Guam

Energy Baseline Report

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Guam: 2023 Energy Baseline Report

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National Renewable Energy Laboratory

Strategic Partnership Project Report
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List of Acronyms

BESS	battery energy storage system
Btu	British thermal units
CCU	Consolidated Commission on Utilities
DER	distributed energy resource
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
GEO	Guam Energy Office
GPA	Guam Power Authority
GTA	Guam Transportation Authority
LEAC	levelized energy adjustment clause
kW	kilowatt
kWh	kilowatt-hours
Mb/d	million barrels per day
MW	megawatt
MWh	megawatt-hours
PAG	Port Authority of Guam
PCU	Public Commission on Utilities
PV	photovoltaic
RE	renewable energy
ULSD	ultra-low sulfur diesel

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Executive Summary

Guam is a U.S. territory in the western Pacific Ocean with a population of about 154,000 residents and currently an additional 22,000 military personnel. The economy is primarily driven by tourism, the U.S. military, and local small businesses. With no indigenous fossil energy resources, Guam is reliant on imported fuel for their energy and transportation needs, with most of the imported fuel coming from Asia.

The Guam Power Authority (GPA) is a public-power utility and autonomous agency of the government of Guam. GPA generates, distributes, and sells retail electricity, but has been moving away from owning generation, instead opting to contract with independent power producers to operate and maintain new fossil fuel and renewable energy power plant facilities. GPA serves nearly 58,000 customers, with the U.S. Navy being the largest single customer, representing 20% of Guam's energy load, a number that is quickly growing. Electricity costs in Guam are almost double the U.S. national average, although somewhat lower than other islands in the Pacific. The average retail electricity cost in 2022 was nearly $0.35/kWh, inclusive of a fuel surcharge that can be adjusted every six months based on the market fuel price.

GPA has over 400MW of installed diesel power generation capacity, but due to typhoon damage and age of its generation fleet, only 272MW is currently available. Typhoon Mawar struck in May 2023, causing 98% of customers to lose power. And currently, the utility is still implementing scheduled rotating outages across the island and an interruptible load program for large customers in order to manage demand. To harden against future storms, GPA has made progress in undergrounding distribution power lines and, in locations where undergrounding is not feasible, replacing wooden utility poles with stronger, more wind-resistant steel or concrete poles.

In addition to increasing the resilience of its power system, Guam is also seeking to increase utilization of renewable energy sources to reduce reliance on diesel powered generation. This goal was codified when Guam's legislature passed a Renewable Portfolio Standard (RPS) in 2008 which was updated in 2019, establishing a goal of meeting 50% of net electricity sales from renewables by 2035 and 100% by 2045. The territory has strong solar and some wind resources that create the potential for cost-effective renewable power generation and use of solar photovoltaics (PV) has grown over the past decade, providing 11% of the island's electricity in 2022. GPA has recently awarded a contract to add another 41MW of solar PV and is currently reviewing proposals from independent power producers for several other significant PV installations. All utility-scale PV systems must include battery energy storage systems to mitigate intermittent power issues and provide stability for the electric grid.

The following energy-related challenges are identified by the report authors:

- For the Guam community, the concerns include high costs of electricity, power factor issues, and frequent rotating outages.
- Guam's exposure and vulnerability to extreme tropical storms is a regular threat. Damage from Typhoon Mawar in 2023 has reduced available power capacity and delayed construction of a 198MW base load power plant.

- Due to geographic isolation and lack of local energy supply, Guam depends on imported fossil fuels to meet all its energy needs. Liquid fuel supply chains are vulnerable to physical, political, and cybersecurity threats as well as market conditions, which can result in supply uncertainty, price volatility, and high energy costs.

- GPA is challenged by the need to retire power plants while reliably and affordably delivering power to its customers. The settlement of an EPA Clean Air Act violation requires GPA to retire older fossil-based generating plants while the RPS mandates a transition to renewable energy supplied electricity. Meanwhile, growth of customer-sited DER can impact existing circuits and require infrastructure upgrades.

- The U.S. Navy currently represents 20% of electricity sales, and military base expansion plans are not complete, leaving GPA uncertain to potential increases to peak demand and impacts to electric distribution system infrastructure. This may also leave the Navy uncertain to their total power needs and the sources needed to address them.

1. Introduction

This report summarizes the currently available data on Guam's energy sector as of December 2023. It describes primary energy consumption, end uses, energy production, relevant policies, and key challenges, including details on the electric power and transportation sectors. The report serves as a baseline of understanding to assess Guam's island-wide energy needs and priorities.

Guam, which became a U.S. territory in 1898, currently has a population of about 154,000 people plus approximately 22,000 U.S. military personnel and their families (U.S. Energy Information Administration 2023a). The Pacific island, located about 5,800 miles west of San Francisco and 1,600 miles east of Manila, Philippines, has no indigenous fossil energy resources (petroleum, natural gas, or coal). Its geographic position makes it a trade and U.S. military hub, but also presents challenges to energy supply (and therefore costs) and disaster recovery. The 2022 peak electric demand was 260 MW and electricity sales was approximately 1.5 MWh (Ernst & Young LLP 2022). See Appendix A-2.5 for historic peak demand. Installed power generating assets are primarily fuel-oil based units, with a combined capacity of over 400 MW. An additional 85.3 MW is currently provided by renewable energy sources with 40 MW of battery power capacity (Benavente 2023). These projects represent a significant increase in renewable energy generation capacity with more renewable energy projects planned. The U.S. Department of Defense (DoD) ,the Guam Government, and the retail and hotel industries represent the largest electricity consumers (Benavente 2023).

The U.S. military alone accounts for approximately one-fifth of Guam's energy consumption (including military housing) (U.S. Energy Information Administration 2023a). The DoD owns about 25% of the 212 square mile island (U.S. Department of Defense n.d.). Military installations include Andersen Air Force Base, Marine Corps Base Camp Blaz, and Navy Base Guam (NBG). Navy Base Guam is the most developed base on the island, occupying about 38,000 acres (U.S. Department of Defense n.d.). Throughout this document, DoD is collectively referred to as the "Navy" as the Navy is the military unit that pays all DoD military unit electricity bills. The Navy relies exclusively on GPA's grid (aside from backup generators). They continue to implement various energy efficiency projects for buildings to reduce their energy use and cost. At the same time, the military is adding facilities, planning to add defense systems, and is subject to Federal legislative and Executive Order requirements for energy efficiency, renewable energy, and vehicle electrification. While the extent of their expansion plans is uncertain, this will have a large impact on Guam Power Authority's peak load.

Apra Harbor, the island's main commercial port, has historically served as an important Pacific port since the 16th century while under Spanish rule. The island was acquired by the United States in the Spanish-American War (Port Authority of Guam n.d.). The U.S. federal government transferred the commercial port facilities to the Guam government in 1968, under the management of the Guam Port Authority (established by Public Law 13-87 in 1975), and continues to maintain naval and air force installations on the island (Port Authority of Guam n.d.). Apra Harbor continues to serve as a critical air and maritime transportation hub linking the Pacific Islands, the United States mainland, and East Asian markets (Port Authority of Guam n.d.). The island is also served by the Antonio B. Won Pat International Airport.

The north-central area around Dededo is the most densely populated part of the island, with the southern portion sparsely populated. The island sits along the southern edge of the Mariana Trench with high volcanic and seismic activity, a tropical marine climate, and stable warm and humid temperatures. A rainy season from May to November brings typhoons and associated hazards. Super Typhoon Paka struck Guam in 1997 setting one of the world's highest recorded wind speeds at 230 miles per hour (U.S. Energy Information Administration 2023a). Figure 1 illustrates the island's key geographic features, settlements, and ports of entry.

Natural hazards common throughout the region include earthquake, tsunami, tropical cyclone, wind, flood, heat, and storm surge. Climate change is already impacting small islands, and emissions models predict that it is likely to continue through the 21st century (Intergovernmental Panel on Climate Change 2023). As a result, Pacific islands will likely experience impacts of climate change including ocean warming, extreme heat, sea level rise, storm surge, coastal erosion, saltwater intrusion, increasing frequency and intensity of tropical cyclones, heavy rainfall events and flooding, ocean acidification, and biodiversity loss. These and other hazards (including accidents or attack) place energy systems and supply chains at risk.

On May 24, 2023, Typhoon Mawar passed across the northern part of Guam with sustained winds of 130+ mph and significant storm surges resulting in power loss to 98% of customers. About 93% of power was restored as of June 30, 2023 (Guam Power Authority 2023a). Scheduled rotating outages were used to manage grid stability during generator repairs, and as of writing, one-hour rotating outages across the island and an interruptible load program for large customers remained in place for periods when demand exceeds generation capacity. Utility-scale photovoltaics (PV) and the associated battery energy storage systems (BESS) survived the typhoon with little damage; some distributed rooftop and ground-mounted PV also survived well while other distributed systems did not. Also, as a result of the storm, the completion of the new Ukudu power plant will be delayed by up to 14 months, as will retirement of the old Cabras power plants. Guam Power Authority (GPA) estimates that damage and delays could cost GPA up to $12 million to get the new plant completed (Cruz and San Nicholas 2023).

This report is organized into seven sections: the first section provides an overview summary of Guam's energy sector. Sections two and three dive deeper into the power and transportation sectors respectively. The fourth section outlines the current energy policy landscape in the territory and known progress toward goals. Finally, key challenges are addressed throughout the report and summarized in section six. The report concludes with key takeaways, limitations, and areas for future study.

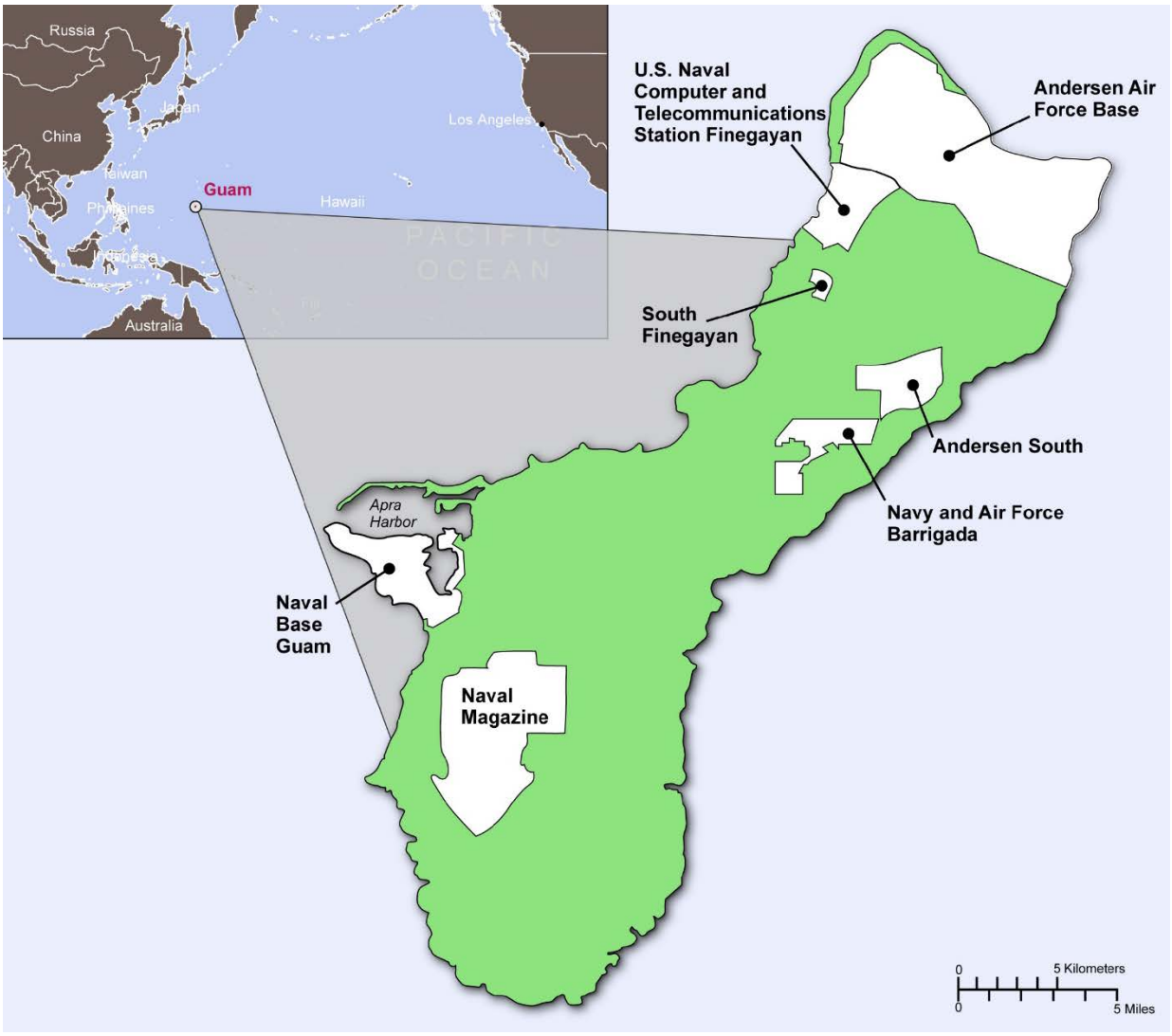

Figure 1. Map of Guam

Map from U.S. Government Accountability Office (U.S. Government Accountability Office 2017)

2. Energy Sector Overview

This chapter provides a high-level overview of primary energy consumption, power sector generation capacity, transportation sector fuel use, key energy entities, major end users, and significant energy challenges.

Guam does not consume coal, natural gas, or nuclear energy (U.S. Energy Information Administration n.d.-e). It also does not produce or refine petroleum or other liquid fuels (U.S. Energy Information Administration n.d.-c), and thus, all petroleum consumed on the island is imported. Historically, power-sector fuel consumption represents between 51-76% of fuel consumption (although in 2021 power generation represented nearly all on-island fuel use, likely as a result of COVID-19 impacts on the tourism industry) (see Table 1).

Table 1. Fuel Consumption 2017 to 2021 (Thousands of Gallons)

	2017	2018	2019	2020	2021
Total Fuel Sales Reported[1]	155, 178	156,241	192,024	192,297	123,936
Guam Power Authority Fuel Consumption Reported [2]	118,055	114,506	116,485	113,377	117,046
% of Total Fuel Sales Consumed by GPA	76%	73%	61%	51%	94%

Data source: [1]The Bureau of Statistics and Plans Guam (2022); [2] Cruz and San Nicholas (2023)

Guam Power Authority is the sole electricity provider on the island. Their electricity generation mix is dominated by fossil fuels, with diesel fuel and residual fuel oil accounting for 89% of electricity generation in 2022, although their renewable energy portfolio has been expanding. Approximately 11% of total GPA sales were met by renewable energy in 2022, a significant increase from recent years (see Table 2).

Table 2. Guam Electricity Generation Mix (MWh) Including Net Metering

Fuel	2018	2019	2020	2021	2022
Fossil fuel generation	1,480,468	1,485,482	1,433,052	1,472,035	1,365,526
Renewables generation	72,907	78,955	84,022	86,901	169, 846
Total sales	1,553,375	1,564,437	1,517,074	1,558,936	1,535,372
% Renewables generation of total	5%	5%	6%	6%	11%

Data source: Sablan and Guam Power Authority (2023)

Power sector end use consumption breaks down to 46% commercial and government, 34% residential, 20% U.S. Navy, and 1% street and outdoor lighting (see Figure 2). The island's tourism economy was heavily impacted by the COVID-19 pandemic (U.S. Energy Information Administration 2023a). This translated to reductions in air travel, transportation, and commercial and government energy consumption, along with increases in residential consumption, particularly in 2020 and 2021.

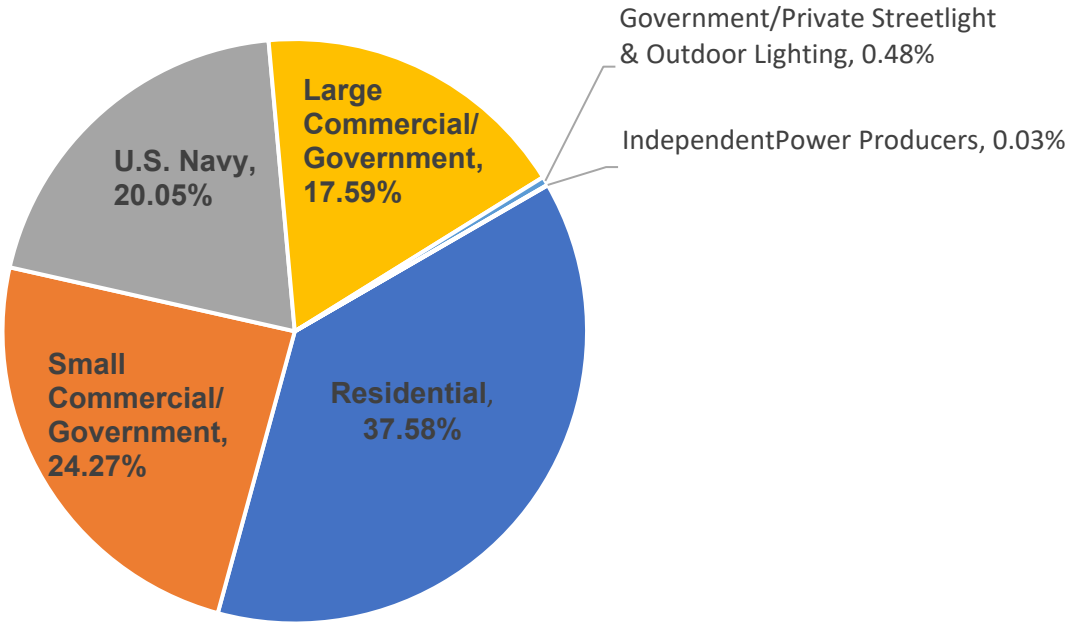

Figure 2. 2021 GPA Energy Sales Composition (MWh)

Data source: Benavente (2023)

Petroleum products are imported from Singapore (37%), Japan (23%), South Korea (18%), Hong Kong (13%), and Malaysia (9%). Figure 3 and Table 3 illustrate the maritime shipping routes for fuel supply chain and average transit time.

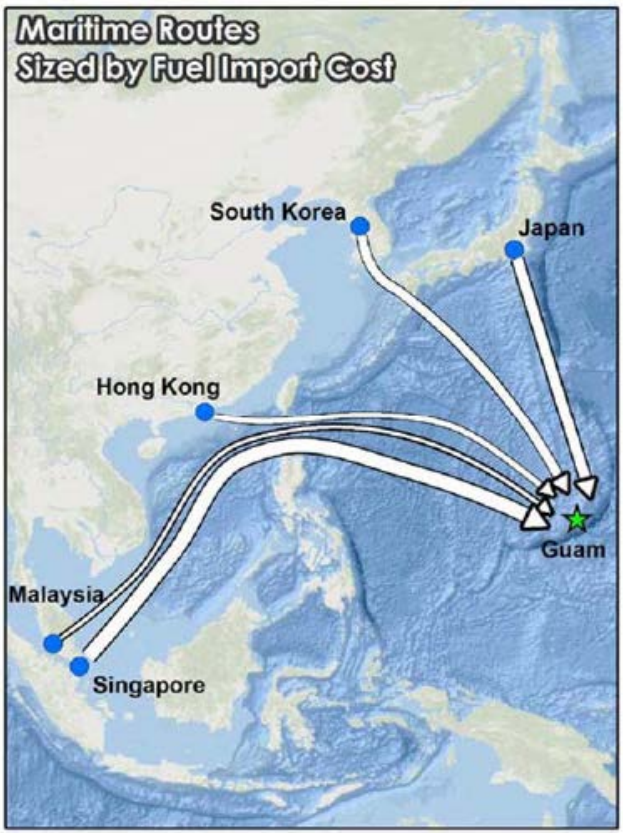

Figure 3. Maritime routes to Guam from various Asian countries

Map from Guam Power Authority (Guam Power Authority 2021b)

Table 3. Sea Shipping Transit Times to Guam

Origin	Transit Time to Guam
Asia	4 - 6 days
Hawaii	7 days
West Coast (U.S.)	13 days

Data source: Guam Power Authority (2021b, Table 16-9)

Energy Sector Challenges

Local spending and investment driven by tourism and military activity helps rank Guam as one of the stronger economies of the Insular U.S. Territories. The U.S. Navy and Air Force have significant land holdings and operations that impact both the economy and energy consumption of the island. As previously noted, the U.S. Navy alone is the island's largest energy consumer, representing 20% of electricity sales (The Bureau of Statistics and Plans Guam 2022).

Like many islands that are dependent on imported fuels and commodities, annual residential electricity spending represents a large portion of annual household income. Table 4 compares the relative approximate household electricity expenditure across the Insular U.S. Territories, Hawaii, and the U.S. average. While Guam's 2019 residential electricity rate of 24.99 cents per

kWh (according to EIA data) may be lower than other areas, its relatively large residential electricity sales bring its relative approximate household electricity burden above Puerto Rico, the U.S. Virgin Islands, Hawaii, and the mainland U.S. See Appendix 4 for details on analysis methods, data sources, and limitations.

Note that the best available data at the time of publication comes from 2019 and does not reflect post-COVID realities. The calculated residential energy burden also does not reflect transportation energy costs. Future studies should seek to improve data collection for improved energy burden calculations.

Table 4. Approximate Baseline Home Electricity Burden for U.S. Territories (2019)[1]

Geography	**Median Household Income** (USD) (2019)	**Average Residential Electricity Rate** (cents per kWh) (2019)	**Residential Electricity Sales** (MWh) (2019)	**Number of Residential Customers** (2019)	**Estimated Average Annual Residential Electricity Consumption** (MWh) (2019)	**Estimated Average Annual Residential Electricity Spending** (USD) (2019)	**Approximate Baseline Home Electricity Burden** (%) (2019)
American Samoa	$28,352	35.26	47,127	10,762	4.38	$1,544	5.45%
Commonwealth of the Northern Mariana Islands	$31,362	25.28	76,795	11,525	6.66	$1,684	5.37%
Guam	$58,289*	24.99***	514,829	44,226	11.64	$2,909	4.99%
Puerto Rico	$20,474	21.43	6,205,152	1,341,424	4.63	$992	4.85%
U.S. Virgin Islands	$40,408	38.75	217,003	46,283	4.69	$1,817	4.50%
Hawaii	$83,102	32.06	2,760,000	438,352	6.30	$2,020	2.43%
U.S. Average	$65,712**	13.01	1,440,288,909	135,249,616	10.65	$1,386	2.11%

Data from U.S. Census Bureau and U.S. Energy Information Administration.

*Median household income for Guam excludes people in military housing units.
** U.S. average does not include the territories of American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, and the U.S. Virgin Islands.
***EIA data in this table differs from other figures in this report. This limitation is discussed in detail in Appendix 4.

[1] This table is meant to provide approximate baseline home electricity burdens for relative comparison purposes. 2019 data are used due to limited data availability for median household income in the U.S. territories. Estimated burden calculations apply only to home electricity use. See Appendix 4 for additional notes on table methodology and data limitations.

3. Power Sector

This section describes the relevant power sector generation, distribution, and regulatory entities. Detailed information is provided about electricity generation, distribution, and patterns of consumption.

3.1 Power Sector: Overview

Guam Power Authority (GPA) is a public power utility and the sole service provider of electricity on Guam (including U.S. military installations) (Benavente 2023). GPA is a component of the territorial Government of Guam. While all power transmission and distribution assets are owned and maintained by GPA, some generating units are owned and managed by private companies through power purchase agreements (Benavente 2023). As a public corporation, GPA is governed by the elected five-member board Consolidated Commission on Utilities (CCU) and rates are regulated by the Guam Public Utilities Commission (PUC) (U.S. Energy Information Administration 2023a), (Benavente 2023).

The island's power transmission and distribution grid includes 29 substations, 204 miles of transmission lines, and 1,650 miles of distribution lines (Guam Power Authority 2021b). Approximately 25% of GPA's customers have underground distribution service lines and nearly all overhead lines have steel or concrete poles (Benavente 2023). Transmission and distribution losses on Guam are estimated to be 4.9% according to the U.S. Department of Energy (2020). This is comparable to the United States as a whole (at 5%) (U.S. Energy Information Administration n.d.-b).

3.2 Electricity Production and Consumption

This section provides details for GPA's electrical production, generation mix, end users, peak demand, expansion plans, rates, and distribution.

Production Capacity and Generation Mix

Guam Power Authority's generating assets are composed of 12 primary generating units for a combined 487.7 MW total generation capacity (Benavente 2023). Table 5 characterizes these units by base load, intermediate, peaking, renewables, capacity, ownership, and year installed; rated capacity does not reflect the variability of available resources therefore operational capacity may be less. Nine primary generating units are fuel-oil based, plus 10 diesel peaking units, with a gross capacity of 402.4 MW. Two renewable energy generating assets are utility-scale solar and one is a small wind turbine for a combined gross capacity of 85.3 MW. GPA also installed 40 MW of battery storage to address underfrequency load shedding and peak shaving. Energy storage systems keep grid frequency stable between 59.85 and 60.15 Hz (Benavente 2023).

Table 5. Guam Primary Power Generating Facilities

	Unit	Year Installed	Owner	Operator	Rated Capacity (MW)
Base Load	Cabras Unit 1	1974	GPA	TEMES	55.0
	Cabras Unit 2	1975	GPA	TEMES	55.0
	Piti Unit 8	1999	GPA	MEC	44.2
	Piti Unit 9	1999	GPA	MEC	44.2
Intermediate	Macheche - CT	1993	GPA	TEMES	20.0
	Yigo – CT	1993	GPA	TEMES	20.0
	Piti 7	1997	GPA	GPA	40.0
	Dededo CT Plant	1993	GPA	TEMES	40.0
	Yigo Diesel Units	2016	GPA	GPA	40.0
Peaking	Diesel Units (10 units)	1993	GPA	GPA	44.0
				Subtotal:	**402.4**
Renewable	Dandan Solar	2015	GlidePath	GlidePath	25.0
	Mangilao	2022	KEPCO	KEPCO	60.0
	Wind Turbine	2016	GPA	GPA	0.3
				Subtotal:	**85.3**
				Total:	**487.7**

Data source: Benavente (2023)

GPA's system is "very dependent on Performance Management Contracts and Independent Power Producers to provide reliable generation" (Guam Power Authority 2021b). Of the 85.3 MW of installed renewable energy capacity, all but 0.3 MW are owned and operated by third parties. GlidePath owns and operates Dandan Solar (25 MW) and KEPCO owns and operates Mangilao Solar (60 MW). TEMES and MEC operate seven of the 12 Authority-owned primary generating units.

Customer-sited DER

Net metering is enabled by several laws and regulations, with rates available for all customer classes, as described further in Section 5. Over 2,000 customer-sited distributed energy resource (DER) systems represent significant assets to Guam's renewable energy (RE) generation. Nearly 22 MW of DER generation capacity accounted for 2.6% of total generation/sales and 23% of total RE generation/sales in 2021 (see Table 6). Growth of net metering impacts 44% of GPA's existing circuits and requires utility infrastructure upgrades (Benavente 2023). GPA estimates that approximately 10% of customer-sited DERs went offline in Typhoon Mawar in May 2023,

based on a review of net metering accounts (Cruz and San Nicholas 2023); the actual extent of damage is unknown as an entire PV system would not need to be damaged or destroyed for the system to stop feeding into the grid. The full extent of grid defection and repair progress is unknown.

Table 6. Electricity Generation (MWh) 2018–2022

Fuel	2018	2019	2020	2021	2022
Net Metering	25,195	30,684	34,059	37,576	40,646
Phase I (GPS/GlidePath)	47,385	48,040	49,643	49,325	50,393
GPA Wind Turbine	327	231	320	-	-
Phase II (KEPCO 60MW)	-	-	-	-	78,223
***Subtotal** Renewables production*	*72,907*	*78,955*	*84,022*	*86,901*	*169, 846*
***Subtotal** Fossil fuels production*	*1,480,468*	*1,485,482*	*1,433,052*	*1,472,035*	*1,365,526*
Total GPA sales	1,553,375	1,564,437	1,517,074	1,558,936	1,535,372
% of total sales from renewable production	5%	5%	6%	6%	11%

Data source: Sablan and Guam Power Authority (2023)

Expansion Plans

Guam's Renewable Portfolio Standard (RPS) was created with Public Law (PL) 29-62 in 2008 and updated in 2019 with PL 35-46, establishing a goal of meeting 50% of net sales from renewables by 2035 and 100% by 2045. GPA's Clean Energy Master Plan (Integrated Resource Plan) roadmaps their potential path to meeting this requirement, identifying 400 MW of new renewable capacity and $230 million in needed upgrades and new technology to meet 50% of demand by 2030. The most recent plan update was approved by the CCU and PUC in 2022 (Benavente 2023). The following four phases are charted to implement the Plan:

- Phase I – GPS/ Clean Capital 25 MW utility-scale solar PV. This project was commissioned in 2015, also known as Dandan Solar, owned by GlidePath.
- Phase II
  - KEPCO Mangilao 60 MW utility-scale solar PV with 32 MWh BESS, commissioned in 2022.
  - Hanwha 60 MW utility-scale solar PV. As of December 2023, this project had concluded downscaling and price negotiations. The expected project is now a 41.4 MW solar PV facility with commercial operation by Dec. 31, 2025, including a 22 MW/66 MWh BESS expected by April 30, 2026.
- Phase III – two 30 MW utility-scale solar PV, cancelled due to bid protest.
- Phase IV – Renewable Energy Resource Acquisition RFP issued December 1, 2022, for a minimum of 60 MW of additional renewable power supply with additional energy storage. GPA may select multiple bids for award resulting in a larger percentage of renewable energy to be integrated onto the grid. As of writing, proposal evaluations are underway.

Figure 4 illustrates GPA's envisioned energy system of the future.

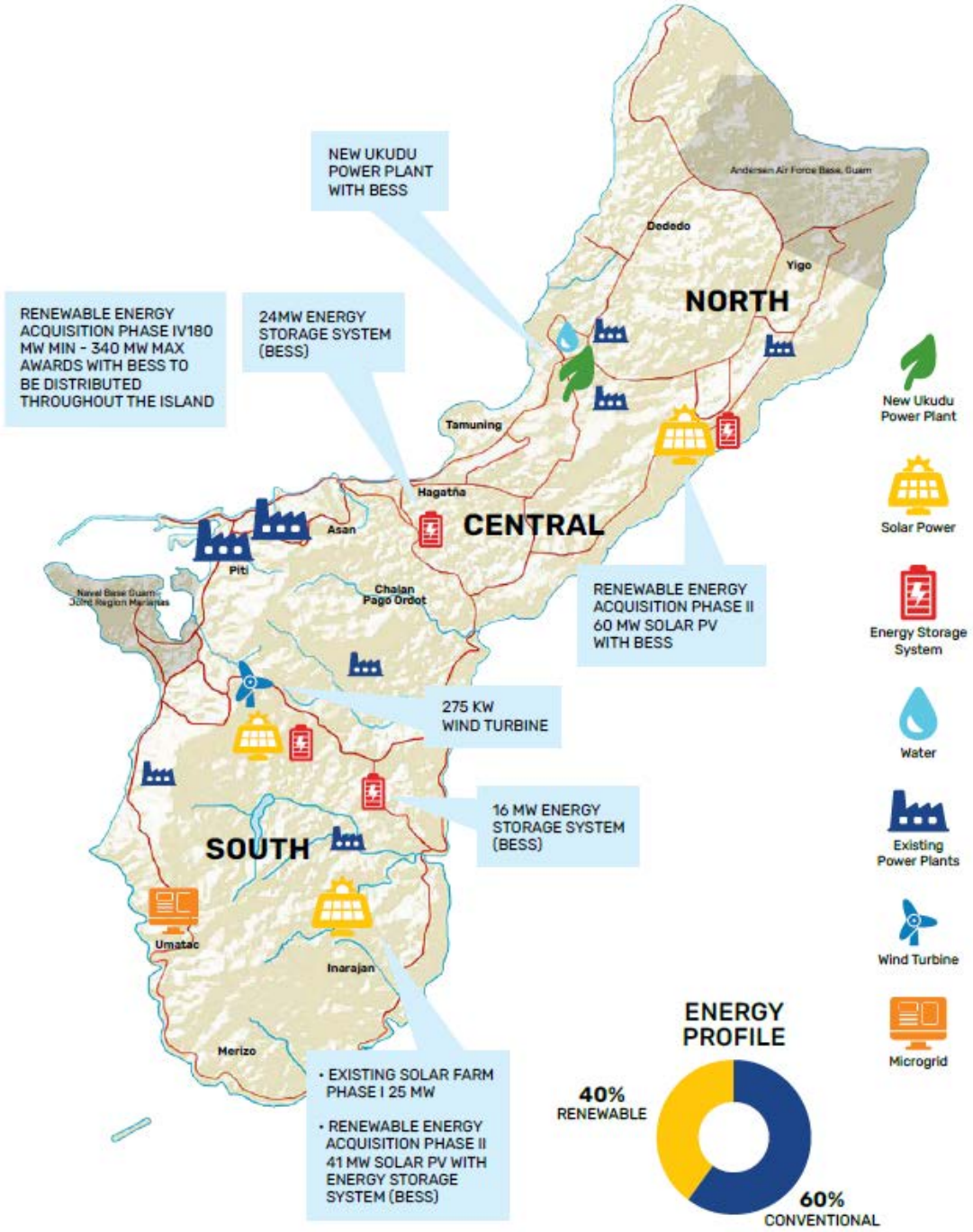

Figure 4. Guam's 2028 island-wide energy future

Map from Guam Power Authority (Guam Power Authority 2022a)

To comply with requirements from an EPA Clean Air Act violation, GPA retired Tanguisson 1&2, is retiring its 48-year-old Cabras fuel oil steam plant, converting Piti 8&9 and RFO delivery systems to ultra-low sulfur diesel (ULSD), constructing the 198 MW ULSD Ukudu plant (also capable of burning liquified natural gas), and planning to add considerable renewable energy and BESS (Benavente 2023). As of 2023, 85.3 MW of the planned solar projects are complete and operational, with the Ukudu plant construction and Cabras 1&2 retirement anticipated to be complete in 2024 (Benavente 2023). However, construction of the Ukudu plant has been delayed by damage from Typhoon Mawar; the timeframe for completion and retirement of the Cabras 1&2 plants is now expected in 2025.

The GPA 2022 Integrated Resource Plan (IRP) notes that GPA must maintain adequate generation capacity reserves, and although it has maintained these reserves, it "still shed load due to unavailability of sufficient generation in 2010" (Guam Power Authority 2021b). While the 2022 IRP reports that since the commissioning of Cabras 3&4, generation insufficiency has not been an ongoing issue, it also reports that load shedding due to insufficient generation did occur on May 14, 2021, and June 3, 2021. Along with the periodic rotating power outages, this highlights the challenge and importance of generation unit operability and reliability as the GPA system evolves into an inverter-dominated variable renewable energy powered system.

Consumption

Guam Power Authority's 2021 sales totaled 1,535,372 MWh, nearly equal to total 2015 sales at 1,536,927 MWh (Sablan and Guam Power Authority 2023). The 2022 peak demand was 260 MW, peaking in May–November (Benavente 2023). A planned reserve margin of 85 MW is maintained (Benavente 2023).

Guam Power Authority reports the U.S. Department of Defense (Navy) as their largest single customer, representing 17.8% of Fiscal Year 2021 total revenue with 311.7 GWh of energy consumption for $57.8 million dollars in sales (Benavente 2023). Power system expansion planning should consider anticipated military growth and impact on peak demand. Although military expansion is underway, there is much uncertainty around those specific plans and increased demand for power. The next largest single customer reported is Guam Waterworks Authority (a public utility), representing 3.9% of Fiscal Year 2021 total revenue with 53.6 GWh of energy consumption for $12.5 million dollars in sales (Benavente 2023). See Table 7.

Table 7. Guam Power Authority Largest Customers, FY 2021

Customer		Industry	Sales (Thousand MWh)	Sales ($MM)	% of Revenue
1	U.S. Dept. of Defense (Navy)	Military	311.7	$57.8	17.8%
2	Guam Waterworks Authority	Utilities	53.6	$12.5	3.9%
3	Department of Education	Government	37.6	$9.5	2.9%
4	Guam Airport Authority	Transportation	21.3	$4.4	1.4%
5	Guam Regional Medical City	Hospital	11.3	$2.2	0.7%
6	Hyatt Regency Guam	Hotel	9.5	$1.8	0.6%
7	Pacific Island Club	Hotel	9.5	$1.8	0.6%
8	GTA Teleguam	Telecom	8.0	$1.7	0.5%
9	Guam Memorial Hospital	Hospital	7.4	$1.5	0.5%
10	University of Guam	Education	6.9	$1.7	0.5%
		Total	**476.8**	**$94.9**	**29.4%**

Data source: Benavente (2023)

According to EIA data, the total number of residential customers in 2021 was 44,748 (U.S. Energy Information Administration n.d.-a). The number of residential customers has risen by 8.5% from 2011 to 2021. Meanwhile, residential sales in megawatt-hours grew by 24% over the same period. In 2011, the average residential customer consumed 11.8 MWh annually, which grew to 13.5 MWh per residential customer in 2021 (see Tables A-2.1–2.3).

The total number of commercial customers in 2021 was 7,516 (U.S. Energy Information Administration n.d.-a, 6). The number of commercial customers grew by 12% from 2011 to 2021. The change in total commercial sale of electricity in MWh over the same period decreased by 14%. In 2011, the average commercial customer consumed 168 MWh annually, which fell to 129 MWh per commercial customer in 2021 (see Tables A-2.1–2.3). It's worth noting that these EIA figures aggregate industrial and government customers into the "commercial" customer class, whereas GPA data is more granular but was not reported over time horizons.

Rates

While electricity prices are subject to global commodities market fluctuations due to reliance on imported fuel, the average price of electricity to end use customers in cents per kilowatt hour decreased from 2011 to 2021 (see Table A-2.4) (U.S. Energy Information Administration n.d.-a, 12). GPA currently provides electric power service under 18 rate classes; Table 8 shows selected GPA base rates across four rate classes. Rates shown do not include fuel recovery or other customer charges which collectively are referred to as the Levelized Energy Adjustment Clause (LEAC). According to the EIA, "GPA imposes a fuel surcharge that can be adjusted every six months to reflect changes in petroleum costs" (U.S. Energy Information Administration 2023a). A full list of GPA rates can be found at https://guampowerauthority.com/rates and LEAC rate adjustments are published at LEAC https://www.guampowerauthority.com/leac.

Table 8. GPA Base Rates by Classes Compared to the United States

GPA Rate Class	U.S. Average as of 2023 (cents/kWh) (EIA)	GPA Customers as of 2023 (cents/kWh) (GPA)	Caps and terms
Residential Schedule "R – Residential Service"	16.14	6.95 plus $15 monthly charge	Up to 200 kWh per day and 500 kWh per month
Commercial Schedule "J – General Service Demand"	12.31	19.67 plus $38.33 monthly charge	Single meter over 200 kWh per day, up to 5,000 kWh per month
Industrial Schedule "P – Large Power Service"	7.75	14.17 plus $59.25 monthly charge	Single meter over 200 kWh per day
Navy/Military Schedule "N – Navy Service"	N/A	0.495 plus $10,990 monthly charge	Not capped

Note: Base rates do not include fuel recovery surcharges and other monthly customer charges.
Data source: U.S. Energy Information Administration (2023b) for U.S. average and Guam Power Authority (2021a) for rate schedules

As noted above, the base rates in Table 8 do not include LEAC fuel recovery charges and monthly customer charges. Thus, the real monthly residential rate is unclear. As of June, 2023, the residential base rate was $0.06955 for the first 500kWh (Guam Power Authority 2021a), the LEAC was $0.231144/kWh (for distribution-level secondary customers) (Guam Power Authority 2024), and the monthly charge was $15 (Guam Power Authority 2021a). The residential LEAC in Guam hit its highest level ever in 2022 at $0.296043, representing over half the residential tariff (Benavente 2023). In July of the same year, residential rates were reported at 34.62 cents, total, including a LEAC charge of 25.62 cents (Benavente 2023). A January 2024 Public Utilities Commission-approved fuel surcharge rate hike of $0.03 per kWh will increase average customer bills by approximately 9% (Taitano 2024).

According to GPA, the current average customer rate is $0.3491 per kWh, which is lower than many other islands and U.S. territories (Benavente 2023). As shown in Figure 5, this rate is almost double the U.S. average residential electricity rate (which was $0.1614 per kWh in 2021) (U.S. Energy Information Administration 2023a).

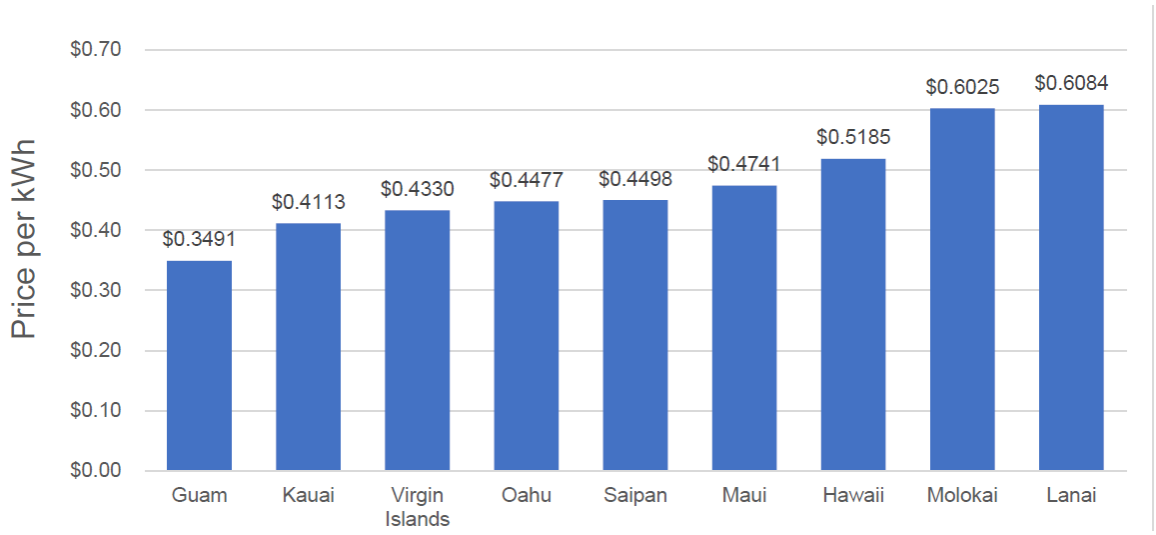

Figure 5. Comparative energy rates ($/kWh), August 2022

Data Source: Benavente (2023)

Net Metering rates apply for all customer-generator energy facilities throughout Guam who own and operate "eligible facilities" designed to operate in parallel with GPA's distribution facilities.

Tiered rates are applied based on kWh per month consumed. For example, General Service class charges $0.196 for the first 2,000 kWh per month, and $0.065 for use in excess of 2,000 kWh (Guam Power Authority 2021a). Rates are also tiered based on service level. For example, General Service customers are charged a slightly different rate for single-phase service and three-phase service, with an additional customer charge per month.

Smart controls and meters, demand management programs, and rebates are in place which helps to stabilize affordability, and support building and grid efficiency as fuel costs increase (GPA Fiscal Year 2021 Annual Report). Demand charges are applied per kW when a customer class exceeds a monthly consumption limit. For example, General Service class is charged $6.16 per kW of consumption over 5,000 kWh per month (Guam Power Authority 2021a). Voltage discounts are applied to energy charges and demand charges by percent.

3.3 Distribution

The island's power transmission and distribution grid is owned and managed by GPA (U.S. Energy Information Administration 2023a). This includes 204 miles of transmission lines, 1,650 miles of distribution lines, 30 substations, and 67 distribution feeders (Benavente 2023). See Figure 6 for a map of assets. Approximately 25% of GPA's customers have underground distribution service lines and nearly all overhead lines have steel or concrete poles (Benavente 2023). Transmission and distribution losses are estimated to be 4.9% according to the U.S. Department of Energy (2020).

Guam Power Authority's delivery system is managed through their Power System Control Center and their Gloria B. Nelson Public Service Building, which incorporated upgraded

Supervisory Control and Data Acquisition (SCADA) control system architecture in 2018 (Benavente 2023).

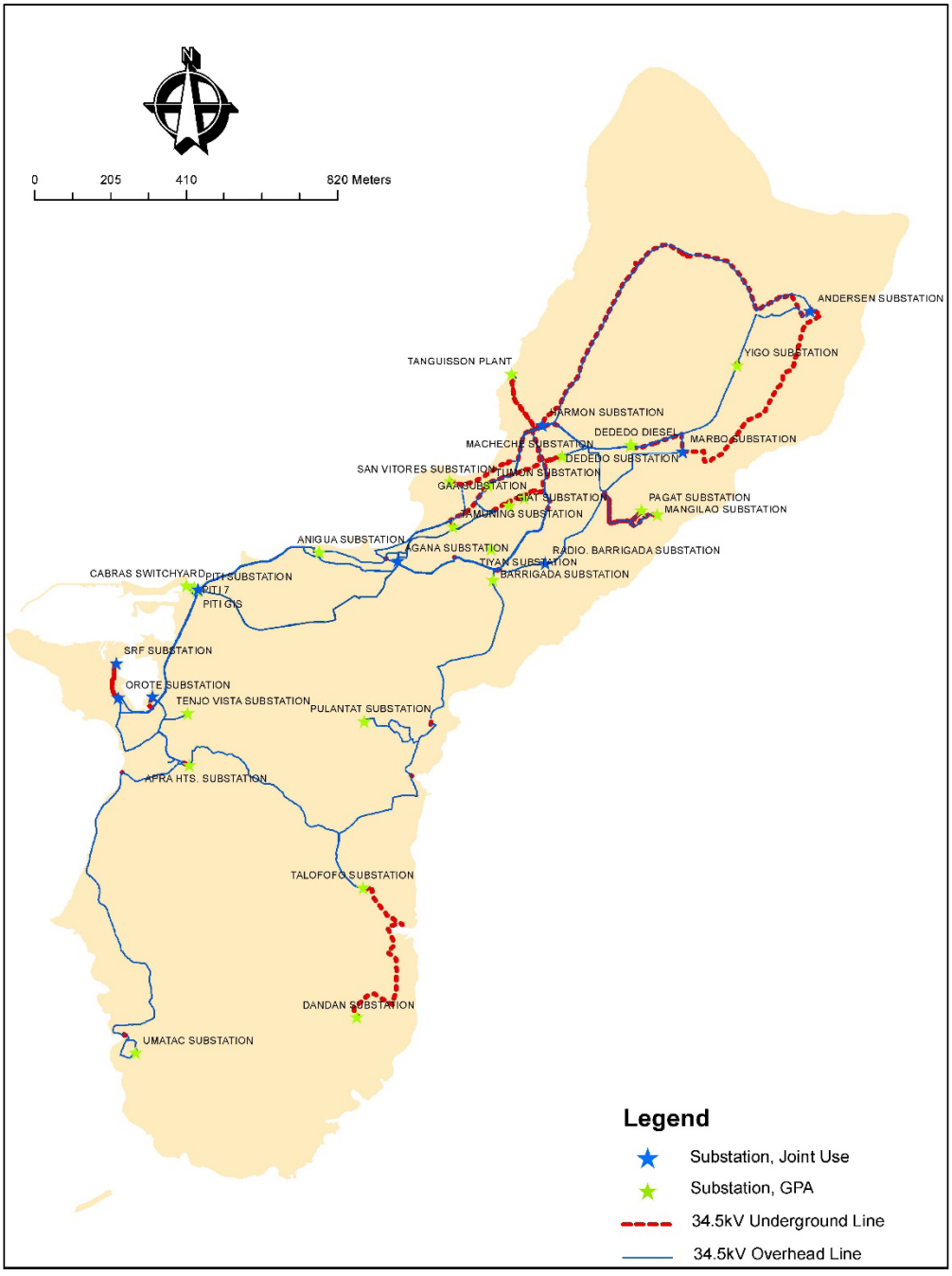

Figure 6. Guam Power Authority transmission asset map

Map from Laurie Tumaneng, Guam Power Authority

With financial support of the U.S. Department of Energy (DOE), GPA deployed over 50,000 smart meters to residential and commercial customers along with substation automation and an outage management system (OMS) (U.S. Department of Energy 2015). These assets improve system monitoring and reliability, decrease operating costs, and help GPA prepare for future distributed generation integration. The OMS includes a fully detailed circuit model integrated with a meter data management system and customer information system. They are also expanding fiber and wireless networks throughout the island.

Other strategies GPA is using to flatten its load profile and generation curve are spinning reserve; demand response; flexible generation; time-of-use rates; daytime charging electric vehicles; reduction of existing generation minimum operating levels; synchronous condensers; solar irradiance sensor network; and optimization through grid controllers (Guam Power Authority 2021b).

3.4 Key Challenges

GPA is challenged by the need to retire old, inefficient power plants while reliably and affordably delivering power. An EPA Clean Air Act settlement requires GPA to retire several old power plants, convert RFO plants to ULSD, and to build cleaner power sources (Benavente 2023). The Cabras 2 and Piti 7 plants' performance are declining, which places greater pressure on completion of the Ukudu plant and strains remaining GPA reserve generation and reliability (Guam Power Authority 2021b). Tanguisson 1&2, and Cabras 3&4 have already been permanently decommissioned.

Uncertainty around load growth due to military expansion and electric vehicle adoption challenge grid planning. Inverter-based distributed generation and utility-scale renewable energy adoption can strain existing circuits and require infrastructure upgrades. GPA also acknowledges the benefits and challenges of the digital transformation, and the unique security threats it presents (Guam Power Authority 2021b).

Repairing baseload generators following Typhoon Mawar has been challenging due to the age of the generators. Some large customers participating in GPA's Interruptible Load Program, including the U.S. Navy, voluntarily use their own generators during times of peak load to help avoid or reduce outages (Guam Power Authority 2023b). Rotating outages may be needed during peak times until repairs are fully complete.

4. Transportation Sector

4.1 Transportation Sector: Overview

Guam's Department of Revenue and Taxation is responsible for tracking the number of registered vehicles on the island. Private vehicles make up over 60% of registered vehicles on the island (The Bureau of Statistics and Plans Guam 2022). See Table A-3.1. The vintage of vehicles is unclear, as well as how many vehicles may be plug-in electric or hybrid electric vehicles. DOE's Alternative Fuels Data Center does not report on Guam. The crowdsourced web platform PlugShare reports four electric vehicle charging stations on the island, with a total of eight plugs (two publicly available near Tumon Bay, and two with restricted access at the Naval Hospital).

The transportation sector was heavily impacted by the COVID-19 pandemic. Although the number of private vehicles licensed on Guam has remained relatively steady at around 81,000 from 2017 to 2021, this figure dropped by nearly 5,000 in 2020 (The Bureau of Statistics and Plans Guam (2022)). Meanwhile, taxicabs, buses, and motorized cycles declined during the same period. Government and veterans' vehicles represent an additional 3,000–4,000 on-road vehicles (excluding military vehicles). See Table A-3.1.

Guam's mass transit system offers three primary services: fixed route, demand response, and paratransit (Parsons Brinckerhoff International Inc. 2008). Fixed-route services provide six regularly scheduled bus route lines. Demand response provides service by reservation and paratransit services are available for people with disabilities. Transit services are provided by private operators, with a total of 32 fleet vehicles, and services are not comprehensive. Fixed-route schedules may not be matched to actual bus travel times, resulting in poor service predictability for customers. Bicycle and pedestrian facilities are also limited with few dedicated facilities (only 26 miles of sidewalks and no marked or designated bike lanes). Sidewalks are often incontiguous and contain many obstructions, with frequent pedestrian-auto accidents.

Guam's major ports of entry include Apra Harbor and Antonio B. Won Pat International Airport (military bases excluded). The Apra Harbor is used by the U.S. Navy, as well as private commerce. Air travel was heavily impacted by COVID-19. The number of weekly airline flights fell from 1,160 in 2017 to 239 in 2021 (The Bureau of Statistics and Plans Guam 2022). Total airline arrivals fell from 1.7 million flights in 2017 to 88,000 in 2021. This does not include military flights from Andersen Air Force Base. See Table A-4.2.

Cargo was less impacted by COVID-19. The number of registered cargo carriers grew marginally from 2017 to 2021(The Bureau of Statistics and Plans Guam 2022). The total number of "unloaded" tons of cargo fell from 2017 to 2021 while the number of "loaded" tons of cargo nearly doubled. This does not include military cargo or other military vessels. See Table A-4.2.

The Port Authority of Guam (PAG) oversees the Agana port. PAG is a public corporation that endeavors to facilitate economic development and maritime cargo services by improving and maintaining port facilities. It is responsible for planning, promotion, development, construction, operation, and maintenance of port facilities critical to securing food and energy supply chains. A 2030 Port of Guam Master Plan recommends improvements to port infrastructure.

Surface Transportation Travel Behavior

The Guam Transportation Authority (GTA) administers U.S. Department of Transportation and Federal Highway Administration funding and regulations and supports transportation planning. According to traffic counts from a 2008 transportation plan commissioned by the GTA (2030 Transportation Plan), an estimated 967 million vehicle miles were traveled in 2008 (Johnson 2013). The total number of registered vehicles in 2008 was about 102,000, bringing the average vehicle-miles-traveled to approximately 9,500 miles per vehicle per year (Johnson 2013). No current data or plans have updated this study.

Most people live outside major employment centers and workers must commute to work (Parsons Brinckerhoff International Inc. 2008). In 2000, 70% of workers in Guam reported driving alone to work while 23% carpooled and fewer than 5% walked, biked, or took public transportation (Johnson 2013). This trend strengthened over the past 20 years, with 81% of workers reported driving alone in 2020, 14% carpooled, and less than 3% walked, biked, or took public transportation (U.S. Census Bureau 2020). The portion of the workforce working from home grew marginally from 1.3% in 2000 to 2% in 2020.

The Guam Transportation Authority's 2030 Guam Travel Program proposed major improvements to the transit system to increase ridership, including new routes, more vehicles, and schedule changes. This includes the purchase or replacement of 80 vehicles by 2030. The plan also recommended improvements to dedicated bike and pedestrian facilities to increase means and safety for non-motorized transportation. A 2013 Petroleum Reduction Plan echoed these recommendations, among other fuel savings solutions. Progress on these plans is unknown.

4.2 Transportation Fuels

The Guam Bureau of Statistics and Plans maintains records of actual fuel sales by petroleum type. In 2020 total fuel sales were over 192 million gallons. Given GPA consumed over 113 million gallons in the same year, transportation and other fuel use are assumed to make up the remaining 41% of total energy consumption on the island (see Table 9). Although data on fuel sales is collected, the breakdown of annual fuel consumption by vehicle type is not reported, nor are vehicle miles traveled or typical fuel efficiencies.

Table 9. Actual Fuel Sales by Type of Petroleum, Guam: 2017 to 2021 (Thousands of Gallons)

Fuel	2017	2018	2019	2020	2021
Unleaded regular gasoline	44,712.8	47,700.4	52,178.7	40,974.8	40,387.0
Unleaded midgrade motor gasoline	306.0	282.0	268.0	236.0	257.0
Premium gasoline	6,333.6	6,444.9	6,789.6	6,539.7	7,535.0
No. 2 diesel oil <5% sulfur	49,128.5	48,840.7	46,617.9	33,342.8	47,591.0
Kerosene-type jet fuel	50,568.4	48,917.6	53,486.0	46,046.9	25,233.0
Residential fuel oil > 1% sulfur	0.0	0.0	28,668.0	62,414.0	0.0
Propane, consumer grade	4,129.0	4,056.0	4,016.0	2,843.0	2,933.0
Total	155, 178.3	156,241.6	192,024.2	192,297.2	123,936

Data source: The Bureau of Statistics and Plans Guam (2022)

In 2010, Guam Energy Office reported 109 million gallons of motor fuel sold, including gasoline, diesel, and jet fuel (but excluding shipping, air transport, freight, and military) (Baring-Gould et al. 2011). Given a 2010 population of 180,865, the per-capita transportation fuel consumption was 602 gallons per person, per year.

In 2013, Guam produced a Transportation Petroleum-Use Reduction Plan in collaboration with the National Renewable Energy Laboratory. The plan reported nearly 60 million gallons of petroleum use for on-road transportation in 2012 (a decrease from 65 million gallons in 2006) (Johnson 2013). On-road gasoline use increased 0.54% per year between 2006 and 2012 while on-road diesel had decreased by 6.1% per year. No alternative fuels or electric vehicles were reported. While gasoline was projected to increase slightly from 45 million gallons in 2012 to 58 million gallons in 2020, diesel fuel was projected to decline from 14 million gallons in 2012 to 8 million gallons in 2020. As a result, estimates of future petroleum use were projected to decline overall by 6%. It was noted that the analysis did not include potential military buildups. Current fuel consumption data isn't available to compare against these projections or measure progress toward targets.

Fuel prices at the pump have hovered around $4.50 from 2019 to 2021, with a noticeable decrease in prices during the COVID-19 pandemic (see Figure 7).

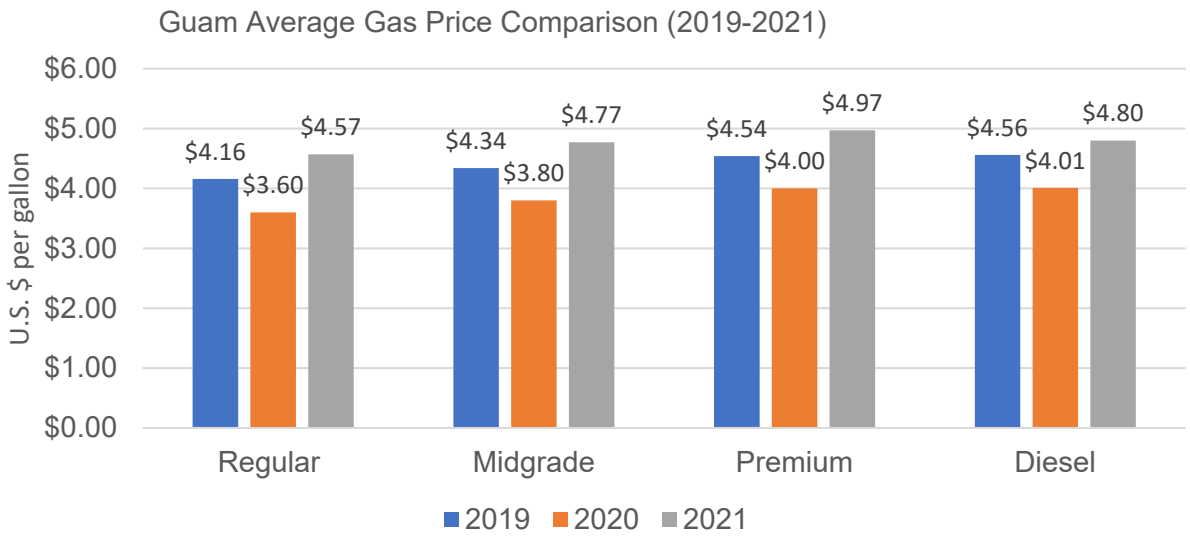

Figure 7. Guam average gas price comparison (2019–2021)

Data source: Guam Energy Office (2021)

4.3 Key Challenges

In addition to high and volatile fuel prices, there is a general gap in transportation data collection and planning. The most recent transportation and fuel reduction plans are from 2013 and draw from 2008 datasets. Although the Bureau of Statistics and Plans reports on vehicle registrations over time, vehicle fuel types, vehicle fuel efficiency, vehicle miles traveled, and fuel

consumption by vehicle type is unclear. It is also unclear who is responsible for the collection of such data and planning for future transportation infrastructure needs. This gap in data and planning could increase the difficulty of planning for electric vehicle and alternative fuel adoption.

5. Current Energy Policy

The following multilateral agreements, strategic plans, and adopted laws illustrate Guam's commitments toward sustainability, clean energy development, and resilience. These include wholistic energy strategies; grid-tied and distributed renewable energy, energy efficiency and conservation, transportation; climate change and resilience; and equity, workforce, and environmental justice ((Guam Legislature n.d.; United Nations n.d.), unless otherwise noted). This list does not include military related policies.

Holistic Energy Strategies, Plans, and Actions

- 2013 Guam Transportation Petroleum-Use Reduction Plan
- 2013 Guam Strategic Energy Plan
- 2013 Guam Energy Action Plan
- 2016 adoption of the United Nations Paris Agreement
- 2020 – P.L. 35-110 renewed the Guam comprehensive development plan to encompass the principles of sustainability.
- 2021– the Department of Interior Office of Insular Affairs' Energizing Insular Communities (EIC) program selected G3 to develop an updated Guam Strategic Energy Plan & Action Plan in partnership with Guam Energy Office.
- 2023 – an EIC grant was awarded to GPA and NREL for a 'Guam 100' renewable energy study to gather stakeholder input, analyze options, and inform Guam's energy transition efforts.

Grid-Tied and Distributed Renewable Energy Policies

1. Renewable Portfolio Standards
    - Public Law 29-62, adopted in 2008, promoted renewable energy development to offset cost and dependency on imported oil, required GPA to adopt renewable portfolio standards (RPS), and required an interim emergency net metering rate for customer generators. In 2019, P.L. 35-46 raised the RPS to 50% net electricity sales by December 31, 2035, and 100% by 2045. Regulations are described in Guam Code § 8311.
    - GPA's Clean Energy Plan (2022 Integrated Resource Plan) roadmaps a path to 100% clean, reliable, resilient, affordable energy by 2045 and builds upon the 2008 IRP. It identifies 400 MW of new renewable capacity and $230 million in needed upgrades and new technology to meet 50% of demand by 2030. The most recent plan update was approved by the CCU and PUC in 2022 (Benavente 2023).
    - GPA has been implementing projects identified in the 2008 and 2022 IRPs. As of April 2023, its customer demand is met by 11% renewable energy through grid-tied and customer-sited DERs (Sablan and Guam Power Authority 2023).
2. Net Metering
    - Public Law 27-132, passed in 2004, first enabled and defined net metering for certain customers. Public Law 30-141 passed in 2010, expanding system capacity limits to 25 kW and 100 kW for residential and commercial customers, respectively.

- Regulations are described in Guam Code ARTICLE 5 § 8501
- Guam Power Authority's Net Metering Program is offered through its rate structure. Rate Schedule "C – Net Metering Interim" describes the terms of program eligibility and customer rates (Guam Power Authority 2008). Customer-generators must submit a "standard interconnection agreement for net metering facilities" and a one-line diagram describing the system configuration.

3. Purchase of Alternate Energy

- Public Law 30-66, adopted in 2011, allowed long-term contracting (up to 30 years), which had the effect of expanded power purchase agreements. In 2013, P.L. 32-095 enabled power purchase agreements for public education facilities. This law is also the most recent modification to the 2004 net metering law.
  - Regulations are described in Guam Code § 8309.

4. As per Guam Code § 8603, GPA must develop a Virtual Power Plant Program. The program would initially be capped at 20 MW and provide an alternative rooftop solar program to address the challenges of the Net Metering program. This program is currently under development.

5. Battery Energy Storage Systems (BESS)

   - Guam Power Authority requires all new utility-scale solar PV power purchase agreements to include BESS (Benavente 2023). BESS requirements are written into each development request for proposals (RFP) (Cruz and San Nicholas 2023). The GPA 2023 Renewable Energy Resource Acquisition, Phase IV RFP included specific provisions for energy storage systems.
   - Guam Code § 8603, regarding GPA's Virtual Power Plant Program, requires DER and RE developers to provide BESS with the capacity necessary to address intermittency and power quality issues.

6. Guam Power Authority is required to meet margin policies, reliability policies, and trigger points for adding generation to support reliability (Guam Power Authority 2021b).

7. Fuel Standards. Public Law 35-15, adopted in 2019, requires "all diesel fuel imported to Guam, for whatever purpose, meet ultra-low sulfur diesel fuel standards" (Guam Legislature n.d.).

Energy Efficiency and Conservation

1. Demand-side management program

- GPA performs scheduled outages for load shedding and has an optional interruptible load program it is currently expanding (Cruz and San Nicholas 2023). GPA maintains a website and distributes media releases to notify customers of scheduled and potential outages. Customers are encouraged to conserve power from 5 p.m. to 11 p.m. and refraining from using unnecessary appliances immediately before and during peak demand hours.

- GPA's Interruptible Load Program (ILP) allows large power consumers to use their own power generators during peak load times in exchange for credits. GPA partners, including the Guam International Airport Authority, the Port Authority of Guam, Guam Regional Medical City, hotels and commercial buildings, and the Navy voluntarily switch to backup generators during peak demand. Together, they contribute nearly 16 MW of energy that can be subtracted from the island's demand (Guam Power Authority 2023b) (Guam Power Authority 2023c).

2. Building energy conservation

- Public Law 35-145, passed in 2023, adopted the 2017 Guam Tropical Energy Code and amended relevant sections of locally adopted building codes. Guam's building energy conservation code initiative began with the passing of P.L. 30-199, mandating the Guam Building Code Council create an energy code in 2010.
- The Guam Energy Office manages the Weatherization Assistance Program that improves residential energy efficiency and affordability for eligible low-income households through building envelope upgrades.
- GPA offers residential, commercial, and government customers rebates on certain energy-efficient appliances through its Energy Sense Rebate Program. The program also offers energy audits and energy savings tips. On May 28, 2020, Guam PUC Order (GPA Docket 20-05) approved GPA to adjust the LEAC rate to include funding for $1.5 million per LEAC period, beginning in June 2020 (Guam Power Authority 2021b). This allowed GPA to expand the Energy Sense Rebate program. Public Law 35-45, adopted in 2019, mandated (to the extent practicable) the purchase of energy-efficient products by the Government of Guam.
- GPA and the Guam Department of Education provide the Bringing Energy Savings to Schools Program to reduce energy costs for public schools.

Transportation

- Electric vehicle adoption incentives – The Guam Energy Office manages the Plug-In Electric Drive Motor Vehicle Rebate Program (established by P.L. 32-164 in 2014). In 2020, P.L. 35-81 expanded the program to private businesses and nonprofit organizations and extended its phase-out period. Rebates offered include 10% of the total base price of qualifying vehicles not exceeding $3,000 (Guam Energy Office n.d.). As of December, 2023, this program had resulted in 52 total electric vehicle rebates issued since the program's inception in 2014 (Tina Mafnas 2023).

Climate Change and Resilience

Policies regarding energy resilience that apply to the utility or other organizations:

- Executive Order 2019-19 created the Climate Change Resiliency Commission in 2019. The order directs the Commission to develop a strategy to build resilience against adverse impacts of climate change and reduce greenhouse gas emissions. It outlines eight outcome areas the Commission shall address: energy, water, ocean and land resources, infrastructure and community resilience, development planning, food security, public health and safety, and greenhouse gas emissions. No deadline for

implementation was established, and it is unclear if the Commission exists, as it has no website nor documentation of its progress toward these eight outcomes.

- The 2019 Hazard Mitigation Plan prepared for the Guam Homeland Security Office of Civil Defense and approved by the U.S. Federal Emergency Management Agency Region IX Mitigation Division, provides an island-wide risk assessment that may serve as a framework for future energy resilience planning. The assessment identifies hazards, inventories island assets, and assesses the vulnerability of assets to hazards. It then provides a risk mitigation strategy, including goals, actions, funding sources, and monitoring guidance.

Partner and Stakeholder Engagement

- Executive Order 2019-23 created the Guam Green Growth initiative. Guam Green Growth (G3) is a public-partnership between the Office of the Governor of Guam, the University of Guam Center for Island Sustainability, the Global Island Partnership, and the Hawaii Green Growth Local 2030 Islands Hub. The G3 Action Framework aims to guide sustainability solutions around five outcome areas (correlated to the 17 United Nations Sustainable Development Goals). A dashboard tracks metrics and Guam's progress around these five outcome areas.

Equity, Workforce Development, and Environmental Justice

As described earlier, Guam's residential electricity burden is relatively higher than some of its peer islands and the U.S. states' average (see Table 4 and Appendix 4). Energy burden is a metric of energy affordability defined as the percentage of household income spent on energy bills. This indicator is a function of home electricity spending, home fuels spending, and home transportation spending divided by household income. The current federal administration's Justice40 Initiative uses various indicators of burden to allocate federal funding to "disadvantaged" communities. A lack of data availability makes burden calculation in the territories infeasible.

Due to data limitations (see Appendix 4), it was only feasible to estimate *approximate baseline home electricity burden* for Territories, Hawaii, and the U.S. average using 2019 data. Despite these limitations, what is evident is that *electricity spending* on islands, and particularly on Guam are disproportionately high relative to the U.S., Puerto Rico, and Hawaii. Guam's energy policy and pursuit of federal funding has an opportunity to lower energy costs for customers to reduce their energy burden. Future studies should center energy equity and improve data collection for more accurate energy burden calculations.

6. Summary of Challenges

The following challenges have been identified regarding fossil fuel dependence, energy security, economic stability, and renewable energy development.

Due to its geographic isolation and lack of local energy supply, Guam has historically depended on imported fossil fuels to meet all its energy needs. Liquid fuel and gas supply chains are vulnerable to physical, political, and cyber threats as well as market conditions. Combined, these conditions cause supply uncertainty, price volatility, and high energy costs. These impacts highlight the criticality of energy conservation and demand response, as well as developing energy generation and storage projects on-island.

As exemplified by Typhoon Mawar, natural disasters and climate change threaten power system infrastructure, cutting off power to life-supporting community services and slowing progress toward energy transition. The Typhoon caused delays to the commissioning of new generation projects, damaged DERs, and damaged transmission and distribution infrastructure causing disruptions in electricity service. Common natural and climate change related hazards include earthquake, tropical cyclone, wind, flood, heat, and sea level rise, many of which are projected to continue threatening the island with increased intensity and frequency.

Guam Power Authority is challenged by the need to retire power plants while reliably and affordably delivering power to its customers. The settlement of an EPA Clean Air Act violation requires GPA to retire older fossil-based generating plants while Renewable Portfolio Standards mandate a transition to carbon-free electricity. Meanwhile, growth of customer-sited DER impacts existing circuits and requires infrastructure upgrades. High electricity prices may lead to grid defection/DER adoption, putting the utility at financial and technical risk.

The U.S. Navy alone is the island's largest energy consumer, representing 20% of electricity sales. The Navy relies exclusively on GPA's grid (aside from backup generators). While they are pursuing various energy efficiency projects to potentially decrease load, they are also adding facilities, pursuing vehicle electrification, and planning to add defense systems. The extent of military base expansion plans are not certain, leaving GPA uncertain to potential increases to peak demand and impacts to their distribution system infrastructure. Navy participation in GPA's Interruptible Load Program means periodically using onsite diesel generators, burning diesel fuel and keeping the generators maintained more frequently.

The military also represents a significant component of the island's economy, along with tourism. Both sectors are heavily dependent on transportation fuels. The tourism economy was particularly impacted by COVID-19. Yet there is a lack of transportation data collection, reporting, and planning. Given that transportation represents nearly half the energy consumption on the island, understanding the probable rate of adoption of electric vehicles and alternative fuel vehicles is important but unclear.

7. Conclusion

Total energy consumption in Guam has been increasing over the past 12 years. In 2021, the island consumed 241 million gallons of imported fossil fuels. Of the total energy consumed on the island, less than 4% is supplied by carbon-free renewable energy.

The power grid is increasingly adopting renewable energy to meet its decarbonization mandates by 2045. However, Guam's 11% renewable energy portfolio is entirely owned by third parties, beyond the direct control of the GPA. Although power purchase agreements and net metering laws have enabled significant increases in RE adoption in recent years, an additional 400 MW of renewable energy would be needed on the grid just to meet GPA's 50% renewable generation target by 2035. This would represent the equivalent of GPA's current fossil fuel-based generation portfolio (19 facilities). Meanwhile, GPA is building a new ULSD/liquified natural gas plant that will have an expected lifecycle exceeding its decarbonization mandate. It also struggles to meet demand while retiring fossil-based plants and integrating variable renewable energy on the grid. This demonstrates the technical and financial challenges of implementing GPA's IRP/Clean Energy Plan. Future planning efforts should address energy equity and workforce development opportunities to reduce the costs and amplify the positive impact of the energy transition on disadvantaged communities.

While the number of GPA customers has increased, the rate of consumption of commercial customers has fallen while the rate of residential consumption has increased. GPA has been making progress on increasing energy efficiency through commercial building energy audits, smart meter replacement, and appliance rebate programs. However, an opportunity remains to improve residential energy efficiency and anticipate building electrification through whole building weatherization upgrades. Time-of-use tariffs and blocked rate structures support energy efficiency but also represent a potential increased costs for uninformed customers. Customer education will be crucial, particularly for energy-burdened customers, as time of demand management tactics are applied. Future studies should improve data collection for more accurate energy burden calculations.

Very little is understood about Guam's transportation sector. Like many islands and U.S. territories without local fuel sources, energy costs are high. The relative home electricity burden figures presented earlier in this document don't include transportation fuel costs. Future planning could develop tools to better understand transportation energy burden. With a military and tourism dependent economy, understanding the impacts of increased transportation electrification will be crucial for grid planning and electric vehicle-charging deployment. Future studies could assess consumer preferences and model probable electric vehicle adoption scenarios on GPA's grid infrastructure. Vehicle data collection could be improved by reporting annual fuel consumption by vehicle type, vehicle miles traveled, and typical fuel efficiencies. Previous transportation plans acknowledge a need for bike and pedestrian infrastructure and proposed adopting a "complete streets" model. Future transportation planning should assess progress made toward these goals or which aspects could be adopted, and consider the impact of remote work, micro mobility, carshare, rideshare, and mass transit ridership on electrification scenarios.

Electric reliability is a strength of GPA, with pole and wire hardening, updated control systems, and battery energy storage requirements for utility-scale renewable energy installations. While SCADA data demonstrates a relatively reliable system, it does not shed light on the location, frequency, or severity of acute outages or trends over time. The distribution of outages and legacy energy system harms should be evaluated for equity considerations. It is also unclear how future military expansion, increased DER generation, variable renewable energy integration, building electrification, and increased electric vehicle adoption will impact electric demand, peaks, and grid infrastructure. Future energy planning must account for uncertainty around and resilience to cyber, physical, climate change, and natural threats to the power system as the grid becomes increasingly distributed in nature.

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Appendix

The following data provides additional territorial context but is not required for the Baseline Report.

A.1 Appendix – GPA Fuel Consumption

Table A-1.1. Guam Power Authority Annual Fuel Consumption

Fuel	2017	2018	2019	2020	2021	2022
High Sulfur Fuel Oil (BBLs)	1,524,120	1,557,446	1,367,123	1,643,720	1,610,218	840,447
Diesel (BBLs)	797,871	776,249	735,941	613,078	712,489	1,227,850
Low/Ultra Sulfur Fuel Oil (BBLs)	488,847	392,638	670,382	442,650	464,068	823,382
Total barrels	2,810,840	2,726,333	2,773,446	2,699,447	2,786,774	2,891,678
Conversion of barrels to gallons	118,055,294	114,505,994	116,484,720	113,376,789	117,044,524	121,450,477

Data source: Cruz and San Nicholas (2023)

A.2 Appendix – GPA Customers, Sales, Revenue, and Price Trends

Tables A-2.1 through A-2.4 capture trends for GPA customers, sales, revenue, and prices from 2011 through 2021.

Table A-2.1. Number of Ultimate Customers

Year	Residential	Commercial	Industrial	Transportation	Total
2011	41,255.00	6,717.00	--	--	47,972.00
2012	41,612.00	6,908.00	--	--	48,520.00
2013	41,708.00	6,890.00	--	--	48,598.00
2014	41,999.00	6,925.00	--	--	48,924.00
2015	42,752.00	6,940.00	--	--	49,692.00
2016	43,943.00	6,956.00	--	--	50,899.00
2017	43,756.00	7,087.00	--	--	50,843.00
2018	44,006.00	7,366.00	--	--	51,372.00
2019	44,226.00	7,517.00	--	--	51,743.00
2020	44,420.00	7,518.00	--	--	51,938.00
2021	44,748.00	7,516.00	--	--	52,264.00

Data source: U.S. Energy Information Administration (n.d.-a)

Table A-2.2. Sales of Electricity to Ultimate Customers (MWh)

Year	Residential	Commercial	Industrial	Transportation	Total
2011	487,230.00	1,130,580.00	--	--	1,617,810.00
2012	459,499.00	1,103,976.00	--	--	1,563,475.00
2013	462,163.00	1,104,247.00	--	--	1,566,410.00
2014	457,835.00	1,075,511.00	--	--	1,533,346.00
2015	463,990.00	1,078,018.00	--	--	1,542,008.00
2016	494,842.00	1,087,317.00	--	--	1,582,159.00
2017	516,682.00	1,103,757.00	--	--	1,620,439.00
2018	510,725.00	1,071,705.00	--	--	1,582,430.00
2019	514,829.00	1,071,513.00	--	--	1,586,342.00
2020	552,083.00	991,159.00	--	--	1,543,242.00
2021	603,924.00	970,623.00	--	--	1,574,547.00

Data source: U.S. Energy Information Administration (n.d.-a)

Table A-2.3. Revenue from Sales of Electricity to Ultimate Customers (Thousand U.S. dollars)

Year	Residential	Commercial	Industrial	Transportation	Total
2011	112,320.00	279,555.00	--	--	391,875.00
2012	122,259.00	315,853.00	--	--	438,112.00
2013	122,463.00	315,369.00	--	--	437,832.00
2014	125,027.60	309,439.00	--	--	434,466.60
2015	106,056.80	260,652.00	--	--	366,708.80
2016	93,568.40	214,840.00	--	--	308,408.40
2017	103,326.60	230,472.00	--	--	333,798.60
2018	121,331.30	260,505.50	--	--	381,836.80
2019	128,641.00	275,266.70	--	--	403,907.70
2020	116,537.40	221,583.10	--	--	338,120.50
2021	121,238.80	207,644.60	--	--	328,883.40

Data source: U.S. Energy Information Administration (n.d.-a)

Table A-2.4. Average Price of Electricity to Ultimate Customers (cents per kWh)

Year	Residential	Commercial	Industrial	Transportation	Total
2011	23.05	24.73	--	--	24.22
2012	26.61	28.61	--	--	28.02
2013	26.50	28.56	--	--	27.95
2014	27.31	28.77	--	--	28.33
2015	22.86	24.18	--	--	23.78
2016	18.91	19.76	--	--	19.49
2017	20.00	20.88	--	--	20.60
2018	23.76	24.31	--	--	24.13
2019	24.99	25.69	--	--	25.46
2020	21.11	22.36	--	--	21.91
2021	20.08	21.39	--	--	20.89

Data source: U.S. Energy Information Administration (n.d.-a)

Table A-2.5 GPA Electric Sales Information (2018–2022)

Electric Sales Information

	2018	2019	2020	2021	2022
Peak Demand (MW)	254	255	247	257	260
Total Electric Sales (MWh)	1,567,052	1,568,286	1,523,579	1,554,962	1,540,160
Sales Growth (%)	(2.7)	0.1	(2.9)	2.1	(1.0)
Total Customers	51,372	51,977	51,771	52,825	52,873

Energy sales decreased slightly by 1.0% in 2022 compared to 2021. In February 2022, Russia invaded Ukraine, causing soaring fuel prices globally. Due to the increase in fuel prices, LEAC increased gradually. On September 30, 2022, GPA had an under-recovery of fuel cost of $39.6 million.

Image from Ernst & Young LLP (2022)

A.3 Appendix – Vehicle Statistics

Table A-3.1. Licensed Motor Vehicles, 2017–2021

Type	2017	2018	2019	2020	2021
Private	81,906	81,579	84,472	75,544	80,609
Taxicab	325	339	351	316	251
Cargo	26,928	26,820	27,649	25,550	28,054
Trailer	3,285	3,541	3,832	3,079	3,416
Cycle	2,079	1,927	1,784	1,394	1,436
Dealer	706	638	598	567	511
Bus	748	733	680	561	479
Equipment	152	141	119	101	130
Veterans	2,519	2,444	2,402	2,191	2,249
Government	1,258	1,319	1,271	917	1,164
Total	119,906	119,481	123,158	110,220	118,299

Data source: The Bureau of Statistics and Plans Guam (2022), Table 20-01

Table A-3.2. Passenger, Cargo, and Aircraft Movement Statistics, 2017–2021

Type	2017	2018	2019	2020	2021
Passengers					
Arrivals	1,703,240	1,625,932	1,715,346	794,593	88,037
Departures	1,660,548	1,596,054	1,720,562	783,532	101,696
In Transit	197,831	184,518	164,546	100,528	33,870
Cargo					
Unloaded (Metric Tons)	8,231	7,454	7,448	6,228	6,239
Loaded (Metric Tons)	6,008	5,339	5,379	16,408	14,073
Mail					
Incoming (Metric Tons)	4,845	4,387	4,762	5,806	12,169
Outgoing (Metric Tons)	1,967	2,085	2,118	2,535	6,258
Aircraft Movements					
Number	60,434	54,592	54,538	29,834	12,408
Gross Takeoff Weight	3,332,805	3,061,959	3,372,358	2,575,582	1,582,331
Airline Flights					
Average Flights Per Week	1,160	1,050	1,048	574	239

Data source: The Bureau of Statistics and Plans Guam (2022), Table 20-07

A.4 Appendix – Supplemental Notes for Table 4. Approximate Baseline Home Electricity Burden for U.S. Territories (2019)

Table A-4 Approximate Baseline Home Electricity Burden for U.S. Territories (2019)

Geography	Median Household Income (USD) (2019) [1]	Average Residential Electricity Rate (cents per kWh) (2019) [2]	Residential Electricity Sales (MWh) (2019) [3]	Number of Residential Customers (2019) [4]	Estimated Average Annual Residential Electricity Consumption (MWh) (2019) [5]	Estimated Average Annual Residential Electricity Spending (USD) (2019) [6]	Approximate Baseline Home Electricity Burden (%) (2019) [7]
American Samoa	$28,352	35.26	47,127	10,762	4.38	$1,544	5.45%
Commonwealth of the Northern Mariana Islands	$31,362	25.28	76,795	11,525	6.66	$1,684	5.37%
Guam	$58,289*	24.99	514,829	44,226	11.64	$2,909	4.99%
Puerto Rico	$20,474	21.43	6,205,152	1,341,424	4.63	$992	4.85%
U.S. Virgin Islands	$40,408	38.75	217,003	46,283	4.69	$1,817	4.50%
Hawaii	$83,102	32.06	2,760,000	438,352	6.30	$2,020	2.43%
U.S. Average	$65,712**	13.01	1,440,288,909	135,249,616	10.65	$1,386	2.11%

Data from U.S. Census Bureau (2020a, 2020b, 2020c, 2020d), U.S. EIA (2021)

*Median household income for Guam excludes people in military housing units.
** U.S. average does not include the Territories of American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, and the U.S. Virgin Islands

Methodology, Data Sources, and Limitations

Table A.4 provides a method for estimating electricity burden in the U.S. territories. It compares indicators of estimated electricity burden across the U.S. territories and includes the U.S. and state of Hawaii for additional context. As noted in the table, the U.S. average does not include the territories of American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, and the U.S. Virgin Islands.[2]

[2] https://www.census.gov/content/dam/Census/library/publications/2020/acs/acs_general_handbook_2020_ch02.pdf

We consider the home electricity burdens listed in Table A.4 to be approximate baselines because these data represent the estimated floor for electricity burdens, which are likely much higher as of early 2024. The estimated burden calculation also applies only to home electricity use. It accounts for neither other home fuel use (such as propane for cooking) nor transportation-related energy consumption. Since our burden calculations only account for home electricity use, total energy use per household could only be higher than the estimates presented.
Due to the limited availability of current income data for U.S. territories, the year 2019 is used across all data sources. Actual home electricity burdens are likely higher post-COVID, and future studies should draw from post-COVID income data as these become available. Future energy burden calculations would also ideally include home fuel use and transportation energy, as well as the impacts of future electrification.

[1] Median Household Income

Methodology: The 2020 Island Area Census data are the most recent available for the U.S. territories of American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, and the U.S. Virgin Islands. According to the U.S. Census Bureau, "income questions on the census asked about income for the prior calendar year."[3] 2019 median household income is thus used, setting the timeframe for burden analysis to maintain data consistency.

Limitations: Median household income is an accepted indicator of an area's average income, but there is an inherent data limitation in using a median that can be insensitive to outliers. Future studies could examine a range of income brackets to understand how electricity burdens impact low- and moderate-income households in the U.S. territories with more granularity.

An additional data limitation is that due to the COVID-19 pandemic, the 2020 Island Area Census did not collect household data for group quarters or military housing units.[4] This is methodologically atypical, and impacted 2020 data tables should not be compared to 2010 and other past census data tables reporting the same characteristics. Guam is the only U.S. Island Area with military housing.[5]

Data Sources:

- 2019 median household income for American Samoa, the Commonwealth of the Northern Mariana Islands, Guam, and the U.S. Virgin Islands (U.S. Census Bureau 2020a)
- 2019 median household income for the state of Hawaii (U.S. Census Bureau 2020b)
- 2019 median household income for Puerto Rico (U.S. Census Bureau 2020c)
- 2019 median household income for the U.S. (U.S. Census Bureau 2020d)

[3] https://www.census.gov/newsroom/press-releases/2022/2020-island-areas-guam.html
[4] https://www2.census.gov/programs-surveys/decennial/2020/technical-documentation/island-areas-tech-docs/demographic_profile/2020-iac-dpsf-technical-documentation.pdf
[5] https://bsp.guam.gov/census-of-guam/

[2] Average Residential Electricity Rate

Methodology: Data come from the U.S. EIA's *Electric Power Annual 2019*. The year 2019 was selected to maintain consistency with the most current available median household income data for the territories of American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, and the U.S. Virgin Islands. EIA reports electric power average prices for ultimate customers in Chapters 2 and 11.

Limitations: EIA rate data may not always accurately depict monthly customer charges or fuel surcharges. EIA uses aggregated data from Form EIA-861 to record average residential electricity prices for the U.S. territories,[6] but a review of some publicly available territorial rate tariffs indicates EIA rate data may not always include all relevant surcharges. Examples of such surcharges in different territories include (but are not limited to) levelized energy adjustment clauses, renewable energy rates, and monthly customer charges. Territorial utilities do not consistently publish historic rate data, so EIA data give us the closest available approximation of 2019 average residential electricity rates in the U.S. territories. Collecting more representative rate data is an area for potential improvement in future studies.

Data Sources: All data from: U.S. EIA (2021). See Tables 2.4, 2.10, and 11.4-11.8.

[3] Residential Electricity Sales

Data Sources: All data from: U.S. EIA 2021. See Tables 2.2, 2.8, 11.2, and 11.5-11.8.

[4] Number of Residential Customers

Limitations: There is a difference between the number of households in a geographic area and the number of residential customers in the area, so EIA residential customer data may not match the number of households reflected in U.S. Census Bureau income data. There may be multiple "customers" (as defined by the EIA) per Census-designated "household," or there may be households that are not electric utility customers. We note the possible discrepancy between "number of households" and "number of residential customers" as a data limitation that has implications for our burden calculations, which is why we present these burden calculations as approximations for relative comparison purposes.

Given that the 2020 Island Area Census did not collect household income data for military housing units in Guam, the inclusion or exclusion of military units from "number of residential customers" is relevant here. EIA collects information on the number of ultimate residential customers directly from the Guam Power Authority via Form EIA-861. The Guam Power Authority classifies military housing units as U.S. Navy rather than residential customers, so

[6] Form EIA-861, Annual Electric Power Industry Report, and Form EIA-861S (the shortform) collect data from distribution utilities and power marketers of electricity. This survey is a census of all United States electric utilities. For more information on Form EIA-861, see here: https://www.eia.gov/electricity/data/eia861/.

EIA's number of residential customers for Guam should not include U.S. Department of Defense housing units or customers.[7]

Data Sources: All data from: U.S. EIA 2021. See Tables 2.1, 2.11, 11.1, and 11.5-11.8.

[5] Estimated Average Annual Residential Electricity Consumption

Methodology: Estimated residential electricity sale amounts in column [3] were divided by the ultimate number of residential customers in column [4].

[6] Estimated Average Annual Residential Electricity Spending

Methodology: Units of electricity consumption from column [5] were converted from MWh into kWh, then multiplied by the average residential electricity rate (in cents/kWh) from column [2]. Results are rounded to the nearest dollar.

[7] Approximate Baseline Home Electricity Burden

Methodology: Home electricity burden is the percent of household income spent on electricity. To calculate approximate baseline home electricity burden, the estimated average annual residential electricity spending amounts in column [6] were divided by the median household incomes in column [1].

Limitations: Burden calculations apply to home electricity use only. These estimates account for neither other home fuel use (such as propane for cooking) nor transportation-related energy consumption. Given these exclusions and the data limitations already discussed (i.e., the lack of more recent median household income data for the U.S. territories), these home electricity burdens should be taken as an estimated baseline rather than a precise percentage. More research is needed to further explore home electricity and energy burdens in the U.S. territories, especially in the context of the COVID-19 pandemic and recent global increases in commodities prices.

Data Sources

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[7] Guam Power Authority representative, personal communication, April 2, 2024.

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