the present.

38. Globalwindatlas.info. 2021. Global Wind Atlas. https://globalwindatlas.info/

39. Carlowicz, M., 2018. Super Typhoon Yutu. https://earthobservatory.nasa.gov/images/144137/super-typhoon-yutu

40. Vergnet GEV MP C 275 kW.

41. Australian Energy Market Operator 2020 Costs and Technical Parameter Review. https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2021/aurecon-cost-and-technical-parameters-review-2020.pdf?la=en

42. GenCost 2020-21, CSIRO. https://www.csiro.au/-/media/EF/Files/GenCost2020-21_FinalReport.pdf

43. Kamil Erkan, Gwen Holdmann, Walter Benoit, David Blackwell, Understanding the Chena Hot Springs, Alaska, geothermal system using temperature and pressure data from exploration boreholes, Geothermics Volume 37, Issue 6, 2008

44. Ronald DiPippo, Chapter 8 - Binary Cycle Power Plants, Editor(s): Ronald DiPippo, Geothermal Power Plants (Fourth Edition), Butterworth-Heinemann, 2016

45. Geothermal Resource Assessment of the Commonwealth of the Northern Mariana Islands, 2010. https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/1635.pdf

46. National Renewable Energy Laboratory. https://atb-archive.nrel.gov/electricity/2019/index.html?t=gt

47. Weather Atlas, Monthly weather forecast and climate - Saipan, Northern Mariana Islands, USA. https://www.weather-us.com/en/northern-mariana-islands-usa/saipan-climate?c,mm,mb,km

48. Electricity (strath.ac.uk)

49. CNMI Strategic Energy Plan 2013 – page 22

50. Off-Grid Power Systems | Solar Battery Storage Systems - Western Power

51. National Renewable Energy Laboratory https://atb-archive.nrel.gov/electricity/2019/index.html?t=gt

52. Grants and funding | energy.gov.au

53. US Energy Information Administration 2020

54. CNMI 2013 Energy Action Plan

55. Energy Transition Initiative Snap Shot 2015

56. Public Law 15-23

57. Public Law 18-62

58. CNMI SEP2013 NREL

59. U.S. Department of Energy Northern Mariana Islands Recovery ACT snapshot

60. DPW response to GHD RFI December 2021

61. IRENA report transforming small island power systems

62. Drivers and inhibitors of renewable energy 2016

63. US Energy Information Administration 2020 update

ghd.com

→ The Power of Commitment