Commonwealth of the Northern Mariana Islands Initial Technical Assessment Report

Ian Baring-Gould, Randolph Hunsberger, Charles Visser, and Philip Voss

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Technical Report
NREL/TP-7A40-50906
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Abstract

On March 1, 2010, Assistant Secretary for Insular Areas Tony Babauta invited Governor Felix Camacho (Guam), Benigno Fitial (Commonwealth of the Northern Mariana Islands (CNMI)), and Togiola Tulafono (American Samoa) and their staff to meet with senior principals at the National Renewable Energy Laboratory (NREL) for discussions on ways to improve energy efficiency and increase the deployment of renewable energy technologies in the U.S. Pacific Territories. This meeting brought together major stakeholders to learn and understand the importance of developing a comprehensive strategic plan for implementing energy efficiency measures and renewable energy technologies.

Dependence on fossil fuels and the burden of high oil prices have been a major concern for years, but never more at the forefront than today. With unstable oil prices, the volatility of supply, and the economic situation in the CNMI, energy issues have become a high priority. Succinctly, improving energy security by reducing the need for imported fossil fuels is critical to the CNMI's future economic development and sustainability.

Under an interagency agreement funded by the Department of the Interior's (DOI) Office of Insular Affairs (OIA), NREL was tasked to provide technical assistance to the CNMI by conducting an initial technical assessment that would detail current energy consumption and production data to establish a baseline. This assessment will be used to inform future analyses and studies needed to estimate energy conservation and efficiency opportunities and renewable energy potential for the CNMI as part of developing an energy plan.

NREL provided an interdisciplinary team to cover each relevant technical area for baseline energy assessments, data analysis, and recommendations. Experts in the following disciplines traveled to the CNMI the week of December 6-10, 2010 and evaluated the following opportunities:

- Integrated Wind-Diesel Generation
- Transmission and Distribution
- Energy Efficiency and Building Technologies
- Solar Technologies
- Biomass and Waste-to-Energy
- Geothermal.

In addition to the above core disciplines, team capabilities also included expertise in program analysis; project financing; policy and energy project planning; and energy committee facilitation.

The intent of the visit was to gather information about the current energy situation and determine opportunities for improvement. This information will be used to develop various scenarios and approaches for deploying cost-effective energy efficiency and renewable energy technologies in a manner that will meet the CNMI's objective to reduce dependency on fossil fuels. The information compiled in this energy assessment report will be used as input in the development of a strategic energy plan.

Executive Summary

This document is an initial energy assessment for the Commonwealth of the Northern Mariana Islands (CNMI), the first of many steps in developing a comprehensive energy strategy. The project plan for the CNMI includes three main objectives:

1. Assist in establishing an Energy Task Force to address energy issues, identify barriers and opportunities, and establish priorities.
2. Gather available information and publish an initial island assessment report to establish a baseline and identify energy efficiency and renewable energy opportunities.
3. Support the Energy Task Force in developing a draft strategic energy plan that will provide the CNMI with various scenarios and approaches to implementing cost-effective energy efficiency and renewable energy technologies in a manner that will meet the CNMI's objective to reduce dependency on imported fossil fuels.

This report meets the second objective of establishing a baseline and identifying opportunities to reduce energy costs. A baseline gathers various data points to establish a reference against which progress can be measured. It allows comparison across sectors through trend identification and serves as a tool for goal setting and measuring success.

The information compiled in this assessment will be used as input in the development of a strategic plan draft to meet the third project objective. This document summarizes data collected regarding energy production, consumption, and efficiencies, discusses renewable energy and energy efficiency technology potential, and describes current opportunities and potential barriers. Additional data or analysis needed is documented in the "Next Steps" sections. The opportunities highlighted in this report can be used as a starting point to formulate an energy plan. Table 1 highlights current energy efficiency and renewable energy opportunities and corresponding estimated impact potential.

Table 1. Energy Efficiency and Renewable Energy Opportunities and Potential Impacts

Opportunity Description	Impact Potential
Create a strategic plan to set goals, determine priorities, and develop strategies to finance and implement energy conservation, energy efficiency, and renewable energy on all three main islands	High
Drill geothermal gradient test well(s) to assess the existence of a geothermal resource	High (if a developable geothermal resource is discovered)
Perform energy and water audits for commercial, government, and residential buildings to prioritize areas for efficiency improvements	Medium - High
Provide energy efficiency training for builders, developers, designers, and trades	Medium - High
Conduct assessment of the wind and solar resource to determine potential and specific locations for development	Medium - High
Design and initiate a cool-roof program	Medium - High
Assess the potential for solar hot water heating in different sectors and develop a program pursuant to PL 15-26	Medium - High
Increase energy awareness through island campaigns	Medium - High
Develop and increase awareness of financing mechanisms	Medium - High
Perform waste characterization and analysis of waste-to-energy opportunities	Medium

Acronyms and Abbreviations

ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
Btu	British thermal unit
CNMI	Commonwealth of the Northern Mariana Islands
CRRC	Cool Roof Rating Council
CUC	Commonwealth Utilities Corporation
DEQ	Division of Environmental Quality
DOD	Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DPW	Department of Public Works
EPA	U.S. Environmental Protection Agency
EBT	Environmental Beautification Tax
FAA	Federal Aviation Administration
GPA	Guam Power Authority
HANMI	Hotel Association of the Northern Mariana Islands
HECO	Hawaiian Electric Company
HVAC	heating, ventilation, and air conditioning
IBB	International Broadcasting Bureau
IBC	International Building Code
IBM	Izu-Bonin-Mariana
IPP	independent power producer
km^2	kilometer squared
kWh	kilowatt hour
kWh/gal	kilowatt hour/gallon
kVA	kilovolt-ampere
lb.	pound

LBA	Leaseback Area
LEAC	Levelized Energy Adjustment Clause
LEED	Leadership in Energy and Environmental Design
LFG	landfill gas
m	meter
MBtu/bbl	million British thermal units per billon bar
MECO	Maui Electric Company
mi^2	mile squared
MLA	Military Lease Area
mm	millimeter
MSW	municipal solid waste
MSWF	Marpi Solid Waste Facility
MW	megawatt
MWe	megawatt electric
MWh	megawatt hour
NMC	Northern Marianas College
NMHA	Northern Mariana Housing Authority
NMTI	Northern Marianas Trades Institute
NREL	National Renewable Energy Laboratory
OIA	Office of Insular Affairs
PL	Public Law
PPA	Power Purchase Agreement
PRD	Puerto Rico Dump
PSS	Public School System
PUC	Public Utilities Commission
PV	photovoltaic
REC	renewable energy credit

RFP	Request for Proposals
RPM	revolutions per minute
RPS	renewable portfolio standard
SMU	Southern Methodist University
SWMD	Solid Waste Management Department
USFWS	U.S. Fish and Wildlife Service

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1 Methodology

To clarify the National Renewable Energy Laboratory (NREL) team's understanding of this project, the approach and background information used for the assessment are outlined in Sections 1.1 and 1.2.

1.1 Approach

Establishing the parameters of developing a baseline provides focus for the assessment team. Certain topic areas, such as transportation, are important to overall energy strategies, however, were not considered in detail within the Commonwealth of the Northern Mariana Islands (CNMI) assessment due to lack of data on energy use by this sector and the priority of targeting energy efficiency and renewable energy opportunities.

Each assessment begins with a background study of existing information and data to understand site demographics and geography. Human and physical geography impact energy consumption and the success of implementation of renewable energy projects, so these elements are essential to the types of recommendations made.

Data collection and researching previous studies allows the assessment team to understand the current baseline consumption and what recommendations have been made in the past. It also provides the team with information on what energy policies, programs, or projects are currently in place as well as understanding those that may have been attempted or implemented previously. The data collection process coincides with a site visit to interview stakeholders and survey the options to be included in the assessment. After the site visit, information is analyzed and opportunities are identified.

Figure 1 illustrates the major components of NREL's assessment methodology.

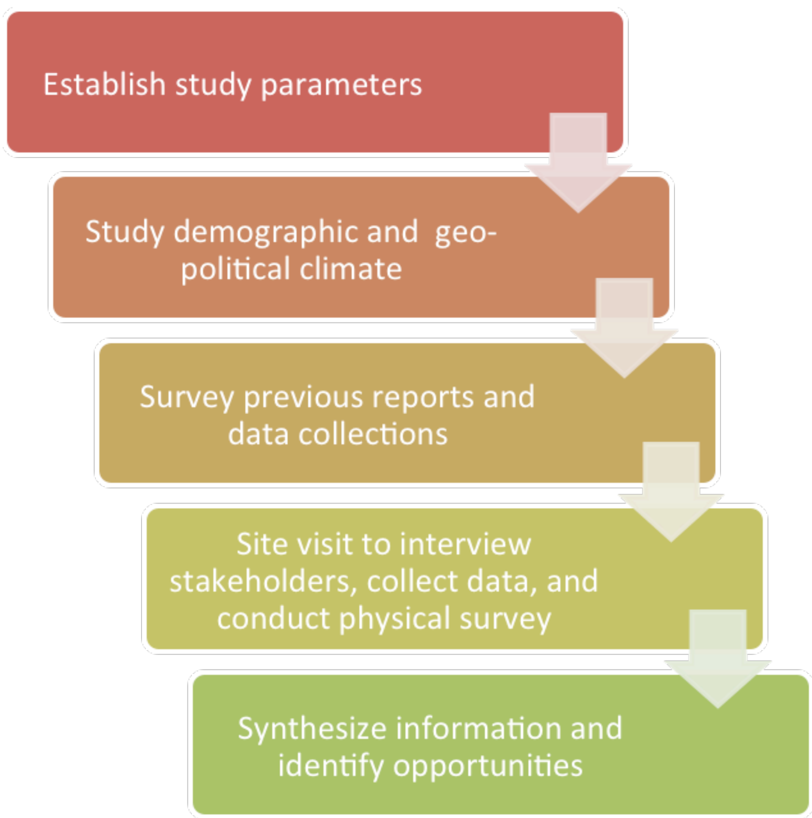

Figure 1. Assessment methodology

There are many energy efficiency and renewable energy technologies on the market today. Included within this study's parameters are mature technologies that are considered commercially available and bankable. There are other technologies that the CNMI may decide to investigate for future study, but for the basis of this assessment, technologies included have the following criteria:

- Commercial availability
    - Tested and demonstrated
    - Carry warranty
    - Service and parts available
- Ready for immediate deployment
- Sound investment
- Financing available from private sector organizations.

It should be understood that there are a number of power generation options potentially available to the CNMI, such as diesel, heavy fuel oil, liquefied natural gas, modular nuclear, and renewable energy technologies including solar, wind, biomass, waste-to-energy, and geothermal. Each of these technologies has its own operational characteristics, initial and operational costs, implementation time horizon, and near and long term environmental impacts. It also must be understood that most power generation choices require a large investment that can impact a community for many years. For these reasons, any technology choice should be arrived at through a process of strategic energy analysis to help ensure that the most appropriate choices are made for the current and future generations of the Commonwealth. This also underscores the importance of energy conservation and efficiency as a cost-effective method to potentially reduce the investment needed for electricity generation.

For the purposes of this assessment, commercial clean energy technologies considered include energy conservation and efficiency, wind, solar (photovoltaic (PV) and water heating), biomass, and geothermal technologies. NREL did not assess opportunities associated with other renewable energy technologies such as ocean thermal energy conversion, off-shore wind, marine hydrokinetic, or other conventional power generation technologies such as nuclear, coal, or natural gas.

This document summarizes data collected regarding energy production, consumption, and efficiencies based on the information that is currently available. The report discusses renewable energy and energy efficiency technology potential as well as current barriers and opportunities. Further investigation is needed to quantify the impact of specific technologies, programs, and/or projects. Environmental, regulatory, legislative, and financial considerations will also need to be addressed during the energy planning and project development process.

1.2 Background

The CNMI is an archipelago that consists of 14 islands located to the north of Guam in the North Pacific Ocean (roughly 15º north and 145º east). The CNMI is an unincorporated territory of the United States under the jurisdiction of the U.S. Department of the Interior's (DOI) Office of Insular Affairs (OIA). The total land area of the CNMI is 464 kilometers squared (km^2), 179 miles squared (mi^2) with 1,482 km (921 mi) of coastline.[1]

Figure 2 provides a basic map of the CNMI.

[1] CIA World Factbook. www.cia.gov/library/publications/the-world-factbook/geos/cq.html. Accessed 6/30/2011.

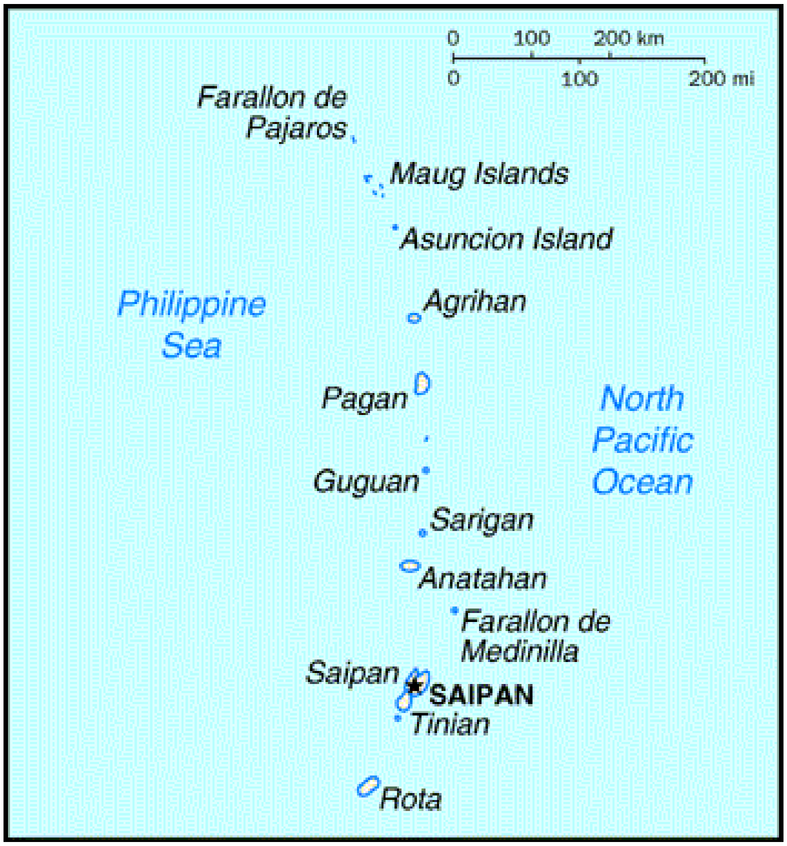

Figure 2. Map of CNMI

Source: US Department of Interior, Office of Insular Affairs

The southern islands are limestone with level terraces and coral reefs in areas; the northern islands are volcanic, with active volcanoes on Pagan and Agrihan. Natural hazards include susceptibility to typhoons between August and November. The CNMI has a tropical marine climate that is warm and humid with little seasonal temperature variation. The typical dry season occurs between December-June and the rainy season is between July-October. Yearly average temperatures range between 72°F and 84°F and average annual precipitation is 82 inches.

Most of the population, land area, economic activity, and energy consumption can be found on the three main islands of Saipan, Tinian, and Rota. About 90% of the population lives on Saipan, which is the center of government and business. In 2000, Saipan had a population of 62,292; Tinian had 3,540; and Rota had 3,283. The Northern Islands are mostly uninhabited. The population has been declining over the past decade; in 2000, the population of the CNMI was 69,221[2], the 2005 estimate was 65,927[3], and the 2010 census population count was 53,883.[4]

The CNMI is made up of a culturally diverse population; ethnic groups include Asian (56.3%), Pacific Islanders (36.3%), Chamorro (23.0%), Caucasian (1.8%), other ethnic origins (0.8%), and mixed ethnicities (4.8%). In addition to English, languages spoken include Philippine languages (24.4%), Chinese (23.4%), Chamorro (22.4%), Pacific Island languages (9.5%), and others (9.6%). The CNMI has a literacy rate of 97%.[5]

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[2] CNMI Department of Commerce: http://commerce.gov.mp/divisions/central-statistics/inside-the-central-statistics-division/census-reports/. Accessed 6/30/2011.
[3] Office of Insular Affairs. www.doi.gov/oia/Islandpages/cnmipage.htm. Accessed 6/30/2011.
[4] U.S. Census Bureau. http://2010.census.gov/news/releases/operations/cb11-cn178.html. Accessed 8/26/2011.
[5] CIA World Factbook. www.cia.gov/library/publications/the-world-factbook/geos/cq.html. Accessed 6/30/2011.

The economy is driven mostly by tourism largely from Asia, although the tourism industry has been declining over the past decade. Total tourist visits in 1997 were estimated at 726,690; in 2007, visits had dropped to 389,345, with Japanese tourists making up over 51% of the total. The garment industry was once a large part of the economy, but as the industry left the CNMI, revenues from the garment factories dropped from $826 million in 2004 to $307.6 million by 2007. By 2010, all of the factories had closed. The basic breakdown of total employment status is summarized in Table 2 below. Note that this information is from 2005, and does not reflect the current impact of the garment industry departure.

Table 2. Employment Statistics[6]

Total employment (2005)	38,935
Private sector employment	32,214
Government employment	3,186
Private sector employment as a % of total	91%
Government employment as a % of total	9%
Unemployment rate	8%

The Economic Census Data from 2007 indicates a total employment estimate of 22,622, down from an estimate of 32,790 in 2002.[7] These figures do not seem to include public administration employees, and employment statistics for some sectors are provided as a range, rather than a specific number. Assuming that the Economic Census Data includes only private sector employment, the Economic Census information would seem to correlate with the OIA data in Table 6, and illustrates a dramatic decrease in employment.

[6] Office of Insular Affairs. www.doi.gov/oia/Islandpages/cnmipage.htm. Accessed 6/30/2011.
[7] U.S. Census Bureau. http://factfinder.census.gov/servlet/IBQTable?_bm=y&-geo_id=04000US69&-ds_name=IA0700A01&-_lang=en. Accessed 7/5/2011.

2 Establishing a Baseline

Site assessments incorporate historical energy consumption data to establish a baseline following a review of the natural and cultural influences of the location. This section summarizes observations from electrical generation, end-use energy consumption and costs, and solid waste management. Additional details are provided in the appendices.

2.1 Overall Fossil Fuel Energy Use

With the exception of a few small renewable energy projects, the CNMI is 100% dependent on imported fossil fuels for its energy supply needs. The primary areas of fossil fuel consumption in the CNMI are:

- Electricity production
- Transportation
- Space cooling, water heating, and self-generation by the commercial sector (primarily hotels).

Total fossil fuel import data was not available at the time of publishing; fuel use for electrical generation is detailed in the sections below.

2.2 Electrical Energy

2.2.1 Electrical Generation

The Commonwealth Utilities Corporation (CUC) is the CNMI's publically owned utility, providing power, water, and wastewater services. CUC operates and maintains power generation and distribution services on all three main islands; however, the power plant on Tinian is owned and operated through a power purchase agreement (PPA) with a private power provider. Transmission and distribution maps for each island are included in Appendix A.

As part of an effort to consider the development of alternative energy options for CNMI, the Department of Public Works Energy Division oversaw the development of *Alternative Energy Development Program in the CNMI*[8], which documents most of the key elements of the existing power system on the three islands as of 2010. A summary of the document follows in Table 3, which was updated based on correspondence with CUC.

Table 3: Basic Power System Information for the Three Main Islands of CNMI

	Saipan	Tinian	Rota
Installed Capacity (diesel power)	69.9 MW	20 MW	4.5 MW
Peak Load	45 MW	5.2 MW	2.0 MW
Base Load	39 MW	4.7 MW	1.5 MW
2015 Peak Load Forecast (3% growth)	52.2 MW	6.0 MW	2.3 MW
Current Customers (March 2011)	13,208	879	820

[8] http://gov.mp/wp-content/uploads/2011/05/QUESTIONNAIRE-RENEWABLE-ENERGY5-FAQs.pdf.

All of the electricity power plants in the CNMI are powered by diesel fuel. CUC is currently using 22-24 million gallons of diesel fuel per year, at a cost of more than $60 million. For the year of 2010, total fuel imported for power generation was 554,811 barrels (23,302,062 U.S. gal) of diesel fuel. CUC has a single power cost structure across the CNMI, which uses a graduated residential rate starting at $0.26/kilowatt hour (kWh) (with a top tier rate of $0.37/kWh for monthly use above 2,000 kWh); a commercial rate—as charged to hotels—of $0.33/kWh; a government rate of $0.335/kWh; and a non-conforming rate (for all non-conforming loads) of $0.466/kWh. These rates are based on a Public Utilities Commission (PUC)-set non-fuel base rate, typically in the area of $0.08/kWh and fuel surcharge, which over the past few years year has ranged from a low of just over $0.24/kWh to a high of more than $0.48/kWh during the height of the oil price shock in the summer of 2008. Due to the temperate climate, there is minimal seasonal load variation.

2.2.1.1 Saipan

Total annual electricity production for Saipan has remained below 300,000 megawatt hours (MWh) for the past several years, most of which is general residential and light commercial loads. The load itself is seasonally fairly constant and has a daily low of around 30 megawatts (MW) to a high of 45 MW. There are 12 major hotels on the island with loads ranging from several hundred kilowatts to 1.5 MW, however some use on-site generation instead of purchasing power from the CUC. There are also several large critical loads, which include the airport (~1 MW), hospital (~0.8 MW) and the International Broadcasting radio station (~1.65 MW), as well as some large retail shopping customers. Historical energy production trends also provide a clear depiction of the power sector on Saipan, as shown in Figure 3.

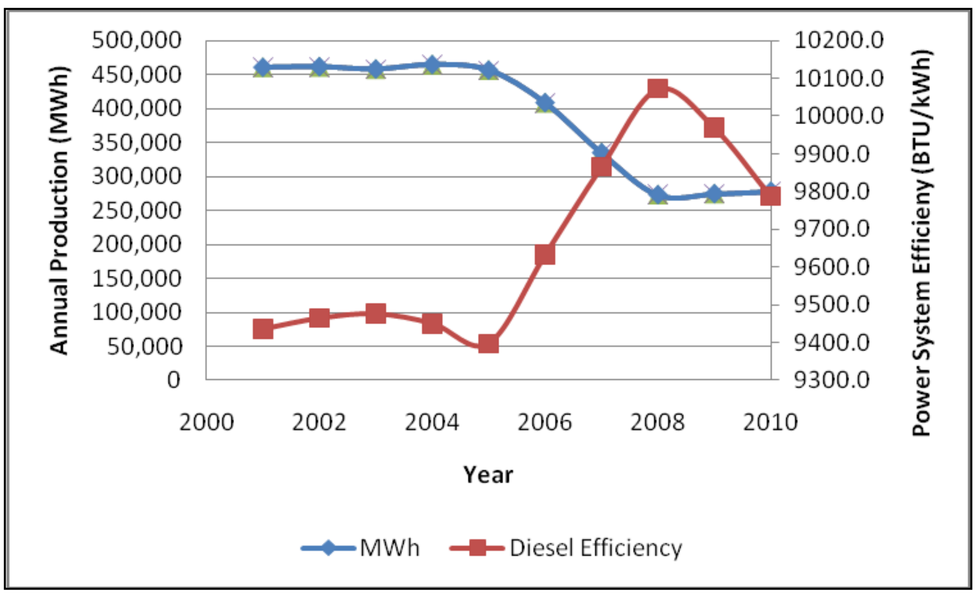


Figure 3. Power generation and efficiency for Saipan from 2001 through 2010

Showing large decrease in power needed experienced in the middle of the decade and the range of power system efficiencies, assuming a diesel heat rate of 137,143 BTU/Gal

Source: CUC

Annual electrical production was quite stable through the first part of the decade, and then saw a significant slump driven primarily by the closing of the garment factories, which was followed by a slump in the tourism industry brought on by the global economic recession. Power generation has since stabilized at current levels and has seen slight increases over the last two years. Long term power growth forecasts remain low, ranging from a low estimate of 1% to a high of 5% per year.

Total power production in 2010 was 279,270 MWh divided between residential, commercial, governmental, and a then-fledgling pre-paid meter program as shown in Figure 4. Based on the total fuel consumption and power production listed above, the diesel system efficiency of 14.01 kWh/gallon is achieved. In terms of energy intensity, in 2010 the overall system efficiency was 9,789 British thermal units (BTU)/kWh, assuming a diesel fuel heating value of 5.760 million BTUs per barrels (MBTU/bbl). As a comparison to other island power systems, Hawaii's overall system heat rate was about 10,500 BTU/kWh[9] and the U.S. Virgin Islands' system-wide average was about 15,200 BTU/kWh.[10] It should be understood that the fuel mix of Hawaii and the U.S. Virgin Islands is different than Saipan, with a stronger reliance on heavy fuel oil. As shown in Figure 3, plant efficiency (in BTU/kWh) improved greatly between 2006 and 2009. Efforts have been made recently to further improve the generation efficiency, including a project currently underway to replace the turbochargers on several of the prime diesel units.

Additionally, Figure 4 demonstrates that a large percentage of the total power generation is actually non-revenue generating and is the difference between what is generated and what is sold to the customer. Although this figure may be relatively high, it must be taken in context as it includes station auxiliary service, technical and non-technical losses, and has been reduced by about 7% from 2009. Losses, both technical and non-technical, are typically found in the electrical system, including transformers, distribution line losses, and meter inaccuracies. Non-technical losses include power theft, and inaccuracies in record keeping or revenue collection. Non-technical losses, which accounted for just over 10% of total generation in 2010, are an issue that CUC has worked to address over the past year. Internal usage includes all power usage required to produce power, including power use at all CUC facilities. Finally, municipal use includes all power needs to operate CUC's water, wastewater and street lighting systems.

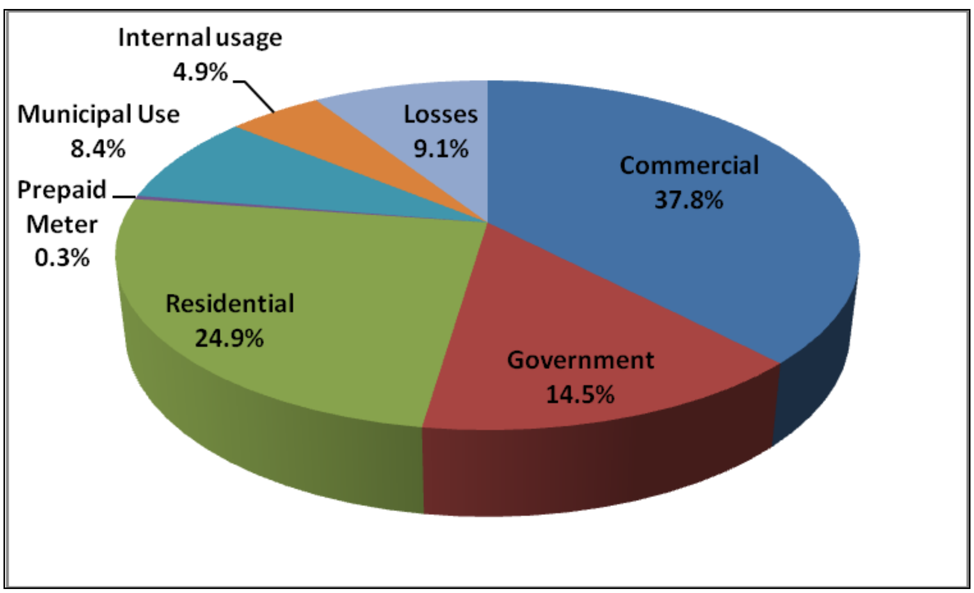


Figure 4. Electrical power consumption by sector for Saipan, 2010

[9] E-mail correspondence with Kenneth Kelly, NREL. March 2011.
[10] E-mail correspondence with Adam Warren, NREL. March 2011.

As learned in discussions with people from every sector, the cost of power is seen as a huge obstacle for not only standard-of-living, but also for future economic development and job creation. Additionally, pressure from the PUC to keep power costs as low as possible has put CUC in a position of forcing the deferment of needed plant repairs and upgrades. Plant managers indicate that it is difficult to justify higher power costs to pay for plant improvements when the cost of power, largely driven by high international oil costs, continues to result in higher costs.

Saipan is supplied power through diesel generators located at two power plants, both located in the central port area of Tanapag. The main power plant, which is classified as Power Plants 1 and 2 due to different installation phases, is operated directly by CUC and consists of six smaller (2 MW) medium speed (900 revolutions per minute (RPM)) diesels and eight large (5 MW and 9 MW) low-speed (450 RPM) generators. Two of the generators have been decommissioned and several others are undergoing rehabilitation or overhauls at the time of this writing. Diesel engine ages range from 1971 through 1992. The plant sits on the coast, within several feet of the water line. The third plant, Power Plant #4 (Plant #3 has been decommissioned) is also installed in the main port area but is located on higher ground. The plant is made up of smaller 1 MW and 2 MW, 900 RPM, units. These smaller diesels represent a large range in age from the mid 1950s to the most recent ones built in 1998. This power plant is operated under a PPA with the private company PMIC. For the month of November 2010, specific fuel consumption was 14.07 kilowatt hours per gallon (kWh/gal), which is quite good, but depending on the diesel engine, ranged from a low of 10 kWh/gal to a high of almost 15.5 kWh/gal. Fuel costs clearly vary with purchase data, but for November 2010 were $2.5848/gal, resulting in an average fuel-only cost of power of approximately $0.18/kWh. Diesel overhaul costs were estimated by CUC to be 0.4 cents/kWh produced, which brings the total diesel production cost to approximately $0.19/kWh.

Power is provided to households on a 13.8 kilovolt-ampere (kVA) multi-feeder distribution system with a single 34.5 kVA transmission link between the central power plant and the Kiya Substation in the southern section of the island. Although the Kiya Substation has capacity for more than double its current load of approximately 16 MW, and the total distribution system is currently under-utilized, the absence of a more expansive high-voltage transmission backbone may pose a problem with the implementation of large wind turbines at specific locations on the island. This is due to the potential need to interconnect directly to the distribution system. A renewable energy grid interconnection analysis may be needed to determine specific limitations or necessary upgrades.

Saipan currently has a maximum diesel fuel storage capacity of over 3 million gallons (when all tanks are in use), allowing for just over two months of active fuel storage based on current consumption, which in 2010 was 19.86 million gallons. The fact that the fuel tanks are privately owned limits competition for fuel purchase on the open market.

2.2.1.2 Rota

Power demands for the island of Rota are much smaller compared to Saipan. The daily load ranges between a low of 1.2 MW to a high of around 1.8 MW during peak times in the late afternoon and early evening. The total energy production for 2009 was just over 8,672 MWh, about 4% of the power generation on Saipan. The load in Rota is also split between residential, government, and commercial sectors. Unlike Saipan, power demand on Rota continues to decrease, dropping by almost 25% since 2006. This decline, however, seems to be tapering off, with reductions from 2008 to 2009 falling only about 5%, as shown in Figure 5. At the time of publishing, a breakout of energy consumption by sector was not available.

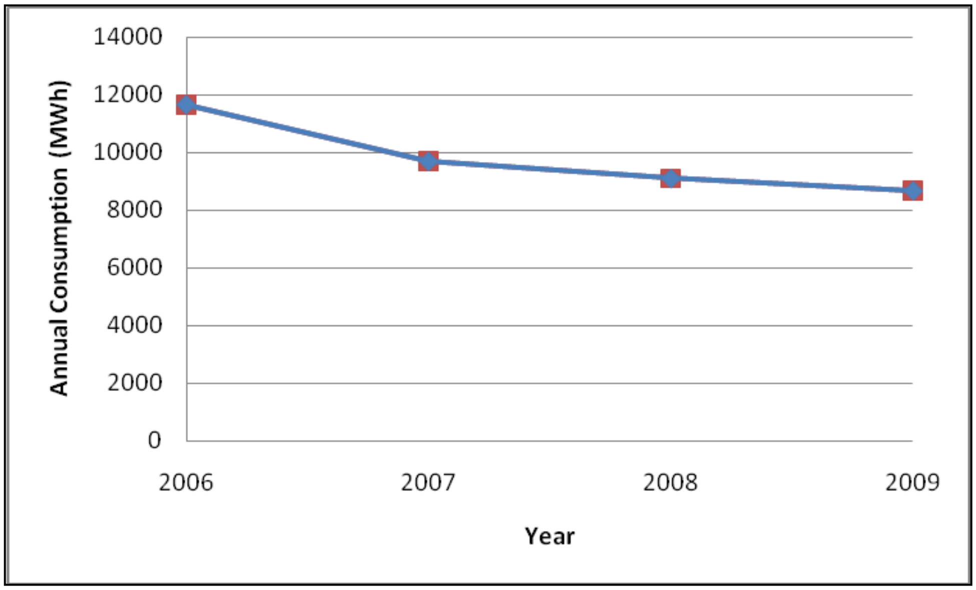


Figure 4. Power consumption for Rota from 2006 through 2009

Showing large decrease in power need over the last several years

Source: CUC

The single power station at Rota is made up of six diesel engines, two of which have been decommissioned. Three of the units are rated at just less than 1 MW continuous operation while the last is rated at 1.8 MW continuous operation. Information on these engines is provided in Table 4 below. The power plant is located on the far southern end of the island in the main community of Songsong. Although very close to the water's edge and the West Harbor, it sits on ground about 20 feet above sea level. The power distribution on Rota is primarily through a 4.16 kilovolt (kV) local distribution line throughout Songsong, although Feeder 3, which supports the airport and the community of Sinapalu, is operated at 13.8 kV. The plant and distribution system are owned and operated by CUC.

Table 4: Diesel Engine Statistics for Electric Generation on Rota

Generator #	Type / Model	De-rated Capacity (MW)	Speed (RPM)	Year
D/E No 1	Mitsui	1.5		1987
D/E No 3	Caterpillar 3516	0.6	1,200 (not confirmed)	
D/E No 5	Cummins KTA 50-G3	0.9	1,800	1998
D/E No 6	Cummins KTA 50-G3	0.9	1,800	1998

2.2.1.3 Tinian

Data on the power consumption for Tinian is less available, primarily because the power system on the island is owned and operated under a PPA contract with the Chicago-based company Telesource. The current load is consistently between 4 MW and 5 MW year round. The population of the island is only about 4,000 people; however, two large customers, the Tinian Dynasty Hotel & Casino and the U.S. Government International Broadcasting Bureau (IBB) facility make up about 50% of the total electric load. At current typical occupancy rates of 30% to 40%, the hotel has a demand of about 0.8 MW to 1 MW (the load increases to 1.5 MW at peak occupancy) while the IBB uses between 1.2 MW and 1.5 MW. Other significant, but much smaller, local loads include the school and airport.

The Mayor's Office is currently developing a 5-year plan that will help define the potential for future growth on Tinian. As part of this effort, an assessment of the energy impact of expected future development will need to be conducted. As indicated below, the energy infrastructure on the island greatly outpaces actual power needs since the original plant was built at a time of very high resort development interest.

The Telesource diesel plant is well maintained and is comprised of five, 4 MW Wartsilla diesel gensets located in a single plant outside of San Jose. The plant is located close to the coast at an elevation of about 25 feet. Distribution is through four 13.4 kV feeders; three to different parts of the community and one dedicated to the IBB facility. As described, the diesel plant is rated at 20 MW installed capacity, although the load is below 5 MW. The large step size of the current diesel engines means that any energy savings will have somewhat limited impact since a single generator will continue to power the load.

2.2.2 Energy End-use

Understanding the building stock is important, as energy use will vary by construction type and materials, the age and function of the building, and the type of equipment in use. Other parameters that impact energy use are climate, culture, and the ability to properly operate and maintain equipment. The key to reducing energy consumption is to understand how it is being utilized and to know where conservation and efficiency measures can be applied. By identifying the specific end-uses of energy, analysis can be undertaken to identify areas where the most impactful and cost-effective improvements can be made. Some of these improvements may be low or no cost, such as operational changes or education, while others may require a larger investment, such as cooling system upgrades.

Buildings in the CNMI are typically constructed of reinforced concrete or concrete block to withstand the wind and water resulting from frequent typhoons. Lightweight buildings that are constructed of wood frames and older buildings with deteriorating structures are the most vulnerable to damage or destruction.

The building portfolio on Saipan is comprised of hotels, the airport, government buildings, schools, hospitals, factory buildings and warehouses (mostly abandoned), commercial property, and residential buildings, such as apartments and single-family dwellings. The number of buildings classified within each category is unknown; however, opportunities to reduce consumption were identified through observations and discussions with government agencies and the CUC.

Discussions with the Department of Public Works (DPW) Energy Division and CUC representatives indicate that the largest energy users in the CNMI are the public school system, hotels, and the IBB radio stations. Most of the hotels on Saipan have their own generators and are connected to the CUC electric grid. In times of poor reliability or higher electricity costs from the grid, the hotels will generate most or all of their own electricity. At the time of NREL's visit, most hotels were generating their own electricity due to high costs. Most residences and commercial buildings have air conditioning; some residences have disconnected their hot water heaters to reduce their electricity costs.

Figure 6 shows electrical consumption by sector for 2010 in MWh of supplied power.[11] There are some customers that would typically be classified as industrial, such as the gravel yard, but due to the low number of industrial customers, all such loads are designated commercial clients.

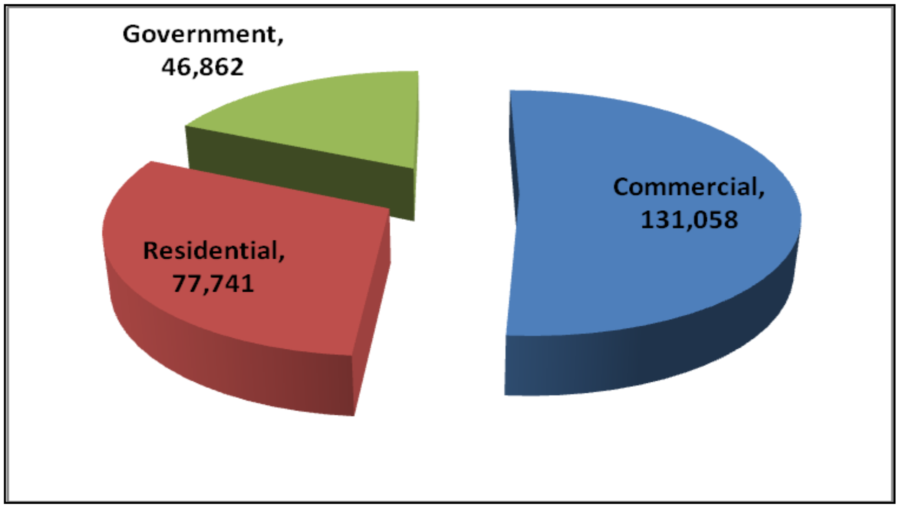


Figure 6. 2010 power consumption by sector in MWh

Source: CUC

2.2.3 End-use for Commercial Sector

Energy consumption in commercial buildings is led by hotels, retail, and small businesses; the garment manufacturing industry, which was previously the largest consumer, no longer has a presence in the CNMI. A specific break out of commercial energy end-use data is not currently available for the CNMI. Building construction is likely very similar to that on Guam, so for the purposes of this report, a graph of commercial end-use on Guam is included as a representative example. End users within commercial buildings for Guam are reported by Guam Power Authority (GPA) as being interior lighting, cooling, miscellaneous equipment, refrigeration, ventilation, exterior lighting, water heating, and cooking. Electricity end-use is broken out for commercial buildings in Figure 7.[12] 1993 is the most current end-use data available.

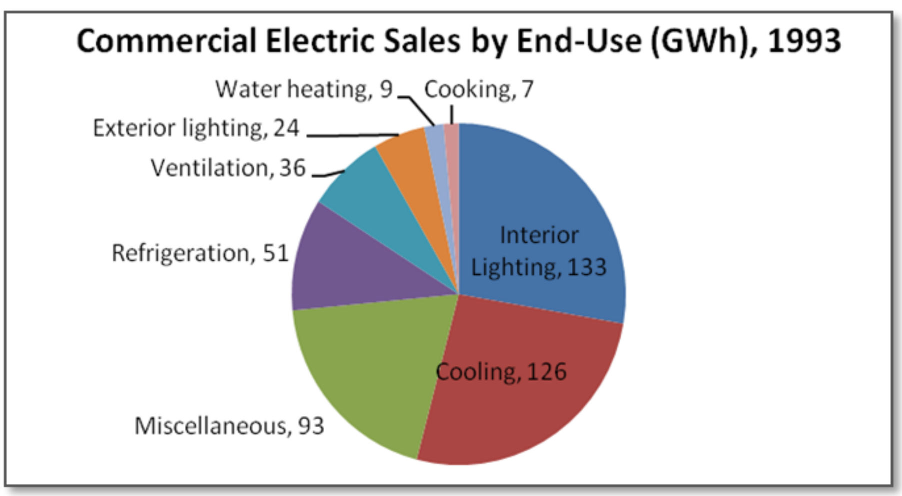


Figure 7. Commercial electric sales by end-use for Guam, 1993

Source: Guam Power Authority

[11] Commonwealth Power Corporation, June 2011.

[12] Guam Power Authority. Demand Side Management Plan. Section II. April 1993.

The major hotels on Saipan make up over 7.3 MW of combined electrical demand. In discussions with the Hotel Association of the Northern Mariana Islands (HANMI), it was learned that their primary electrical loads are space cooling (chiller systems), water heating, and reverse osmosis for water purification. Some hotels have implemented energy efficiency measures to reduce their utility costs, and most generate their own electricity when it is cost effective to do so. Improvements to generator efficiency, combined heat and power for water heating, or use of biofuels may present an opportunity to lower fuel costs. There may also be opportunities to considerably reduce consumption through solar water heating, lighting upgrades and occupancy sensors, and key-activated guest room lighting and air-conditioning.

The second largest energy user on Tinian is the Tinian Dynasty Hotel & Casino. Hotel management has made significant efforts to reduce their energy use, including limited restaurant operating hours, closing over 60% of the casino to customers, disconnecting lights and cooling in certain areas, retrofitting lighting and kitchen equipment, and using room-key activated systems to turn off electrical loads in guest rooms when unoccupied. There is still an opportunity to improve cooling efficiency by relocating the chiller system to a central location, which is an estimated $700,000 investment; at current energy consumption and costs, the payback for this project would be a little over one year.

With the commercial sector accounting for almost 38% of the CNMI's energy consumption, strategies to reduce energy use should be identified. Energy audits can help determine specific opportunities in commercial buildings and across commercial sectors, and should include an examination of all energy and water end-use systems. By understanding more about the equipment and plug loads that are consuming energy, commercial organizations will have better control over managing and reducing their energy consumption.

Opportunities should also be investigated for the radio broadcasting stations on Saipan and Tinian, although most of their use is likely radio signal transmission.

2.2.4 End-use for Residential Sector

As with specific end-use for the commercial buildings sector, the specific end-use for electricity in residential buildings in the CNMI could not be determined due to lack of available data. A representative chart of residential electricity end-use in 1993 from Guam is provided as reference, as the end-use types are likely very similar.

In 1993, the highest energy consumption on Guam within the residential sector was water heating, followed by air conditioning, and household appliances, as shown in Figure 8.[13] This tells us the best opportunities for the residential sector have been reducing electrical use for water heating, improving air conditioning, improving appliances, and changing to more-efficient lighting. Recovery Act programs in the CNMI have funded efficient appliance rebates, compact fluorescent lighting, and weatherization projects. Further improvements could likely be made through solar, heat-pump, or high-efficiency water heating and incentives for higher efficiency air conditioning.

There is an affordable housing project currently under construction in Chalan Kanoa on Saipan that includes solar water heating for each of the residential units. This could serve as a demonstration of the technology to encourage wider implementation throughout the CNMI.

[13] Guam Power Authority. Demand Side Management Plan. Section II. April 1993.

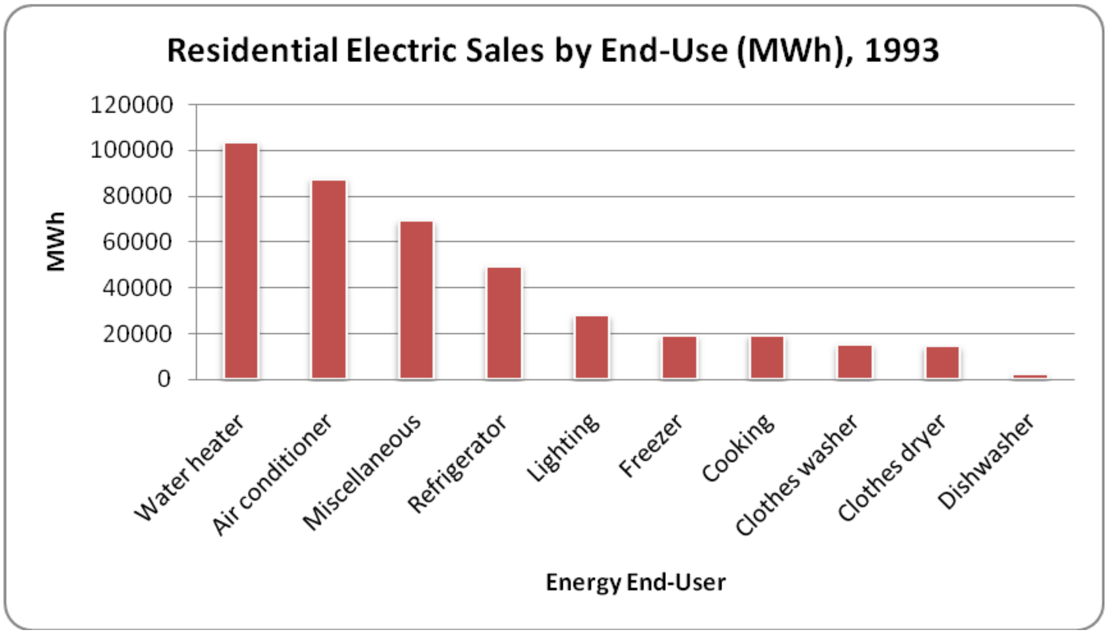


Figure 8. Residential electric sales by end user for Guam

Source: GPA

2.2.5 End-use for Government Sector

The primary electricity consumers in the government sector include the CNMI Public School System (PSS), the Commonwealth Health Center, and the Francisco C. Ada International Airport on Saipan. Specific usage data for each government agency is not available. Most of the CNMI's government offices appeared to be smaller buildings or located within other office buildings. It was also observed that many government (and other) offices used unitary room air conditioning that could be turned off when a room is not in use—this is a far more efficient practice than central cooling systems.

The PSS has 20 school campuses—15 on Saipan, three on Rota, and two on Tinian—and currently spends over $4 million per year for electricity. Some efficiency improvements have been undertaken through Recovery Act funding, including air conditioning upgrades and cool roof installations, which is expected to save as much as $1 million per year. The PSS has completed a small wind and photovoltaic (PV) system at Saipan Southern High School through grant funding. Recovery Act funding is now being used to replicate this effort at 10 other schools, including some on Tinian and Rota, although installation of wind turbines is currently on hold until environmental studies are completed by the U.S. Fish and Wildlife Service. There are likely more cost-effective efficiency opportunities in many of the school facilities that could be determined through energy audits. Opportunities not included in the current efforts that should be investigated include lighting retrofits, solar window film, insulation, dehumidification, and refrigeration upgrades in cafeterias. Savings from the Recovery Act-funded energy efficiency and renewable energy projects could be used to fund energy audits and additional energy efficiency improvements.

The DPW Energy Division, which manages the energy related Recovery Act efforts for the CNMI, has indicated that there will be energy audits performed for government facilities through Recovery Act funding to identify energy saving opportunities. The Energy Division is working to secure training for energy auditors in order to begin the audits later this year. As the audit reports are completed, an implementation program for the highest priority opportunities should be developed.

2.2.6 Water

A significant amount of energy is required to pump and treat potable water, and to collect, pump, and treat wastewater. Reducing water consumption and improving the efficiency of water pumping systems reduces overall fuel use and energy costs.

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 are tiered from a low of $1.81/kgal for the first 3,000 gallons to a high of $7.24/kgal for over 60,000 gallons. Government customers are charged $54.30/kgal regardless of consumption.

Wastewater service is only provided on Saipan; residents and businesses on Tinian and Rota have individual septic tanks. Residential rates increase from $1.00/kgal for the first 6,000 gallons per month to $3.13/kgal for above 6,000 gallons. Rates for commercial customers are relatively flat at $3.00/kgal for the first 6,000 gallons, and $3.13/kgal above that. The government is charged a rate of $68.00/kgal.

The total energy use for water and wastewater services in the CNMI was not determined for this report, but should be considered as part of the energy planning effort. Water conservation and efficiency may significantly reduce costs for CNMI government customers due to their very high water rates, and reduce overall energy and fuel consumption. CUC estimates that almost 50% of the potable water is lost due to leaks in the piping system. Repairing these leaks and investigating opportunities to improve pumping efficiency should present an opportunity to lower energy expenses.

2.2.7 Renewable Energy

There are a few renewable energy systems currently installed and operational in the CNMI, and several more in the planning phase. The exact number of commercial and residential systems was not quantified for the purposes of this report. Table 5 shows the known commercial systems currently operating.

In 2009, a 2.0 kW ground mounted PV system and a 2.4 kW Skystream wind turbine were installed at Saipan Southern High School. This project is serving as a model for a Recovery Act funded project to install a 2.4 kW wind turbine and 2.5 kW PV system at 10 other public schools, including three on Tinian and two in Rota. An additional 120 kW of wind and 45 kW of PV is planned for Saipan Southern, also through Recovery Act funding, and will be grid-connected and net metered. Installation of the wind turbines for these projects is currently on hold due to U.S. Fish and Wildlife Service concerns regarding fruit bat and endangered bird habitats.

Recent installations include a small wind and PV demonstration project at the DPW Energy Division offices and a 54 kW net metered roof-mounted PV system at the American Memorial Park.

Table 5. Commercial RE Systems Currently Operating in the CNMI

Location	Technology	Power Output	Year Installed
Saipan Southern High School	Solar PV, small wind	2.0 kW PV, 2.4 kW wind	2009
American Memorial Park	Solar PV	54 kW	2010
CNMI DPW Energy Division Office Building	Solar PV, small wind	2.5 kW PV, 2.4 kW wind	2010

Additional planned renewable power projects include a 211 kW ground-mounted PV array near As Matius on Saipan, being installed by a private company who will sell the electricity to CUC through a power purchase agreement, and a 460 kW PV system covering a parking lot at the Marianas Business Plaza, which will be net metered.

NREL also observed several solar water heating systems on local businesses and residences, mostly with evacuated tube collectors. The Sandy Beach Homes Affordable Housing Project, currently under construction in Chalan Kanoa on Saipan, includes solar water heating for each of the 60 residential units.

2.3 Energy Policy

Many states, territories, local governments, and communities across the globe are adopting strategies that promote increased use of energy efficiency and renewable energy. Policy is a mechanism that governments can use to provide support for the development of programs that will advance and support energy efficiency and renewable energy objectives. Policy implementation can aid in market adoption and assist in laying a foundation for a green economy while providing investors with certainty in the local market. This can be an effective tool to help the CNMI achieve their energy efficiency and renewable energy goals, increase energy diversity, and decrease dependence on imported fossil fuels.

The CNMI's government has adopted new and modified existing energy efficiency and renewable energy policies over the past few years. Public Law (PL) 15-23, adopted in 2006, set forth a range of energy policies to encourage the use of renewable energy and incorporate energy efficiency in both the private and public sectors. Since that time, PL 15-23 has been amended and new energy policies have been enacted. The following subsections discuss the energy policies currently in place in the CNMI.

2.3.1 Net Metering

A net metering policy for distributed generation was adopted as part of PL 15-23 in 2006, allowing net metering of residential and commercial renewable energy systems up to 100 kilowatts (kW). This policy was amended by PL 15-87 in 2007, increasing the limit to 10 MW to allow large-scale renewable electricity sales to CUC by independent power producers (IPPs). New net metering customers can be added until total net-metered capacity reaches 30% of CUC's peak demand. Metering is accomplished with a single, bi-directional meter. Any excess electricity generated by the customer in a given month will be credited to the following month's bill and reconciled annually at a rate of 50% of the total net metered energy rate. PL 17-34, enacted in 2011, removes IPPs from the definition of a net metering customer, eliminating the rate reimbursement restriction and requiring CUC to issue a Request for Proposals (RFP) to select IPPs for any large-scale renewable electric generation. Any renewable energy system connected to the electric grid is required to meet National Electric Code, Institute of Electrical and Electronics Engineers, and Underwriters Laboratories standards; however, interconnection requirements are not specifically addressed.

Northern Mariana Islands Administrative Code Title 50, Chapter 11, establishes interconnection requirements and net-metering regulations, and CUC has recently prepared a simple form for net metering customers to request interconnection to the electric grid.

2.3.2 Renewable Portfolio Standard

The CNMI adopted a Renewable Portfolio Standard (RPS) in 2006 under PL 15-23, and increased the requirements one year later in PL15-87, which set renewable energy targets far more aggressive than most RPS. This law amended previous laws with the purpose of establishing an RPS to require implementation of renewable energy to mitigate the high cost of diesel fuel used for electricity generation. It established a stepped approach with an ultimate goal of achieving 80% of net electricity sales from renewable energy by 2014.

If the CNMI is to move toward decreased fossil fuel use and increased energy diversity, an RPS can be a very effective tool, however, the requirements must be realistic in terms of total renewable energy generation potential and the timeline to meet those requirements. The following is the renewable energy integration timeline set forth for CUC to meet as spelled out in the RPS Goal of 2007:

- 10% of net electricity sales by December 31, 2008

- 20% of net electricity sales by December 31, 2010
- 40% of net electricity sales by December 31, 2012
- 80% of net electricity sales by December 31, 2014.

The law includes stipulations that allow for non-compliance if meeting the requirements is not cost effective. Currently, the CUC is not in compliance with these goals, but has recently released an RFP for private development of utility-scale PV systems up to 10 MW. CUC is also open to wind, waste-to-energy (WTE), and geothermal electricity generation, and plans to pursue those technologies as resource assessments are performed to determine their potential.

To further support this effort, PL 15-87 requires the Department of Lands and Natural Resources and the Department of Public Lands to work with CUC and renewable energy developers to locate potential sites for development, publish a catalog of lands available for renewable energy development every two years, and provide assistance in planning and permitting to ensure development is expedited. The Department of Public Lands administers leases of up to 25 years on public property. It is recommended that these CNMI government agencies and CUC work together to determine public lands potentially available for renewable energy development in advance of the issuance of RFPs for renewable energy, as this is likely to attract more interested bidders and more accurate proposals. Additionally, PL 15-87 instructed DPW and Commerce to develop a program to maximize use of renewables in each government agency, Commonwealth Ports Authority, Public School System, and Northern Marianas College. Other than the Recovery Act funding that is providing renewable energy to public schools, the development status of a territorial program is unclear.

2.3.3 Government Energy Efficiency

There are several policy efforts in place to encourage public building energy efficiency in the CNMI. PL 15-23 established a requirement for the CNMI government use of ENERGY STAR appliances and office equipment, allowed agencies to enter into third-party finance arrangements to improve building efficiency to ENERGY STAR performance levels, and required new government buildings to achieve a Leadership in Energy and Environmental Design (LEED) Silver rating. PL 16-35, enacted in 2008, suspended the LEED rating requirement for "one year from the date that this act becomes law or until the Department of Public Works obtains a LEED-certified professional, whichever comes first." LEED certified construction within the CNMI government has not been pursued as there are currently no new government buildings planned, and LEED-accredited personnel have not been needed.

2.3.4 Building Energy Codes

In an effort to update building energy codes and qualify for Recovery Act funding, the CNMI government amended the regulation of the DPW, Building Safety Division to adopt both the International Building Code (IBC) residential and commercial energy codes and the local CNMI Tropical Energy Code in May 2009. The specific version of IBC is not specified, but it is assumed to be the latest version (at the time of this writing, IBC 2009) as the Public Notice of Regulations states: "Through the IBC bring the CNMI building codes up to date and further empower the Building Safety Official to update as the construction industry and its professions update." The CNMI Tropical Energy Code (the Code) provides reasonable and achievable requirements for the climate and for local expertise in construction and operation. The Code provides efficient specifications for mechanical equipment (ventilation and air conditioning), controls, cool roofs, and the building envelope to supplement the IBC. Interior lighting power densities are adequate but could be improved by reference to a newer version of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 90.1 code, such as 90.1-2007. During the NREL site visit in December 2010, the code requirements were not being enforced due to untrained code officials, builders, and trades. The DPW Energy Division has indicated that code training has since been provided to its code inspectors as well as local builders and trades through Recovery Act funding, and these new codes are currently being adhered to.

2.3.5 Residential Solar Water Heating

In addition to more recently enacted efficiency requirements, a previous law (PL 15-26 of 2006) authorized the Northern Marianas Housing Authority (NMHA) to either require new home loan applicants to include solar thermal technologies into new homes, or to develop a loan program to provide homeowners greater access to these technologies. It is unclear whether this type of program has been developed or is currently in place and accessible.

2.3.6 Clean Energy Transportation

Article 7 of PL 15-87 established a policy to use either biodiesel or electricity generated by clean fossil-fuel plants or renewable energy for fuel in buses and mini-buses. The policy also requires CUC to provide at least two electric vehicle charging stations for these vehicles. No electric or biofuel vehicles were observed at the time of NREL's site visit, and as there is no public transportation system in the CNMI, this policy has not developed into a program.

2.4 Solid Waste

For many years, the primary waste disposal site on Saipan was the Puerto Rico Dump (PRD). The PRD began as a military dump along the shoreline of the Saipan lagoon, but due to environmental concerns, the U.S. Environmental Protection Agency (EPA) required the CNMI to close the PRD in the early 1990s. A site was chosen for a new landfill at the north end of the island in the Marpi depression. According to an article by Steve Hiney and Ted Hawley, "The goal for a new solid waste system was not only to bring Saipan into compliance with federal environmental regulations, but also to utilize state-of-the-art waste reduction and diversion technologies".[14] This eventually included implementation of diversion and recycling programs, a new solid waste transfer station and materials recovery facility, and a new municipal solid waste (MSW) landfill—the Marpi Solid Waste Facility (MSWF).

The CNMI uses private waste collectors for residential, commercial, and industrial waste collection. The waste haulers take their loads to the transfer station or to the landfill; as much of the material as possible is recycled. Currently, items such as paper, glass, plastic, and metals are recycled at eight centers on Saipan and one center on Tinian. There are currently no recycling facilities on Rota. Neither Tinian nor Rota has solid waste systems as developed as Saipan.

In 2009, NREL met with the Acting Director of Solid Waste and visited the Marpi landfill. At that time, the waste input to the landfill was estimated to be about 100 tons per day. The Marpi landfill had two cells; cell number 1 was being filled at that time. In addition to the non-recyclable materials, the landfill receives waste from the sewage treatment plant and the hospital. The main electrical loads at the landfill include the leachate pump, scales, and a small office. Diesel fuel is used for the equipment that moves the waste onsite. The landfill operators are investigating installation of a 100-kW diesel generator to serve the landfill electrical loads, and are interested in small-scale WTE plants.

NREL obtained data on waste and recycling numbers from the Director of Solid Waste, who is also one of the authors of the above-referenced report. Descriptions and numbers in the following sections are derived from the 2005 report, the NREL site visit, and various other sources, including a status report written in 2010.

[14] Saipan's Solid Waste Management System. Steve Hiney and Ted Hawley. Government Engineering November–December 2005.

Figure 9. NREL Saipan landfill and waste photos, 2009

Source: NREL/PIX 18940, 18943, 18941, 18942

2.4.1 Refuse Transfer Station

The $4.3 million Lower Base Refuse Transfer Station includes three structures—truck weigh scales and scale house, office/materials recovery facility building, and solid waste transfer building. The facility has on- and off-site access roads and parking; an area for sorting, grinding, and storing green waste (vegetation); and all utilities (water, sewer, power, communications). The transfer facility is an 8,000 square-foot building where residential and commercial vehicles can drop off solid waste for loading into roll-off bins for transport to the landfill.

2.4.2 Marpi Solid Waste Facility

In February 2003, the Marpi Solid Waste Facility (MSWF) began accepting waste on Saipan. The $9.4-million facility includes site-support services (truck weigh scales and scale house, office building, maintenance building), a small-haulers drop-off area, a diesel electrical power generation facility, a 12-acre lined waste management unit, a 5-million gallon leachate storage pond, water and wastewater systems, storm water control systems, fuel storage systems, and site access roads and parking. The landfill is used only for disposal of MSW and other non-hazardous waste.

2.4.3 Recycling

Recycling provides a landfill diversion opportunity, as well as a potential economic opportunity within the commercial sector. There is considerable diversion of certain types of waste away from MSWF on Saipan, composed of backfill (dirt and rocks) and recyclable materials. It is not clear what is being done with the cardboard, paper, and tires, as shipping costs to send the material to off-island markets are quite high. If recycled materials cannot be used on the island or economically shipped, they could be used for energy or liquid fuels production. Solid waste managers and planners need to carefully consider all of the costs and benefits of both waste-to-energy and recycling within a unified framework. The lifecycle economics of recycling in the CNMI need to be carefully evaluated as on-island markets are likely to be limited and the costs of shipping overseas may be prohibitive. A detailed waste characterization would help determine the specific amount of recyclable material available.

2.4.4 Solid Waste Generation Characterization

Very little data on the amount and composition of the CNMI's solid waste stream is available. When the MSWF was being planned, garment waste was a significant portion of the material being delivered to the PRD. Since that time, the garment factories have closed, and garment waste has practically been eliminated. As of 2010, garment waste totaled only about 1,350 tons per year. Between January 2004 and June 2004, the MSWF received and managed 19,564 tons of materials. The composition of the diverted materials, according to the 2005 Solid Waste Management System report, is shown in Table 6.

Table 6. MSWF Waste Characterization in 2005

Item	tons Jan-Jun	tons/year
Greenwaste	1,229	2,457
Soil	480	960
Concrete	408	816
Cardboard	318	637
White goods	74	149
Used tires	65	129
Glass	28	56
Office paper	16	33
Aluminum	12	24
Old newsprint	1	2
Plastic bottles	1	2
	2,633	**5,265**

A report titled *CNMI Integrated Solid Waste Management System*[15], which was published in 2010, provided an update on the materials received over the previous four years. The amount of materials received in 2010 was expected to be about 43,000 tons, of which about 11,000 tons was diverted and 32,000 tons (87.5 ton per day) was sent to the landfill. The diverted materials were primarily backfill, which consists of dirt, rock, and construction and demolition waste at 7,600 tons per year. The backfill materials are used in the landfill for daily cover and to repair site roads. Most of the other diverted materials are recycled. Table 7 shows the characteristics of the diverted materials.

[15] CNMI DPW-SWMD Status Report. *CNMI Integrated Solid Waste Management System*. February 1, 2006 to January 31, 2010.

Table 7. Diverted Material Characterization in 2010

Item	tons/year
Backfill	7,600
Green waste	1,671
Cardboard	445
Paper	109
Tires	158
Mixed recyclables	61
Sewage sludge	480
Metals	83

Due to the difference in categorization between the two reports, it's difficult to make any general conclusions about the changes in materials over the last five years. Tire collection increased from 129 tons to 158 tons, and cardboard decreased from 816 to 445 tons. Paper seems to have increased significantly, but that could be due to differences in categorization.

2.4.5 Economics

The costs and revenue presented in this section are derived from previously-referenced reports.

For the last few years, the Solid Waste Management Department (SWMD) costs have exceeded income. DPW has estimated that tipping fees collected for dumping at MSWF would need to be increased from the current $25-$35 per ton up to approximately $137 per ton[16], and self-haul fees would need to be imposed for costs to be covered by income. This estimate has not been verified.

2.4.5.1 SWMD Income

In 2003, PL 13-42 instituted the Environmental Beautification Tax (EBT). This is a 0.42% charge applied to all goods entering the CNMI. It is divided between the three major islands: 80% to Saipan, 10% to Tinian, and 10% to Rota, and is used to cover part of the cost of waste disposal. Due to changes in the local economy, revenue from EBT has been decreasing; the revenue for 2010 was estimated to be $1.35 million.

The other main source of income for SWMD is tipping fees. In 2010 the tipping fee was $25 per ton, with certain loads assessed a special handling tipping fee of $35 per ton. In practice, the higher fee is rarely charged. In addition to commercial waste collectors, which constitute the majority of the tonnage delivered, many people do not have trash pick-up and thus deliver their waste to the landfill or transfer station. Self-haul residential users do not have to pay fees unless their load exceeds 500 pounds.

At the same time that the EBT money has been decreasing, income from tipping fees has also been going down. In 2010, tipping fee income was estimated to be $400,000, for a combined SWMD income of $1.75 million per year.

2.4.5.2 SWMD Operating Costs

The annual direct cost of operating the Marpi landfill in 2010 was estimated to be $2.5 million, which is significantly higher than the $1.75 million income from EBT and tipping fees. The majority of these costs are fixed, meaning that they are not dependent on the quantity of waste processed. Materials recovery facility operations cost an additional $280,000 per year, resulting in a total loss of over $1.0 million annually.

[16] CNMI Department of Public Works. Solid Waste Management Division. Status Report. *CNMI Integrated Solid Waste Management System.* Period February 1, 2006 through January 31, 2010 (Four Operating Years).

2.5 Transportation

All three islands have a well-defined road system and personal transportation vehicles are readily available. No official public transportation system is available on any of the islands, although some hotels or shopping areas provide limited bus service. Typically cars, and to a limited degree motorcycles or mopeds, are used as the primary mode of transportation. Due to the condition of some roads, large heavy-duty trucks and SUVs are common. Many major car brands are available on Saipan, providing a relatively good selection of vehicles. Although total fuel imports data for all sectors is not readily available, Table 8 demonstrates fuel use by type for the CNMI government, which can be used to get a sense of the total fuel imports. Clearly the use of diesel fuel outside of the power generation sector is very large, but gasoline imports are also strong.

Table 8. 2010 CNMI Government Fuel Consumption

Fuel Type	Gasoline (Mogas)	Diesel (Excluding power sector)	Oil
2010 CNMI Government fuel consumption (million gallons)	4.52	34.8	.281

Efforts to decrease fuel use in the transportation and other sectors could be undertaken, such as the implementation of high-efficiency public transportation. The DPW performed a comprehensive study of traffic patterns and highway needs in 2009, which could be used as a starting point to inform an assessment of the need, costs, and fuel savings of a public transportation system.

Since almost all electricity is produced by diesel and the import cost of alternative fuels is typically high, the implementation of alternative fuel and electric vehicles is not likely to be a strong option in the near term. In scenarios with high contribution of renewable energy sources, hybrid or standard electric vehicles may be more appropriate, especially to provide storage or stabilization to the grid using vehicle-to-grid technology. Costs and benefits of policies that encourage or incentivize fuel-efficient vehicles should be examined as a potential near-term fuel reduction effort.

3 Energy Efficiency and Renewable Energy Opportunities

As with many islands worldwide, the CNMI represents a high-priority location for the development of an integrated energy plan due to high energy costs, dependence on imported fossil fuel, and associated economic challenges. The CNMI currently meets all of its electric power needs with diesel-fueled generation at an average cost to consumers exceeding $0.30/kWh. Additionally, there are environmental concerns associated with fossil fuels and conventional power generation, such as emissions, water consumption, thermal pollution, and adverse land-use impacts. Oftentimes, these environmental effects can be included in a cost-benefit analysis comparing future fossil fuel electricity generation with alternative sources.

There are many energy efficiency and renewable energy opportunities for the CNMI. This section outlines opportunities that have been identified based on the initial assessment. Further assessment and analysis is warranted, and the Energy Task Force will need to determine its priorities and which opportunities should be pursued. Some initial opportunities identified are summarized in Table 1 shown earlier. Additionally, although not specifically addressed in this document, strides could also be made in increasing plant and distribution control and efficiencies and reducing fuel consumption, as well as the potential to look toward longer term power options.

This section of the report provides information on various opportunities as they relate to developing a strategic plan. Specific savings are difficult to quantify at this time due to the limited amount of data available during the site visit. Savings could be calculated based on energy audits from private industry and scaled-up across the sector, or more detailed audits could be conducted to determine specific savings. The areas of opportunities presented in this section are based solely upon observations made during the site visit conducted by the NREL team while on-island the week of December 6, 2010, as well as subsequent conversations with the DPW Energy Division, Commonwealth Utility Corporation, the Governor's Office, and other members of the Energy Task Force.

3.1 Energy Conservation and Efficiency

Energy conservation and energy efficiency can be combined to create an effective strategy to achieving overall island energy use reduction. **Energy conservation** is any behavior that results in the use of less energy. Turning the lights off when you leave the room is an example of energy conservation. **Energy efficiency** is the use of technology that requires less energy to perform the same function. A compact fluorescent light bulb that uses less energy than an incandescent bulb to produce the same amount of light is an example of energy efficiency.[17] Both conservation and efficiency measures result in lower costs of electricity to the consumer.

The initial opportunities that have been identified for energy conservation and efficiency measures include raising island energy awareness in various sectors, performing energy audits to prioritize savings opportunities, creating a cool-roof program, and investigating alternative cooling technologies.

3.1.1 Education and Outreach

An energy and water awareness campaign targeting residential customers, businesses, and hotel guests can result in substantial energy savings. Water reduction strategies should be included in education and outreach campaigns as gathering, moving, and treating water uses energy, and therefore reducing water consumption saves energy. An energy and water awareness campaign is a low-cost solution for encouraging energy and water conservation. In order to begin an awareness campaign the audience needs to be identified, materials prepared, communication methods determined, and launch dates selected. Campaigns should be ongoing and will need to be reviewed and revised every few months in order to communicate intended messages to target audiences. Outreach activities within a community

[17] Energy Information Administration. www.eia.doe.gov/energyexplained/index.cfm?page=about_energy_efficiency.

may include inserting articles in newsletters or a weekly newspaper insert, radio programs or interviews, posters and flyers, stickers for light switches and equipment, events for children and adults that are fun and educational, and information inserts in electric bills. A different campaign may be needed for each specific audience.

There is also a need for stakeholders in the building construction and remodeling industry to be educated in energy and water efficiency. In addition, architecture and engineering firms should have a targeted outreach program regarding climate-specific design and energy-efficient and water saving technologies. In 2009, the DPW adopted the 2009 IBC for both residential and commercial buildings, and the CNMI Tropical Energy Code, which also applies to residential and commercial buildings including new construction and renovations, and any individual cooling, water heating, and lighting system replacements. Ensuring the requirements of the new code are understood by the design and construction industries will assist in improving adoption of energy efficient construction techniques.

Some efforts that may result in both behavioral and technical improvement are summarized by sector below.

Residential

- Education campaigns for local communities focused on energy awareness and conservation strategies

Commercial

- Work with various sectors to increase awareness through posters, stickers, fact-sheets, etc.; this should include conservation strategies, efficient technologies, and proper operation and maintenance
- Work with island suppliers and retailers to source energy efficient technologies

Construction industry

- Provide information and training for the design and construction industry on building codes, design practices, and energy efficiency measures that should be incorporated into new construction and renovations, such as external shading for windows, coating coastal air conditioning unit coils to protect from sea mist, proper insulation techniques, high SEER air conditioning units, etc.

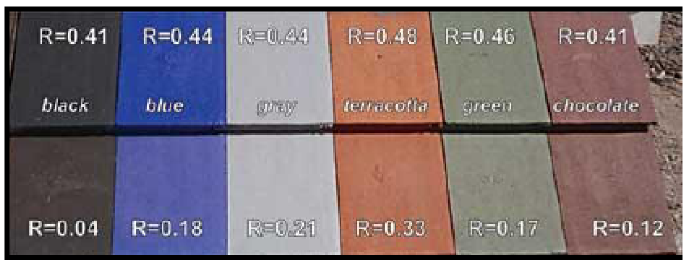
3.1.2 Create an Energy and Water Audit Program

Energy audits of government facilities have been funded under the Recovery Act, and are expected to begin following the training of local audit providers. Results from this effort should be used to prioritize investment in energy-efficient strategies and technologies, and no- or low-cost measures (such as a change in operational settings for ventilation or air-conditioning, turning lights and computers off when not in use, etc.) should be identified that can be implemented immediately. Water usage and reduction measures should be included due to the cost of water as well as the cost of energy to provide potable water and remove and treat wastewater. It is also recommended that building audit results from these activities be applied to developing a strategy where conservation measures are relevant to multiple buildings within a specific sector. For example, audit results of a representative sample of typical office buildings should be used to inform owners and tenants of similar structures. It is also recommended that local private companies or tradespeople be trained to perform the audits, as those services would then be available to the community at-large, benefitting the local economy. The hotel sector and the Public School System should be high priorities for reducing energy use across the Commonwealth. Small businesses and residential users should also be included as electricity is a large portion of their expenses.

The EPA's Portfolio Manager can be a useful tool for managing building stock and benchmarking energy use across a portfolio of buildings. Once energy and water use information has been assembled, the tool allows you to consolidate the data into a Web-based database to track energy consumption, performance, and cost information. This may be useful for benchmarking and tracking performance of the portfolio of CNMI government buildings. The Portfolio Manager tool and more information can be found on the EPA website.[18]

3.1.3 Establish a Cool-Roof Program to Improve Efficiency

Cool roofs are roofs that are designed to maintain a lower roof temperature than traditional roofs while the sun is shining, typically through reflective technologies, decreasing the cooling load on the building. This lowers electricity costs by reducing the air conditioning needed, and increases comfort in non-air conditioned spaces. White roofing materials have a high solar reflectance value, but colored roofing can also be manufactured to reflect sunlight, as indicated by the cool-roof tiles in Figure 10.[19]



Cool-colored tiles (top row) look just like conventionally colored tiles but have higher solar reflectance (R). *Image Source: American Rooftile Coatings and Lawrence Berkeley National Laboratory*

Figure 10. Cool roof tiles in colors other than white

The Cool Roof Rating Council (CRRC) has developed methods to test and label the solar reflectance values of roofing products. Rated products are listed in a directory, provided as public information on the CRRC website.[20]

Cool roof technologies are available for both commercial and residential buildings. A cool roof program could be implemented throughout the CNMI by using low-cost technologies, such as elastomeric paint (~$40/gallon), which would need to be applied to roofs and maintained through a cleaning program (to prevent debris and mold build-up). To ensure appropriate products are used, information regarding cool roof products should be included in educational efforts. Demonstration projects could also be undertaken, and should include measurement of energy savings. More information about selecting buildings and implementing a cool roof program can be found on the DOE website.[21]

3.1.4 Consider Alternative Cooling Technologies

Cooling is one of the largest uses of energy in the CNMI across all sectors. Considering and implementing promising alternative cooling technologies will assist with reducing fossil fuel consumption related to conditioning indoor spaces. There are a number of options available under the umbrella of alternative cooling technologies.

One low cost option in buildings with no air conditioning or humidity control requirements is to install ceiling fans. Where moisture buildup is not a concern it may be possible to utilize natural ventilation (from breezes and open structures of windows, doors, etc.) and the use of ceiling fans, which are in operation only when needed. There may be open structures where this could be a suitable option.

[18] http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager.
[19] DOE. *Guidelines for Selecting Cool Roof.* July 2010. www1.eere.energy.gov/femp/pdfs/coolroofguide.pdf.
[20] Cool Roof Rating Council. http://www.coolroofs.org/aboutthecrrc.html
[21] DOE. www1.eere.energy.gov/femp/features/cool_roof_resources.html.

Planting 'Green roofs' may also be a lower cost option to consider. Flat, structurally sound roofs can be used to plant vegetation, which not only provides a thermal barrier, but also creates a wicking-type action. The wicking of moisture and heat upward and out of the building is beneficial in reducing cooling loads, particularly in single story and low-rise buildings.[22]

A medium-cost option is to install solar air conditioning units. This technology typically consists of a solar thermal system to provide hot water to an absorption chiller or heat pump to provide space cooling. While relatively new on the market, solar air conditioning units are available from a number of manufacturers and suppliers, and have a variety of different installation applications from split wall, window units to larger outdoor units.[23]

A high-cost option to reduce the CNMI's energy consumption related to space cooling is a sea-water cooling system. This technology is being investigated on Guam by private consultants for the U.S. Navy as well as Guam Power Authority and Johnson Controls for the hotel loop in Tumon Bay. The CNMI Energy Task Force is encouraged to review the findings of that study to determine if a cost-benefit analysis for locations in the CNMI, particularly hotels, may be warranted.

3.1.5 Evaluate Energy Policy Opportunities

The CNMI has several public laws in place that create energy efficiency and renewable energy policies that address renewable portfolio requirements, net metering, territorial government energy efficiency, energy codes, and residential solar water heating. Most of these policies have not been fully implemented or developed into programs. The existing policies should be reviewed and evaluated for effectiveness; effective policies should remain and be promoted, while ineffective policies should be evaluated for potential improvement and amended. Creating an effective policy environment is important for the deployment of energy efficiency and renewable energy technologies.

3.1.6 Next Steps

The following next steps are recommended:

1. Develop a strategic energy plan.
    - Through the assistance of the CNMI's Energy Task Force and the development of a strategic energy plan, address policy and technology opportunities or challenges, and identify implementation strategies. The Energy Task Force has been established and is currently identifying opportunities to be addressed. As opportunities and challenges are identified, assignments should be delegated to subcommittees to gather or analyze information that will be used to inform the energy planning effort. The resulting plan should be a guiding document that is periodically revisited and revised based on evaluation of the CNMI's progress. Recommendations below and in other sections of this assessment report should be considered when developing the energy plan.
2. Conduct energy and water audits and apply measures where they are broadly applicable.
    - An energy audit program for the government sector is expected to begin following a training of auditors. This effort should include training local private companies or tradespeople with the applicable technical background (for example, electricians, mechanical equipment technicians, etc.) to perform energy audits on different types of buildings. These audits should continue and, where possible, the measures that are applicable to similar buildings should be gleaned from audit reports and implemented across the building stock. A strategy for identifying and implementing the most commonly recommended measures could be a next step, but would require disclosure

[22] DOE. http://www1.eere.energy.gov/femp/pdfs/fta_green_roofs.pdf .
[23] http://en.wikipedia.org/wiki/Solar_air_conditioning

from the entities conducting the energy and water audits. The audit effort and implementation of results should be prioritized based on a balance of total impact and individual cost savings.

3. Begin an energy awareness campaign within the various building sector types.
    - An energy awareness campaign is a low-cost solution for implementing energy conservation. Pilot projects could be carried out within specific buildings or communities to highlight the impact of the campaign on energy consumption. In order to begin an awareness campaign the audience would need to be identified, materials prepared, proper communication forums determined, and launch dates selected. Campaigns are ongoing and need to be renewed every few months to communicate specific messages to target audiences. Materials within individual communities may include articles in newsletters or the weekly newspaper insert, posters and flyers, stickers for light switches and equipment, and educational fun events for children and adults. A different campaign should be created for each specific audience which may include the following:
        - Hotel staff and guests
        - Medical staff
        - Education staff, teachers, and students
        - Community residents (adults and children).
4. Design a strategy for implementing a cool roof program, beginning with identifying buildings to be used in a pilot program. This would provide an implementation mechanism to achieve the CNMI Tropical Building Code requirements.
    - These buildings should be selected following the guidelines provided in the cool roof information on DOE's website.[24] Buildings would ideally have engaged facilities management staff who could monitor the energy consumption prior to and after the cool roof installation to measure the change in energy consumption. Buildings that vary by sector and cool roof application type would be most beneficial to display what is most effective at reducing energy consumption. Facilities in need of roof replacement, particularly if there is a budget for replacement in the near-term, may be most applicable as initial projects. Once this pilot program has been completed, the results should be analyzed and shared with community leaders and the design and construction industry. A strategy should be developed to replicate the most effective cool roof type throughout the building stock, with continued monitoring and savings reports.
5. Provide training materials for the design and construction industry to increase knowledge related to energy-efficient technologies and practices.
    - Training materials could take the form of curriculum for workshops, handbooks, presentations, websites, and other tools. A training module would need to begin with an assessment of the current level of knowledge and determine areas of the greatest need for improvement. The audience would need to be assessed in advance so that materials could be tailored to be the most effective.
6. Encourage the use of alternative cooling technologies, where appropriate, within retrofits and new construction.

[24] DOE. www1.eere.energy.gov/femp/features/cool_roof_resources.html.

- Evaluate opportunities for green roofs and solar air-conditioning for commercial buildings.
- Investigate solar air-conditioning technologies and opportunities, particularly for buildings with large cooling loads. This should be included in energy audit efforts.
- Review the results of the salt-water cooling research and determine if implementation in specific industries (e.g. hotels) is beneficial to reducing fossil fuel consumption. Ensure that any new technologies considered are fully understood by staff responsible for maintaining the system.

7. Review existing energy related policies for effectiveness.
    - For policies that are ineffective or have not been implemented, evaluate whether the policy is still needed and what would be needed to improve the effectiveness.

3.2 Renewable Energy

Although energy efficiency will play a critical role in addressing energy consumption and costs across the CNMI, the costs for diesel-derived commercial and residential power generation will remain a drain on the CNMI's economy. The incorporation of renewable energy technologies, initially at lower levels, but increasing in overall contribution over time, is a critical part of reducing the amount of fuel imported for power generation. Additionally, as seen in other isolated communities, with lower cost or cleaner electrical power it may become possible to convert some of the transportation sector to electric technologies, further reducing the impacts of fossil fuel imports.

There are many renewable energy opportunities for the CNMI, although more detailed project and resource assessments are needed to confirm the viability of specific options for development. Most notably and discussed at greater length are wind, solar, geothermal, and biomass technologies. Micro hydropower is also briefly addressed, although the power generation potential is small. Additional technologies, such as ocean thermal, tidal, and wave power could also be considered but are not currently viable technologies from a cost or technology readiness perspective, and thus are not included in this document. Each of the major renewable power options for the CNMI, as well as additional information and analysis needed for development, are discussed in the following sections.

3.2.1 Wind

Wind energy has the potential to play a major role in supplying electrical energy to the CNMI. The apparent available wind resource combined with reasonable infrastructure, general small size, and high energy costs make wind technology a very viable option. However, the limited grid infrastructure and limited available land on each of the primary islands of Saipan, Tinian, and Rota, will make the installation of large wind technologies more complicated and costly. This is especially true due to the locations of defined air strips on the islands.

There have not been detailed wind assessments on any of the CNMI's islands in locations that would represent free wind speed viable for the assessment of full-scale wind projects. Quality wind resource measurements conducted on Guam through an Interagency Agreement between the Naval Facilities Engineering Service Center and NREL assessed the wind speed using a 60 m tower located on Mount Alifan, elevation 775 ft, which determined a viable wind resource of 7.9 m/s. This does indicate that this general region has viable wind resources and although all of the potential project sites on any of the other main CNMI islands are at lower elevations, wind energy is likely a viable resource for any of the islands. The general wind profile for the region indicates prevailing winds from the northeast with typhoon winds from the east. For this reason any wind development needs to have generally clear access to the primary wind direction.

Although not verified nor assessed in detail, potentially viable wind sites were identified through field assessments conducted by NREL staff on the islands of Saipan and Tinian. Rota was not visited, but Google Earth-based assessments demonstrate several sites with the potential for measurement and development.

The environmental impact of any development must be assessed, and since wind power development threaten primarily avian species, any resource assessment or eventual wind turbine installation will have to include an assessment of these impacts. This becomes more critical in the CNMI since several threatened and endangered species are present, leading to the required consultation with the U.S. Fish and Wildlife Service (USFWS) either through the Endangered Species Act Section 7 or the Habitat Conservation Plan process. Although wind turbines could potentially be installed on all three main islands, the presence of the endangered Mariana Crow on the island of Rota will require extensive assessment before the implementation of any wind resource assessment towers or turbines. Initial discussions with USFWS staff are underway to assess the applicability of the sites described below.

3.2.1.1 Saipan

The topography of Saipan creates a complex wind development environment. The main mountain ridge that runs almost the full length of the island represents a clear challenge to wind development, especially combined with the typically cliffy nature of the topography. Due to the prevailing wind direction, only sites exposed to these winds should be considered. Two promising sites were identified for wind data measurement, marked “Tower Location 1” and “Tower Location 2” in Figure 11. Two additional sites, Potential Measurement site 1 and 2, are also identified on the map. These represent existing communications towers that could be used to install wind measurement equipment, providing a long-term data correlation to site-specific measurement programs conducted around Saipan and Tinian.

Figure 11. Island of Saipan

Showing potential development and wind measurement sites

Source: Google

The southern site shown in Figure 12 (also Tower Location 1 in Figure 11), west of the quarry and south of the airport, is located in an area with minimal development, is close to existing electrical infrastructure, and has good access to the northeast winds. A slight ridge runs along this area at a height of about 300 feet. The site has exposure to the east and a run of around 1 km in length that could be used for development. This would allow the installation of up to 10 MW of wind (assuming five 2-MW wind turbines) at very close spacing, which may be acceptable based on the general prevailing wind direction. It may be possible to install multiple rows of wind turbines but since the ground slopes down to the west and south, these turbines would likely be much less productive. The turbines could be installed in a row from approximately (15°6'50.28"N x 145°45'1.55"E) to (15°6'50.28"N x 145°45'1.55"E). This site, shown in Figure 13, is located in close proximity to the airport so considerations of airport and radar impact must be assessed, but generally, since the closest turbine would be approximately half a mile perpendicular to the end of the runway, this is not likely to be an issue.

Figure 12. Potential wind-turbine development area on the southern end of the Island of Saipan near the quarry and to the south of the airport

Source: NREL/PIX 18936

Figure 13. Slight ridge to the east of the quarry on southern Saipan that could allow the installation of a single line of wind turbines

Red line represents potential turbine alignment

Source: NREL/PIX 19365

The second potential site (shown in Figure 14) is located on the north end of the island, on the bluff overlooking the new dump and the northeast coast. The bluff sits at about 300 feet with a slight trailing off to the south. The area is surrounded by cliffs over 100-feet-tall on the north, east, and south sides, and is accessible from an unimproved road from the west. The land in this area does not seem to be in use but is in relatively close proximity to and visible from locations with cultural sensitivity such as Banzai Cliffs, Bird Island, and the Grotto, which may cause development concerns. The bluff would allow approximately 6 MW (three 2-MW turbines) installed in a north/south row from approximately (15°15'54.64"N x 145°49'7.11"E) to (15°15'54.64"N x 145°49'7.11"E). Multiple rows of turbines could be installed at this site, likely doubling the potential installed capacity, though the performance of the second row of turbines would have to be analyzed carefully due to local topography. The steep ridges to the east would also indicate that careful assessment of the wind resource and wind flow patterns in this area would need to be conducted as part of any initial development plan. As an additional complication, current power infrastructure only extends to a point about three miles from this current location (15°16'16.50"N x 145°47'40.94"E) following roadways. A planned transmission expansion is being considered that would move the grid further up the island to the National Cemetery, but even this location would likely require the construction of more than 2 miles of transmission to interconnect with the site. The fact that this site is also located quite far away from existing power generation infrastructure would also require more power conditioning equipment to ensure high-quality power on the northern end of the island.

Figure 14. Bluff on the northeastern coast of Saipan that may be a viable location for one or two rows of wind turbines

Source: NREL/PIX 18932

Other locations may also be viable, such as the low area between Banzai Cliffs and the new dump (approximately 15°17'1.65"N x 145°48'59.22"E to 15°16'25.59"N to 145°49'21.96"E). This area is at a relatively low elevation of approximately 150 feet, but slopes more gently down to the sea and generally faces northeast. The site would largely be blocked from winds to the south and west but would continue to have good fetch from the northwest through southeast. Once the transmission line has been extended to the National Cemetery, this site would also be close to developed power infrastructure. The site could likely support up to 14 MW of installed capacity located in one row that would run northeast/southeast along the coast. It was difficult to assess the quality of this site during the NREL site visit due to the limited accessibility.

Other potential sites, such as along the eastern coast or on the northeast coast on the outskirts of the community of Kagman are not considered viable due to local topography and close proximity to population centers. Additionally, depending on magnitude of resource and costs, the shallow 3.5 mile channel between Saipan and Tinian could potentially be bridged via undersea electrical cable, allowing electricity generated by renewable energy on one of the islands to be used on the other; similar to what is being considered for several of the Hawaiian Islands.

Concerned avian species on Saipan include the Nightingale Reed-warbler, the Mariana Swiftlet and to a limited degree the Mariana fruit bat. Concern for the warbler will primarily focus around habitat conservation areas, and since a habitat conservation plan for this species is already in place, it is unlikely be a large issue.

3.2.1.2 Tinian

Tinian runs north/south with a clear rocky eastern coast. Two potential sites were identified on Tinian based on the assumption that any land on the northern end of the island, land currently leased by the U.S. military, would not be available for development. An additional complication of wind development on Tinian may be the port and heavy lift capabilities on the island, both of which are limited. The port facility is large and has good access, but is rather dated; a more detailed assessment would need to be undertaken to determine its capability to receive large and heavy cargo.

The first site is located on elevated land to the northeast of Marpo Heights, Area of Potential Measurement 1 in Figure 15.

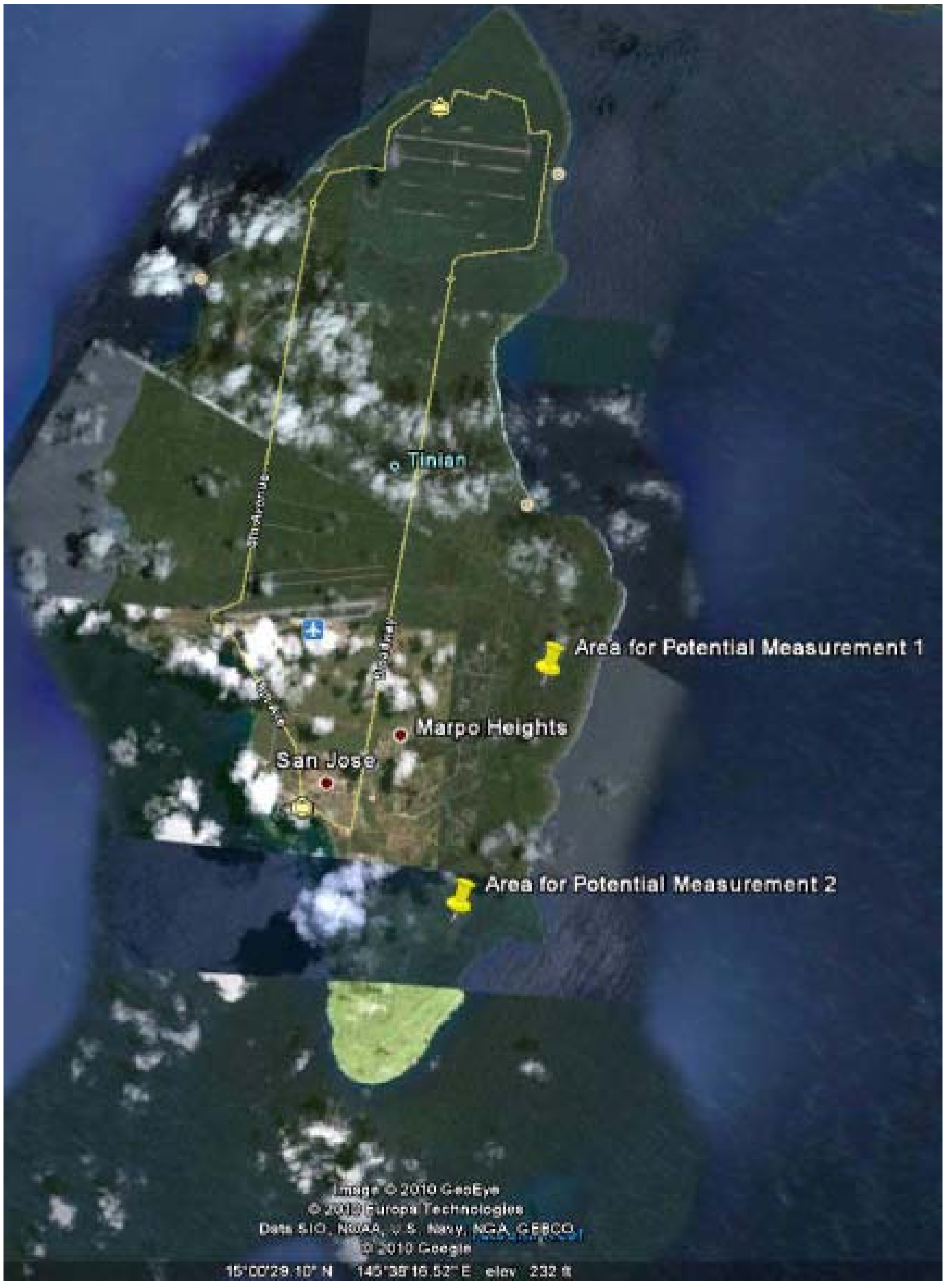


Figure 15. Island of Tinian showing potential development and wind measurement sites

Source: Google

This bluff runs north/south at an elevation of approximately 300 feet. As shown in Figure 16, there is ample room for wind turbines in this area and although it is off the end of the runway, it is about 2 miles from the end and a mile to the south. The best location for this area would likely be on the northern end of the bluff, but this would put it directly in line with the runway approach and therefore should be avoided. The potential site is approximately 0.5 miles from Feeder 1 in the Marpo Heights area. There is road access to this area, however it is likely unimproved and would need significant improvements to allow development. Turbines installed here would have good fetch to winds from the all directions, but most specifically the northeast through southeast. Care would need to be taken to assess the wind shear profile due to cliffs on the eastern coast of the island. This site would require the development of at least 0.6 miles of transmission.

Figure 16. Potential measurement and wind installation site along the eastern coast on the Island of Tinian

East of Marpo Heights; photo was taken from a banking aircraft which accounts for the photo slant

Source: NREL/PIX 18931

The second location would be on the bluff to the south east of San Jose, beyond the cell tower, identified as "Area of Potential Measurement 2" in Figure 15. This area, shown in Figure 17, is a broad plateau with an elevation of around 500 feet and does have several roads into the area, though it is likely that all of them are unpaved. This area is quite large and development in the area of 14°57'0.78"N x 145°38'57.91"E at over 550 feet would be viable. There currently is no transmission infrastructure to this area, but several feeders round the site; approximately 0.6 miles of transmission would need to be implemented to interconnect this site. Being a local highpoint of the island, fetch in all directions is reasonable, although winds from the north through northeast would be over land and cliffs from the east through southeast would have to be assessed with care. There is currently no transmission infrastructure in this area; an extension of approximately 0.75 miles would have to be implemented to support any wind project.

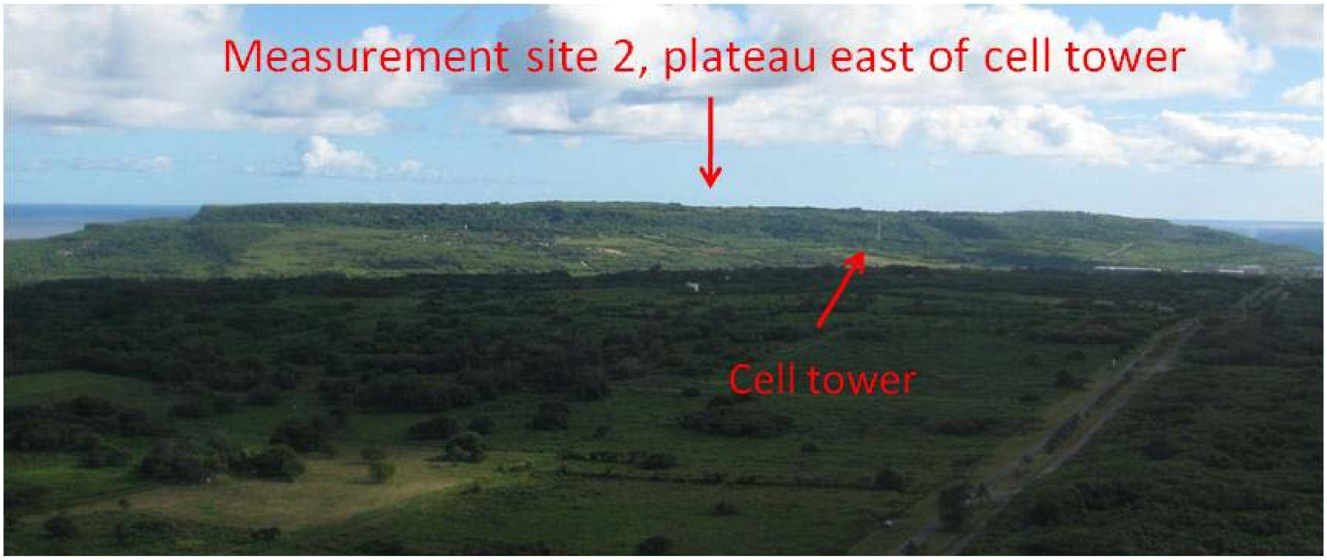


Figure 17. Potential measurement and wind installation site along the southeastern coast on the Island of Tinian, to the south east of San Jose

Source: NREL/PIX 18935

Concerned avian species on Tinian include the Mariana fruit bat and several bird species that pass over the island, but these are not likely to be large issues for wind development.

3.2.1.3 Rota

Rota has fewer locations for potential wind deployment due to the airport's location on the flat, northern end of the island, and the small community being developed along the northeast coast. It might be possible to locate turbines on the high plateau on the southern end of the island, but since the island was not visited during the NREL site visit in December 2010, it is difficult to determine. Additionally, turbines installed on the southern plateau may get interference from the islands topography, given that the predominant wind direction is from the northeast. The northeast-southwest orientation of the island indicates that the northern end of the island provides the best location for general wind development, although the land is relatively low at 500 feet, compared to other sites considered in the CNMI. An additional complication is that the Rota power plant is in West Harbor, installations on the north side of the island are far away from the power plant, thus requiring expanded grid stabilization equipment depending on the total installed capacity of wind energy implemented. As with Tinian, port, local transport, and heavy lift capabilities on the island will need further assessment to determine the size of turbines that could be handled.

Rota is home to several species of specific concern to the U.S. Fish and Wildlife Service including the Mariana Crow, of which very few mating pairs remain, the Mariana fruit bat, and the Rota Bridled White-eye. Although not the final word regarding wind project development, the endangered Mariana Crow would dictate that if wind power is to be developed, much more detailed environmental impact assessments will be required to determine the potential impacts. If wind projects are implemented, they may also likely require more extensive post construction monitoring, habitat restoration or protection, and possibly periodic curtailment (the intentional shutting off of the turbines) during times of potential species impact. A draft conservation plan for the Mariana Crow is being developed by USFWS and the CNMI government, and as further studies are conducted that determine allowable locations for wind turbines on Rota, the considerations described in this section should be taken into account.

Figure 18. Potential development and wind measurement sites on the northeastern end of Rota

Source: Google

The first site is located to the north of the runway by approximately one half of a mile, as shown in Area of Potential Measurement 1 in Figure 18. Several turbines could be installed in this area on high ground along a northeast line. This area does not currently have electrical service but the close proximity to the airport means that the turbines could be connected via approximately one mile of additional transmission; however, some of this may have to be buried due to the airport. Depending on the final turbine layout, this site would have good access to winds from every direction except the southwest, but would have very good access to winds from the northwest through southeast. The second site, Area of Potential Measurement 2 in Figure 18, is located to the east of the airport, south of the runway approach, which is one of the major concerns. While the site is approximately 1.5 miles downwind of the airport and over a half mile south of the approach, acceptability of wind turbines in this location would need to be determined through the Federal Aviation Administration (FAA) screening process. As with the other site, the closest interconnection point would be eastern Sinapalo, requiring more than two miles of additional transmission infrastructure. The site would have good access to easterly winds, with slightly diminished fetch from the north.

3.2.1.4 Key Challenges to Wind Development

There are several key elements that need to be taken into account when considering the deployment of wind technologies. In the context of the CNMI, environmental impacts, specifically related to threatened species and ground cover, radar/communications impacts, social acceptance, and the impact of wind on grid stability will be critical components for wind deployment on the island.

The environmental and radar impacts of wind deployment are two of the most critical factors due to their binary nature in that if the proposed site and/or turbines are likely to have adverse environmental or radar impacts, the site is likely non-viable. Grid impacts are primarily technical in nature and can be addressed using a number of techniques, many of which will have a cost impact. Due to the high cost of conventional power generation, it is likely that even with the additional cost of power control system modifications the wind project will remain financially viable, reducing the likely impact of this barrier. As has been expressed in the previous sections, the generally low voltage level and limited transmission infrastructure on all three islands will be a key area of additional concern.

Social acceptance of wind technology could become a major issue in successful project development and thus must be carefully orchestrated. Due to the small size of each of the CNMI's islands any development site will result in a social impact. The fact that all of the sites identified have seen previous development helps; virgin land would not be impacted by development. The relatively low population density of the islands will likely lessen the impact of any turbine development, but noise, visual clutter, and flicker (the strobe effect of shadow caused by the wind turbine blades) would need to be assessed. As noted earlier, the potential site along the northern coast of Saipan is in a less developed area with historical significance and thus could have additional sensitivities to the installation of wind technology. Additional issues, such as noise, ultra-sound (low-frequency sound reportedly felt as a vibration in homes), and adverse health impacts could also be brought up as concerns. Local opposition could develop around these issues if people felt that the site of the wind turbines would negatively impact island life.

Generally speaking, project implementation is greatly improved if the local community feels that the project provides community and/or personal benefits. The fact that the wind project can represent a means to reduce or stabilize the cost of power to communities in the Commonwealth, and that it would reduce dependence of imported energy sources, will decrease the likelihood of potential community criticism, however the control of this communication will be critical for eventual project success. Examples of wind developments on other islands, and input from residents of those communities regarding perceived and actual impacts, can assist in addressing potential societal concerns.

3.2.1.5 Infrastructure

The infrastructure for the development of large-scale wind deployment on the islands of the CNMI will pose a significant challenge, especially for Rota and Tinian. Although this may differ for other island locations, roads, on-island transportation, transmission, general construction, and shipping infrastructure on each of the islands will require at least some level of upgrade if large wind turbines are to be installed. This is likely less of an issue for the single site on the southern end of the island of Saipan, which does have improved roads and existing transmission close to the potential site. A definite limiting factor is the availability of a heavy lift crane to support turbine installation. Although the earlier sections indicate that generally large turbines would be implemented, a more thorough assessment of harbor, heavy lift, and transport should be made to determine specific weight thresholds, defining an upper limit for turbine size for each island. In all cases, however, this issue will reflect on project economics but will not impact the technical viability.

Typhoons pose an important risk in the use of wind technologies in island environments. All larger wind turbines (above approximately 30 kW in size) are designed to stop operating in high wind conditions, meaning that in all except the most extreme cases storm-related damage is going to focus on that caused by airborne debris, typically to the turbine blades. The other potential issue would be the wind loading on the turbine structure exceeding the tower or foundation design loads, which are controllable factors, although this can be an engineering design issue that results in increased implementation costs. Although there has not been much experience with large turbines in the Pacific, a number of turbine installations in the Caribbean have been operating and not reported major issues, including a small system of four turbines installed at Guantanamo Bay on the eastern end of Cuba, and a larger wind farm in Manchester, Jamaica, both in areas prone to hurricane (typhoon) activity.

Implementation of wind turbines in areas where extreme weather events are common requires careful consideration of turbine selection and an assessment of the risk for the turbine structure, which may lead to the need for insurance. Every large wind turbine is designed around an international standard for wind intensity, provided in a class rating. The class rating also impacts the size of the wind turbine rotor, which has an impact on the resulting energy generation from the turbine.

At least two manufacturers have a typhoon-rated wind turbine, however it is not clear if this includes up to Class V typhoons. Additionally, Vergnet makes a 220 kW turbine that is designed to be lowered during potential typhoons and extremely high wind events, and is production-testing a larger turbine where the rotor of the turbine can be removed. In all cases, however, the purchase of insurance or in cases of self-insured companies, a risk assessment is needed to determine the appropriateness of installing wind turbines in any typhoon prone environment.

Historically insurance companies have not been willing to provide insurance for turbines in Class V typhoon areas, but with the development of turbines rated for typhoon environments, it may now be possible to do so. In any case, one of the first steps in the development of potential projects will be to contact wind turbine manufacturers, either informally or through a competitive process, to better determine what products are available. Turbine survival wind speed, as well as typhoon experience, should clearly be one of the key competitive requirements.

Although almost all wind turbines being implemented today sit on top of a tower with an axis of rotation horizontal to the ground, some manufactures are producing small wind turbines that sit and rotate vertically. These vertical axis turbines can be preferable since they do not typically sit on tall towers and don't pose much visual disturbance. However, these turbines are typically very small in size, up to several 10s of kW, and because they sit low to the ground, do not generally have good performance in forested terrain or areas with lower wind speeds, such as are seen in the CNMI. Although they are not currently applicable large scale power generation, in some cases it may make sense for remote loads or in specific net metering applications. At this point there are no conclusive studies looking at the avian impact of these turbines and few have been certified to either domestic or international standards, so care must be taken in selecting units for any application. Since the turbines are typically installed close to the ground, they may be susceptible to damage from flying debris during high wind events such as typhoons.

3.2.1.6 Next Steps

The following next steps are recommended.

1. Conduct detailed wind resource and development assessments.
    - With the expectation that the development of any site in the CNMI will be conducted through a competitive RFP, collecting and providing as much information as possible about any potential site will result in improved project design and economics. This activity will also lay the groundwork by conducting all of the initial screening studies that will be required for site development. Other elements of the study would include:

    - Resource assessment combined with data correlation. This would include the installation of a 50 m or 60 m meteorological mast (a tower instrumented to record wind speed and direction) for a minimum of 1 year on at least one potential site on each island. It will also be critical to an overall analysis to correlate the wind resource data with any local data, including the U.S. Navy Mt. Alifan tower in Guam if no other good source of data is available.
    - Based on the sites identified in this report, an additional screening of other potential wind sites should be undertaken, either formally or informally. Once all potential sites have been identified, a review process should be undertaken to rank all of the sites based on the following criteria:
        - Available land and title assessments
        - Zoning requirements
        - Initial environmental impact assessments, including consultation with USEPA and USFWS
        - Initial FAA and Department of Defense (DOD) review of perspective sites
        - Geotechnical assessments
        - Initial grid interconnection, road access and infrastructure assessment
        - Initial social acceptance screening.
  - This activity would be followed by more detailed feasibility and economic assessment of the best project sites. Aside from the resource assessment, these activities should cost approximately $50,000 per site. Additionally, costs of resource assessments can be significantly reduced if the met tower is classified as a temporary structure and not subjected to typhoon building codes.
2. Initiate an active social acceptance outreach and education activity around wind.
  - For successful project development it will be critical to educate the local community around the deployment of wind technologies in the CNMI, potentially building on the current planned developments at Southern High and other public schools on Saipan. This would include performing a cost-benefit analysis and gathering information regarding potential negative impacts, such as conducting a noise impact assessment, an avian study, and visual simulations for the most likely sites. All of this information should be publically available with open forum discussions conducted by CUC or another organization to identify and address these potential issues. If possible, this should be implemented during the initial assessment phase (within the next year) to avoid the development of potentially inaccurate pre-conceived notions. These efforts should not directly advocate for a wind project, but should provide fair and unbiased information on the impacts of wind development.
3. Investigate additional potential sites for community and large wind development.
  - Given the potential savings that could result from wind deployment on the islands and clear access to a viable wind resource, efforts should be made to identify additional potential sites on each of the islands for wind development. This would include an island-wide screening study using land ownership, resource through an island-wide wind map, environmental sensitivities and restrictions, and known development limitations. This would allow the identification of additional potential locations that could be developed at

varying degrees of cost. This information would then be used to support longer term strategic planning.

4. Conduct an initial screening of potential turbine options for typhoon environments.
    - If wind development is to be seriously considered, an assessment of available equipment as well as a risk assessment considering the frequency of typhoons of different classes will be needed. Through turbine manufacturers or independently, insurance companies could be contacted to determine if insurance policies for wind turbine projects in the CNMI could be obtained and, if so, at what cost.

3.2.2 Solar

Solar renewable energy technologies are often broken down by solar thermal and solar PV applications. Solar thermal technologies capture energy from the sun to heat a fluid or air, which is generally used to heat water. Solar PV technologies are used to capture the photons from the sun to create electricity. These two technologies and their applications are outlined in this section.

3.2.2.1 Solar Hot Water

Solar thermal technologies, also known as solar hot water, are typically low- to medium-cost and easy to install. A solar collector captures the heat from the sun and then gravity typically draws a fluid out of the collector to act as a heat exchanger to transfer the heat to another material, such as water in a tank. Pressure relief valves and circulation pumps are needed to maintain pressure and keep the fluid moving through the distribution system. Basically, these systems convert sunlight to thermal energy by absorbing the sun's radiation to produce heat, which is transferred to water. Like most technologies, there are several types of systems that follow this basic operation and can be applied to various applications in both residential and commercial sectors. This technology works well for heating domestic hot water and in recreational settings, such as pool heating.

Figure 19 shows a common solar thermal system used for hot water heating.[25]

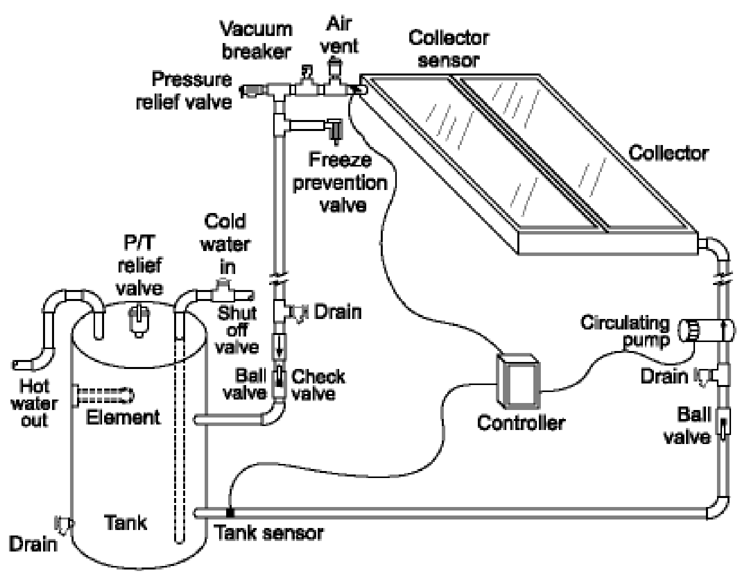


Figure 19. A common solar water heating system

Source: NREL

[25] NREL. www.nrel.gov/docs/gen/fy04/36831m.pdf.

Solar water heating works well in most situations. The system efficiency is improved with the use of evacuated tubes, however even low-tech collectors are able to generate a low-grade heat, which offsets the amount of energy required to heat water in most applications. By reducing the amount of hot water being generated through conventional forms of heating, the demands on fossil fuels can be lessened.

Although somewhat common in residential applications, solar thermal technologies should also be considered for hotels, hospitals, Laundromats, and residences where hot water demands offset the capital costs of installing solar thermal panels. Larger systems would also allow the pre-treatment of water or the design of a closed-loop system that would partially address issues with water hardness.

Panels should be installed where there is full exposure to the sun without shading from buildings or vegetation (see residential solar water heating system in Figure 20), and according to local building regulations, including plumbing and access codes. They should also be installed in locations where they will not be tampered with or vandalized.[26] Panels installed flat against the roof surface are more likely to withstand typhoon winds than those installed at an angle, although several older evacuated tube collectors were observed mounted at an angle on rooftops in the CNMI.

Figure 20. Residential Solar Hot Water, Hickam AFB, Hawaii

Source: NREL/PIX 09188

As a comparative case study, the United States Coast Guard in Honolulu, Hawaii has installed 278 active/direct solar thermal systems to replace electric water heaters for a housing complex. The average cost at that time was $4,000 per system with a discount of $800 that the utility had previously set in a rebate program. The energy savings is 4,801 kWh per year with a demand savings of 1.62 kW per house, resulting in $446 cost savings per year and a payback of just over 7 years.[27] Figure 21 shows the reduction in average hourly power consumption per household within a 24-hour period.

[26] NREL. www.nrel.gov/docs/fy99osti/26579.pdf .

[27] DOE. http://www1.eere.energy.gov/femp/technologies/renewable_uscg_hawaii.html?m=1&

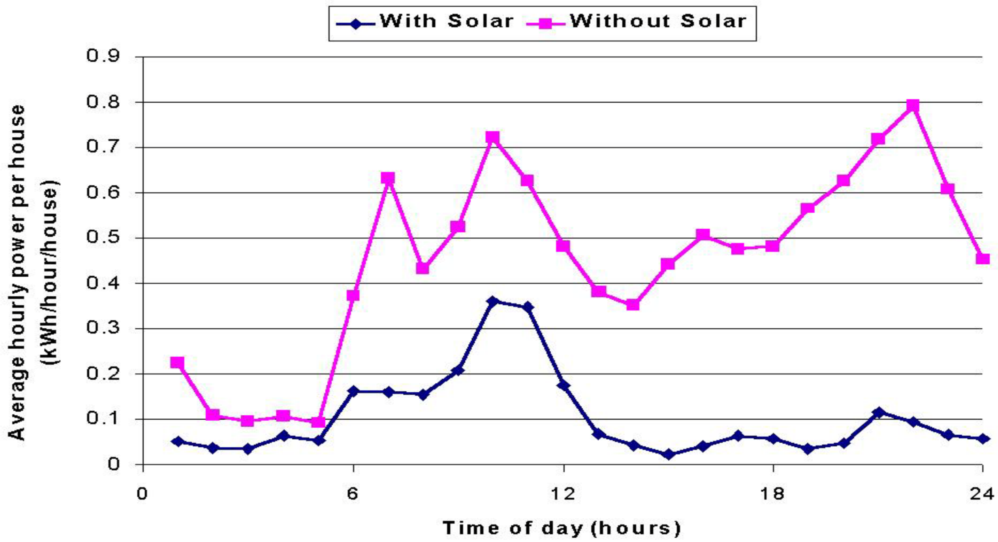


Figure 21. U.S. Coast Guard housing, Honolulu, Hawaii

Source: NREL

In the current market, solar thermal systems have significantly decreased in price and increased in efficiency. Based on current electricity costs in the CNMI, solar hot water systems provide an opportunity for energy and cost savings in both commercial and residential applications. Conversations with the local hotel association have indicated that the second largest energy cost for hotels is hot water (after air conditioning and chiller loads). Discussions with residential consumers indicated that in some cases people have disconnected their hot water heaters, which are primarily electric, due to the high cost, and thus have limited access to hot water. Solar hot water is a low- to medium-cost application that should be considered within the larger industries where hot water consumption is high, or for residential customers to provide most of their water heating needs.

Several solar hot water systems were seen on Saipan, but due to the hardness of the water, unit life was said to only be several years for most applications. The affordable housing project being built in Chalan Kanoa on Saipan with solar water heating for the residential units could serve as a demonstration of solar water heating technology and encourage wider implementation.

3.2.2.2 Solar Photovoltaic (PV)

Unlike solar water heating, solar PV directly generates electrical power and can be interconnected to the electric distribution network. Solar power then acts as a direct offset to diesel power generation. Similar to wind power, the implementation of PV does not reduce the total installed capacity of diesel technology, and depending on detailed solar assessments, may not reduce the spinning reserve (unused and available capacity) requirements of diesel operation. It does lead to reduced fuel consumption and thus reduced expenditures for fuel on the islands.

Most PV systems installed today are in flat-plate configurations, which are typically made from solar cells combined into modules called panels. Many solar panels combined together to create one system form a solar array. For large electric utility or industrial applications, hundreds of solar arrays are interconnected to form a large utility-scale PV system.[28] These systems are generally fixed in a single position, but arrays that rotate to track the sun are also available. Although typically mounted at an angle to maximize sun exposure, arrays can be mounted flat against the roof surface in climates susceptible to high wind events with only a small reduction in power produced. Figure 22 shows a typical rooftop PV system installation.

[28] NREL. http://www.nrel.gov/learning/re_photovoltaics.html.

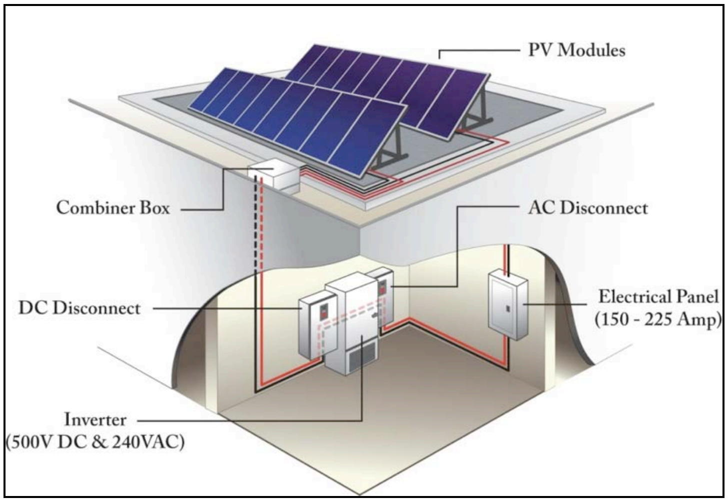


Figure 22: PV system schematic

Source: NREL

Although solar data is not readily available for the primary islands of the CNMI, data is available for Guam that allows initial calculations of solar potential. Since Guam is slightly closer to the equator, the solar resource in each of the CNMI islands will be slightly lower than the 4.81 kWh/m^2 per day indicated for Guam. Clearly Rota, being closest to Guam, will reflect the most similar solar resource. Based on calculations assuming an installed cost of $8/peak Watt, the levelized cost of PV electricity is on the order of $0.18/kWh, which is lower than the current Levelized Energy Adjustment Clause (LEAC) cost of power from CUC of $0.24446/kWh as of June 1, 2010. The cost of $8/peak Watt-installed may be a high estimate for large-scale installations (100 kW or larger) for similar locations, but land lease or purchase expenses are unknown, so it is likely representative. Increasing the costs to $10/peak Watt-installed, which may be more applicable for small-scale installations, such as residential or small commercial locations, still results in a cost of electricity lower than the LEAC cost. Roof mounted PV has the additional benefit of reducing the solar load on the building, and therefore reducing energy use for air conditioning.

PV can also be implemented to provide electricity to specific buildings or businesses. In the case of smaller installations, renewable technologies, including PV, are installed in what is typically called a “behind the fence” or “net metering” application. In these cases, PV systems are installed on the customer side of the electrical meter and the energy generated is used by the consumer. Any excess electricity is sold back to CUC at a rate defined under the CUC/CNMI net metering regulation, PL15-26 (2006), PL15-87 (2007), and PL17-34 (2011). The specifics of the CNMI net metering policy are provided in section 2.3.1 of this document, but the policy allows non-IPPs to install net metering applications up to 10 MW in size. Although 10 MW is large given the size of each of the electrical networks, limits in the sale price of power under the net metering policy economically limit the size of power systems that will be implemented. Installation of net metered systems allows users to reduce their electrical consumption from the grid when the PV is producing power, which can save residential and commercial customers money depending on the current cost of electricity from CUC and the correlation between expected energy usage and PV output.

CUC is actively seeking proposals for IPP-based renewable power systems that are economically competitive to power produced from diesel generators. Several companies have approached CUC regarding the installation of solar PV systems; one going as far as identifying and securing a site for potential installation. The identification of available land is a secondary issue, especially those suitable for the large-scale deployment. Calculations completed by Winzler and Kelly on behalf of Guam Power Authority and in consultation with R.W. Beck determined that a 10-MW PV plant on Guam would require 60 to 80 acres of land. Sites for PV systems in the CNMI are potentially abundant, but would have to be identified as part of an independent or CUC screening process, likely in conjunction with the Department of Land and Natural Resources and Department of Public Lands. If a screening process were to be implemented, the following steps should be undertaken to assess potential locations for larger-scale PV system implementation.

- Review topological data, access roads, proximity to transmission/distribution systems, other improvements, and land use and property ownership, based on publicly available information from the Department of Land and Natural Resources and Department of Public Lands
- Develop a Technical Memorandum that describes advantages and disadvantages for the potential solar development locations, including potential plant sizes in investigated areas
- If appropriate, develop an initial numeric screening process to identify the best locations for development, which are similar to renewable or clean energy development zones. This may assist private developers or CUC to more easily implement solar projects.

Although not typically highlighted as with wind technologies, the power variability in large-scale PV installations can be high due to the reduction in voltage when clouds pass between the sun and the PV array. If large PV systems are to be considered, grid flow and power balancing studies should be completed as part of the development process.

An additional application of solar technology, independent or in conjunction with CUC, is the application of remote solar power systems, such as solar electric street lighting, water pumping, and off-grid power supply. Due to the somewhat limited grid available on each of the islands, independent PV/battery remote-powered systems could be used in place of small diesel-powered systems. Power could be provided to locations such as Bird Island, Bonsai Cliff's, and the Grotto, likely at a greatly reduced cost as compared to conventional options.

3.2.2.3 Next Steps

The following next steps are recommended.

1. Assign a subcommittee within the Energy Task Force to explore possibilities of policies and programs for solar hot water systems for all sectors. Consider creating incentives or other policies for supporting the installation of solar hot water heaters, particularly in high hot water use applications such as hotels, Laundromats, and restaurants. Residential water heating programs should also be considered, potentially in conjunction with the local housing authority.
2. Initiate the collection of solar resource data to support public and private development of PV and solar hot water systems.
3. Conduct a feasibility study to analyze the potential for both large- and small-scale PV installations in the CNMI. This can aid in utility planning for new infrastructure including controls, storage, and dispatchable power sources.
4. In accordance with PL 15-87, conduct a screening assessment of potential large PV application sites as described previously on each of the islands. Consider including a PV interconnection study for high probability sites to support the development of potential sites.

3.2.3 Geothermal

Due to the enormous need for clean baseload power and the increasing need for energy diversity, the potential for geothermal power production should be assessed to determine whether it may be a likely technology to implement for the CNMI. Geothermal power would be a tremendous asset if it could be found and economically developed on Saipan, which has by far the highest electric load in the CNMI. Since geothermal is a baseload energy source, whereas wind and solar PV are intermittent, it is a highly desirable option if the geologic conditions support geothermal being economically developed. The

Principal Scientist from NREL's Geothermal Program participated in the site visit and conducted an assessment to determine evidence of geothermal potential on Saipan. The full report of the field observations can be found in Appendix C.

3.2.3.1 Evidence of Geothermal Potential on Saipan

Saipan lies on a regional trend of high heat flow associated with the Izu-Bonin-Mariana (IBM) volcanic arc system. The central and northern islands of the IBM arc (from the island of Anatahan, 120 km north of Saipan, northward) are volcanically active, with an eruption frequency on average of every 5 years. Saipan itself is not volcanically active, but its bedrock, beneath a blanket of reef limestone, consists of volcanic rock extruded as recently as 13 million years ago.

The island of Saipan has no obvious surface features suggesting geothermal potential and has never been the focus of an intensive geothermal exploration program. However, a preliminary investigation conducted by a team from the Southern Methodist University's (SMU) Geothermal Laboratory revealed evidence of elevated water temperatures in existing shallow water wells.[29] This potential evidence of geothermal fluids at shallow depths suggests that geothermal reservoirs may exist at greater depths on Saipan. Certainly, there appears to be enough information to warrant further investigation and exploration for geothermal systems. A crucial step will be to drill one or more temperature gradient holes to verify the presence of heat at economically drillable depths.

The presence of elevated heat at economically drillable depths is just one of three primary geologic conditions required for development of a geothermal system. Geothermal exploration must also verify the presence of rocks with sufficient permeability and fluid to enable fluid circulation through a well field to sustainably mine heat from the subsurface (see Figure 23).

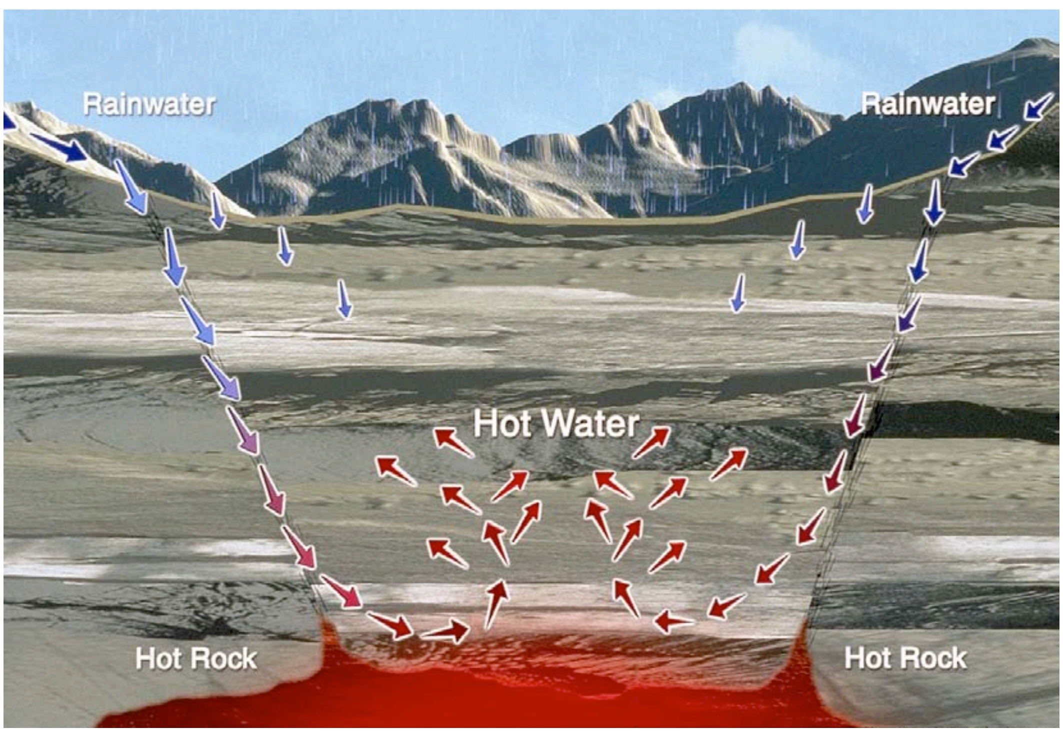


Figure 23. Schematic of a hydrothermal system indicating the three essential geologic components: hot rock, fluids, and permeability

Source: NREL

[29] Richards, M; Mink, R.; Waibel, A.; Blackwell, D. 2010. *Initial Review of the Geothermal Potential of Saipan (unpublished draft).*

In order to determine whether a geothermal power resource exists, and to potentially attract private investment in development of the resource, gradient holes (test wells) need to be drilled. Experience has shown that in some cases gradient holes deeper than 2,000 feet, and a set of several holes, are required for reliable assessment of the geothermal gradient because the geology, rock type, and fluid temperatures can and often do vary laterally. A single well up to 2,000 feet appears be sufficient to penetrate far enough in the volcanic rocks below Saipan's carbonate blanket to measure the background geothermal gradient. However, the risk of drilling a gradient hole shallower than 2,000 feet, and indeed the risk of drilling only a single temperature gradient hole to evaluate an area the size of Saipan, is that a single well might not be representative of the background geothermal gradient. The strategy for temperature gradient drilling on Saipan must weigh the risk of a "false negative" result from a single shallower well against the added cost of drilling more and deeper wells, along with the incremental cost to drill additional wells.

3.2.3.2 Status of Geothermal Investigations

During the site visit to Saipan, an overview of the geology and geomorphology of Saipan was conducted with the aid of an advance copy of a soon-to-be-published new geologic map of Saipan.[30] The sites of the water wells with elevated temperatures were visited, and several springs were re-sampled for geochemical analysis that had been sampled by SMU in 2008. Water samples were collected at Susupe Lake, Donni Spring, Tanapag I Spring, Achugao Spring A, and Achugao Spring B. Previous SMU samplings had found somewhat elevated silica concentrations in the Achugao and Donni springs. NREL re-sampled several of the SMU sites in order to collect additional data and provide a comparison between a dry season (when SMU sampled in 2008) and a wet season (when NREL sampled in December 2010).

Following the same protocol as the 2008 SMU samples, the NREL water samples were sent to the Desert Research Institute in Reno, Nevada, for chemical analysis. The results of the NREL water analyses were very similar to the earlier SMU results. Silica concentrations in the Achugao and Donni Springs were somewhat elevated, while the silica concentration at Tanapag Spring was significantly higher. While the water analyses are inconclusive with regard to the presence of geothermal fluids, the high silica concentrations at Tanapag Spring suggest that these cool spring waters may be in communication with deeper volcanic rocks.[31]

As reported in the SMU report, two water wells drilled in the Gualo Rai area of western Saipan encountered elevated temperatures above what would be expected in the groundwater aquifer. The hotter of the two wells, GR-3, was anecdotally reported to have temperatures "too hot to touch." The drilling report also mentions that a downhole pump failed due to overheating of the well. Anomalous temperatures were also encountered in a nearby well, GR-6, which was also assessed by SMU in 2008. The SMU team recorded a temperature log that showed temperatures increasing from 27.03°C (80.65°F) at 60 m to 33.84°C (92.91°F) at 125 meters (410 feet, the maximum depth that could be reached with the temperature probe due to well collapse since drilling).[27] These data suggest a thermal gradient of 71°C/km (159.8°F), an attractive gradient for geothermal potential if it is sustained with increasing depth. Elevated temperatures in these two water wells, GR-3 (anecdotal report) and GR-6 (verified by temperature logging), provide potential evidence that hydrothermal systems may be present in the volcanic basement rock underlying the carbonate aquifer blanketing Saipan.

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[30] Weary, D.J.; Burton, W.C. A New Geologic Map Of The Island Of Saipan. Commonwealth Of The Northern Mariana Islands.

[31] Richards, M; Mink, R.; Waibel, A.; Blackwell, D. 2010. *Initial Review of the Geothermal Potential of Saipan (unpublished draft).*

At the time of the NREL field visit in December 2010, there were no ongoing geothermal investigations on Saipan. However, the SMU team had just completed a draft report recording the findings of their previous field work. In addition, Dr. James Quick has recently been engaged as a renewable energy advisor to the Governor of the CNMI. The SMU team had previously recommended that a 2,000-foot temperature gradient hole be drilled on Saipan.[27] Funding has not been available for this work and no deeper drilling has been conducted to evaluate Saipan's geothermal resource potential.

The CNMI government Water Task Force currently owns and operates a Schramm T685WS rotary air drilling rig that appears to be in excellent condition and may be capable, with some modifications, of drilling to depths sufficient for a temperature gradient hole. The rig is currently used for drilling water wells. Drilling to the maximum depth capability of the Schramm rig would require an upgrade from air drilling to mud drilling equipment, as well as a blow out preventer and surface casing set to protect the vital shallow aquifers from any damage during drilling operations of deeper, potentially hotter, and likely faulted basement rocks. Sufficient drill pipe for drilling depths beyond 900 feet are not presently available on Saipan. Schramm has advised the Water Task Force that a polymer mud system, also not currently available on Saipan, would be needed to control lost circulation in the carbonates.

3.2.3.3 Next Steps

Next steps would include further studies to determine whether a geothermal resource exists and is worth developing. NREL's preliminary assessment concludes that a geothermal system or systems may exist on Saipan, but the island is at present a high-risk exploration province for geothermal energy compared with other areas of the world with greater surface or subsurface evidence. Initial assessments need to be carried out, followed by exploration if the assessment results are positive. A detailed description of a program plan for geothermal resource exploration is provided in Appendix C, 'Evaluation of the Geothermal Potential of Saipan – A Path Forward'.

1. Evaluate the capability, or modifications needed, for the Water Task Force owned Schramm drilling rig to drill temperature gradient holes to a depth of 2,000 to 3,000 feet.
2. Drill one or more temperature gradient holes to verify the presence of heat at economically drillable depths. This requires a qualified geothermal geologist and experienced drilling engineers. A 2,000-3,000-foot temperature gradient hole, or a program of temperature gradient holes consisting of one deep and several shallower wells, could provide evidence of an attractive geothermal gradient that would encourage further exploration for geothermal systems on Saipan by private sector developers. This process could begin through an RFP process to select a qualified company to develop a detailed drilling plan and carry out the temperature gradient hole drilling and analysis.
3. Develop a plan forward based on the results of the TGH analysis. Potential paths are described in Appendix C.

3.2.4 Biomass

Biomass is generally defined as any organic feedstock available on a renewable basis. Typical biomass resources include wood and wood waste, municipal solid waste (MSW), landfill gas (LFG), agricultural and crop residues, used vegetable oil, human solid waste, and animal manures. Biomass technologies can be used for heating, to produce electricity or liquid fuels and chemicals, or to produce a substitute for natural gas through gasification of feedstocks. LFG can be cleaned up and used for any of the above, or can be used directly to produce heat or electricity. One of the primary benefits of electricity production from biomass, compared to other renewable sources like solar or wind, is that feedstocks can be stored, thus allowing for baseload, dispatchable generation. If using a biofuel, such as biodiesel, the fuel can be used directly in the existing equipment, thus allowing for renewable fuel switching at minimal capital cost.

Biomass resources that are potentially suitable for CNMI include:

- Electricity generation using biodiesel or straight vegetable oil in existing fuel oil boilers or engines
- Use of MSW to produce power or liquid fuels
- LFG capture for energy recovery
- Anaerobic digestion to generate biogas at waste water treatment plants, or small-scale digesters for converting animal manure to biogas
- Dedicated feedstock for production of solid or liquid biofuels.

The NREL team evaluated potential opportunities to develop each of these options during the December 2010 site visit.

3.2.4.1 Waste-to-Energy Opportunities on Saipan

According to the CNMI Division of Environmental Quality (DEQ) Solid Waste website, illegal dumping is rampant in the CNMI, with five popular sites on Saipan. This is a potential environmental hazard, and also leads to uncertainty of the total amount of waste generated on the island. Although tipping fees may be increased, raising them too drastically could lead to additional illegal dumping.

The DEQ distinguishes between two categories of solid waste, general solid waste and MSW, as described below[32]:

General Solid Waste

- Garbage (e.g. milk cartons and coffee)
- Refuse (e.g. metal scrap, and empty containers)
- Sludges from waste treatment plants.

Municipal Solid Waste

- Durable goods (e.g. appliance, tires, batteries)
- Non-durable goods (e.g. newspaper, books, and magazines)
- Containers and packing, food waste, yard trimmings, and various organic waste from residential, commercial, and factories.

Materials from each of these categories could potentially be used for energy production.

3.2.4.2 Energy Production Potential

The generation and disposal of MSW presents challenges for most communities, but especially for islands. Converting MSW to energy is one option that many communities have undertaken and others are considering. Advantages of producing energy from waste include a reduction in the volume of waste to be land-filled and reduction of greenhouse gas (e.g. methane, carbon dioxide) emissions. This opens up the possibility of carbon credits or renewable energy credit (REC) sales.

As discussed previously, information indicates that the Marpi landfill receives approximately 43,000 tons of MSW per year; about a quarter of which is diverted, the rest is landfilled. Some of the materials, such as paper, cardboard, wood waste and tires, could be used as feedstock for a combustion or

[32] CNMI Division of Environmental Quality Solid Waste website. www.deq.gov.mp/article.aspx?secID=11&artID=31.

gasification system. Some of these materials are recycled, but the high cost of handling and shipping these materials to off-island markets makes this option uneconomical.

Other waste products, such as green waste, wastewater treatment plant sludge, agricultural residues, and animal wastes, could also be used as feedstocks to produce thermal or electric energy. These resources have not been quantified and are not included in the following analysis.

As shown in Table 9, we estimate that current rates of MSW disposal would be sufficient to fuel a 2.6 MW to 4.2 MW (net output) plant with an 85% capacity factor. The actual generation will be highly dependent on the selected technology, overall composition and energy content of the feedstock, how the feedstock is handled and prepared, system design, and overall operating conditions.

Table 9. Summary of WTE Potential

Total waste (tons/year)	43,000
Estimated non-combustibles (%)	11,000
Combustible waste (tons/year)	**32,000**
Capacity factor	85%
Tons/operating day	104
Net power - low efficiency (MW)	2.6
Net power - high efficiency (MW)	4.2
Net energy - low efficiency (MWh)	18,000
Net energy - high efficiency(MWh)	31,000

The value for "low efficiency" in Table 9 is based on an assumed yield value of 600 kWh per ton of MSW processed. This is equivalent to a typical mass burn combustion plant today. The value for "high efficiency" assumes a conversion factor of 900 kWh per ton MSW. This is equivalent to what some manufacturers of advanced conversion technology gasification and plasma units are claiming to be able to obtain from their systems. It should be pointed out that there are no commercial advanced conversion technology WTE projects operating in the United States, although there are several reported to be operating in Asia and Europe. Of the commercially-viable WTE systems that are operating in the United States, nearly all (if not all) of the plants use either stoker or fluidized bed combustion technology. Combustion technology is fully commercial and lenders are willing to finance well-structured projects that have a guaranteed supply of MSW and a power purchase agreement with a credit-worthy customer.

The numbers in Table 9 assume that 15% of the output from the plant will be used for parasitic loads. Because WTE systems can be operated essentially 24 hours per day, a WTE plant will produce more energy over a year than an equivalent wind or solar plant. Therefore, a 2.6-MW WTE plant would produce approximately the same amount of energy each year as a 6-MW wind farm (at 35% capacity factor), or 12-MW of solar photovoltaics at an 18% capacity factor. In addition, a WTE plant would take up far less space and could be co-located at the Marpi Landfill.

It must be pointed out that the numbers above are preliminary and need to be investigated in greater detail. These are "rule-of-thumb" numbers, and there are many companies and technologies available. The best way to determine the market potential for WTE is for either CUC or the DPW Energy Division to develop an RFP for a WTE plant (after a waste characterization study is completed and any regulatory/legal issues are addressed) and evaluate the bids from potential developers.

Using the numbers provided previously, NREL conducted a preliminary economic analysis of a 2.6 MW (~100 ton per day) WTE electric generation system at the Marpi landfill. Capital cost is assumed to be $54 million. A summary of the results is presented in Tables 10 and 11.

Table 10 shows the results of the economic analysis for various electricity sales prices and tipping fees, assuming that the business energy investment tax credit (ITC) is not available for this project. Note that the net present value (NPV) does not become positive unless electricity sales prices is $0.30 per kWh and tipping fee is $40 per ton or higher.

Table 10. Economic Sensitivity Analysis of 2.6 MW Electric Generation at Marpi Landfill – no ITC

Electricity - Sales price ($/kWh)	Tipping Fee ($/ton)	NPV ($)	Minimum DSCR	Average DSCR
0.150	$ 30.00	$(29,739,130)	0.51	0.60
0.150	$ 40.00	$(26,888,131)	0.57	0.68
0.150	$ 50.00	$(24,037,131)	0.63	0.76
0.150	$ 60.00	$(21,186,131)	0.69	0.84
0.200	$ 30.00	$(20,045,731)	0.72	0.87
0.200	$ 40.00	$(17,194,732)	0.78	0.95
0.200	$ 50.00	$(14,343,732)	0.84	1.03
0.200	$ 60.00	$(11,492,733)	0.90	1.10
0.250	$ 30.00	$(10,352,333)	0.92	1.14
0.250	$ 40.00	$ (7,501,333)	0.98	1.21
0.250	$ 50.00	$ (4,650,334)	1.04	1.29
0.250	$ 60.00	$ (1,799,334)	1.10	1.37
0.300	$ 30.00	$ (658,934)	1.13	1.40
0.300	$ 40.00	$ 2,192,065	1.19	1.48
0.300	$ 50.00	$ 5,043,065	1.25	1.56
0.300	$ 60.00	$ 7,894,065	1.31	1.64

Table 11 shows the same analysis, but includes ITC. In this case NPV becomes positive for electricity sales price of $0.20 per kWh and tipping fee of $60 per ton, or electricity sales price of $0.25 per kWh and tipping fee of $30 per ton. It is not known if these are achievable values, but they indicate that a more thorough analysis of the available waste stream could prove profitable.

Table 11. Economic Sensitivity Analysis of 2.6 MW Electric Generation at Marpi Landfill – with ITC

Electricity - Sales price ($/kWh)	Tipping Fee ($/ton)	NPV ($)	Minimum DSCR	Average DSCR
0.150	$ 30.00	$(16,233,876)	0.51	0.60
0.150	$ 40.00	$(13,382,877)	0.57	0.68
0.150	$ 50.00	$(10,531,877)	0.63	0.76
0.150	$ 60.00	$ (7,680,877)	0.69	0.84
0.200	$ 30.00	$ (6,540,477)	0.72	0.87
0.200	$ 40.00	$ (3,689,478)	0.78	0.95
0.200	$ 50.00	$ (838,478)	0.84	1.03
0.200	$ 60.00	$ 2,012,521	0.90	1.10
0.250	$ 30.00	$ 3,152,921	0.92	1.14
0.250	$ 40.00	$ 6,003,921	0.98	1.21
0.250	$ 50.00	$ 8,854,920	1.04	1.29
0.250	$ 60.00	$ 11,705,920	1.10	1.37
0.300	$ 30.00	$ 12,846,320	1.13	1.40
0.300	$ 40.00	$ 15,697,319	1.19	1.48
0.300	$ 50.00	$ 18,548,319	1.25	1.56
0.300	$ 60.00	$ 21,399,319	1.31	1.64

One potential arrangement for a WTE facility would be to locate a plant "behind the fence" of the new landfill. In this manner, tip fees could be paid at the gate that could be used for debt repayment for the current landfill. Rather than burying the material directly in the landfill, it could be directed to a WTE plant to produce and sell energy. The residual ash and non-combustibles could then be recycled and/or sent to the landfill. Production of energy would extract additional value from the CNMI's solid waste and prolong the life of the new landfill by reducing the amount of material that gets buried. A detailed cost benefit analysis of this option would need to be undertaken; the cost of this analysis is not included in the cost estimate projected above.

3.2.4.3 Landfill Gas

Saipan's previous waste disposal site, the Puerto Rico Dump (PRD), was closed when the Marpi landfill opened. NREL could not obtain information on the status of the PRD (how much material it contains, the waste composition, the current closure status, etc.), but it may be worth investigating the feasibility of collecting the landfill gas and using it to generate electricity. This would be particularly easy if the landfill is to be properly capped and if the gas will be collected and flared.

There is also potential for biogas collection from the Marpi landfill. According to the Insular Areas Energy Assessment Report, the landfill design includes the potential for gas extraction[33], so the potential energy production and its cost effectiveness should be assessed.

3.2.4.4 Anaerobic Digestion

According to the Insular Areas Report, biogas production has been tested at piggeries in the CNMI, but most of those trial projects are no longer in service. That report recommended that the Commonwealth Energy Office (CEO) survey animal and poultry farmers regarding the market for digesters as a waste control measure and for energy production.

Also from the Insular Areas Report, page 192:

[33] United States of America Insular Areas Energy Assessment Report: An Update of the 1982 Territorial Energy Assessment. Prepared for: US. Department of Interior. Washington, D.C. 20585. Prepared by:Pacific Power Association, Suva, Fiji. 2006.

> A number of technology demonstrations were built and an interwoven scheme developed for putting a biogas digester at the energy focus of a process that integrated aquaculture, agriculture, silviculture, and pig farming. The Integrated Farm used aquaculture to grow aquatic plants and algae that could be processed into nutritious pig feed, then used the pig manure in a digester to produce a nutrient-rich effluent for the aquaculture tanks. The solid wastes and excess effluent from the digester could be used as fertilizer for agriculture and for trees in a biomass plantation.
>
> … When the concept champion left the CEO in the late 80s, the momentum was lost and the demonstrations were closed down soon after.

Since the report was published in 2006, anaerobic digestion technologies have improved, as have gas clean-up and conditioning. In addition, energy prices have also increased, improving the economic potential of energy generation from animal waste. These technologies could be reviewed as part of a renewable energy portfolio for the CNMI, but will provide limited opportunities.

3.2.4.5 Biodiesel or Vegetable Oil

The use of biodiesel or vegetable oils in diesel generators and boilers is gaining wider acceptance around the world. The ability of biodiesel to be used within the existing utility diesel infrastructure is a compelling reason for exploring this option. There are minimal capital costs associated with using a biodiesel or vegetable oil/diesel blend in existing diesel or residual fuel-oil-fired generators, combustion turbines, or boilers. Biodiesel blends of 2% up to 20% can typically be used in existing equipment with only minor modifications. There have been several testing programs, particularly in Hawaii, investigating firing 100% biodiesel in utility-scale boilers, turbines, and generators. Several utilities have been running biodiesel in standby generators as a way to implement peak load reduction and reduce emissions associated with running the generators beyond their annual permitted hours.

The use of 100% biodiesel in utility-scale generators is being pioneered in Hawaii where there are at least three different projects underway:

- Hawaiian Electric Company (HECO) recently completed co-firing tests of various blend percentages of petroleum diesel and biodiesel fuels at the 90-MW Kahe Power Plant. On January 28, 2011, HECO issued a press release stating that they successfully tested 100% biodiesel in Kahe at the full load of 90 MW. The next test will demonstrate 24-hour operation on biofuels. One of the major observed results of the tests is that the use of biodiesel reduced opacity, nitrogen oxide, and criteria pollutant emissions below the levels associated with ultra low sulfur diesel fuel.[34]
- Maui Electric Company (MECO) uses biodiesel to start up and shut down two of its generators. MECO is also conducting tests to determine the long term impact of using biodiesel on heat rates, emissions, and engine reliability.
- HECO's Campbell Industrial Park Generating Station, Combustion Turbine Unit 1, is a 110-MW combustion turbine unit installed in 2009, and designed to run on 100% biodiesel. Renewable Energy Group of Iowa presently has a contract to supply three to seven million gallons of biodiesel per year. All biofuel procured by HECO must meet stringent sustainability guidelines. HECO has determined that the use of biodiesel is its most cost-effective option for complying with Hawaii's renewable energy targets.

Biodiesel is made through the transesterification, or chemical breakdown, of animal fats or vegetable oils. The feedstock can come from waste sources, such as grease from restaurants, or from virgin

[34] HECO Press Release. Available online at: www.heco.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510b1ca/?vgnextoid=9fbfb7ba04ecd210VgnVCM1000005c011bacRCRD&vgnextfmt=default&cpsextcurrchannel=1. Accessed June 12, 2011.

sources, such as oil seeds, coconut, palm, Jatropha, or algae. In Hawaii, biodiesel is procured from the mainland and Malaysia, though long term plans call for production of feedstocks locally.

The major issues in evaluating whether the use of biodiesel technologies is viable for the CNMI are supply and cost. The amount of waste grease produced in the CNMI is not known, as there is no known inventory of fats, oils, and greases. There are also some concerns over shelf life, with some evidence suggesting biodiesel can begin to break down after six months. This concern can be addressed by ensuring that the supply is matched to potential demand. Also, there are significant costs associated with converting vegetable oils to biodiesel. The process requires methanol and lye, both of which would need to be imported. There is also a question over economies of scale, and it is likely that the supply of feedstock in the CNMI is too limited to warrant construction of a biodiesel plant.

It is possible to use waste vegetable oil directly without conversion to biodiesel, which can be a cost effective approach for hotels and other businesses generating their own electricity.

The University of Guam has been conducting research on the oil yields of Jatropha and Calophyllum and has planted test plots of these species. The research is on-going and focused primarily on the quality of the oil. Research on production costs, available land, and potential yields has not yet been undertaken.

While not likely to be a significant source of fuel for the CNMI, the use of waste oil in boilers and engines should be explored further, as should the economics of producing oil from local plants.

3.2.4.6 Production of Dedicated Biomass Feedstocks

There is a potential for biomass crops to be grown on the islands in the CNMI, but that potential is dependent on precipitation, soil conditions, and other factors. Some of the data in this section is from Tropical Dry Forests of the Pacific.[35]

Saipan receives between 1,866 millimeters (mm) and 2,286 mm of annual precipitation and has a dry season caused by monsoon weather from December to June. Under Japanese administration, Tinian was largely a sugar plantation. The forests of the Mariana Islands were most seriously impacted during World War II, especially the largest islands Saipan and Tinian, which were the center of the war-time activity.[36] The U.S. Navy maintains a training area on Tinian, consisting of about two-thirds of the public area of the island. Training on Tinian occurs within the 16,000 acre leased area known as the Military Lease Area (MLA), with limited activities in San Jose Harbor. The MLA is divided into two sections; the northern half is the Exclusive Military Use Area and the southern half is referred to as the Leaseback Area (LBA).

The LBA is a joint-use area, where both military and non-military activities take place. The LBA has been leased back to the CNMI for uses judged by the U.S. Navy to be compatible with long-term DOD needs, primarily grazing and agriculture. Under the leaseback agreement, the LBA may be used for training activities that would not be detrimental to ongoing CNMI economic and agricultural activities.

The MLA remains largely undeveloped, with no permanent military installations or staffed facilities; at the present time, there are no major construction projects planned. None of the roads are fenced or gated and public access to North Field during non-maneuver times is not restricted. Depending on the military plans, some of the LBA may potentially be available for biomass crops, including Jatropha, Calophyllum, palm, or other local species.

[35] Tropical Dry Forests of the Pacific. Gillespie, T.W. www.geog.ucla.edu/tdfpacific/marianas_islands.html. Accessed 5/8/2011.
[36] www.globalsecurity.org/military/facility/tinian.htm.

3.2.4.6.1 Jatropha[37]

Jatropha can grow on low fertility soils, but better soils result in higher yields. The Jatropha seeds contain 27% to 40% oil that can be used as-is or converted to a high-quality biodiesel fuel, which can be used in a standard diesel engine. A wide range of values for yield of oil from Jatropha have been published, ranging from 60 U.S. gallons/acre/year up to 1,600 gal/acre/year for experimental varieties in Florida.[38] This yield depends on numerous factors, such as Jatropha variety, rainfall (sources suggest a minimum requirement of 600 mm of rain per year), amount of sun received, soil properties and depth, and amendments such as fertilizers added to the soil.[39] Jatropha trees are reported to be productive for up to 40 years.

Jatropha can be used as straight vegetable oil, which requires minimal processing but does require engine modification, or it can be refined to diesel and used in existing diesel engines or generators for electricity production. The economics and technical ability to use the oil in mechanical equipment need to be evaluated in greater detail.

If half of the LBA on Tinian could be utilized for Jatropha production, that would provide about 8,000 acres under cultivation. Assuming a conservative yield of 60 gallons/acre/year, this land could produce about 500,000 gallons of oil per year.

3.2.4.7 Next Steps

Biomass utilization and WTE should make up some component of a wider energy strategy for the CNMI. Biomass offers many strategic benefits, such as fitting into the existing oil-based infrastructure nearly seamlessly. Other resources, such as WTE, LFG, and methane from waste water treatment plants, can be used to produce baseload power and are not subject to intermittent outages like wind and solar.

One of the next steps would be to conduct a comprehensive biomass resource assessment and analysis of opportunities. The assessment could be performed all at one time by a single entity, or the work could be split up amongst a team of researchers. Several activities might lend themselves to being performed by students and staff from Northern Marianas College.

Major next steps for each of the biomass sub-technologies are described below. Detailed budget estimates would need to be prepared for each category. The cost would be dependent on the level of detail required.

1. Evaluate the potential for waste-to-energy. The cost to further evaluate WTE could range from $25,000 for a pre-feasibility evaluation, to $300,000+ for a detailed waste characterization and investment-grade economic and technical analysis of WTE options.
    - Issue an RFP to perform a waste composition analysis and use the data to refine estimates of waste-to-energy potential.
    - Evaluate other potential sources of feedstock for a WTE plant, including tires, corrugated cardboard, and organic matter. Some of these materials might currently be part of the recycle stream, but it is not clear what is being done with those materials. Include the quantity and characteristics of the material being dumped at illegal sites, and pursue efforts to eliminate illegal dumping.

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[37] www.reuk.co.uk/Jatropha-for-Biodiesel-Figures.htm.

[38] Padgett, T. February 2009. "The Next Big Biofuel?". *Time Magazine*. www.time.com/time/magazine/article/0,9171,1874835,00.html.

[39] Dar, W.D. December 2007. "Research needed to cut risks to biofuel farmers". *Science and Development Network*. www.scidev.net/content/opinions/eng/research-needed-to-cut-risks-to-biofuel-farmers.cfm. Retrieved 2007-12-26.

- Evaluate local recycling efforts, markets, and options and determine potential impacts on the waste stream and the economics of WTE.
- Conduct a technology search for commercial units operating in the size range needed.
- Perform an economic analysis of project feasibility. Include evaluation of financing and ownership options–government (CUC, SWMD) vs. private sector and potential sales of RECs and carbon credits, as well as incentives and tax benefits.
- Evaluate the potential for energy production from landfill gas at the former PRD and the current Marpi landfill.
- Investigate the potential production of digester gas from agricultural sites and from waste-water/sewage treatment plants.

2. The production and use of biodiesel or vegetable oil warrants further investigation. Hawaii is using both locally produced and imported biofuels to help meet its renewable energy targets. The cost of this analysis for the CNMI is estimated to be $25,000 to $50,000, excluding the costs of a direct test in CUC's engines. The cost for that would need to be determined.
    - Conduct a survey of waste grease supplies in the CNMI, particularly on Saipan. Determine who produces the material, how it is collected and disposed, what the costs are, and if there are opportunities for a local business to manufacture biodiesel locally.
    - Determine the expected costs of procuring biodiesel from off-island sources.
    - Gather case study data associated with the use of biofuels or vegetable oil in diesel systems in Hawaii, other islands, and other communities.
    - Determine equipment modifications needed to use biodiesel or vegetable oils in the CUC system. Based on other case studies or work done in Hawaii, it would be useful for CUC to conduct a test of biofuel use within its system. This would be a comprehensive assessment that evaluates costs, impacts on heat rates and performance, fuel storage and handling, air emissions, and overall feasibility.
    - Estimate the levelized cost of energy produced from biodiesel in various blends of biodiesel/petroleum diesel percentages.
    - Prepare a report and briefing to communicate results of the detailed assessment.
3. While there may be challenges to growing dedicated biomass for energy, it may make sense to explore this option further. The following steps are recommended. The cost to perform this analysis is estimated at $25,000 to $50,000.
    - Using geographical information systems, filter out all steep lands and developed areas to identify areas that are simply not suitable for biomass feedstock production.
    - Overlay land use and vegetation maps to determine current usage of the land base.
    - Evaluate land ownership of large contiguous parcels. The objective would be to identify potential lands suitable for growth of biomass feedstocks. DOD may have the land—whether it is available for purposes of biofuel production would need to be determined.
    - Based on estimated acreage available as well as potential yields of various species, evaluate technical and economic feasibility of producing biofuels or solid feedstocks.

3.2.5 Micro Hydropower

The potential for small hydropower systems in the CNMI has not been assessed in detail; however interest from the Mayor of Rota resulted in NREL performing initial calculations for potential on Rota.

Micro hydropower systems use moving water to rotate a turbine to create electricity, and by definition typically produce less than 100 kW of power. This can be a grid-connected or stand-alone system. Run-of-the-river systems require water to be diverted through a channel or pipeline that delivers it to the turbine, usually near the point of use. The potential power from a micro hydro turbine is determined from the available head (the vertical distance the water falls) and the flow (the amount of water falling).[40]

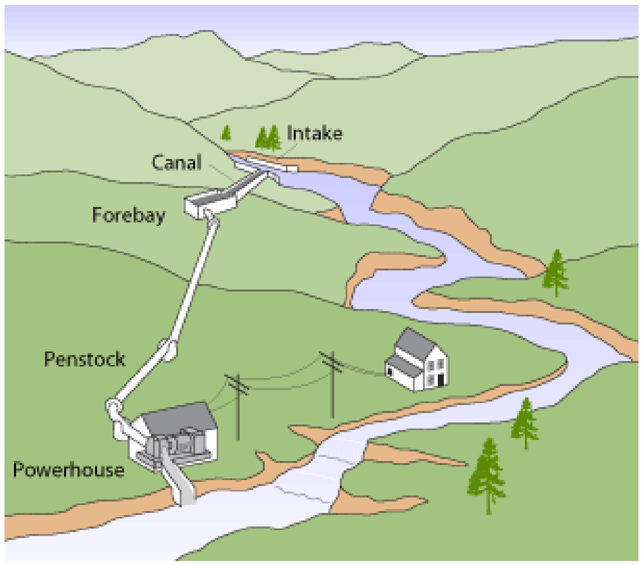

Figure 24. Typical "Run-of-the-River" Micro Hydropower System

Source: DOE Office of Energy Efficiency and Renewable Energy

In the case of Rota, two 8" diameter pipelines are already in place to deliver water from a water source at an elevation of 1,100 feet to the villages of Songsong and Sinapalo. For Songsong Village, based on the village elevation of 100 feet above sea level, a distance of 6.2 miles of pipe, and a flowrate of 550 gallons per minute, the estimated maximum potential power would be 49 kW. If a turbine were installed at Sinapalo Village, based on their elevation of 500 feet, 12.5 miles of pipe, and a flowrate of 580 gallons per minute, the estimated maximum power output of 30 kW could be generated.

NREL estimates costs for these systems to be about $275,000 for Songsong and about $175,000 for Sinapalo. Assuming an average cost of electricity at a conservative $0.30/kWh results in a payback of less than 2.5 years. While the power output is relatively small, the feasibility should be investigated further as this initial screening indicates favorable economics. A similar high level screening should be performed for Saipan and Tinian to determine the need for a more detailed assessment.

3.2.5.1 Next Steps

1. Conduct a more detailed evaluation of micro hydropower potential on Rota.
2. Perform a screening for micro hydropower potential for Saipan and Tinian.
3. Perform detailed feasibility assessments where screening indicates potential to determine specific implementation costs, power usage configuration (grid connected or stand-alone), and estimated cost savings.

[40] DOE. http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=11050.

4 Workforce Development

The development of a trained workforce to develop and expand new energy industries will be critical in order for the CNMI to increase the use of energy efficient and renewable energy technologies. Additionally, the local development of these industries as compared to their importation from other locations will also allow more economic development for CNMI residents. The CUC has almost 15,000 unique customers, which provides an indication of the number of potential customers that could benefit from additional energy services in the form of energy audits, energy efficient retrofits or distributed renewable energy systems.

Although renewable energy components are not likely to be manufactured in the CNMI (with the possible exception of the production of PV modules), the installation of all renewable energy technologies is generally labor intensive and could provide a good amount of jobs if the communities are able to take advantage of these opportunities.

The CNMI has the groundwork in place to develop a strong local renewables and efficiency implementation industry. The implementation of renewable technologies at Saipan Southern High School and the planned expansion of wind and solar technologies to other K-12 schools expands the knowledge base and demonstrates the viability of these technologies, and allows incorporation of renewable energy technology and applications into the curricula. The Northern Marianas Trades Institute (NMTI) is a functioning vocational education institution that could potentially be harnessed to conduct training on residential or commercial energy efficiency and green building skills, renewable technology implementation and maintenance, and other trades directed skills. The Northern Marianas College (NMC) provides critical business development skills and could provide more advanced accredited education and training opportunities such as energy audit training, either individually or in conjunction with the University of Guam.

Lastly, the CNMI already has several renewable energy focused private companies as well as interested citizens, both of which will play a key role in developing an active industry on the islands. Any strides in this area will require the training and retraining of individuals in green building techniques, home energy auditing, and energy efficiency retrofit or new construction, and renewable energy installation and maintenance. Many of these skills can be applied through traditional vocational training programs combined with apprentice programs while others must be conducted by accredited programs that provide associate and other certificate degrees.

4.1 Next Steps

1. The Energy Task Force Education subcommittee should determine opportunities, resources, and curricula available to offer increase energy education within the existing K-12 courses.

2. Determine needs, opportunities, resources, and curricula available to incorporate energy efficiency and renewable energy training into vocational classes at the NMTI and degree programs at NMC.

5 Summary of Recommendations and Conclusions

The site visit and subsequent research on the CNMI's energy efficiency and renewable energy opportunities resulted in a basic, preliminary overview to provide the Energy Task Force with a set of opportunities and next steps. The areas of opportunity that have been identified are based on this preliminary review and further investigation or consultation may be required before undertaking some of the recommended next steps. The key opportunities, potential steps for policy, and concluding points are summarized in this section.

5.1 Key opportunities

Examples of energy efficiency and renewable energy opportunities to include in strategic planning or for further consideration are summarized below.

General

- Based on existing overall baseline energy use, set priorities and develop specific goals to reduce overall fossil fuel consumption. Energy efficiency and conservation efforts should be at the forefront of this discussion.
- Develop a strategic energy plan. The plan should include an implementation strategy for near-term opportunities such as those identified in this report, as well as approaches for further feasibility analysis to identify and implement longer-term opportunities.
- Review policies, programs, and regulations for energy efficiency and renewable energy targets. The CNMI has several energy related policies currently in place, and programs should be developed to effectively carry out the intent of the policies.
- Conduct a transportation assessment to determine fuel usage, analyze options, and identify transportation fuel reduction and/or renewable strategies.

Energy Efficiency

- Provide educational materials to address specific information and outreach needs. Flyers, posters, and stickers can be designed that could be distributed among the appropriate building sectors.
- Provide training courses and materials for both architects and workers in the construction sector to improve energy awareness and responsible practices. Energy efficiency in retrofit, renovation, and new construction can be integrated into the construction process terms of planning, design, materials, and equipment.
- Create a cool roof program by identifying potential buildings that can be used as pilot projects, carry out demonstration projects, and publicize results to encourage replication.
- Perform energy and water audits and utilize the results to benefit the entire building portfolio. Develop residential audit programs or incentives to encourage energy conservation and efficiency in homes.
- Create guidebooks and self-assessment checklists. These guidebooks could be designed as stand-alone products for specific sectors or integrated into the training courses described above.
- Evaluate and consider alternative cooling technologies such as green roofs and solar air-conditioning. Evaluate results of sea-water cooling assessments for the hotel sector on Guam to determine if an assessment would benefit the CNMI.

Renewable Energy

- The CNMI Energy Task Force should work with CUC, Department of Land and Natural Resources, and Department of Public Lands to identify available land area for renewable energy development. This should consider zoning, avian, and other environmental considerations, and may require input from US EPA and USFWS.

- To determine if a geothermal resource exists on Saipan, pursue efforts to drill one or more geothermal temperature gradient holes 2,000 to 3,000 feet deep to verify the presence of heat at economically viable depths.
- Conduct wind anemometry studies at the locations identified in this report and analyze results to determine wind energy potential. This should be followed by a detailed feasibility and economic assessment of the best project sites, including a grid interconnection study.
- Conduct a feasibility study for solar PV installations. Consider including a PV grid interconnection study as part of this effort.
- Develop solar water heating implementation programs for residential, commercial, and appropriate government buildings.
- Consideration should be given to all alternative fuel potential in the form of WTE, LFG, biofuels, and biomass crops. A waste characterization study is needed to determine waste-to-energy potential, and resource assessments as described in this report should be conducted to determine biomass opportunities.

5.2 Conclusion

There are many opportunities to be found in the CNMI for the adoption of energy efficiency and renewable energy technologies as well as implementation of existing energy policies, standards, and codes that have been outlined in this report.

As a result of the economic impacts of fluctuating energy prices, including the record high price for oil in 2008, the CNMI recognizes the immediate need to address energy consumption and costs. The CNMI is in a unique position to undertake a concerted effort to address current energy and environmental challenges. Due to its geographic isolation, non-renewable resources are extremely limited and subject to large volatility in pricing and availability. Energy security is fundamental to the long-term economic future and sustainability of the Commonwealth. Consequently, creating a stable investment atmosphere remains challenging, while the quality of life for residents and visitors continues to be affected. However, the unique position of the CNMI also offers many natural advantages, as the territory is endowed with diverse sources of alternative energy.

With OIA and NREL assistance, an Energy Task Force has been established by the Governor. The following mission has been adopted as noted in the Energy Task Force Charter for the Commonwealth of the Northern Mariana Islands:

> "The CNMI Energy Task Force (ETF) is charged with development 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 solution for the Commonwealth in the interest of improving quality of life and promoting economic prosperity. It is anticipated that the strategy will be a living document, evolving as potential energy strategies are tested, and therefore beyond creation of the initial strategic plan. The role of the ETF will be to assess the efficacy of energy strategies implemented and to evaluate and recommend new approaches as appropriate."

Five subcommittees of the Energy Task Force have been created and subcommittee chairs have been named Education and Training, Legislation and Policy, Energy Technology, Project Financing, and Business Assessment. Next steps for the ETF include identifying challenges to efficiency and renewable implementation, adding members to each subcommittee as needed, determining priorities, and recommending solutions and strategies to be included in the strategic energy plan.

A strong energy plan begins by surveying the current energy situation and assessing current and future needs. The plan provides analysis and recommendations for appropriate technologies and programs relevant to the local environment while addressing economic viability. It addresses a full range of energy options with a focus on energy efficiency and renewable energy technologies, prioritizes opportunities, and lays out a roadmap for long-term energy security. The roadmap will include actionable implementation strategies to ensure efficiency and renewable energy programs and projects achieve local market adoption and deployment. This will serve as the starting point and pathway to greater energy security and economic sustainability.

Appendix A. Utility Baseline Information

A.1. Saipan Utility Information

Peak Electric Load Profiles

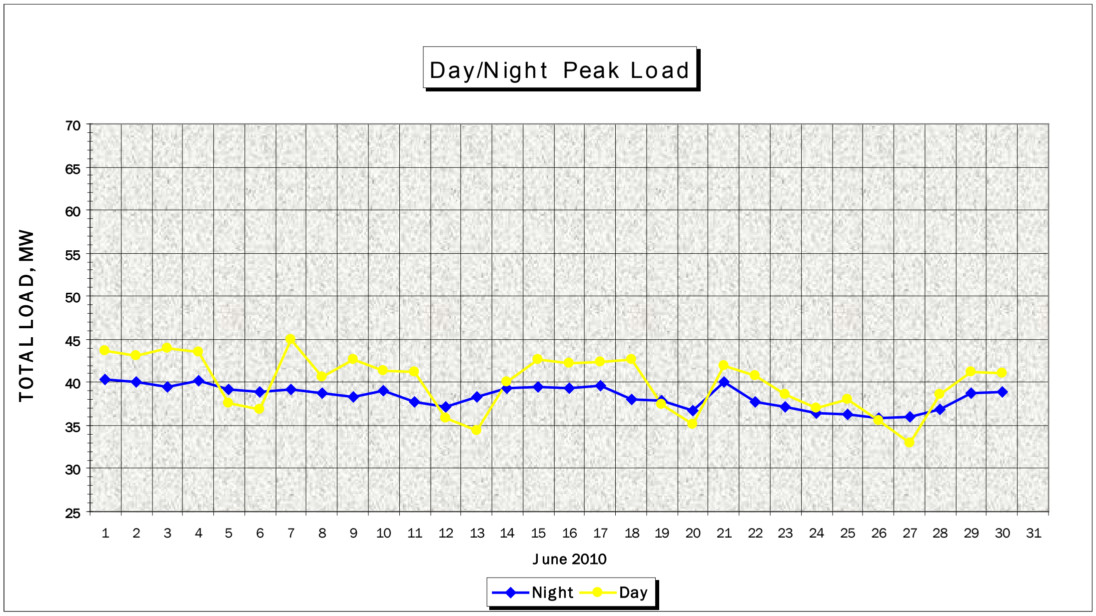

Figure 25. Daily Load Graph - June 2010

Source: CUC

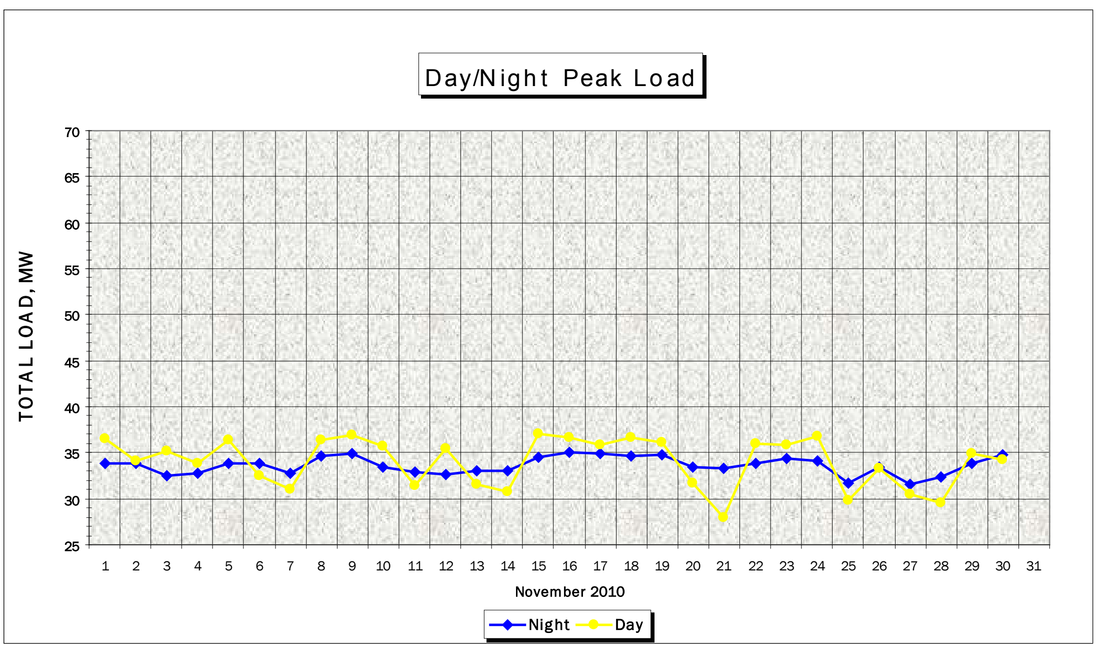

Figure 26. Daily Load Graph - November 2010

Source: CUC

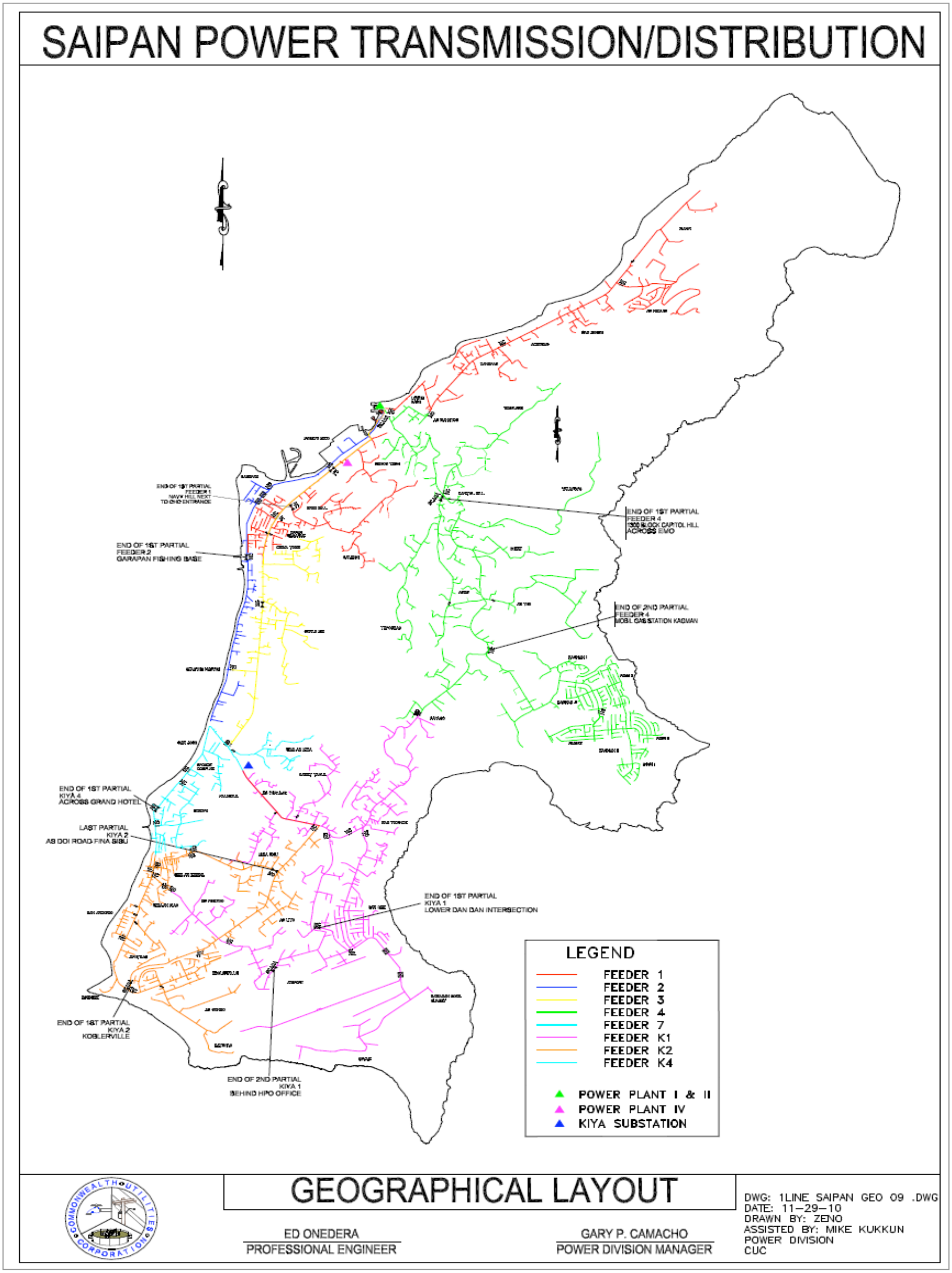

Figure 27. Map of electrical grid on Saipan

Source: CUC

A.2. Rota Utility Information

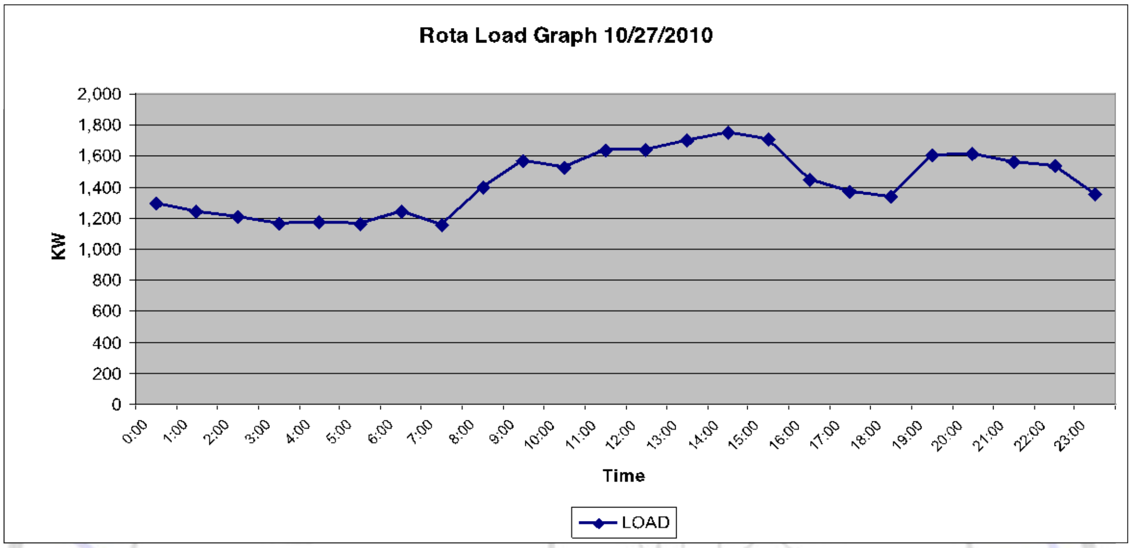

Figure 28. Load Profile

Source: CUC

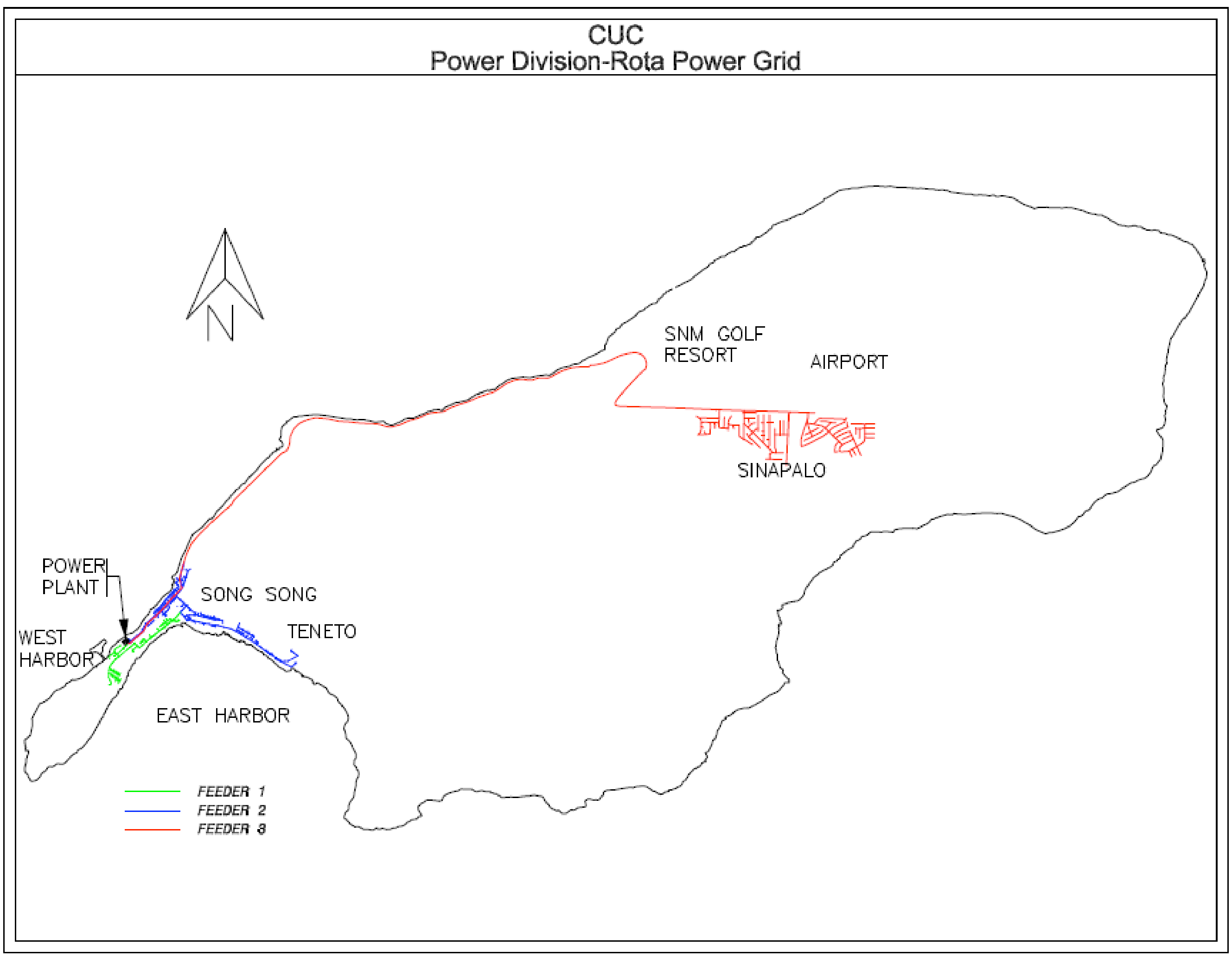

Figure 29. Map of electrical grid on Rota

Source: CUC

A.3. Tinian Utility Information

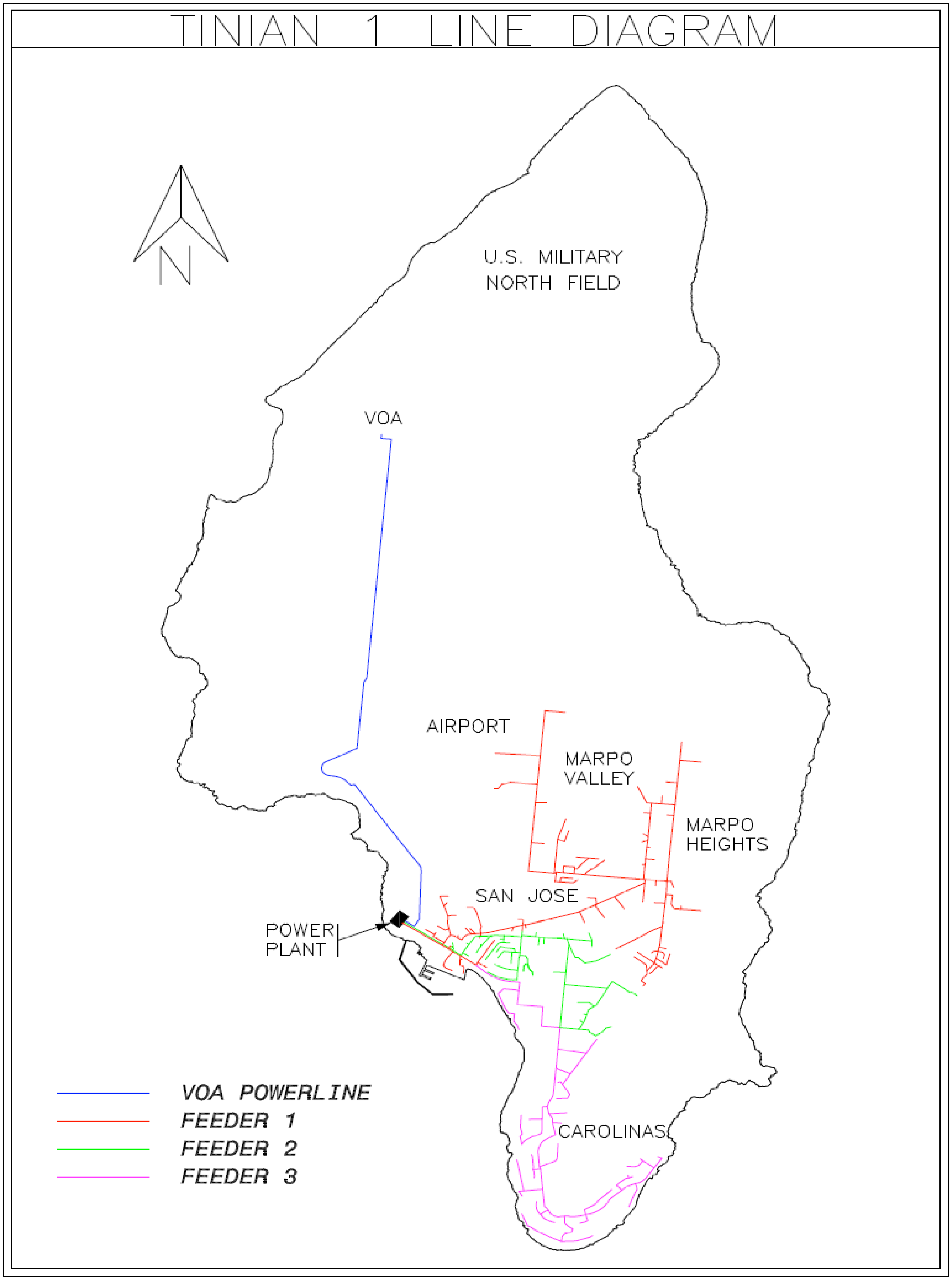

Figure 30. Map of electrical grid on Tinian

Source: CUC

Appendix B. American Recovery and Reinvestment Act

Energy-related American Recovery and Reinvestment Act funding was requested and received from DOE for the State Energy Program, Weatherization Assistance Program, Energy Efficiency and Conservation Block Grants, and the Energy Efficiency Appliance Rebate Program. A summary of the funding by program is provided in the figure below.

American Recovery and Reinvestment Act

U.S. DEPARTMENT OF ENERGY • NORTHERN MARIANA ISLANDS RECOVERY ACT SNAPSHOT

Funding for selected DOE projects: $29.2 million

DOE Recovery Act projects in Northern Mariana Islands: 4

For total Recovery Act jobs numbers in Northern Mariana Islands go to www.recovery.gov

The American Recovery & Reinvestment Act (ARRA) is making a meaningful down payment on the nation's energy and environmental future. Through these investments, Northern Mariana businesses, non-profits, and local governments are creating quality jobs today and positioning the Northern Mariana Islands to play an important role in the new energy economy of the future.

EXAMPLES OF NORTHERN MARIANA ISLANDS FORMULA GRANTS

Program	State Energy Program	Weatherization Assistance Program	Energy Efficiency Conservation Block Grants	Energy Efficiency Appliance Rebate Program
Award	$18.7 million	$29.4 million	$9.6 million	$0.1 million
	The Commonwealth of the Northern Mariana Islands has received $18.7 million in State Energy Program funds to invest in state- and territory-level energy efficiency and renewable energy priorities.	The Commonwealth of the Northern Mariana Islands has received over $29.4 million in Weatherization Assistance Program funds to scale-up existing weatherization efforts in the islands, creating jobs, reducing carbon emissions, and saving money for Commonwealth of the Northern Mariana Islands' low-income families. Over the course of the Recovery Act, the Commonwealth of the Northern Mariana Islands expects to weatherize nearly 200 homes. The program also includes workforce training and education as part of the islands' efforts to develop a green workforce.	The Northern Mariana Islands has received $9.6 million for Energy Efficiency and Conservation Block Grants (EECBG) to develop, promote, implement, and manage local energy efficiency programs.	The Commonwealth of the Northern Mariana Islands has received $100,000 for the Energy Efficient Appliance Rebate Program, which offers consumer rebates for purchasing certain ENERGY STAR® appliances. These energy efficient appliances reduce energy use and save money for families, while helping the environment and supporting the local economy.

Figure 31. Summary of CNMI Recovery Act funding by program

Source: DOE

Recovery Act programs in the CNMI include funding for energy efficiency such as residential CFL exchange, appliance rebates, home weatherization, residential cool roofs, code official training and energy audits for government buildings, and LED streetlight retrofits. Renewable energy funding is provided for small wind and PV systems at K-12 schools, a waste characterization analysis, and PV systems on government buildings. Power generation efficiency is also addressed through implementation of turbochargers and retrofitted generators.

Appendix C. Renewable Energy

C.1. Geothermal Energy Site Assessment and Field Notes, December 6-10, 2010

Among the several renewable energy options being considered by Saipan, and the subject of NREL's evaluation, is the utilization of geothermal resources to generate electricity. Because geothermal is the only potential baseload energy source it is a highly desirable option if the geologic conditions on Saipan support it being economically developed.

Charles Visser, Principal Scientist from NREL's Geothermal Program, visited Saipan in December 2010 to conduct an assessment of the geothermal potential of the island. The objectives of the geothermal assessment trip to Saipan were to:

- Meet with the Commonwealth of Northern Marianas Islands (CNMI) government, utility, private sector, scientific, and water stakeholders to discuss the potential for and to gauge interest in geothermal energy.
- Build on the prior geothermal investigations by Southern Methodist University's (SMU) Geothermal Laboratory and to strengthen collaboration with SMU's efforts by spending time in the field with SMU's Dr. James Quick and to re-sample surface groundwater springs previously sampled (in a dry year) and analyzed for geochemistry by the SMU team in 2008.
- Educate and calibrate the aforementioned stakeholders on Saipan regarding expectations of the geothermal exploration process, outcomes, and risks.
- to bBetter understand the energy, economic, logistical and environmental context for potential geothermal energy development on Saipan.

Saipan Tectonic Setting and Geothermal Potential

Saipan lies on a regional trend of high heat flow associated with the Izu-Bonin-Mariana (IBM) volcanic arc system, an active convergent plate boundary with a subduction zone and the Marianas Trench caused by westward-directed subduction of the Pacific lithospheric plate (Figure 26) The central and northern islands of the IBM arc (from the island of Anatahan, 120 km north of Saipan, northwards) are volcanically active, with an eruption frequency of every five years on average. Saipan itself is not volcanically active, but its bedrock, beneath a blanket of reef limestone, consists of volcanic rock extruded as recently as 13 million years ago. Since that time, the axis of volcanism has apparently shifted tens of miles to the west of Saipan, where submarine eruptions in progress have been observed in deep water on a trend of seamounts about 30 km west of Saipan.

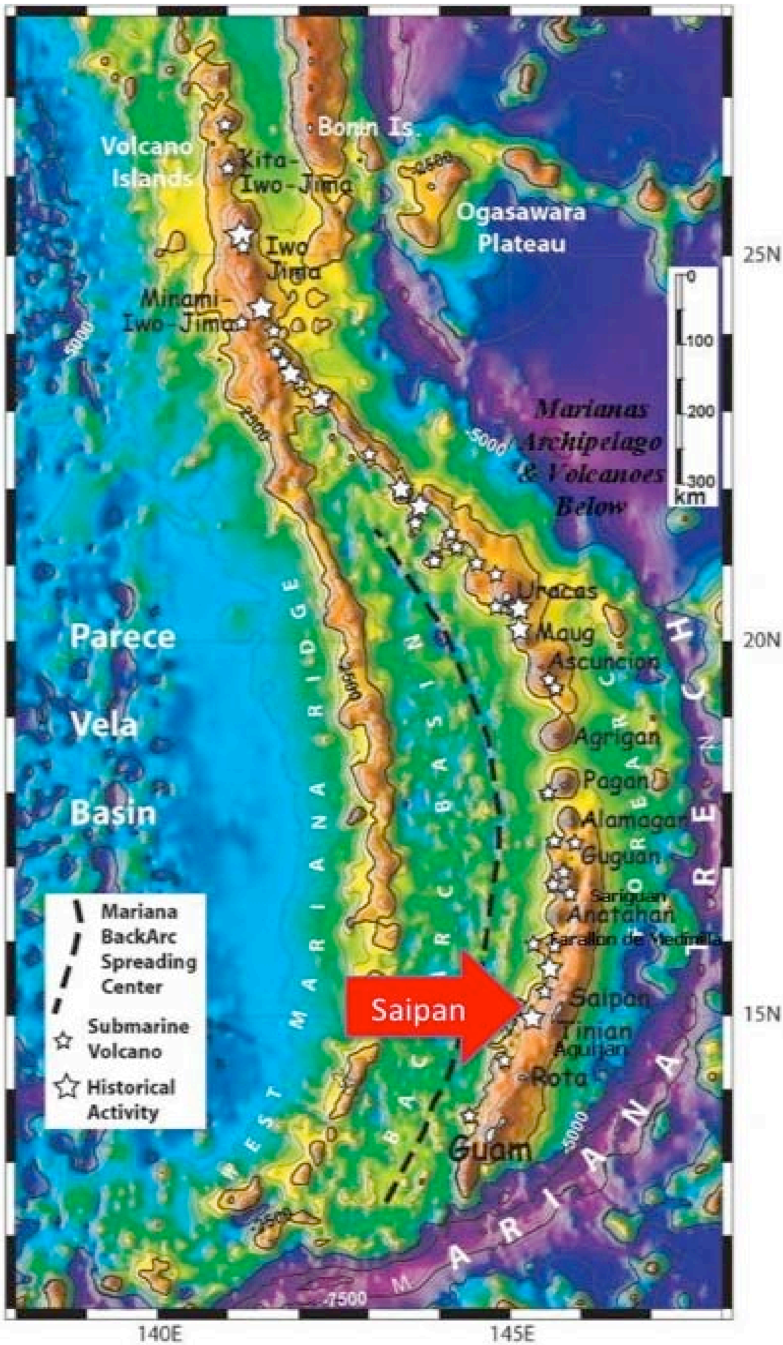

Figure 32. Volcanoes of the Mariana Arc near Saipan

(Note the Submarine Volcanoes located northwest of Saipan)

Source: NOAA, http://oceanexplorer.noaa.gov/explorations/03fire/background/plan/media/marianas.html.

Evidence of Geothermal on Saipan

The island of Saipan (Figure 31) has no obvious surface features suggesting geothermal potential and has never been the focus of an intensive geothermal exploration program. However, a preliminary investigation of Saipan by a team from the SMU Geothermal Laboratory (Richards, et al 2010, in prep.) revealed evidence of elevated water temperatures in existing shallow water wells. This tantalizing evidence of geothermal fluids at shallow depths suggests that geothermal reservoirs could exist at greater depths on Saipan. Certainly, there appears to be enough information to warrant further investigation and exploration for geothermal systems. A crucial step will be to drill one or more temperature gradient holes on Saipan to verify the presence of heat at economically drillable depths.

Figure 33. View of Saipan from the summit of Mt. Tagpochao, elevation 1,554 feet

Source: NREL/PIX 18934

While some may consider the age of Saipan’s volcanic bedrock (13-41 million years) as an unlikely source of geothermal heat, the evidence of elevated temperature in water wells, the proximity of Saipan to active submarine volcanism, widespread hydrothermal activity elsewhere in the IBM arc system, and the strongly extensional tectonic regime of the island arc suggests that favorable conditions for hydrothermal systems at depth may actually exist on Saipan. The lack of near surface evidence of geothermal systems on Saipan (i.e., hot springs, fumaroles, mud pots and steaming ground) is not surprising given the pervasive blanket of young reef carbonates that contain an extensive aquifer fed by much cooler meteoric (rain) water. (Figure 33)

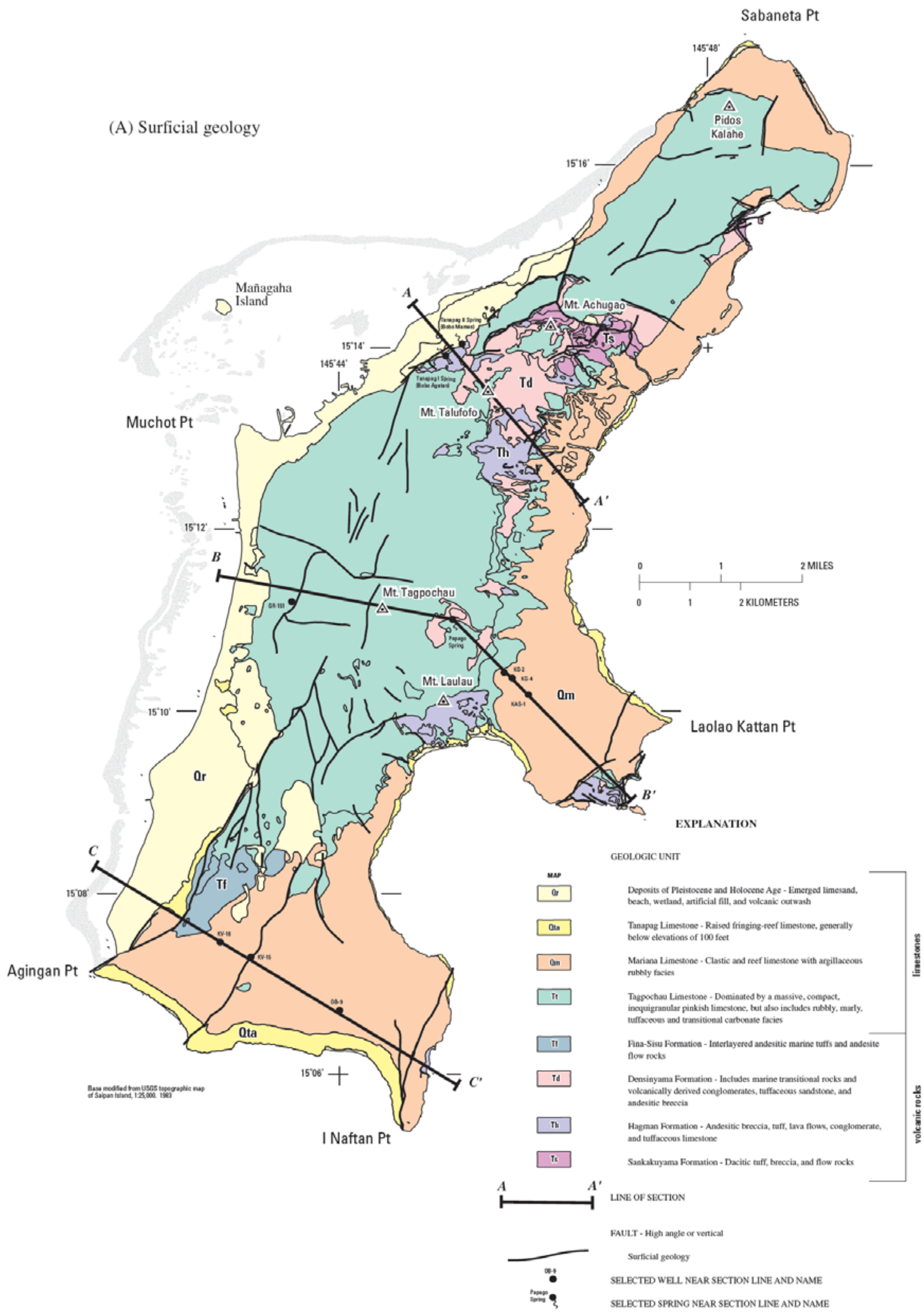

Figure 34. Generalized geologic map of Saipan

(Carruth, 2003) Showing the blanket of reef limestones (green and buff) and the older, underlying volcanic rocks (blue, pink, rose, and purple)

Source: U.S. Geological Survey, http://pubs.usgs.gov/wri/wri034178/htdocs/wrir03-4178.html.

December 2010 Field Observations and Assessment

During a five day visit to Saipan, Mr. Visser conducted an overview of the geology and geomorphology of Saipan with the aid of an advance copy of a soon to be published new geologic map of Saipan (Weary 2010.) Mr. Visser also spent one day with Dr. James Quick of SMU visiting sites on the island, exchanging thoughts on the geology and geothermal potential of Saipan, and meeting with select Saipan stakeholders.

Mr. Visser visited the sites of the water wells with elevated temperatures and re-sampled several springs for geochemical analysis that had been sampled by SMU in 2008. Water samples were collected at the following sites whose locations were provided to NREL by the SMU team:

- Susupe Lake - 145.7104 15.1529
- Donni Spring -145.7671 15.1980
- Tanapag I Spring -145.7551 15.2316
- Achugao Spring a -145.7683 15.2353
- Achugao Spring b -145.7678 15.2371

Due to high flow conditions, only one source was sampled in 2010 at Achugao (Figure 29.)

Figure 35. Abandoned structure at Achugao Spring, Saipan

Source: NREL/PIX 18929

Sampling and analysis of spring and well waters can in certain cases provide clues to the presence or influence of deeper geothermal fluids. The SMU sampling had found somewhat elevated silica concentrations in the Achugao, and Donni springs. The SMU team speculated that silica concentrations in the spring waters (and similar silica concentrations measured in the water well with elevated temperature) could be due to faults that allow circulation of groundwater into the silica-rich volcanic rocks that are overlain by the low-silica reef carbonates. Silica values at the Tanapag Spring were about three times higher than the other springs and the well, possibly suggesting a longer flow path or deeper circulation within the volcanic rocks. While none of these observations were especially diagnostic of deeper geothermal activity, NREL resampled several of the SMU sites in order to collect additional data and provide a comparison between a dry season (when SMU sampled in 2008) and a wet season (when NREL sampled in December 2010).

The NREL water samples were sent to the Desert Research Institute in Reno NV for chemical analysis following the same protocol as the 2008 SMU samples. The results are shown in Table 12.

Table 12. Water Analysis Results

Sample Name	Date	pH	EC	SiO2	HCO3	CO3	Cl	SO4	Na	K	Ca	Mg	F	B	Li
			uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
NREL SP1 Susupe Lake	7-Dec-10	8.06	5840	8.6	200	NA	1810	255	931	33.7	122	116	0.11	0.36	0.02
NREL SP2 Tanapag Spr	7-Dec-10	7.90	554	56.4	275	NA	31.4	24.7	34.6	6.33	57.9	15.3	0.15	<0.1	0.01
NREL SP3 Achugao Spr	7-Dec-10	7.84	716	17.2	417	NA	33.6	9.85	20.6	1.11	134	5.06	0.07	<0.1	0.01
NREL SP4 Donni Spr	10-Dec-10	7.67	675	7.8	373	NA	35.1	7.2	21.3	0.80	114	4.40	<.05	<0.1	<.01

The NREL water analyses are very similar the earlier SMU results. Silica concentrations in the Achugao and Donni Springs were somewhat elevated, while the silica concentration at Tanapag Spring was significantly higher.

Status of Geothermal Investigations

As reported by Richards, et al 2010 (in prep.) two water wells drilled in the Gualo Rai area of western Saipan encountered elevated temperatures above what would be expected in the groundwater aquifer. The hotter of the two wells, GR-3, was anecdotally reported to have temperatures “too hot to touch.” The drilling report also mentions that a down hole pump failed due to overheating of the well. (Note: Anecdotal reports of melted PVC pipe in GR-3 were not corroborated by Peter Sasamoto of the Saipan Water Task Force. NREL is attempting to locate original well reports taken by USGS geologist R. Carruth during the drilling of GR-3.) No downhole temperatures were measured in GR-3, and the well was unfortunately (but understandably) plugged because the water contained levels of arsenic above drinking water standards.

Anomalous temperatures were also encountered in a nearby well GR-6, which was accessed by the SMU team in 2008. The SMU team recorded a temperature log that showed temperatures increasing from 27.03°C at 60 m to 33.84°C at 125 m (the maximum depth that could be reached with the temperature probe due to well collapse since drilling.) These data suggest a thermal gradient of 71°C/km, an attractive gradient for geothermal potential if it is sustained with increasing depth.

Elevated temperatures in the two shallow water wells GR-3 (anecdotal report) and GR-6 (verified by temperature logging) provide tantalizing evidence that hydrothermal systems may be present in the volcanic basement rock underlying the carbonate aquifer blanketing Saipan. It is the opinion of Mr. Visser that the blanketing carbonate hydrologic overprint on Saipan is so strong that it is remarkable and fortuitous to even find heat at the shallow depths of these water wells. Both wells lie adjacent to a normal fault, a structural setting that is consistent with a connection to a deeper geothermal system. (Note: Anecdotal reports of two other wells on Saipan with high temperature, both on Mt. Tagpochao, were not corroborated by parties involved in the drilling.)

Next Steps in Saipan Geothermal Exploration

NREL's preliminary assessment is that a geothermal system or systems may exist on Saipan, but the island is presently a high-risk exploration province for geothermal energy compared with other areas of the world with greater surface or subsurface evidence. A 2,000-3,000 foot temperature gradient hole, or a program of temperature gradient holes consisting of one deep and several shallower wells, could provide evidence of an attractive geothermal gradient that would encourage further exploration for geothermal systems on Saipan. Given the huge energy challenge facing Saipan and the potential benefits of geothermal baseload power to Saipan's economy, it is the opinion of the NREL Geothermal Program that an investment in one or more temperature gradient holes on Saipan is well worth the expense to determine whether further exploration should be pursued. In NREL's opinion, it behooves the CNMI to make the strategic investment in temperature gradient holes in the near future, to better inform sound strategic business decisions on whether to invest in geothermal, other alternative energy options, or some combination of solutions. Furthermore, because the private sector geothermal industry is typically averse to taking the large upfront risk of exploration in speculative provinces such as CNMI, it would be to Saipan's benefit to conduct some early stage exploration such as the temperature gradient hole(s) in order to attract private investment if early results are encouraging.

Plans were made in 2008, and an RFP was issued in 2009 by the CNMI to drill a 2,000 foot temperature gradient well using an existing rig on Saipan. A number of logistical problems prevented a temperature hole from being drilled, including the lack of sufficient stands of drill pipe, and ultimately, the lack of funding. Moving in a rig from off island was considered but mobilization costs were challenging. Future planning of temperature gradient drilling on Saipan might consider combining drilling on Saipan and Guam to share the costs of mobilization if an off-island rig is chosen.

The CNMI government's Water Task Force currently owns and operates a Schramm T685WS rotary air drilling rig in apparently excellent condition that may be capable of drilling to depths sufficient for a temperature gradient hole. The rig is rated for 2,000 feet depth, has drilled on Saipan to 900 feet, and appears to be capable of drilling, with some modifications, temperature gradient holes to 2,000 feet. The Schramm rig was observed in operation by Mr. Visser during December 2010 while it was used to drill a water well. The Water Task Force employs a drill crew for three months each year for drilling wells with this rig. The rig manufacturer makes annual trips to Saipan to provide ongoing technical support. Drilling to the maximum depth capability of the Schramm rig would require an upgrade from air drilling to mud drilling equipment, as well as a blow out preventer and surface casing set to protect the vital shallow aquifers from any damage during drilling operations of deeper, potentially hotter, and likely faulted basement rocks. Sufficient drill pipe for drilling depths beyond 900 feet are not presently available on Saipan. Schramm has advised the Water Task Force that a polymer mud system, also not currently available on Saipan, would be used to control lost circulation in the carbonates.

Experience has shown that in some cases gradient holes deeper than 2,000 feet, and a set of several holes, are required for reliable assessment of the geothermal gradient because the geology, rock type and fluid temperatures can and often do vary laterally. A single well to 2,000 feet appears be sufficient to penetrate far enough in the volcanic rocks below Saipan's carbonate blanket to measure the background geothermal gradient. However, the risk of drilling a shallower 2,000 foot gradient hole, and indeed the risk of drilling only a single temperature gradient hole to evaluate an area the size of Saipan, is that a single well might not be representative of the background geothermal gradient. The strategy for temperature gradient drilling on Saipan must weigh the risk of a "false negative" result from a single shallower well against the added cost of drilling more and deeper wells, along with the incremental cost to drill additional wells.

Geothermal Potential Elsewhere in the CNMI Region

The NREL assessment focused solely on the geothermal potential of Saipan, as it is the most populated island in the CNMI chain. No specific assessment has been attempted for the geothermal potential of the volcanically active but uninhabited islands to the north, where evidence of near surface heat is ample, but which would pose very challenging transmission issues due to distance from Saipan and the great water depth between the islands. Some brief observations are added for regional context.

The SMU team conducted a preliminary assessment of the active volcanic and uninhabited island of Pagan, located approximately 400 km north of Saipan. Pagan has been shown by the SMU team to have very favorable surface evidence of geothermal systems, and extensional faulting. It is likely that other active volcanic islands in CNMI, the closest to Saipan being Anatahan Island, have attractive geothermal potential as well.

A preliminary assessment of the geothermal potential of Guam was conducted in earl 2010. Guam is located on the IMB island arc 200 km south of Saipan, and has no surface evidence of geothermal. Guam's geology resembles Saipan's, with a carbonate hydrologic blanket over older volcanic basement rocks, and active submarine volcanism ten of kilometers offshore to the west. There is anecdotal evidence of steam emanating from a limestone quarry (Sabin, Alm, Visser and Bedard 2010, unpublished report) that provides some encouragement for further exploration for hidden geothermal systems. Guam has equally profound dependence on costly fossil energy and urgent need for renewable energy alternatives. In the opinion of NREL, Guam, like Saipan, warrants further investigation of its geothermal potential, including the early drilling of temperature gradient holes to inform strategic decisions on future investments in energy alternatives.

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2010 GSA Denver Annual Meeting (October 31 –November 3, 2010). Paper No. 108-11.

C.2. Geothermal Power Generation – Assessing Resource Potential

Evaluation of the Geothermal Potential of Saipan
A Path Forward

Charles F. Visser
National Renewable Energy Laboratory
May 18, 2010

The NREL Geothermal Team submits the following guidance to CNMI and OIA regarding a path forward in assessing the geothermal potential of Saipan, scaled to an assumed project funding level of $1 million enabling a temperature gradient drilling program to advise future decisions on the pursuit of geothermal energy on Saipan. We have integrated the suggestions of Dr. James Quick of SMU.

The recommended path forward consists of drilling a minimum of one temperature gradient hole (TGH) on the island to measure the geothermal gradient. Shallow water well drilling on Saipan has provided tantalizing evidence of anomalous heat at shallow depths that could indicate the presence of geothermal resources on the island. Deeper temperature gradient drilling is the essential next step to verify whether the temperature gradient on Saipan holds promise for economic geothermal development. As a currently inactive volcanic center with volcanic rocks dating several million years old, there is a risk that Saipan is relatively cool at depth and does not host geothermal systems. However, the elevated temperatures observed in shallow water well drilling, together with Saipan's proximity to the active offshore volcanism to the west, suggest there is a basis for optimism that a potential geothermal heat source exists beneath Saipan at economically reachable depths.

A typical TGH program conducted by the geothermal industry over an area the size of Saipan would include multiple TGH wells. A single TGH hole on the island, which is probably the most that can be expected to achieve under a $1 million program, entails some risk of yielding false negative information (locally cool temperatures.) However, it is the judgment of NREL and Dr. Quick that there is a high probability that a single TGH to 2,000-3,000 feet will provide a reliable indication of the background gradient and provide CNMI with a sound basis for deciding whether to pursue a more extensive geothermal exploration program. Nonetheless, if two TGH wells could be squeezed into the program or funding can be acquired to enable multiple TGH wells, it would be preferable.

With a minimum of one TGH as the critical objective, the following path forward is suggested:

1. Define the target depth and location of a TGH well designed to penetrate below Saipan's shallow limestone aquifers to measure the background geothermal gradient within the deeper volcanic rocks with reasonable certainty.

   If the volcanic rocks underlying the reef limestone cover of Saipan are generally impermeable, as we expect them to be, a 2,000-3,000' TGH is very likely sufficient to measure a representative regional temperature gradient. While there are places in the world where fluids at this depth are mixed with meteoric (surface) waters, obscuring the background temperature gradient and possibly providing false negative information about the geothermal potential, our opinion is that the risk of this outcome with a 2,000-3,000 foot TGH on Saipan is low.

   Selecting a site for the TGH well is not as complex from a geologic standpoint as later siting decisions to evaluate prospective hydrothermal systems. NREL supports the recommendation of the SMU Geothermal Lab, conveyed to NREL by Dr. Quick, to site the TGH at or near one of the water wells that encountered warm water. Other manifestations of hydrothermal activity are virtually nonexistent on Saipan, and constraints from surface geology are so limited that drilling anywhere else would be an absolute shot in the dark. While additional surface geologic and remote sensing work could be conducted, our opinion is that it would ultimately have little impact on the TGH siting decision. Siting could be reconsidered in the event that a multiple TGH program is within the funding scope, but one location will almost certainly be at or near the warm water anomaly.

A typical TGH program would engage a qualified geothermal geologist to participate in the siting decision, to participate in drilling engineering planning, and to participate in field drilling operations and subsequent geologic data interpretation. CNMI has the advantage of prior work and ongoing support from SMU and NREL, which may be sufficient to select a site and to execute a single TGH well (assuming CNMI chooses continued SMU and NREL support during a TGH program, of course.) Regardless, CNMI should consider engaging a fully dedicated consulting geologist to coordinate the geological aspects of the program, especially for the geologic and logging operations and evaluation during and after TGH drilling. These geological support resources would be part of the cost of the TGH program.

2. Evaluate the capability of the existing Water Task Force (WTF) Schramm drilling rig to drill a TGH to 2,000-3,000 foot depth.

   Using the WTF rig is critical to drilling the TGH within the assumed $1 million budget, since mobilization of a rig from off-island is likely to be prohibitively expensive. The rig must be capable of drilling through the shallow carbonate aquifers, installing casing to protect shallow aquifers and isolate them from deeper fluids, and then drill most of the total depth through the underlying volcanic rocks, providing sufficient hole stability to reach target total depth and to allow logging of the hole. Availability of suitable drill stem and casing has been one of the challenges encountered in previous efforts to get TGH drilling underway on CNMI.

   Well logs must include, at minimum, a temperature log. Additional logs are recommended to collect geologic information that will be useful in the event of further exploration. Sourcing quality logging tools and logging support services on Saipan will be an issue and should be investigated early in the program.

   The 2,000-3,000' target appears to be within the capability of the Water Task Force's Schramm drilling rig with some mandatory upgrades. The suitability of the Schramm rig to drill a 2000-3000 foot TGH will need to be verified by a qualified drilling engineer. A drilling engineer must also assess needed rig upgrades and additional equipment required such as the drill stem, a blowout preventer, and casing, most of which will need to be sourced outside Saipan, requiring sufficient lead times before drilling operations.

   This task requires a qualified drilling engineer with experience drilling to these depths, preferably with rig of this type. The drilling engineer must also be experienced in sourcing the required additional equipment from outside Saipan and preparing the rig. CNMI will need to engage this drilling engineering resource and it will be part of the cost of a TGH program.

3. Develop a detailed drilling plan and cost estimate to safely reach the target depth while protecting shallow aquifers (setting surface casing to some depth), to safely protect against any fluid emissions to surface, to collect rock information by sampling and logging to assist future exploration, and to acquire a high quality temperature log to establish equilibrium temperature gradient. The drilling plan must include contingencies for unexpected events and problems during drilling.

   This task requires a qualified consulting drilling engineer, whom CNMI will need to engage, working with CNMI Water Task Force (the rig owner/operator, who is best positioned to understand operational costs of this rig drilling at a Saipan location) and the geological support resources. Schramm, the rig manufacturer, is also a potential resource regarding its capabilities and any needed modifications for deeper drilling.

4. Based on the well cost estimate, fine tune the scope of the TGH program that is achievable within the assumed $1M funding, and revisit site selection if multiple TGH wells are possible.

   This task requires teamwork among the drilling engineer, CNMI government and Water Task Force staff, and the geological support resources.

5. Screen the potential location(s) based on non-geologic factors: access, cost, permitting, environmental impact, and site preparation. These factors will probably have as much or greater impact on the final TGH site(s) location than geology, so this task should begin early in the course of the TGH program.

   This task can best be performed by CNMI-based government and legal resources with experience in site access, land and water/mineral rights ownership, permitting, environmental regulations, and site preparation, with input from the drilling engineer and geological support resources.

6. Proceed with final site selection, permitting, and other pre-drilling logistics including rig modifications, acquiring casing, site preparation, and planning for the TGH logging program including the availability of logging tools and logging support services.

7. Drill the well. Collect geological information (most critically a high quality temperature log) and evaluate results.

8. Decide a subsequent path forward based on the outcome of the initial well. Possible outcomes of the initial TGH well include:

   - Confirmation of a sufficiently high thermal gradient to encourage further geothermal exploration on Saipan
   - Evidence of cold low-gradient conditions at depth that could condemn further geothermal exploration
   - Evidence of a potential hydrothermal system connected to the warm water anomaly that warrants further evaluation (a very unlikely outcome from a single TGH well, given the general complexity of subsurface geology and the coincidence of multiple geologic factors that need to occur to create a hydrothermal system).

   Depending on the outcome, programmatic follow-up could include additional TGH drilling, more extensive surface geologic work, broader exploration on the island using geophysics and other remote sensing, and the drilling of a larger diameter well to evaluate a potential hydrothermal system in the very unlikely event the initial TGH confirmed a potential hydrothermal system connected with the warm water anomaly in the prior water wells.

Depending on the outcome of the initial TGH, the budget for subsequent geothermal exploration and validation activities could vary across a very wide range from zero to tens of millions of dollars prior to verification of an economic hydrothermal system and the decision to develop the system and a geothermal power plant. However, the more promising the temperature gradient and other technical data from the TGH program, the greater the likelihood that the private sector can be engaged by CNMI to carry the risk and cost of geothermal exploration and development.

C.3. Wind and Solar Measurement Equipment

In response to a request from DPW Energy Division, the following description of a wind and solar data collection program was provided in a memo to the Energy Division in December 2010.

Equipment for a CNMI Wind and Solar Measurement Program

The following outlines the basic equipment and concept for a wind and solar energy resource measurement program for Saipan, Tinian and Rota. This plan uses a combination of site specific measurement activities and then the collection of longer term data sets through the instrumentation of existing communication towers on each of the islands. The recommended activities use measurement systems that would be typical for the assessment of a resource of the implementation of utility grade wind and solar energy technology. The data obtained could also be used for the completion of validated solar and wind maps for the islands, allowing better potential for small or distributed wind and solar installations.

This letter report was completed in support of Department of Interior, Office of Insular Affairs funded renewable energy assistance to the government of the Commonwealth of the Northern Mariana Islands.

Saipan:

Due to the size of the island and the load, I would recommend considering two met towers and then at least one measurement site tied to an existing telecommunications tower, such as the ones at the old radar site of on top of Mt. Tagpochao. Although this will be confirmed in the report, I would suggest measurements at two locations using 60 m towers, one in the north on the bluff overlooking the new dump and then the second in the south near the quarry. Although the two potential sites with communications towers are not suitable for the installation of wind, they do provide an exposed location that can provide a longer term reference data set through which other potential sites could be compared.

- 2 x NRG-(or equivalent) NOW System 60 m XHD Calibrated SymphoniePLUS™, High-Visibility Top
- 2 x NRG (or equivalent) 4288 80 m Sensor and SymphoniePLUS logger Kit with a Symphonie iPack CDMA-WindLinx Ready w/PV for a lattice tower to install on current lattice communications towers

Figure 36. Island of Saipan showing potential development and wind measurement sites

Source: Google

Tinian

More limited time was spent on Tinian and a good overview of potential towers locations could not be determined; however several sites do pose promises. Additionally only one tall communications tower was noticed in the southern side end of island and this was almost directly east from the Dynasty Casino at an elevation lower than the ridge directly to the east. Although not the best location, if one of the Voice of America towers could be instrumented (I am not sure if this is possible technically) then this would be an additional location due to their high height. If there are additional telecommunications towers, these should be considered.

- 1 x NRG-(or equivalent) NOW System 60 m XHD Calibrated SymphoniePLUS™, High-Visibility Top

- 1 x NRG (or equivalent) 4288 80 m Sensor and SymphoniePLUS logger Kit with a Symphonie iPack CDMA-WindLinx Ready w/PV for a lattice tower to install on current lattice communications towers.

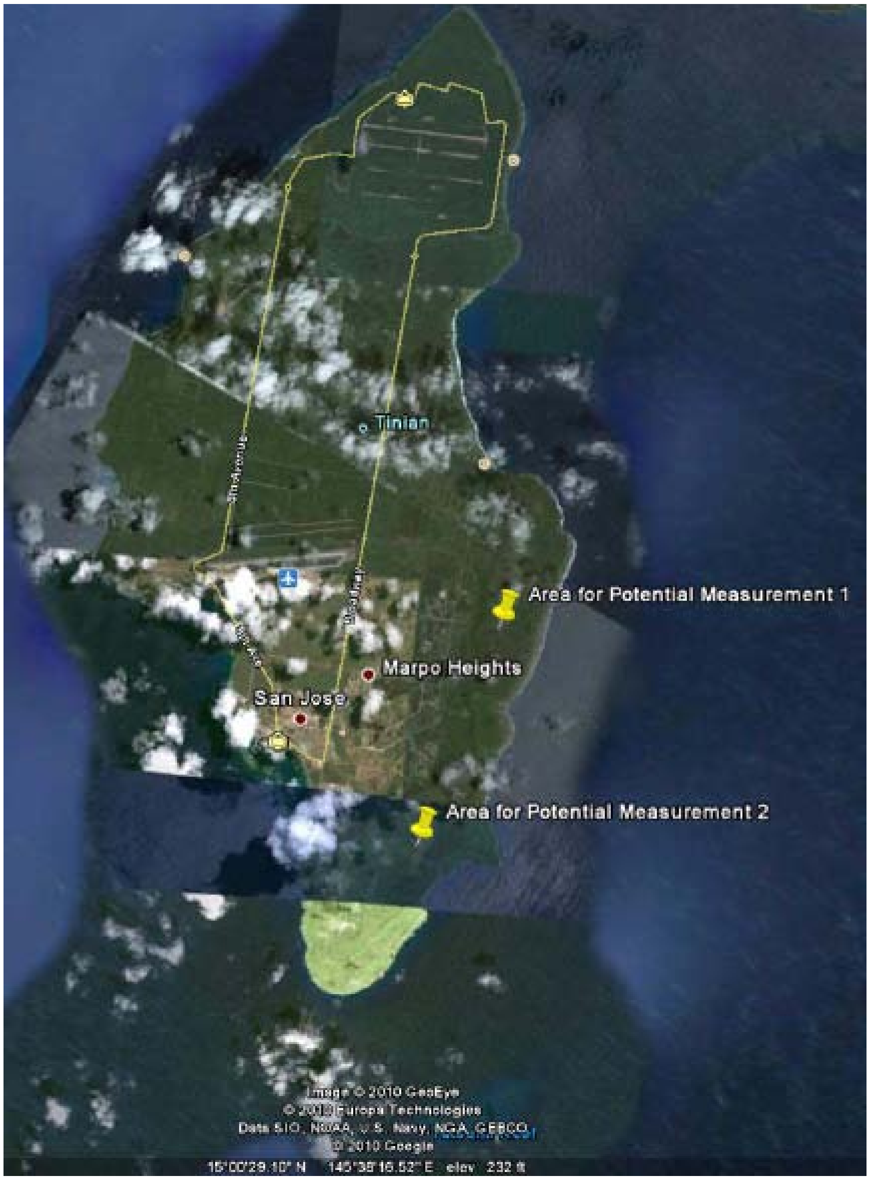

Figure 37. Island of Tinian showing potential development and wind measurement sites

Source: Google

Rota

Rota has more limited locations due to the airports location on the flat, northern end of the island and the small community being developed along then northeast cost. It might also be possible to locate a measurement tower on the high plateau on the southern end of the island, but care would have to be taken in the assessment of a specific location. Since I did not visit Rota I did not have a chance to assess potential locations of existing towers, but assume that there is at least one on a relative high point that may be instrumented.

- 1 x NRG-(or equivalent) NOW System 60 m XHD Calibrated SymphoniePLUS™, High-Visibility Top
- 1 x NRG (or equivalent) 4288 80 m Sensor and SymphoniePLUS logger Kit with a Symphonie iPack CDMA-WindLinx Ready w/PV for a lattice tower to install on current lattice communications towers

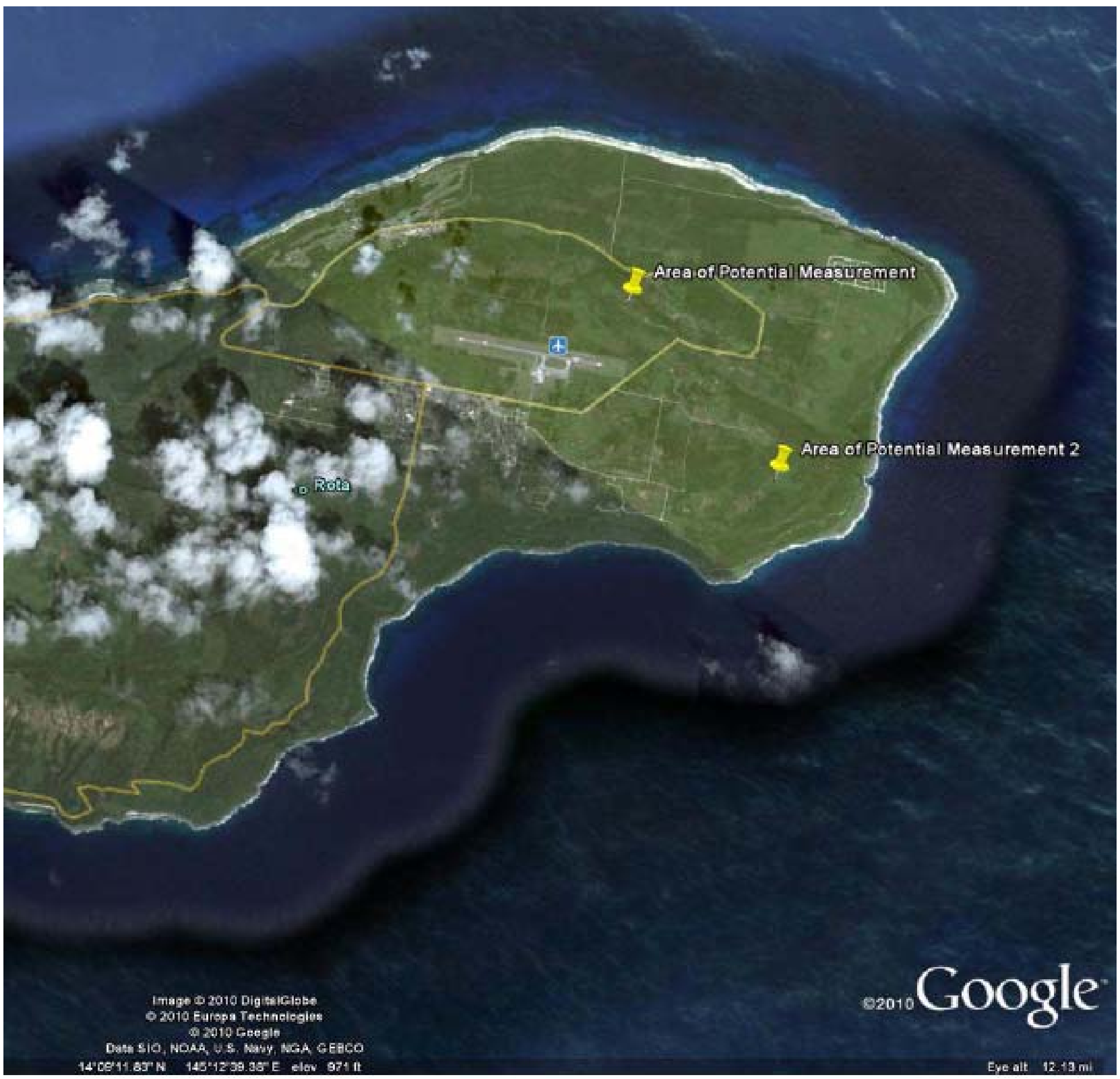

Figure 38. Island of Rota showing potential development and wind measurement sites

Source: Google

Equipment:
The following equipment list has been identified (see next page) but NREL cannot specifically recommend a particular brand, so the following is provided as examples only. Second Wind (http://www.secondwind.com/index.html) has a similar 60 m tower and data logger option. The total cost for the equipment is approximately $115k. Each of these data loggers can be fitted with a cell phone transmitter that would limit the need to visit the site on ~ a monthly basis to collect the data card. In this case I have specified a cell phone systems (and the associated power system to support it) for the four logging systems that would be installed on the communications towers as these will likely be installed for a longer period of time and may become an oversight burden if someone has to visit them regularly. Generally unless some of these sites are going to be very difficult to get someone to visit on a regular basis, I would recommend not using the cell packages on any tower system as having someone visit each tower site on a monthly basis is important.

As we discussed, this equipment does not conform to the new typhoon standard for structures and so to avoid the problems that Guam Power Authority had with installing measurement towers, these should not be classified as permanent structures. My sense is that you install them and if you are unlucky enough to be hit by a major typhoon in the first few years they are up (and they are damaged) you then consider purchasing another one. You could clearly find a tower that would meet the standard, but this would mean a much higher price tag for the project and would end up being similar to taking out a gold-plated insurance policy on an old Pinto.

I would definitely recommend that someone with experience in the installation of tall met towers such as these take part in the installation of these towers as they can be quite dangerous. This would likely include an initial site visit to identify the specifics of the location, such as soil conditions and general siting, and then being at the site during the installation process. Although some companies will provide a complete installation team, I think it makes more sense to work out something with CUC so that only one installation expert needs to come and supervise the installation process.

My feel is that once the towers were installed, visiting the towers to collect the data could be handled by someone from CUC and that someone from your office or the community college could do the data processing. If timing became difficult it is also likely that someone from Saipan could do the data processing, having someone from one of the off island consulting companies do this would likely be expensive.

Table 13. Example Equipment List for CNMI Wind and Solar Resource Assessment

Name	Product number	Cost	Number	Total	Notes	Reference
NRG-NOW System 60m XHD Calibrated SymphoniePLUS™, High-Visibility Top	4476-4292-4200	18100	4	$ 72,400	2 sites on Siapan, One site on Tinian & Rota	http://www.nrgsystems.com
80m Sensor and SymphoniePLUS™ Logger Kit for Lattice Tower	4288	5990	4	$ 23,960	2 sites on Siapan, One site on Tinian & Rota	http://www.nrgsystems.com
Symphonie iPack CDMA-WindLinx Ready w/PV	4601	1440	4	$ 5,760	Installation with all communications tower sites	http://www.nrgsystems.com
Li-Cor #LI-200SZ Pyranometer	1948	465	3	$ 1,395	Solar measurement on each island	http://www.nrgsystems.com
Boom-Pyranometer/Antenna, .52m(20.5"), Galvanized, with Clamps	3902	90	3	$ 270	Boom for Paranometer	http://www.nrgsystems.com
Symphonie SCM Card for Licor Pyranometer (LI200SZ)	3154	39	3	$ 117	Card for Paranometer	http://www.nrgsystems.com
InstallKit for 60mHD, 60m/50m XHD TallTowers	3931	8000	1	$ 8,000	For installation	http://www.nrgsystems.com
Windogropher	Professional	1800	1	$ 1,800	Data analysis software	http://windographer.com
				$ 113,702		

Similar equipment is also available from Second Wind (http://www.secondwind.com/index.html).