CONFIDENTIAL

Independent Engineering Report

Aguirre Power Plant Complex

Prepared for

Puerto Rico Electric Power Authority

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Final

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Project 14495.001

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This is to certify that this document has been prepared, reviewed, and approved in accordance with Sargent & Lundy's Standard Operating Procedure SOP-0405, which is based on ANSI/ISO/ASSQC Q9001 Quality Management Systems.

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TABLE OF CONTENTS

FIGURES AND TABLES

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition/Clarification
Aguirre	Aguirre Power Plant Complex
BFP	boiler feedwater pump
CAPEX	capital expenditure
CC	combined cycle
DA	deaerator
DMR	discharge monitoring reports
EAF	equivalent availability factor
ECHO	(EPA's) Enforcement and Compliance History Online
EFOR	equivalent forced outage rate
EMS	energy management system
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
EQB	Environmental Quality Board
ESST	emergency station service transformer
FD	forced draft
FGR	flue-gas recirculation
FY	fiscal year
GE	General Electric
GT	gas turbine
HFO	heavy fuel oil
hp	horsepower
HP	high pressure
HRSG	heat recovery steam generator
ID	induced draft
IP	intermediate pressure
LP	low pressure
MATS	Mercury and Air Toxics Standards
MPT	main power transformer
NAAQS	National Ambient Air Quality Standards

Acronym/Abbreviation	Definition/Clarification
NCF	net capacity factor
NERC	North American Electric Reliability Corporation
NFPA	National Fire Protection Association
NO_X	nitrogen oxide
NPDES	National Pollution Discharge Elimination System
O&M	operations and maintenance
PM	particulate matter
Phase I ESA	Phase I Environmental Site Assessment
Plant	Aguirre Power Plant Complex
PREB	Puerto Rico Energy Bureau
PREPA	Puerto Rico Electric Power Authority
psig	pounds per square inch, gage
rpm	rotations per minute
SH	superheater
SPCC	spill prevention, control, and countermeasure
ST	steam turbine
STAG	steam turbine and gas (combined-cycle unit)
STG	steam turbine generator
TRI	toxic release inventory

EXECUTIVE SUMMARY

OVERVIEW

The Puerto Rico Electric Power Authority (PREPA) is the electric power company responsible for generating, transmitting, and distributing electricity for the island of Puerto Rico. PREPA engaged Sargent & Lundy to perform an independent technical review of the Aguirre Power Plant Complex ("Aguirre" or the "Plant").

Aguirre is located on the south coast of Puerto Rico in the Salinas municipality and is owned and operated by PREPA. The Plant has two 450-MW thermal steam power generation units, two 296-MW combined-cycle (CC) power generation units that can also operate in simple-cycle mode, and two 21-MW black-start capable gas turbines (GTs). The nameplate capacity of the Plant is 1534 MW (gross), including the units that are currently out of service for repairs.

This technical report includes an assessment of the plant design, operations and maintenance (O&M) activities, plant organization and personnel, technical performance, commercial arrangements and obligations, and provisions for environmental permitting. Sargent & Lundy's objective is to provide an overview of the condition of the asset, assess whether the facility has been operated and maintained in accordance with generally accepted industry practices, and identify significant challenges to continued successful operation. The assessment is based on various site visits conducted in 2018 and 2019 and data provided through April 2021.

Sargent & Lundy understands that this review is being conducted in connection to the request for proposals (RFP) to manage, operate, maintain, and decommission, as applicable, one or more of the base-load generation plants and GT peaking plants located throughout the island of Puerto Rico, including Aguirre.

TECHNICAL REVIEW

The two 450-MW thermal units, referred to as Units 1 and 2, were commissioned in 1971 and 1972, respectively. A 1991 upgrade to 500 MW on their General Electric (GE) (formerly ABB) steam turbines (STs) is based on 3430-kilopound/hour main steam flow at 2400 psig and 1000°F and hot reheat conditions of 594 psig and 1000°F. Boiler restrictions on steam flow have limited the units to their original 450 MW. The boilers burn heavy fuel oil (HFO) and are tangentially fired models by Combustion Engineering, now GE Power.

The two CC units are referred to as STAG 1 and STAG 2 and were commissioned in 1977, each with four 50-MW GE 7B GTs burning HFO, four single-pressure GE heat recovery steam generators (HRSGs), and one GE 96-MW ST (4x4x1 configuration). In 1994 and 1995, the HRSGs had significant replacements of their pressure parts. Later, from 1997 through 2001, the eight GTs were modified by GE from Model 7B to Model 7EA.

Beginning in 2007, modifications to the CC units began, which would have allowed the GTs to burn either natural gas or No. 2 fuel oil. These modifications were approximately 80% complete when the work was halted. The GTs were converted to burn No. 2 fuel oil and continue to operate on No. 2 fuel oil only. Modifications were designed in 2011 for the thermal units to be converted to natural gas. The gas fuel trains and boiler conversion parts were delivered but not installed. The project was put on hold, and the parts are in outdoor storage at the Plant. The thermal plant boilers continue to operate on HFO. Natural gas is not available at the site, and the Plant no longer plans to convert any units to natural gas operation.

The Unit 1 ST high-pressure (HP) and intermediate-pressure (IP) rotors were replaced in 2012, and the generator was replaced at the end of 2015. The thermal units' spare HP and IP rotors were installed in Unit 2 during 2017, and rewinding of the Unit 2 generator was planned for the first quarter of 2021. The generators on Units 1 and 2 are 60-Hz Brown Boveri & Cie units with ratings of 570 MVA at 60 psig hydrogen and 0.85 power factor.

The STAG 1 and STAG 2 GT generators are by GE and located on the exhaust side of the GTs. The ST generators are also by GE and are rated for 132 MVA at 30 psig hydrogen and 0.85 power factor.

Process water for the entire plant is supplied from shared offsite wells, and it is received and treated at the thermal units. Approximately 450 gallons per minute of demineralized water are needed each day for the Plant, which is well within the supply capability of the two 600-gallons-per-minute mixed-bed demineralizer trains. Treatment costs have been increasing, mainly due to high dissolved solids in the well water because of low local water table. PREPA is underway with a project to bring water from the PREPA-owned Patillas Lake to the Aguirre site. This project is planned for completion in Q4 of 2022, and the alternate source is expected to reduce water treatment costs and be a more stable supply than the wells.

Seawater from the Jobos Bay is pumped by four 1000-horsepower (hp) vertical circulating water pumps for Units 1 and 2 and a single installed spare for the two units for use in cooling once-through condensers at the thermal plant. Each of the CC blocks has its own seawater cooling tower and two 2000-hp circulating water pumps for condenser cooling. The plant has recently upgraded the CCWP 2-2 pump capacity and motor size to 2200 hp to increase water flow and subsequently improve condenser vacuum. Startup testing for the retrofitted pump was targeted for October of 2020.

ABB's S90 Turbotrol turbine controls were installed in 2014 for the Unit 1 ST generator (STG) and in 2015 on the Unit 2 STG. The Unit 2 STG controls were upgraded in 2017 to the Alstom BlueLine version. The HRSG controls are being upgraded by Foxboro. In 2019, the STAG 1 STG controls were upgraded to Mark VI-E along with an exciter upgrade to model EX-2100. STAG 2's STG controls and exciter have not yet been upgraded. The Plant plans to upgrade the remaining STAG 2 GTs to Mark VI-E controls in 2020 and has requested new EX-2100 model exciters.

Both John Brown 21-MW black-start GTs for the thermal units were installed in the 1970s; they burn No. 2 fuel oil. They are owned and operated by the PREPA Hidro-Gas division. The CC units no longer have black-start engines.

EQUIPMENT CONDITION

In general, Units 1 and 2 were found to be in good condition and are consistent with comparable units of similar vintage. The CC units are in moderate condition; however, they have experienced more wear than like units of similar age and have faced some issues from seawater cooling tower drift. Of the four power blocks—two thermal and two CC—both thermal units and five of the eight CC combustion turbines are available for full or partial load.

Thermal Unit 1 was forced offline in August of 2020 due to problems with ID Fan 1-2 and high conductivity in the condensate system but has since returned to service. The issues with the Unit 1 ID Fan 1-2 have been addressed, and a broken tube in the condenser was repaired, making Unit 1 available for full load as of October 2020. Unit 2 completed an environmental outage in May of 2020, during which the main power transformer was replaced.

CC GT Units 1-2 and 1-3 were brought offline on September 30, 2020 with synchronization issues and a problem with the transmission gear, respectively. CC Unit 1-4 is limited to a 30-MW output due to high temperatures in the charging compartment, and CC Unit 2-2 is offline for a major inspection.

STAG Unit 1 was offline for part of September 2020 for issues with a hydrogen leak but has since resumed limited service with steam from GT Unit 1-1. STAG Unit 2 has been out of service since June of 2017 and is undergoing maintenance to correct deficiencies before it can resume service.

Finally, as of October 2020, of the two 21-MW black-start GTs, Unit BSGT 2-1 was out of service due to holes in the transition pieces; however, Unit BSGT #2-2 was available after having a bad motor starter corrected in September of 2020.

For all the Aguirre units, corrosion is an issue, more so with the CC units. Additional concerns are the need to repair or replace some of the thermal Unit 1 and 2 boiler internals, replace the spare Unit 1 and 2 HP and IP steam turbine rotors, and increase corrosion mitigation efforts at the CC units. During the spring of 2019, Unit 2 lost its main transformer due to failure but it has since been replaced.

New or rebuilt equipment has been installed recently improving the condition of the Plant, including the following:

- A new rotor in GT 1-3 of the CC
- A new CC boiler feedwater pump (BFP) in 2018 along with rebuilt circulating water cooling towers
- New thermal plant ST controls in 2014/2015
- New HRSG controls installed in 2019
- An upgraded CC circulating-water impeller with an uprated/rewound motor in 2020
- A new Unit 1 ID fan rotor in 2017
- A new main power transformer for Unit 2 in 2020
- New thermal plant BFP motors in 2012 and 2015
- Preheaters on both thermal units modified from three layers to two layers of heat exchange baskets
- New thermal plant condenser waterboxes and refurbished ones on STAG 2
- A new Unit 1 ST generator in 2015
- Spare HP and IP steam turbine rotors on Unit 1 (2012) and Unit 2 (2017)

INFRASTRUCTURE & INTERCONNECTIONS

Aguirre receives HFO from Freepoint Commodities and No. 2 fuel oil from Puma Energy Caribe. HFO and No. 2 fuel oil are delivered by tanker to the site. Water processed by the demineralizers for use in the steam cycle is delivered from offsite wells shared by the community.

OPERATIONS & MAINTENANCE

Each of the two thermal units generally operates 24 hours a day, 7 days a week between 230 MW and 430 MW for grid frequency control as directed by PREPA (now LUMA) dispatch. The CC is dispatched as a peaker in either simple-cycle or CC mode. A generation employee roster dated September 9, 2020 indicates a total Plant staff of 207 people, but a more recent organization chart has not been received. A previously furnished organization chart from 2018 indicated a Plant staff of 223 people (144 thermal and 79 CC), with three shifts of operations personnel daily and single shifts of maintenance and administrative staff on weekdays. Extended hours and additional personnel are used during outages. Units 1 and 2 have regular outages every 12–18 months for maintenance and environmental reasons, per an EPA consent decree and PREPA direction. The CC units do not fall under the consent decree. Their planned outages are driven by the operating time on the GTs, with internal inspections every 5300 operating hours. The CC staff utilizes periods of reduced demand for power to have major repairs done, such as on the HRSGs.

There are no service agreements with manufacturers, but GE is normally used for the thermal units' boiler and turbine inspections and parts and for CC GT inspections. The Plant uses its machine shop and Costa Sur's machine shop as much as possible for repairs of equipment. HRSG inspections are generally done by Plant staff, and a contractor is brought in to make the required repairs. Rebuilds of motors, generators, and rotors are done by specialty shops. The Costa Sur simulators for the boilers and steam turbines are used for Aguirre thermal unit training and troubleshooting.

PERFORMANCE BENCHMARK

Sargent & Lundy reviewed performance data provided by PREPA for January 2015 through December 2020. The steam units have relatively good heat rates and availability, and their average capacity factor has been relatively steady near 40%, with a few notable dips in 2016 and 2019 caused by major maintenance outages for Unit 2. The average capacity factor of the CC units has increased in the last two years after repairs to the circulating water cooling towers' hurricane damage were completed. The CC GTs, on average, have had at least 70% availability over the past five years, and one of the two STGs averaged over 60% availability in that period. The heat rate of the CC units is poor due to significant operating hours in simple-cycle mode. The black-start GTs have mainly been used for emergency use; usually at least one GT has availability.

FINANCIAL REVIEW

Sargent & Lundy compiled the historical operations and maintenance costs (O&M) and capital expenditures (CAPEX) for Aguirre from reported PREPA data and fiscal plan forecasts up through the 2020 fiscal year. This information was used to calculate fixed and variable O&M costs for the project. Sargent & Lundy compared these values with O&M and CAPEX for existing units in operation in North America of similar configurations and operating profiles. From the data, Sargent & Lundy determined that the Aguirre costs are within the typical range of costs for similar units considering that higher expenditures are required for plants firing HFO as compared to natural gas.

ENVIRONMENTAL & REGULATORY REVIEW

Sargent & Lundy performed a limited environmental review of publicly available information and information provided by PREPA to evaluate the compliance status for Aguirre. Sargent & Lundy did not find any compliance-related issues that would prevent renewal of the existing permits or impact near-term operation of the facility; however, the items listed below were identified as having unknown or potential compliance implications for Aguirre:

- Air Emissions
  - Unit 2 particulate matter emissions exceed the EPA's Mercury Air and Toxic Standards (MATS) limit.
  - Salinas is currently designated as non-attainment for the one-hour SO2 National Ambient Air Quality Standards (NAAQS). EPA/EQB's forthcoming plan for bringing the area into attainment with the one-hour SO_2 NAAQS may require SO_2 reductions from Aguirre.
- Water and Wastewater
  - Violations are identified in the ECHO[1] database as "reportable noncompliance" and "significant Category 1 noncompliance." Sargent & Lundy has not been provided information concerning violations from 2019 and 2020.

RECOMMENDATIONS & CONCLUSIONS

Overall, the thermal units were found to be in good condition and are consistent with comparable units of similar vintage; however, the CC units and black-start GTs were found to be in moderate condition and have experienced more wear than like units of similar age, likely due to their initial operation firing HFO. The thermal and CC units at Aguirre are nearing the end of their useful life and have been approved for retirement over the next five years according to the recent resolution of the Puerto Rico Energy Bureau (PREB) addressing PREPA's proposed integrated resource plan (Case No. CEPR-AP-2018-0001). The retiring thermal units may be repurposed as synchronous condensers (although it is likely new equipment may be needed) to provide dynamic reactive support and stability to PREPA's grid with the addition of new solar generation directed by the resolution. Despite the likely retirement over the next five years, it is important that efforts are made to preserve existing generating units to maintain grid reliability until sufficient new generation is brought online.

PREPA currently is completing a load demand and resource study to evaluate their generation assets. Sargent & Lundy recommends that this study be completed before retiring any of the units at Aguirre. If the study determines that repowering efforts or other operating features are desired for capacity or flexibility, then a third-party feasibility study is encouraged to ensure that proper planning and selections are made to avoid the operating challenges that Aguirre has seen during its service.

[1] (EPA's) Enforcement and Compliance History Online

Due to its proximity to Ponce, Aguirre—especially with the availability of seawater supply for cooling, nearby port services, and future water supply from the PREPA-owned Patillas Lake—is a strategic location for power generation on the island. With the removal of Units 1 and 2 and the CC Units 1-1 through 1-4 and 2-1 through 2-4, a modern repowered design—one that uses efficiency, environmental, and emissions advancements currently available from original equipment manufacturers—could be considered. The new design can have additional operational flexibility in response to load demands and the shifting generation of renewable sources of power like wind and solar. A redesign must include better ambient protection for the coastal-based equipment and hardening of the facilities to enable command and control of power production during emergency conditions, such as harsh weather events.

Smaller, rapid-start GT equipment with integrated synchronous condensing options, such as those in place at the PREPA Central Hidro Gas Mayagüez Plant, could be planned for the reclaimed space at Aguirre. New fast-start generation equipment that integrates purge credit, battery storage components for instantaneous response, integrated/clutched synchronous condensing, and similar features could provide quicker support and flexibility for a future grid that is planned to integrate a larger amount of less stable renewable power. These new units can also provide black-start capability for Aguirre. The diminished capacity of the existing black-start GTs can no longer start a thermal unit. Reciprocating engine plants provide even faster startups than GT equipment and also can be configured to operate on natural gas and in CC configurations while providing black-start capability.

While a natural gas pipeline was once partially completed from the EcoEléctrica Plant to the west of Aguirre, the project was never completed; therefore, natural gas has never been a fuel available for use. Offshore floating liquefied natural gas vessels with regasification systems could provide a source for cleaner burning fuel at Aguirre. Alternatively, field fabricated LNG storage tanks may be filled from the nearby port and utilized for receiving fuel for regasification and supply to any new equipment at the Aguirre site. Note however, that natural gas is not planned to be brought to the site.

Care must be taken to ensure that replacements or upgrades to the Plant are suitable for an aggressive, salt-laden marine environment exposed to coastal winds. Typically, competitively priced original equipment manufacturer standards for power generation and balance-of-plant equipment are not well-suited for this type of operating environment. New equipment must be configured for the challenging conditions at Aguirre. Failure to make allowances for suitable materials, equipment selection, buildings/enclosures, and other aspects of the facility designed to protect the plant from the corrosive operating environment will result in excessive future O&M costs and a shorter plant design life for any new installation. Suitable design specifications appropriate for this location include: (i) corrosion-resistant material requirements; (ii) marine-specific coatings; (iii) appropriate welding selections and special treatment of metal seams and stitched connections; (iv) fastenings with sealants, gaskets, and coatings; and (v) increased use of protective equipment enclosures. Due to these requirements, coastal power generation sites are inherently more expensive than those installed in less aggressive operating environments.

Ongoing proposals for Plant replacements, upgrades, and new generation should consider the guidelines provided herein. Any new operating regimes and other comparisons at the Plant must be made so equipment is selected to suit the future direction of the power generation and distribution system planned for Puerto Rico.

The Plant may continue to operate until such conversions or repowering projects take place. Units 1 and 2 and the Plant's common systems are in a condition to support near-term operation. The two CC units are in moderate condition, and ongoing maintenance and improvements are expected to keep them serviceable as well. Mobile generation units may be put in place to temporarily support generation. Future repowering work should be carefully planned, and a third-party feasibility study is suggested to ensure the design includes attention to corrosion protection, coordinated unit sizing and selection, and a sensible method of phased replacement for the next era of power generation at Aguirre.

Sargent & Lundy has the following recommendations for improved operations and reliability. This report also contains other recommendations that may be considered; however, the significant suggestions are as follows:

- Evaluate the condition of all gas equipment that is on site for future use. Long-term preservation should be pursued for all purchased equipment for natural gas firing such as relocating the equipment to indoor storage, assessing the equipment's design conditions, and evaluating how the equipment may be useful for future use at other PREPA facilities that use natural gas.
- Implement layup procedures for idled equipment and systems that include draining, dehumidifying, protecting, and, when needed, nitrogen-blanketing.
- Conduct a water study to confirm that a temporary source of process water will not be needed before the Patillas Lake water is delivered. Monitor, and, if needed, expedite the timeline for completion of the Patillas Lake pipeline project.
- Install HRSG stack dampers to preserve heat for cycling operations.
- Upgrade the protection of components being stored outdoors (in addition to the natural gas components).

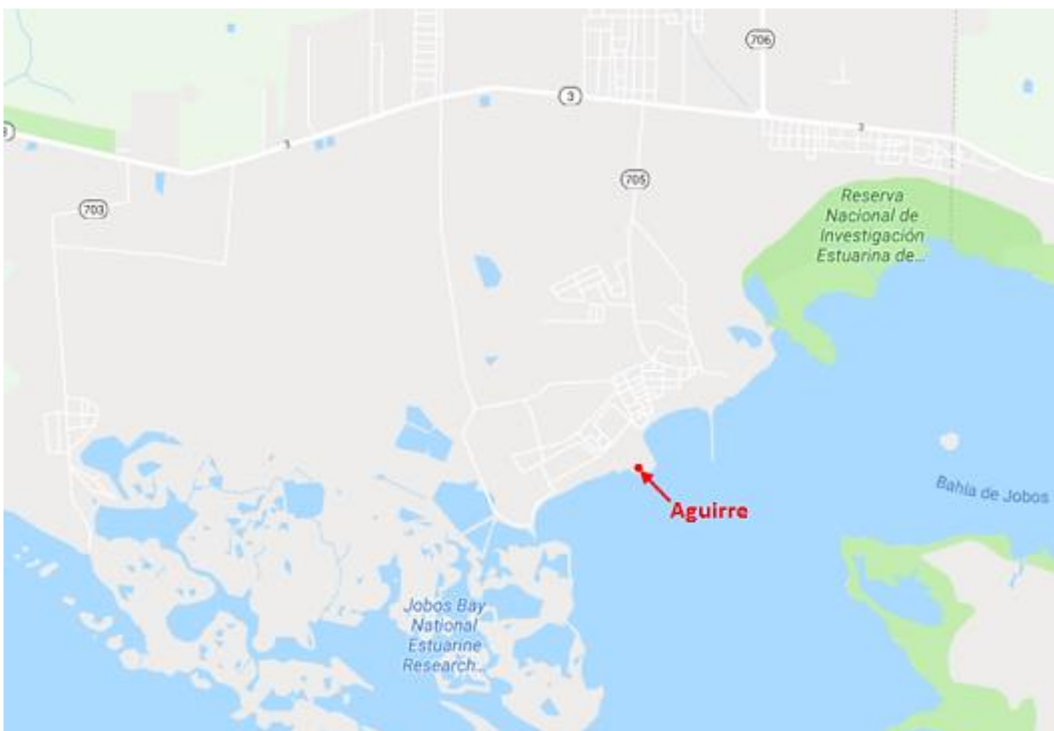
1. INTRODUCTION

The Puerto Rico Electric Power Authority (PREPA) is the electric power company responsible for generating, transmitting, and distributing electricity for the island of Puerto Rico. PREPA engaged Sargent & Lundy to perform an independent technical review of the Aguirre Power Plant Complex ("Aguirre" or the "Plant"). This report documents the technical assessment of the facility based on documentation provided by PREPA, previous site visits, and interviews with PREPA employees familiar with the Plant.

1.1. PLANT DESCRIPTION

Aguirre is located on the southern coast of Puerto Rico in the Salinas municipality and is owned and operated by PREPA. The Plant has two 450-MW thermal steam power generation units (Units 1 and 2), two 296-MW combined-cycle (CC) power generation units that can also operate in simple-cycle mode (STAG[2] 1 and STAG 2), and two 21-MW black start capable gas turbines (GTs). The nameplate capacity of the Plant is 1534 MW (gross), including the generating units and the black-start GT out of service for repairs as of October 2021. Aguirre's geographic location and proximity to Jobos Bay is shown in Figure 1-1:

Figure 1-1 — Aguirre Geographic Location



[2] STAG (Steam and Gas) is a descriptor trademarked by General Electric (GE) for their pre-engineered CC plants.

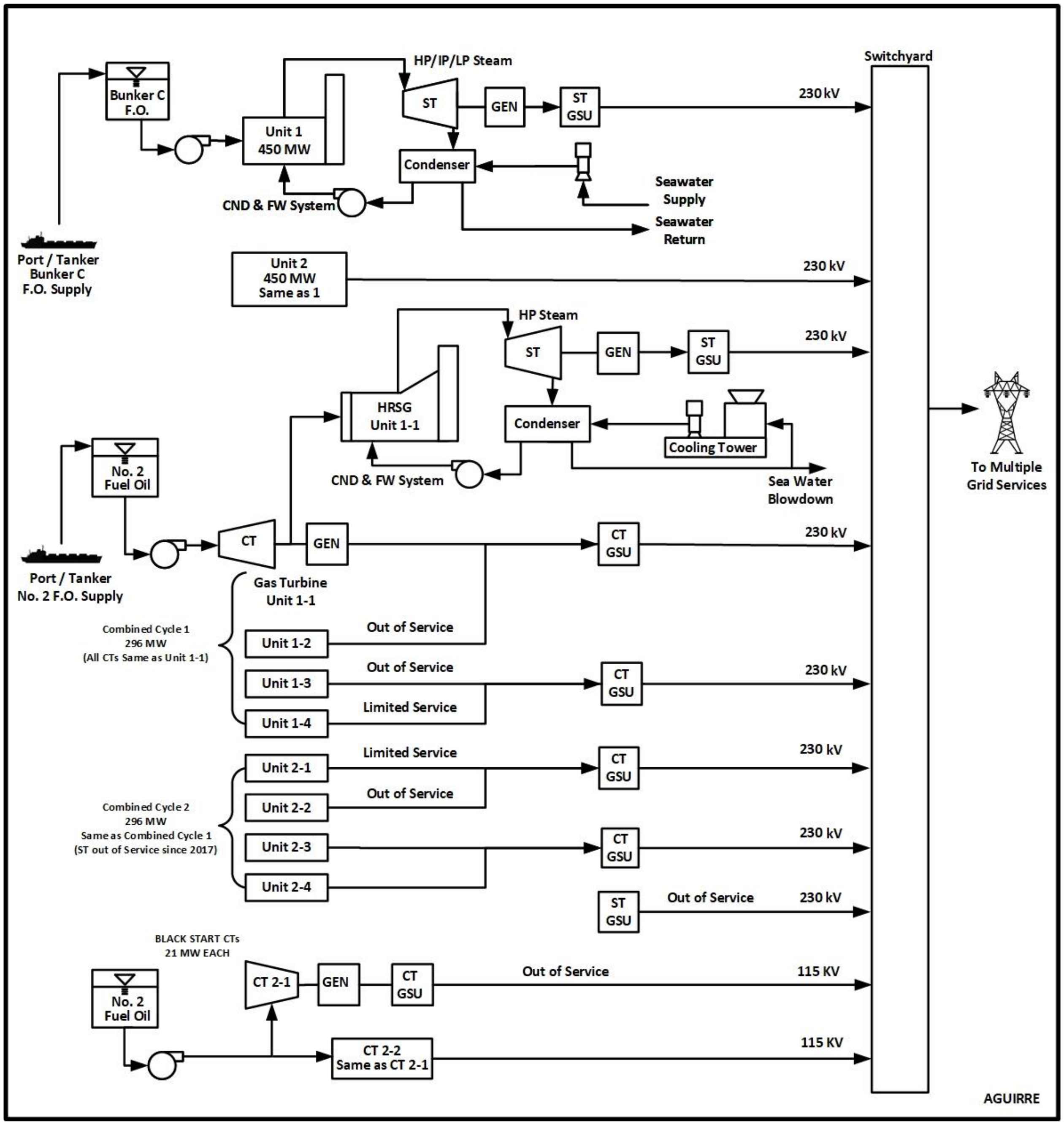
Units 1 and 2 and began commercial operation in 1971 and 1972, respectively, STAGs 1 and 2 began commercial operation in 1977, and the two black-start GTs began commercial operation in 1972. The Plant refers to the entire thermal and CC complex, including the two black-start GTs.

The two thermal steam units, Units 1 and 2, operate on heavy fuel oil (HFO) while the two CC units STAG 1 and STAG 2 and the two black-start units operate on No. 2 fuel oil. STAGs 1 and 2 are no longer capable of operating on HFO.

STAG 1 and STAG 2 are both 4x4x1 configurations with 50-MW GE 7EA GTs. Each of the eight GT discharge ducts has a diverter damper and stack, and the units operate in either simple-cycle mode or CC mode as needed to meet dispatch demand. Individual GTs and heat recovery steam generators (HRSGs) at the CC are identified as 1-1 through 1-4 and 2-1 through 2-4.

Each of the Plant's steam turbine (ST) generators (STGs) is connected through a dedicated transformer to the 230-kV switchyard. The gas turbine generators in the CC plant are connected in pairs, where each pair shares a transformer connecting them to the 230-kV switchyard. A schematic representation of Aguirre is provided in Figure 1-2.

Figure 1-2 — Aguirre Overall Plant Configuration



1.2. SCOPE OF REVIEW

This technical report includes an assessment of the plant design, operations and maintenance (O&M) activities, plant organization and personnel, technical performance, commercial arrangements and obligations, and provisions for environmental permitting. Sargent & Lundy's objective is to provide an overview of the condition of the asset, assess whether the facility has been operated and maintained in accordance with generally accepted industry practices, and identify significant challenges to continued successful operation. Recommendations for demolition, equipment upgrades, or operational improvements are also included within this report. Additionally, Sargent & Lundy performed a Phase I Environmental Site Assessment (Phase I ESA) in May 2019 with the site visit in December 2018; for the resultant findings, see Report SL-014468.AG.ESA [1].

Sargent & Lundy acquired information to conduct its review from several sources:

- Documentation provided by PREPA's corporate operations and plant personnel through December 2020
- Discussions with Plant personnel on the phone and during several site visits of the facility from 2018 to early 2020
    - Due to recent travel restrictions related to the 2020 global pandemic, no further visits to the site were made to support this report update. Updates of current equipment conditions and Plant activities were solicited from PREPA via an exchange of interview questions with Plant personnel in the fall of 2020 and winter of 2021.
- Industry data obtained from market research databases and publicly available sources to evaluate plant characteristics

Sargent & Lundy understands that this review is being conducted in connection to the request for proposal (RFP) to manage, operate, maintain, asset manage, and decommission, as applicable, one or more of the base-load generation plants and gas turbine peaking plants located throughout the island of Puerto Rico, including Aguirre.

2. TECHNICAL DESCRIPTION

2.1. MECHANICAL SYSTEMS

Aguirre includes two thermal units, two CC units, and two black-start GTs. The total capacity of the Plant is currently 1164 MW (gross) but will be 1534 MW (gross) when both STAG steam units, all CC GTs, and the black-start BSGT 2-1 return to service. The characteristics of the generating units at Aguirre are shown in Table 2-1:

Table 2-1 — Production Plant Overview

Unit Name	COD	Technology	Fuel	Capacity (MW)	Status (as of October 2020)
Aguirre Steam Turbine #1 (Unit 1)	1971	Steam	HFO	450	Operational
Aguirre Steam Turbine #2 (Unit 2)	1972	Steam	HFO	450	Operational
Aguirre Black-Start Turbine BSGT #2-1	1972	GT	Oil No. 2	21	Non-Operational; repairs in process
Aguirre Black-Start Turbine BSGT #2-2	1972	GT	Oil No. 2	21	Operational
Aguirre Combined-Cycle Gas Turbine #1-1	1977[3]	CC GT	Oil No. 2	50	Operational
Aguirre Combined-Cycle Gas Turbine #1-2	1977[2]	CC GT	Oil No. 2	50	Non-Operational; repairs in process
Aguirre Combined-Cycle Gas Turbine #1-3	1977[2]	CC GT	Oil No. 2	50	Non-Operational; repairs in process
Aguirre Combined-Cycle Gas Turbine #1-4	1977[2]	CC GT	Oil No. 2	50	Operational (30 MW available, 20 MW derate due to high temperature in charging compartment)
Aguirre Combined-Cycle Steam Turbine #1	1977	Steam	Oil No. 2	96	Operational (18 MW available, 78 MW derate due to non-operational GTs)
Aguirre Combined-Cycle Gas Turbine #2-1	1977[2]	CC GT	Oil No. 2	50	Operational (45 MW available, 5 MW derate)

[3] From 1997–2001, GE converted CC GTs from 7B to 7EA units (MS7001B/EA). GT Units 1-1 and 1-2 were converted in 2000, Units 1-3 and 1-4 were converted in 1997, Units 2-1 and 2-2 were converted in 1998, Unit 2-3 was converted in 1999, and Unit 2-4 was converted in 2001.

Unit Name	COD	Technology	Fuel	Capacity (MW)	Status (as of October 2020)
Aguirre Combined-Cycle Gas Turbine #2-2	1977[2]	CC GT	Oil No. 2	50	Non-Operational; major inspection in progress
Aguirre Combined-Cycle Gas Turbine #2-3	1977[2]	CC GT	Oil No. 2	50	Operational
Aguirre Combined-Cycle Gas Turbine #2-4	1977[2]	CC GT	Oil No. 2	50	Operational
Aguirre CC Steam Turbine #2	1977	Steam	Oil No. 2	96	Non-Operational; repairs in process
Aguirre CC Black Start Engines #1 and #2	1977	Reciprocating Engine	Oil No. 2	2	End of Life; demolished

1. **Operational**—Functioning and suitable for power generation
2. **Non-Operational**—Out of service temporarily and not generating power
3. **Irreparable**—Equipment requires major expenditure to restore for power generation
4. **End of Life**—Equipment in its last stage of useful life. Replacement plans or retirement should be considered.

2.1.1. Gas Turbines (Combined Cycle)

STAGs 1 and 2 are comprised of two duplicate units. Each unit consists of four 50-MW Frame 7EA GTs with individual HRSGs—i.e. boilers, powering a single 96-MW STG. Each unit is a 4x4x1 configuration and yields a nameplate unit capacity of 296 MW. The total CC nameplate capacity is 592 MW. These units are primarily used for cycling duty due to the cost of No. 2 fuel. Each unit was 80% modified to burn natural gas; however, the facility currently does not have natural gas supply and continues to operate on No. 2 fuel oil. They no longer fire HFO as originally designed.

Each GT exhaust duct has a diverter damper and a gas bypass stack, allowing the GT to operate in simple-cycle mode as peakers. If additional power is needed, the STAG is operated in partial or full CC mode, relying on a steam line from the thermal units during startup.

In 1997, GE began converting the GTs from 7B to 7EA units (MS7001B/EA). In 2007, their controls were upgraded.

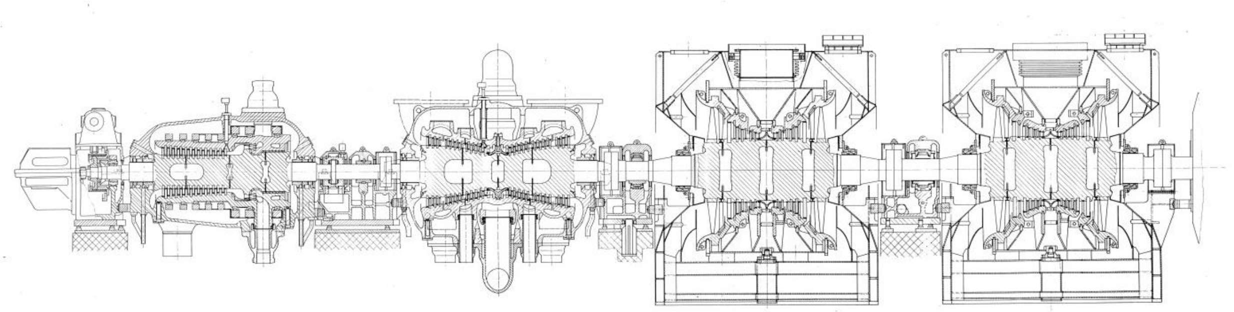
Figure 2-1 — STAG 2 and GT Inlets

2.1.2. Steam Turbines

2.1.2.1. Units 1 & 2

The STG for both thermal units was manufactured by ABB (now GE Power), each with a gross rated capacity of 500 MW. The units currently use 450 MW as their maximum capacity due to boiler limitations. The STGs on Units 1 and 2 have a four-flow low-pressure (LP) turbine section and began commercial operation in the early 1970s. The turbine's 100% heat balance for a 1991 upgrade shows a nominal maximum continuous rating output of 500 MW at a 3430-kilopounds/hour main steam flow at 2400 psig[4] and 1000°F and hot reheat conditions of 594 psig and 1000°F.

Figure 2-2 — Diagram of STG Longitudinal Section View, Units 1 and 2



Source: Aguirre O&M Manual – Volume 1 of 5

[4] Pounds per square inch, gage

Figure 2-3 — Picture of STG Longitudinal Section View, Units 1 and 2

The Unit 1 and 2 turbines are located outdoors on a common turbine deck with weather shelters for each turbine and generator. The deck is wide, unobstructed, and conveniently located adjacent to the control rooms and the engineering offices in the administration building. A gantry crane rated at 50 tons is installed on the deck for servicing the turbine equipment. The crane has access to the bays between the units for equipment laydown.

Figure 2-4 — Turbine Deck Gantry Crane, Units 1 and 2

2.1.2.2. STAGs 1 & 2

The STAG STs were manufactured by GE and are located outdoors with weather enclosures. They include a high pressure (HP) and LP section and do not have an intermediate pressure (IP) section. In Figure 2-5, the single-flow HP rotor is on the left and the double-flow LP rotor is on the right.

Figure 2-5 — ST Rotor, STAG 1

Source: GE-Atlanta 2013 inspect/repair service report #26826/Order#20591

2.1.3. Generators

2.1.3.1. Units 1 & 2

The generators for Units 1 and 2 are hydrogen-cooled with an additional water-based cooling system for the stators. The thermal plant has a spare generator. The generators are 60-Hz units with continuous output ratings of 570 MVA at 60 psig hydrogen pressure, 24 kV, and 0.85 power factor. They are type WT21S-112AF3 by Brown Boveri & Cie.

2.1.3.2. STAGs 1 & 2

The air-cooled 60-Hz CC GT generators are by GE and are hot-end driven. The GT exhaust is turned horizontally 90° away from the generator, then 90° toward the HRSG. The hydrogen-cooled STGs are by GE and are rated at 132 MVA, 30 psig hydrogen pressure, and 0.85 power factor. The thermal units have a hydrogen generator while the CC units use bottled hydrogen.

2.1.4. Boilers & Heat Recovery Steam Generators

2.1.4.1. Units 1 & 2

Aguirre Units 1 and 2 are tangentially fired Combustion Engineering (now GE Power) HFO-fired boilers built in 1971 and 1972, respectively. Based on the Combustion Engineering description, both units have an original maximum continuous rating of 3170 kilopounds per hour for main steam flow and outlet steam conditions of 2950 psig and 1005°F. The units start with No. 2 fuel oil warm up guns with propane ignitors.

Flue-gas recirculation is used for temperature control on each unit from 150 MW to full unit output (one fan per unit, each with a turning gear). The flue-gas recirculation fan motors are 2250 horsepower (hp) and 890 rpm. Both Unit 2 induced-draft (ID) fans and one Unit 1 ID fan are driven by 4500-hp, 890-rpm motors. ID Fan 1-2 has a 6000-hp, 890-rpm motor. Only the Unit 1 ID fans have turning gears, which were installed in 2013. These reduce the starting electrical load and are used to deter shaft bowing during shutdown. The forced-draft (FD) fans have 1750-hp, 595-rpm motors. The FD and ID fans are 50% capacity. The air preheaters on both units were recently modified from three layers to two layers of heat exchange baskets.

2.1.4.2. STAG 1 & 2

The CC units each have four vertical single-pressure HRSGs, one per GT. They were provided by GE as part of their pre-engineered CCs (STAG units). There used to be a damper in each of the eight HRSG stacks, but the dampers have been removed for reasons not known to the current staff. Two concrete exhaust stacks remain that have been abandoned. They were used for each power block as a single emission point for four gas turbines when HFO was burned.

2.1.5. Steam & Condensate Cycle

2.1.5.1. Units 1 & 2

Aguirre Units 1 and 2 each have a main condenser located below the LP turbine exhaust duct with the turbines high above the auxiliary spaces and equipment rooms. The turbine exhaust steam is condensed in a Foster Wheeler two-pass surface-type condenser with aluminum-brass tubes cooled by a once-through circulating water system. They have a ball-type cleaning system, but it is not being used due to third-party contract issues. Each unit has two redundant vacuum pumps to remove air and other non-condensable gases from the condenser during normal operation.

Water from the condenser hotwell is forwarded by one of two 500-hp 100%-capacity vertical condensate pumps to the condensate polisher. It then goes to a feedwater heater and two 1750-hp 100%-capacity Ingersol Rand deaerator pumps, and finally to three additional LP feedwater heaters and the deaerator. The boiler feedwater pumps (BFPs) draw the deoxygenated water from the deaerator and boost its pressure for the two HP feedwater heaters (#6 and #7) and the boiler economizer.

Three extractions from the LP turbines are directed first to three of the LP feedwater heaters (upstream of the BFP). The extraction to Heater #4 is from the last stage of the IP turbine. Higher-pressure extractions from the IP turbine go to the deaerator (Heater #5) and to Heater #6. An extraction from the final stage of the HP turbine, which coincides with the cold reheat line, goes to Heater #7.

The thermal units each have a motor-driven BFP and a turbine-driven BFP, both by deLaval. The electric BFP is used up for startup through 200 MW and then shut off as the turbine-driven BFP takes over. The thermal units generally operate above 200 MW and remain on the turbine-driven BFP. Each unit's electric BFP is driven by two 5000-hp motors.

2.1.5.2. STAG 1 & 2

STAG Units 1 and 2 each have an elevated steam turbine located adjacent to the centralized joint control room. Each STG has two condensers located below its LP turbine exhaust ducts. The turbine exhaust steam is condensed in surface-type condensers cooled by a circulating water system with a seawater cooling tower. The condensers are Foster Wheeler two-pass designs with aluminum brass tubes. They do not have a ball-type tube cleaning system; instead, a contractor comes to clean the tubes. Each unit has redundant vacuum pumps to remove air and other non-condensable gases from the condenser during normal operation.

Water from the condenser hotwell is forwarded to one of the redundant vertical condensate pumps, a feedwater heater, and the deaerator. There are two condensate storage tanks. One of the two 100%-capacity 1750-hp BFPs draws the deoxygenated water from the deaerator and boosts its pressure for the HRSG economizer.

2.1.6. Circulation Water Systems

2.1.6.1. Units 1 & 2

The thermal units draw seawater from the Jobos Bay for once-through cooling water to the condensers. There are five screenwell chambers with traveling intake screens, 3x100%-capacity screen wash pumps, and five 1000-hp vertical circulating water pumps—two for each unit with an installed spare that is shared for redundancy. A chemical injection system to minimize microfouling from the seawater is administered by GE Betz (SUEZ).

The circulating water pumps are mounted to the concrete deck above the water intake basin. A platform is provided at the motor level for service and inspection of the units. There is an overhead crane for maintaining the circulating water pumps, the traveling screens, and the screen wash pumps.

The circulating water pumps discharge to the condenser waterboxes for heat rejection. After cooling the condenser, the circulating water is piped to the circulating water discharge channel, at the end of which are seven discharge channel water pumps. The return water is piped several hundred yards offshore.

2.1.6.2. STAG 1 & 2

The CC circulating water system uses two five-cell cooling towers, each with redundant 2000-hp circulating water pumps. There is a combined discharge channel to the Jobos Bay, with blowdown from the freshwater closed cooling water towers and the CC seawater cooling towers joining the once-through discharge from the thermal condensers. A slipstream from the discharge channel provides makeup water to the CC cooling tower basin.

Figure 2-6 — Combined-Cycle Seawater Cooling Towers

Looking south. STAG 1 fiberglass tower on the left, STAG 2 to the right. Each tower has two stairways.

2.1.7. Closed Cooling Water System

The closed cooling towers (one for each unit) remove heat from independent closed cooling water circuits in the Plant. These circuits service various equipment coolers located throughout the units. Treated well water is used in the closed cooling systems and is the source of makeup water to the towers. An outside contractor, Industrial Chemical, supplies the chemicals and controls the water chemistry. Blowdown from the cooling towers is directed to the Plant's discharge channel to the bay.

Figure 2-7 — Closed Cooling Tower for Thermal Units 1 and 2

Looking south. There are two cells for Unit 1 are on the left and two cells for Unit 2 are on the right. In the foreground are two full capacity closed cooling water pumps per unit.

Figure 2-8 — Closed Cooling Tower for Combined Cycle Unit

There is one cell and redundant closed cooling water pumps per STAG.

2.1.8. Black-Start Gas Turbines & Engines

The black-start reciprocating engines at the CC facility have been demolished. Two black-start No. 2 fuel oil gas turbines, 2-1 and 2-2, are located near the thermal units. These are Frame 5000 GTs manufactured by John Brown and installed in the 1970s. Their original rating was 22 MW, and their current capability is 21 MW. The GT generators are owned, maintained, and operated by the Hidro-Gas division of PREPA. The 21-MW capacity of the John Brown GTs limits their ability to black start a thermal unit; instead, one of the John Brown GT's black starts a 50-MW CC GT that in turn may be used to black start a thermal unit.

Figure 2-9 — Black Start BSGT 2-1

2.1.9. Fuel Systems

HFO and No. 2 fuel oil are brought to the site by tanker. The HFO is stored in two of the three reserve tanks on the northwest portion of the site, each with a 10.7 M-gallon capacity. HFO is also stored in two 1.5 M-gallon service tanks on the northeast portion. No. 2 fuel oil is stored in one 11.8 M-gallon reserve tank on the northwest portion of the site and two 1.45 M-gallon service tanks on the northeast portion, adjacent to the black-start GTs. Additional No. 2 fuel oil storage is provided on the southeast portion of the Plant near the fuel unloading pier in two 1.1 M-gallon reserve tanks. The CC facility has three 950,000-gallon No. 2

fuel oil storage tanks (a fourth tank was retired in place). Fuel oil tanks have containment and foam-based fire protection.

Propane is used for the ignitors on Units 1 and 2, which then use No. 2 fuel oil for startup and HFO to run. The CC starts and runs on No. 2 fuel oil.

Figure 2-10 — No. 2 Fuel Oil Tanks at Combined Cycle Unit

2.1.10.Fire Protection

The plant fire protection system consists of diesel and electric motor driven fire water pumps that draw suction from dedicated reserves in the well water tanks. An electric jockey pump maintains pressure in the underground firewater loop that feeds the plant hydrants and sprinkler systems. The fuel oil storage tanks include a foam fire suppression system, and there are carbon dioxide fire suppression systems installed on the CC units.

2.2. ELECTRICAL SYSTEMS

2.2.1. Units 1 & 2

The two steam units' generators are each connected via isolated phase bus to their respective generator main power transformer (MPTs). The isolated phase bus of each STG is arranged with a tap to feed the two oil-filled station service transformers, which step down the voltage and in turn provide power to a 4.16-kV switchgear bus. These two buses at each generating unit are known as the normal buses, and they provide power to the unit's auxiliary loads. In addition to the normal busses, there is an additional 4.16-kV switchgear bus, called the emergency bus, which is fed from the emergency station service transformer.

The normal busses feed larger motor loads directly at 4.16 kV as well as low-voltage auxiliary transformers that step the voltage down to 480 V for distribution to low-voltage switchgear buses and motor control centers throughout the plant.

The step-up transformers (or MPTs) for both thermal plant units connect the generators to the 230-kV switchyard. The Unit 1 MPT is rated 334/444/554 MVA, 24/230 kV while the Unit 2 MPT is rated 344/457/570 MVA, 23/230 kV, OA/FA/FOA. The MPT for Unit 2 was recently replaced during the 2020 environmental outage. Additionally, the two units share a common emergency station service transformer (ESST) that connects to the 115-kV switchyard. The two MPTs are connected to the 230-kV switchyard through a combination of an overhead conductor and an underground cable. The ESST is connected to the 115-kV switchyard via underground cable.

2.2.2. STAGs 1 & 2

The STAG 1 and STAG 2 generators are arranged in two blocks. There are two GT generator pairs (a total of four GTs) plus an STG in each block. Each pair of GT generators feeds into a three-winding step-up transformer. Each STG has its own dedicated step-up transformer.

The 230-kV switchyard at Aguirre is connected to the PREPA grid through four transmission lines: Aguas Buenas Line 50900, Aguas Buenas Line 51000, Sabana Llana Line 50700, and Costa Sur Line 50300.

The 115-kV switchyard is connected to the PREPA grid through four transmission lines: Ponce Line 40300, Jobos TC Line 40100, and Jobos TC Line 40200.

There are four main transformers for the GTs in the CC plant. These transformers are all three-winding, with a top rating of 125 MVA, and each is connected to a pair of GTs. Each of the two STGs in the CC plant is connected to a dedicated two-winding main transformer with a top rating of 130 MVA. The CC MPTs step up the generator voltage to 115 kV before power is connected to the grid through the 230-kV substation via overhead conductor.

2.2.3. Interconnection

The existing demarcation point for Aguirre is on the low side of the MPT and the ESSTs due to the division of responsibility on the maintenance of the large power transformers. All maintenance on the large power transformers is performed by the Conservation Group within PREPA’s substation group; this includes the MPTs, ESSTs, and normal station service transformers. Additionally, the controls and relaying for the PREPA transmission center are located in the Plant control room rather than in the switchyard.

Engineering design is planned to identify and further separate the Plant from the PREPA transmission and distribution system. A high-level review of the separation required work is included in Sargent & Lundy Report TD-0003, “Demarcation of PREPA Generation Assets from the Transmission and Distribution System” [2].

2.2.4. Controls

There is a common control room for Units 1 and 2 with separate controls for each unit. There is a similar arrangement for the CC units. The Plant uses Foxboro distributed control systems and has a contract agreement with Schneider Electric for maintenance of their boiler controls systems through August 2021. Recent updates to controls hardware and software are discussed in Section 3.1.6.6.

2.3. STRUCTURES

The Plant has many structures on site to support the operation, maintenance, and administration of the facility. The thermal unit plant control rooms and administration offices are located in the building that spans between Streets C and D and between the Unit 1 and 2 boilers and STs. The control building for the CC units is located between CC Units 1 and 2, and an additional administration building is located to the northwest of the CC units. A maintenance shop is located southwest of the CC Units, and three warehouses are arrayed to the north and west of the CC Unit 2 power block. Additional structures on site house various equipment ancillary to the Plant generation operations.

2.4. NATURAL GAS CONVERSION COMPONENTS

The Plant was evaluated for conversion to natural gas, and a liquefied natural gas importation terminal (i.e., a floating facility to receive and gasify liquefied natural gas shipments for delivery to the Aguirre Plant) was proposed. The terminal is referred to as the Aguirre Offshore Gas Port; however, the United States Federal Energy Regulatory Commission permit for the project was recently cancelled. Several studies to ready the Plant for natural gas operation were completed. Additionally, several components were purchased and partially installed. There are no current plans to bring natural gas to the site or complete the conversion to natural gas; however, the discussion below is provided for information.

Converting the CC units to natural gas was evaluated and, with what appeared to be a pending gas contract with EcoEléctrica (a gas pipeline project, “Gasoducto del Sur”), each CC unit was modified in 2007 and 2008 to burn natural gas or No. 2 fuel oil. Approximately 80% of the modifications to the CC units were installed to support natural gas operation but have not been used. The GTs operate on No. 2 fuel oil. The Plant was unable to retrieve information for Sargent & Lundy’s review on the dual-fuel conversion.

The Coen Company conducted a natural gas conversion study in 2011 for Units 1 and 2 and provided the following recommended modifications to accommodate 100% natural gas firing:

- Replace the existing superheater (SH) platen section and intermediate SH horizontal section with new sections using improved tube materials.
- Replace the existing intermediate SH horizontal inlet header with a new inlet header using improved material.
- Replace the existing intermediate SH horizontal outlet header with a new outlet header using improved material.
- Replace the existing intermediate SH desuperheater inlet links with new inlet links using improved material.
- Replace the existing SH desuperheater with a new desuperheater using improved material properly sized for the required increase in spray water flow.
- Remove 42% of the existing #2 low temperature reheater section surface.
- Retain the existing vibration baffles. Details on potential modifications to account for reheater surface reduction and revised support requirements will be determined at material contract stage.
- Increase the superheater desuperheater spray-water flow capacity to 430,000 pounds per hour.

These modifications were implemented, and the gas conversion parts and fuel trains are stored outdoors at the Plant.

3. EQUIPMENT CONDITION

The condition assessment of the Plant is a descriptive summary of the main equipment, facilities, balance of plant, and site-specific items of interest. The units are discussed individually, as a group where reasonable, or as a combined facility for common infrastructure assessment where applicable.

3.1. CONDITION ASSESSMENT

3.1.1. Methodology

Based on interviews, walkdowns, and data gathered on site and sent by PREPA, Sargent & Lundy developed a high-level overall condition assessment for each of the units by using a scoring matrix. The matrix is comprised of six major categories: safety hazards, corrosion control, mechanical assessment, electrical assessment, instrumentation and controls assessment, and civil and structural assessment. A short description of each category follows.

1. **Safety Hazards**—This is based on visual observations during walkdowns from experienced engineering staff.
2. **Corrosion Control**—With most of the facilities located near the coast, corrosion has proven to be a significant aspect of maintenance planning, capital costs, and safety and reliability of facilities.
3. **Mechanical Assessment**—This is a high-level review of all major mechanical equipment and systems.
4. **Electrical Assessment**—This is a high-level review of all major electrical equipment and systems.
5. **Instrumentation and Controls Assessment**—This is a high-level review of all major instrumentation and controls equipment and systems.
6. **Civil and Structural Assessment**—This is a high-level review of all major civil and structural equipment and systems.

Each of the above categories was scored after Sargent & Lundy's site visits and includes a combination of visual assessment, interviewing, and data review as indicated in the scoring tables. The color-code scoring system for this assessment is defined in Table 3-1.

Table 3-1 — High Level Condition Assessment Point Scoring System

Dark green	System like new (replaced or refurbished within the past five years)
Light green	System has been maintained with general O&M on a routine basis; no major issues noted
Yellow	Deficiency was noted or components were out of service
Orange	Major issues noted causing a safety, reliability, or unit output issue
Red	Not in operation due to end of life

As part of a consent decree with the EPA, each Aguirre thermal production unit is mandated to take an environmental outage at intervals of 12–18 months. Sargent & Lundy assumed that all required maintenance activities are conducted during each mandatory environmental outage except where progress is noted. The CC units do not fall under the consent decree; their planned outages are driven by the operating time on the GTs, with internal inspections every 5300 operating hours. The CC staff utilizes periods of reduced demand for power to have major repairs done, such as on the HRSGs. These key assumptions were used in evaluation of each of the six major condition assessment categories.

3.1.2. Thermal Unit 1 Condition

3.1.2.1. Boiler Thermal Unit 1

A portion of the existing superheater (SH-8) has reached its end of life, and based on a 2013 inspection report [3], it is not suitable for continued service. A replacement superheater component for Unit 1 is currently in outdoor storage but was designed for natural gas firing. Sargent & Lundy recommends GE Power be contacted to determine the impact on Unit 1 performance if the superheater is replaced with the redesigned natural gas fired superheater while operating on HFO.

With the Aguirre Offshore Gas Port being postponed indefinitely (see Section 2.4), Unit 1 reliability due to steam leaks and potentially the end of life of major pressure part components becomes a major concern.

The unit has recently been dispatched for full load, and Plant personnel expect the unit to be able to achieve 100% boiler maximum continuous rating in its present condition. It is unknown when the next boiler inspection will be scheduled, but the unit should be included in PREPA's boiler condition assessment program, which begins in 2021 and extends through 2026. Sargent & Lundy recommends that all identified issues from the 2013 boiler inspection report be assessed.

3.1.2.2. STG Thermal Unit 1

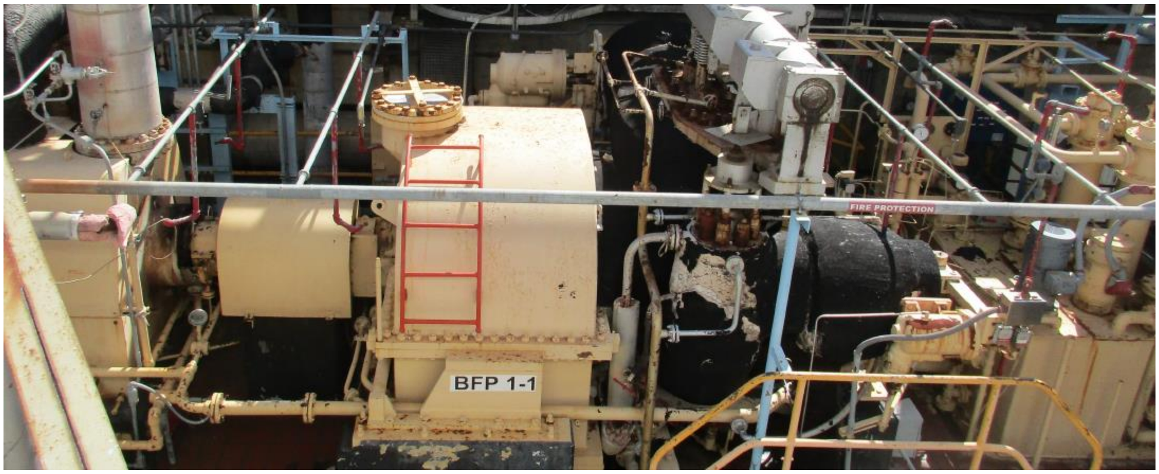
The overall appearance of the Unit 1 STG is acceptable given the age and location near a coastal area. Figure 3-1 is generally representative of the entire machine's condition. Note that some doors were found open or non-functional. This is a concern if the fire protection system needs to be activated. The HP and IP rotors have around 43,000 operating hours since they were replaced in 2012, and they are due for a 50,000-hour major inspection. The LP rotors are overdue for inspection, with approximately 65,000 operating hours since they were replaced at the end of 2008. No inspection has been scheduled at this time; however, the Plant recently received refurbished spare HP and IP rotors, and a project to requalify the spare LP rotors on site is pending. Quotes have been solicited for the project of interchanging these with the aging Unit 1 STG rotors.

Figure 3-1 — Unit 1 STG HP Section with Turning Gear

3.1.2.3. Balance-of-Plant Thermal Unit 1

The major balance-of-plant equipment is in good condition, with a few minor exceptions. Figure 3-2 shows the steam driven boiler feed pump and is generally representative of the condition of this equipment. The Unit 1 auxiliary condenser, which serves the steam-driven BFP, has some corrosion on one of its three circulating water flanges but overall appears to be in good condition. The Unit 1 condensate polisher system is in good condition, and the two 5000-hp motors for the Unit 1 motor-driven BFP were replaced in 2012. Based on inspection reports from the Plant, flow accelerated corrosion is not an issue with the feedwater heaters.

Figure 3-2 — Steam-Driven BFP, Unit 1



Steam-driven BFP is in moderate-to-good condition.

The fan rotor in ID Fan #1-2 was replaced in 2017 due to high vibration. In general, the FD, ID, and gas recirculation fans and motors are in good-to-moderate visual condition, including their foundations, actuators, bearings, and lube oil skids. Plant staff notes that they have corrected recent issues with FD Fan 1-2 that included missing insulation on its inlet duct and corrosion on its inlet vane actuator arm. No further issues have been reported concerning the FD Fan 1-2.

3.1.2.4. Electrical System Thermal Unit 1

Most of the major electrical equipment is original and nearing the end of their useful life, but some equipment has been replaced as needed. The excitation control system was upgraded in 2012. Online oil sampling monitors were installed on the MPT of Unit 1 in 2014. The generator was replaced at the end of 2015. The automatic voltage regulator is outdated. The generator, power transformer, switchgear, batteries, and relays undergo periodic maintenance and testing.

3.1.2.5. Condition Assessment Rating Table Thermal Unit 1

Unit 1 was in a forced outage for problems with ID Fan 1-2 and high conductivity in the condensate system in early September of 2020. The Plant notes that issues with the Unit 1 ID Fan 1-2 have been addressed, and a broken tube in the condenser was repaired, making Unit 1 available for full load (450 MW) as of October 2020. The overall condition of the unit is similar to other units of the same vintage, except corrosion control is below average. Keeping corrosion in check is extremely difficult on a unit burning HFO located on a seawater bay. On Unit 1, about 25% of the piping, tanks, and structural steel have corrosion that is noticeable, which may affect the integrity of support structures and interfaces with equipment foundations. In some instances, the corrosion is widespread on uninsulated or uncoated surfaces. Overall, the unit's corrosion control is effective where applied, but Sargent & Lundy recommends it be expanded to cover more items. In general, the major equipment appears to be in good condition and, in some cases, recently replaced or refurbished.

Our overall condition assessment summaries of Aguirre Unit 1 can be found in Table 3-2:

Table 3-2 — Aguirre Thermal Unit 1 Overall Condition Assessment

Plant Name: Aguirre Unit 1									
Item	System	Assessment Method			Scoring Category				Notes
		Visual	Interview	Data	End of Life	Reliability	Unit Output	Subtotal	
1	**Safety Hazards**	yes	no	no		*n/a*	*n/a*		
2	**Corrosion Control**	yes	no	no		*n/a*	*n/a*		Some piping, structural steel and tanks need attention.
3	**Overall Cleanliness & Housekeeping**	yes	no	no		*n/a*	*n/a*		
4	**Mechanical Assessment**								
4.1	Steam Generator (boiler/HRSG)	yes	yes	yes					SH headers are near their end of life. Replacement parts were purchased but these were for the gas conversion project and remain in outdoor storage. No further repairs are scheduled which need addressing soon.
4.2	FD and ID Fans and Auxiliaries	yes	yes	yes					No derates noted from the plant or the data. Plant recently corrected FDF 1-2 inlet duct insulation and corroded actuator arm.
4.3	High Energy Piping (HEP)	yes	yes	no					
4.4	Condensate System	yes	yes	yes					Plant intends to bid work to refurbish Unit 1 waterboxes during FY 2020-2021.
4.5	Feedwater System	yes	yes	yes					BFP motors replaced 2012
4.6	Turbine and Auxiliaries	yes	yes	yes					Plant recently received spare HP and IP rotors and are planning for interchange with Unit 1 rotors. Unit 1 HP and IP blades were last replaced in 2011. Plant is reviewing proposals for requalifying the spare LP rotors on site.
4.7	Circulating Water and Closed Cooling Water Systems	yes	yes	yes					Closed cooling water tower fill was replaced in 2019 outage.
4.8	Compressed Air Systems	yes	yes	no					Redundant equipment in operation to meet demand. Units 1 and 2 are interconnected, and service air system can back up the instrument air system. Plant notes that one of the four instrument air dryers (#2-2) is out of service on maintenance.
4.9	Emission controls	no	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	No emissions controls installed
4.10	Fuel Systems	yes	yes	yes					
4.11	Seawater Intake	yes	yes	no					Surface barrier installed for seasonal sargassum sea weed. GE SUEZ chemical feed used. Traveling screens #1 and #3 are out of service and a project is underway to replace all traveling screens.
4.12	Water Treatment	yes	yes	no					Water level in deep wells is low, increasing the conditioning cost. Patillas Lake supply expected in 2022. Demin system condition and capacity are good.
4.13	Underground Piping	no	yes	no					No issues noted from plant personnel (with exception of the fire protection system UG piping).
4.14	Fire Protection Systems	no	yes	yes			*n/a*		Underground fire loop has unidentified leak(s). Pumps were replaced in 2013.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	yes					Replaced at the end of 2015. Spare gen. is on site. AVR is outdated.
5.2	Transformers	yes	yes	no					Spare MPT needs to be replaced
5.3	Switchgear	yes	yes	no					
5.4	Protective Relays	yes	yes	no			*n/a*		
5.5	Black Start Engine #21	yes	yes	no			*n/a*		Normally not used as a peaker; black start only
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		
6.2	Turbine Controls	yes	yes	no			*n/a*		Turbine controls upgraded to Alstom Blueline in 2019
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no					Some damage to insulation from Maria but currently being addressed.
7.2	Structural Steel	yes	yes	no					Corrosion issues being addressed.
7.3	Tanks / Containment	yes	yes	no					Corrosion issues being addressed.
7.4	Cranes	yes	yes	no			*n/a*		2 of 6 overhead cranes out of service. Mobile cranes used, and are sufficient.
8	**Overall Condition Assessment**								Deficiencies were noted.

3.1.3. Thermal Unit 2 Condition

3.1.3.1. Boiler Thermal Unit 2

Similar to Unit 1, Unit 2 has boiler issues that need addressing. A portion of the existing superheater (SH-8) has reached its end of life, and based on several recent inspection reports, it is not suitable for continued service. A replacement superheater component for Unit 2 is currently in outdoor storage but was designed for natural gas firing. Sargent & Lundy recommends GE Power be contacted to determine the impact on Plant performance if the superheater is replaced with the redesigned natural gas fired superheater.

The conversion to natural gas was expected to extend the life of the unit because new components would be installed and there would be less corrosion by using a fuel without sulfur. With the Aguirre Offshore Gas Port being postponed indefinitely (see Section 2.4), Unit 2 reliability—due to steam leaks and potentially the end of life of major pressure part components—becomes a major concern.

Plant personnel indicated ongoing air infiltration issues throughout the flue-gas ductwork due to corrosion that impacted the ID fan capacity and would previously limit the unit to under full boiler output. Ductwork repairs were recently made, but the unit has not been dispatched for full load, so it is unclear whether these repairs were sufficient to help improve ID fan capacity and allow the unit to achieve 100% boiler maximum continuous rating. Air heater baskets were replaced during the last major outage in December of 2019.

A 2016 inspection report [4] identified key maintenance concerns for the Unit 2 boiler components. Indications of component degradation were noted, and it is assumed that the Plant made the recommended repairs from the inspection report summary. It is unknown when the next boiler inspection will be scheduled, but the unit should be included in PREPA's boiler condition assessment program, which begins in 2021 and extends through 2026

3.1.3.2. STG Thermal Unit 2

The overall appearance of the Unit 2 STG is acceptable given the age and location near the sea. Note that some doors were found open or non-functional. This is a concern for fire protection if the fire protection system needs to be activated. The Plant's spare HP and IP rotors were installed in 2017 and have since logged about 9000 operating hours. The LP rotors have 50,000 operating hours and were due for a major inspection in 2019. Figure 3-3 is representative of the ST's condition.

Figure 3-3 — Unit 2 STG IP Section

The cross-over piping to the LP section is seen above with black insulation.
The HP section is on the right (not shown in photo).

3.1.3.3. Balance-of-Plant Thermal Unit 2

The major Unit 2 balance-of-plant equipment is in good condition. Notable observations and feedback from Plant personnel are given below:

- Vacuum Pump 2-2 was replaced in 2015.
- The Unit 2 condensate polisher system is in good condition.
- The Unit 2 steam-driven BFP is in moderate condition.
- Both 5000-hp motors on BFP 2-2 were replaced in 2017.
- HP Water Heater 7 was repaired in 2019.
- Air heater baskets were replaced in 2019.
- Based on inspection reports from the Plant, flow accelerated corrosion is not an issue with the feedwater heaters.

Figure 3-4 — Steam-Driven BFP Unit 2

The steam-driven BFP is in moderate condition.

The steam air preheater coils on the FD fans for both units are out of service. The Plant evaluated proposals for their repair in 2019, but no corrective work has been completed to date, and the coils remain out of service. The coil operation only has a small effect on fan performance. Their main purpose is to raise the cold-end temperature of the air heater to minimize the condensation of flue-gas sulfuric acid and its resulting corrosion and pluggage. FD Fan 2-2 is working well after its inlet vane assembly was repaired in May 2018. In general, the FD, ID, and gas recirculation fans and motors are in good to moderate visual condition, including their foundations, actuators, bearings, and lube oil skids.

The boiler blowdown system is working well, even though the tank and many of the drain lines are uninsulated and corroded; however, tank internal erosion and blowout is a concern at this stage of the Plant life. See Figure 3-5.

Figure 3-5 — Unit 2 Boiler Blowdown Tank

The tank drains to the sump on right, from which the water is pumped to the raw water tank for reprocessing as demineralized water.

3.1.3.4. Electrical System Thermal Unit 2

Most of the major electrical equipment is original and nearing the end of their useful life, but some equipment has been replaced as needed. The MPT for Unit 2 was replaced in 2010 due to catastrophic failure. Online oil sampling monitors were installed on the MPT of Unit 2 in 2016. Plant staff reports that rewinding of the Unit 2 generator was planned for the first quarter of 2021; however, the automatic voltage regulator is outdated. Unit 2 completed an environmental outage in May of 2020, during which time the MPT was replaced and the Plant plans to perform a stator rewind for the Unit 2 generator in 2021. The generator, power transformer, switchgear, batteries, and relays undergo periodic maintenance and testing.

3.1.3.5. Condition Assessment Rating Table Thermal Unit 2

The overall condition of the unit is similar to other units of the same vintage, except corrosion control is below average. Keeping corrosion in check is extremely difficult on a unit that is burning HFO and located on a seawater bay. On Unit 2, about 25% of the piping, tanks, and structural steel have small areas of noticeable corrosion. In some instances, the corrosion is widespread on uninsulated or uncoated items. Overall, the Plant's corrosion control, where applied, is effective, but Sargent & Lundy recommends its application be expanded. The major equipment appears to be in good condition and, in some cases, appears recently replaced or refurbished. See the figures and notes below along with the condition assessment table.

Sargent & Lundy's overall condition assessment summaries of Aguirre Unit 2 can be found in Table 3-3.

Table 3-3 — Aguirre Thermal Unit 2 Overall Condition Assessment

Plant Name: Aguirre Unit 2									
Item	System	Assessment Method			Scoring Category				Notes
		Visual	Interview	Data	End of Life	Reliability	Unit Output	Subtotal	
1	**Safety Hazards**	yes	no	no		n/a	n/a		
2	**Corrosion Control**	yes	no	no		n/a	n/a		
3	**Overall Cleanliness & Housekeeping**	yes	no	no		n/a	n/a		
4	**Mechanical Assessment**								
4.1	Steam Generator (boiler/HRSG)	yes	yes	yes					SH headers are near their end of life. Replacement parts were purchased but these were for the gas conversion project which is no longer planned and the parts remain in outdoor storage. Air heater baskets were replaced during December 2019 outage. No further repairs are scheduled which need addressing soon.
4.2	FD and ID Fans and Auxiliaries	yes	yes	yes					Modifications were recently made to the inlet vanes and expansion joints to help resolve capacity issues. Plant believes these have been resolved but unit has not had an opportunity to run at full load due to the market.
4.3	High Energy Piping (HEP)	yes	yes	no					
4.4	Condensate System	yes	yes	yes					
4.5	Feedwater System	yes	yes	yes					BFP motors replaced 2017. HP FW heater #7 repaired in 2019.
4.6	Turbine and Auxiliaries	yes	yes	yes					HP and IP rotors replaced in 2017. Spare HP and IP rotors are on site, but will be interchanged with Unit 1. LP rotors due for inspection. Plant is reviewing proposals for requalifying the spare LP rotors on site.
4.7	Circulating Water and Closed Cooling Water Systems	yes	yes	yes					Redundant screen wash pump being serviced. Closed cooling water tower fill was recently replaced.
4.8	Compressed Air Systems	yes	yes	no					Redundant equipment in operation to meet demand. Units 1 and 2 are interconnected, and service air system can back up the instrument air system. Plant notes that one of the four instrument air dryers (#2-2) is out of service on maintenance.
4.9	Emission controls	no	yes	no	n/a	n/a	n/a	n/a	No emissions controls installed
4.10	Fuel Systems	yes	yes	yes					
4.11	Seawater Intake	yes	yes	no					Surface barrier installed for seasonal sargassum sea weed. GE SUEZ chemical feed used. Traveling screens #1 and #3 are out of service and a project is underway to replace all traveling screens.
4.12	Water Treatment	yes	yes	no					Water level low in deep wells is low, increasing the conditioning cost. Patillas Lake supply expected in Q4 of 2022. Demin system condtion and capacity are good.
4.13	Underground Piping	no	yes	no					No issues noted from plant personnel (with exception of the fire protection system UG piping).
4.14	Fire Protection Systems	no	yes	yes			n/a		Underground fire loop has unidentified leak(s). Pumps were replaced in 2013.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	yes					Generator rewound and wedged in 2017, Plant is planning rewind of the stator in 2021. Spare gen. is on site. AVR is outdated.
5.2	Transformers	yes	yes	no					Spare MPT installed on Unit 2 in 2020; Spare needs to be replaced.
5.3	Switchgear	yes	yes	no					
5.4	Protective Relays	yes	yes	no			n/a		
5.5	Black Start Engine #2-2	yes	yes	no					Normally not used as a peaker; black start only.
6	**Instrument and Controls Assessment**						n/a		
6.1	Plant Controls	yes	yes	no			n/a		
6.2	Turbine Controls	yes	yes	no			n/a		Turbine controls upgraded to Alstom Blueline in 2017
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no			n/a		Some damage to insulation from Maria but currently being addressed.
7.2	Structural Steel	yes	yes	no			n/a		Corrosion issues being addressed.
7.3	Tanks / Containment	yes	yes	no					Corrosion issues being addressed.
7.4	Cranes	yes	yes	no			n/a		2 of 6 overhead cranes out of service. Mobile cranes used, and are sufficient.
8	**Overall Condition Assessment**								Deficiencies were noted.

3.1.4. Combined-Cycle Units 1 & 2 Condition

3.1.4.1. General

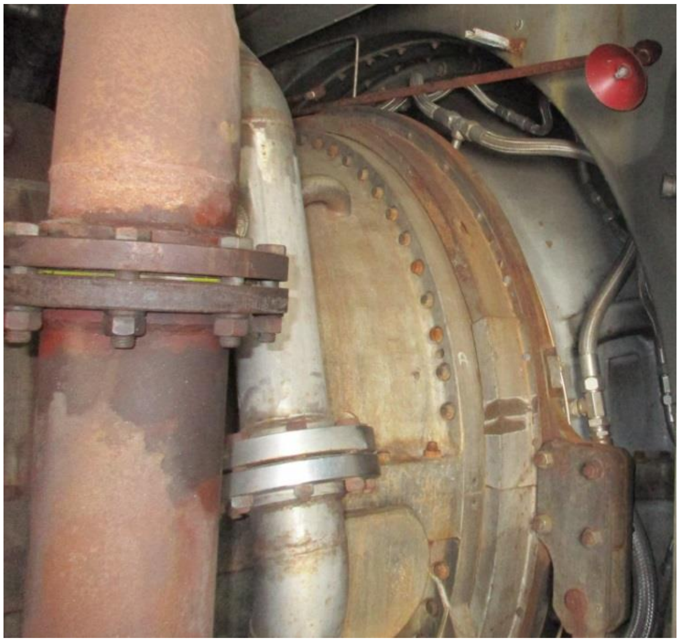
The Plant staff was unable to provide CC O&M manuals for Sargent & Lundy use in extracting equipment information and for comparing original equipment manufacturers recommendations to plant practices. The figures and notes throughout Section 3.1.4 should be considered applicable to both CC units unless otherwise noted.

3.1.4.2. GT Generators

Inspections of the GTs have occurred per GE's recommended intervals and scope and have often occurred with GE participation on site. Required maintenance and component replacements take place during the inspections. The GTs are considered to be in good operating condition due to this inspection and maintenance program. The Plant staff was unable to provide the number of starts for Sargent & Lundy review or information on the Plant's method of tracking and implementing recommendations from GE in their technical information letters.

Due to extensive corrosion, the GT enclosures are generally in poor condition, the GT casings are in good-to-moderate condition, and the GT auxiliary equipment is in moderate condition. See Figure 3-6 through Figure 3-8 for examples. Note that a new GT rotor was installed in GT 1-3 in 2003 and that GT 2-2 has recently been reassembled after being dissembled for repairs.

Figure 3-6 — Combined-Cycle GT Casings



GT1-4 compressor casing

GT1-4 combustors

The effectiveness of the CO_2 fire suppression systems for the GTs is questionable because the turbine and auxiliary enclosures are corroded with damaged or missing seals across all enclosures; this makes them unlikely to hold suppressant per NFPA requirements.

Figure 3-7 — Lack of GT Enclosure Sealing

The GT auxiliary compartment is shown above. The GT enclosures (not shown) are in better visual condition, but not all the doors seal when latched.

GT 2-2 has recently been reassembled after being dissembled since 2016. Over that period the GT 2-2 rotor was sent to the mainland United States for repairs, but it was poorly protected during the return shipment, rejected on site, and sent back for remediation. The rotor returned to site again in the spring of 2019, and the unit is in the final stages of reassembly. Figure 3-8 shows the lower half of the GT 2-2 housing as it was stored during this period, partially tarped in the GT enclosure.

Figure 3-8 — GT 2-2 Compressor Rotor Storage and GT Housing Layup

Across all of the GTs, the intake filter houses were replaced by Braden Manufacturing between 2003 and 2011. The new filter houses and rain hoods were constructed of Cor-ten steel with galvanized structural steel and stainless-steel filter frames. After 2011, the Plant replaced the 95% efficient final filters provided by Braden with 98% efficient filters from Freudenberg Filtration Technologies. The filter houses have some corrosion but are in acceptable condition. Sargent & Lundy noted the use of stainless-steel hardware, clips, and media. The inlet filters on GT 2-2 are in poor condition because the unit has been dismantled since 2016. Plant personnel noted that new filters will be installed as part of the ongoing final works associated with bringing GT 2-2 back online. The filters on the other GTs are in good condition.

3.1.4.3. HRSGs

Major pressure part components of the GE HRSGs, including superheater, evaporator, and economizer modules at the CC plant, were replaced by Senior Engineering in 1994 and 1995. From visual inspection, the HRSG casings are in poor condition, and obvious hot spots were noted, as shown in Figure 3-9. Electrical junction boxes were moved away from the middle of the HRSGs to avoid damage from flue-gas leaks.

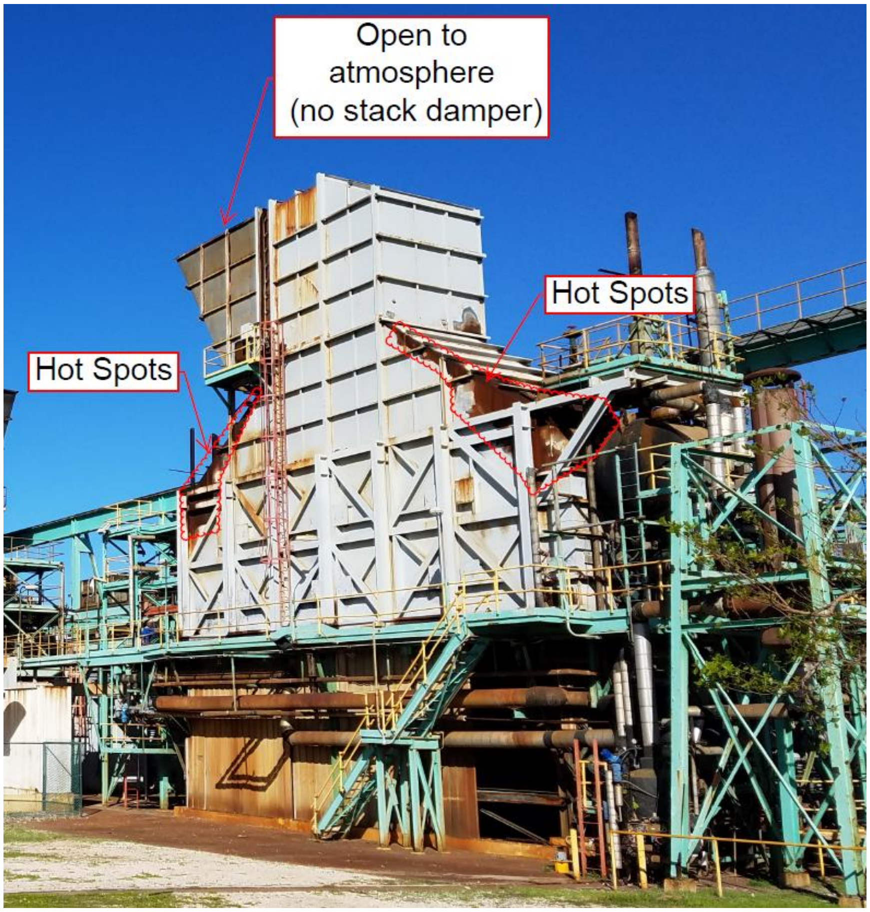
The HRSG stacks do not have dampers, which causes a concern of water collection and corrosion within the HRSG, particularly due to the duct work configuration. The Plant indicated that the facility has been operating in mostly simple-cycle mode since Hurricane Maria, mainly due to cooling tower damage, but it has been operating in CC mode more frequently since Sargent & Lundy's last visit in May 2018.

The Plant staff was unable to provide recent operating data or HRSG and high-energy piping inspection history and reports for Sargent & Lundy.

Soot-blowers are no longer required since the unit operates on No. 2 fuel oil and the system hasn't been in use for several years. With the unit being located in a coastal environment and the soot-blower system not being maintained, the Plant planned to remove the soot-blower system due to its poor condition. The Plant has completed removal of soot-blowers in six of the eight HRSGs on site. The remaining soot-blowers are scheduled for removal in Fiscal Year 2020–2021 for HRSG 2-2 and Fiscal Year 2021–2022 for HRSG 1-3 during their respective major inspections.

Details on the layup procedure for the HRSGs were not provided, but based on Sargent & Lundy visual inspection and interviews, proper layup procedures were likely not used for extended shutdowns. The HRSGs have not been inspected within the last several years, so it is recommended that a detailed inspection be performed on each HRSG soon, and this inspection may also require pressure part cleaning. Improper layup procedures, coupled with open atmosphere stacks and a coastal location, would result in a corrosive environment that will accelerate the end of life for major HRSG components. It would also reduce thermal performance when in operation. Installing stack dampers will help minimize corrosion and can shorten startup durations depending on the amount of time between starts.

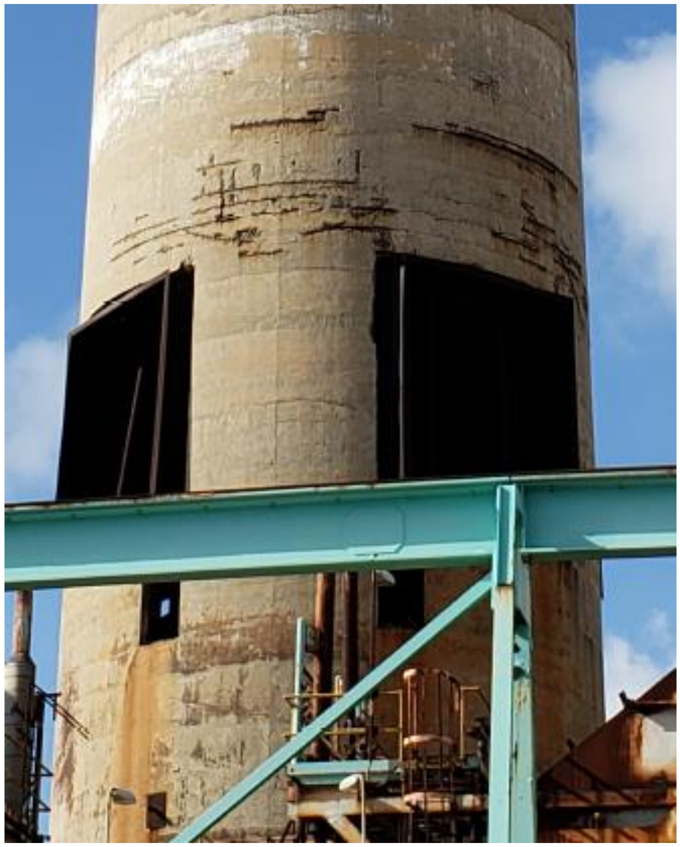
Figure 3-9 — STAG 2 HRSG 2-4



3.1.4.4. Stack

A common masonry stack was used for each power block when they burned HFO, but these two stacks have been abandoned and the ductwork removed. They have become a hazard, as some masonry is shedding from the stacks. Over time, additional debris can be expected to drop from the stacks. No concerns were noted from the last hurricane events; however, Sargent & Lundy recommends the condition of these stacks be monitored for changes in integrity and/or further deterioration and possible impact to the equipment in the vicinity below the stacks.

Figure 3-10 — Abandoned Concrete Stack



The deteriorating and abandoned HFO exhaust stack presents safety hazards because both spalled concrete and the structure are exposed to tropical storms and shed material. Both stacks are in a similar condition.

3.1.4.5. STG STAG Units

The ST enclosures were damaged during the 2017 hurricanes. The STAG 1 ST HP section and valves have external corrosion, which is not of much concern unless it restricts the moving parts of valves and operators. For example, valve stems are often problematic when pitting prevents valves from stroking in a smooth manner. The LP section and its bearings appear to be in good condition, including the LP/generator bearing.

The most recent STAG 1 ST inspection and repair scope was completed by GE in the summer of 2013. The work on the HP and LP rotors was performed in GE's Atlanta and Minneapolis service centers. New buckets were installed in the L-1 and L-2 LP sections and in the third stage of the HP rotor.

Plant personnel explained that the most recent major inspection of the STAG 2 STG was in 2008. Since then, the ST has had about 1.5 years of operating time. The Technical Services Division within PREPA is deciding when the next inspection should be scheduled for STAG 2 ST. It was taken out of service in June

2017 due to high vibration on Bearing 3, which is between the generator and the LP turbine. A specialty contractor, ESI Energy, identified the root cause, and PREPA made the coupling and bearing repairs. Plant staff notes that their resources are correcting some minor deficiencies prior to startup, which is scheduled for October 2020.

The Plant staff was unable to provide additional ST inspection history and reports for Sargent & Lundy.

3.1.4.6. Balance-of-Plant, STAG Units

For the CC unit, the staff repairs and replaces components as needed and as approved. For example, they have a 280-kW/350-kVA essential services generator supplied by SDMO with a 2012 nameplate. Other examples are shown and explained herein. Plant staff was unable to provide information on flow accelerated corrosion for Sargent & Lundy to review and incorporate into the feedwater heater assessment.

The diverter dampers are in good condition and work well (see Figure 3-11). The mechanisms are exercised when not in use to keep them in a ready condition. Though the appearance of the adjacent duct is poor, maintenance is performed to ensure operability as indicated, with a recent replacement of the expansion joint shown.

Figure 3-11 — GT Discharge Duct Diverter Damper and Stack

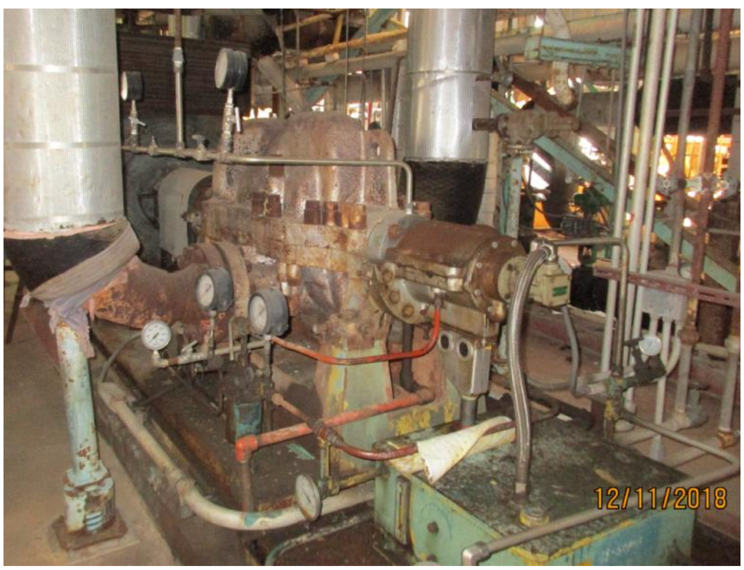
Figure 3-12 — HRSG 2-1 Inlet Duct

Seen above are HRSG inlet duct repairs addressing corrosion and leakage. Also, the flow path is being modified to improve efficiency.

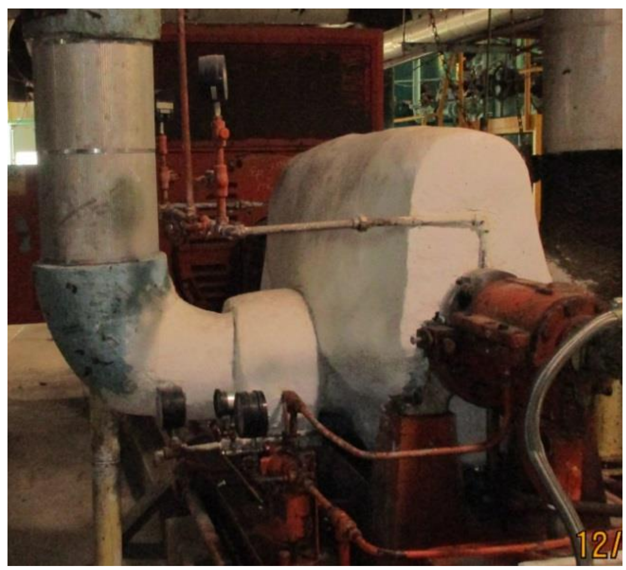
On the roof of the control room building is the deaerators for both units. The STAG 1 deaerator, shown in Figure 3-13, is in good visual condition. The STAG 2 deaerator is in a similar condition.

Figure 3-13 — Combined-Cycle Deaerator

Figure 3-14 — Combined-Cycle BFPs



BFP 2-1. BFP 2-2 (not shown) is in a similar condition.



BFP 1-2 (insulated). BFP 1-1 was replaced in November 2018 with its motor rewound. The new pump is not shown. It was manufactured by Byron Jackson and will be insulated.

3.1.4.7. Electrical System STAG Units

Most of the major electrical equipment is original and nearing the end of its useful life, but some equipment has been replaced as needed. The generators for both steam turbines were refurbished by GE in 2008. In

2013, GE rewound the STAG 1 generator in their Atlanta service center, and GE re-wedged the stator on site. The generators, power transformers, switchgear, batteries, and relays undergo periodic maintenance and testing. The Plant staff was unable to provide generator inspection history and reports for Sargent & Lundy to review.

3.1.4.8. Condition Assessment Rating Table STAG 1 & 2 Units

In 2019 and 2020, only STAG 1 operated in CC mode, generally with one or two HRSGs making steam from GTs 1-1 and 1-3. The STAG 2 steam turbine has been out of service since June 2017 but is expected to return to service soon with the completion of maintenance and repair activities on various steam-cycle equipment. The CC units show significant wear, more than typical units of the same vintage. Corrosion control appears to be more challenging than the thermal units, which may be due to the proximity of the CC units to the seawater cooling towers, the Jobos Bay, and the circulating water discharge channel. The prevailing southeast wind carries cooling tower drift towards the CC units. As expected, seawater drift across power generation equipment creates a challenge to keep coatings and materials intact. Future repowering studies should ensure that there are suitable design specifications appropriate for this operating environment, including: (i) corrosion-resistant material specifications, such as appropriate welding selections, special treatment of all metal seams, stitched connections, and fastenings with sealants, gaskets, and coatings; (ii) use of protective equipment enclosures; (iii) proper system selections; and (iv) marine coatings systems. Due to these requirements, coastal power generation sites are inherently more expensive than those installed in less aggressive operating environments.

The CC plant is in the process of removing equipment and structures no longer in service such as the soot-blowers and their access stairs on the HRSGs. Following this work, the HRSGs, which are insulated on the inside, will be re-coated. The soot-blower and stairway removals have been completed on HRSGs 1-1, 1-2, 1-4, 2-1, 2-3, and 2-4 and should be completed on all eight HRSGs by the fall of 2022. Repairs and modifications to the HRSGs are a top priority. Pipe support issues will be addressed after HRSG repairs are completed.

Sargent & Lundy's overall condition assessment summary of CC Units 1 and 2 can be found in Table 3-4.

Table 3-4 — Aguirre Combined Cycle STAG 1 & 2 Overall Condition Assessment

Plant Name: Aguirre STAG 1 and 2 (combined cycles)

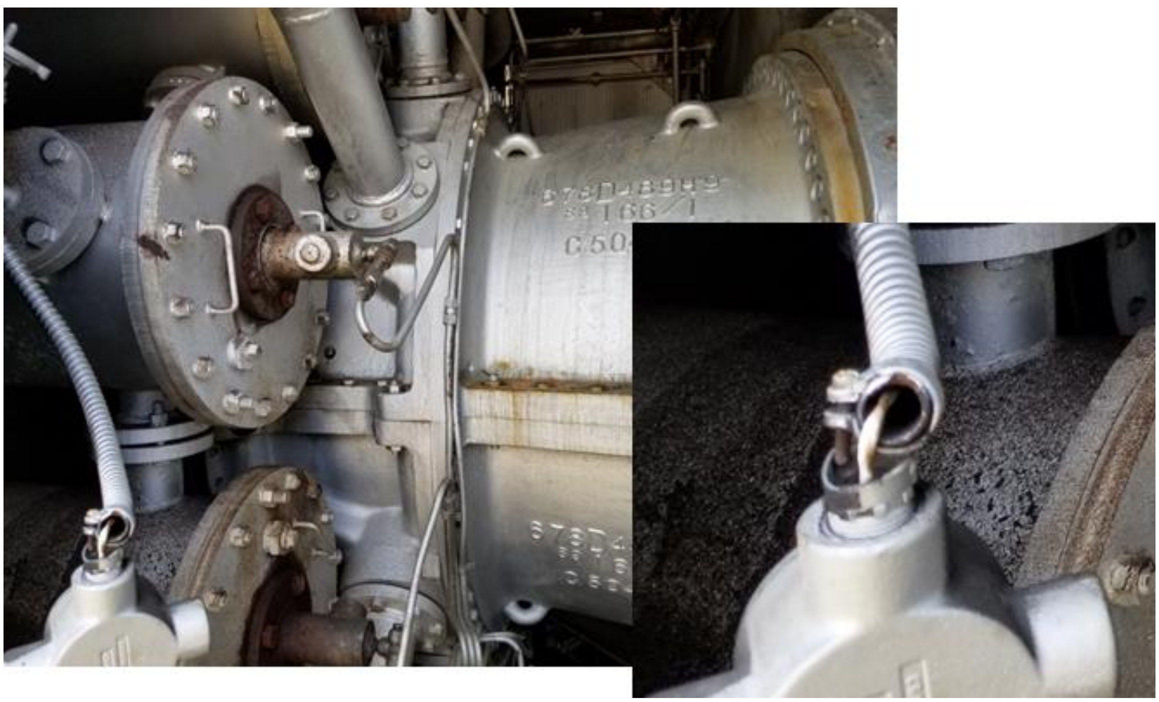
Item	System	Assessment Method			Scoring Category				Notes
		Visual	Interview	Data	End of Life	Reliability	Unit Output	Subtotal	
1	**Safety Hazards**	yes	yes	no		n/a	n/a		Corrosion noted throughout the facility and is a safety issue. Walkways and structural steel structure in poor condition (refer to photos).
2	**Corrosion Control**	yes	yes	no		n/a	n/a		Corrosion noted throughout the facility and is a safety issue. Walkways and structural steel structure in poor condition (refer to photos).
3	**Overall Cleanliness & Housekeeping**	yes	yes	no		n/a	n/a		No issued noted.
4	**Mechanical Assessment**								
4.1	Steam Generator (boiler/HRSG)	yes	yes	no					Major replacements of HRSG internals done in 1994-95. HRSG casings are in poor condition and pressure parts may need cleaning due to corrosion. The HRSGs do not have stack dampers and water collection in HRSG may be an issue. Steam Unit 2 has not operated since 2017 but should be available fall of 2020. Unit 1 operates occasionally as peaker, often as simple cycle, and sometimes with the HRSG and ST.
4.2	Combustion Turbines	yes	yes	yes					External corrosion is an issue on the CT/compressor housings (casings), enclosures and auxiliary equipment. Dismantled inspections being done on schedule for most units. Each CT has a single fuel pump. Spare CT nozzles on site.
4.3	High Energy Piping (HEP)	yes	yes	no					Hangers are currently an issue and have planned repairs following the current HRSG repairs.
4.4	Condensate System	yes	yes	no					Unit 2 condenser waterboxes were recently refurbished, project completed in 2019. Condensate storage tanks are in poor condition. Condensate tank 1 was recently repaired and painted and a contract has been awarded to replace its internal liner. Plant has considered converting Demin tank 3 to condensate storage which would have sufficient capacity for all units.
4.5	Feedwater System	yes	yes	no					BFP 1-1 replaced Nov 2018 and its motor rewound
4.6	Turbine and Auxiliaries	yes	yes	no					STAG2 ST has over 1.5 yrs operating time since major inspection in 2008. STAG1 HP bearing housings and HP valves have external corrosion. STAG1 ST enclosure has damaged/missing siding from hurricanes. Limited ST spares on site.
4.7	Circulating Water and Closed Cooling Water Systems	yes	yes	no					Cooling tower fill and fan deck replaced after Hurricane Maria. CCW Pump #2-2 recently received a rewound 2,200 hp motor and up-sized impeller.
4.8	Compressed Air Systems	yes	yes	no					No issues with instrument and station air systems; air is shared between the CC units.
4.9	Emission controls	no	yes	no	n/a	n/a	n/a	n/a	No emissions controls installed
4.10	Fuel Systems	yes	yes	no					Diesel ok. Nat gas untried - 80% installed when put on hold.
4.11	Seawater Intake	yes	yes	no					Surface barrier installed for seasonal sargassum sea weed. GE SUEZ administers the chemical feed.
4.12	Water Treatment	yes	yes	no					Demin water supplied by Aguirre Thermal. Chem feed added by cc demin equipment. Well water level is low, increasing cost for water conditioning. Patillas Lake water expected in 2020.
4.13	Underground Piping	no	yes	no					No issues noted from plant personnel (with exception of the buried fire protection loop discussed in next row).
4.14	Fire Protection Systems	no	yes	no			n/a		CTG enclosure corrosion to be addressed, but is currently hindering FP system effectiveness. Aguirre buried fire loop has unidentified leak(s). Fire pumps replaced in 2014.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					CTs have hot side generators; spare gen. rotor on site. STAG2 ST generator inspected 2008 - limited operation since then.
5.2	Transformers	yes	yes	no					
5.3	Switchgear	yes	yes	no					
5.4	Protective Relays	yes	yes	no			n/a		
5.5	Black Start Engines	no	yes	no			n/a		Reciprocating engines were removed.
6	**Instrument and Controls Assessment**						n/a		
6.1	Plant Controls	yes	yes	no			n/a		Currently being upgraded by Foxboro.
6.2	Turbine Controls	yes	yes	no			n/a		STAG1 controls being upgraded; STAG2 STG control upgrade being requested; CTG controls upgrade planned for 2019.
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no			n/a		Some damage to insulation from Maria but currently being addressed.
7.2	Structural Steel	yes	yes	no					Corrosion noted throughout the facility and is a safety issue.
7.3	Tanks / Containment	yes	yes	no					One of two raw water tanks has moderate corrosion issues. Fuel tanks ok. See item 4.4 above for condensate tank.
7.4	Cranes	yes	yes	no			n/a		CT crane removed; structure in poor condition. Aguirre cranes: 3/6 out of service.
8	**Overall Condition Assessment**								Deficiencies were noted

3.1.5. Black-Start Equipment Condition

The CC's black start reciprocating engines are no longer operational and have been removed. The black-start BSGT 2-1 has been out of service since it went into an outage for a combustor inspection in mid-January 2019. The recent dispatch report notes that BSGT 2-1 remains out of service due to holes in the transition pieces. BSGT 2-2 is available for emergency use, such as for a black start. It is limited to four hours of operation before it trips on high oil temperature in the lubricating oil tank. This may be an indication that the cooling systems are fouled or the temperature control valves are no longer stroking to maintain proper lube oil temperature.

In general, these GTs have degraded over time due to age and disuse in a marine environment. The inlet air filters were found to be in good condition, but there are some areas that should be inspected/repaired to ensure reliability, such as the exposed wiring noted in Figure 3-15.

Figure 3-15 — Black-Start GT Combustor Area



The open conduit exposes wiring. There is a risk of shorting when the wire rubs and chafes against sharp metal components.

3.1.6. Common Systems Condition

Two of Aguirre's six overhead cranes are out of service awaiting repairs: the mechanical shop crane, and the travelling screen/circulating water pump area crane. Portable cranes are used in these areas while the permanent cranes are out of service. There is no longer an overhead crane at the STAG 1 and 2 GT area because the support structure was unsound from corrosion. The structure needs budget for removal. As part of the removal scope, the cable trays attached to the southern part of the structure would have to be supported differently or relocated.

Hurricane damage to the siding and roofs of the main buildings has been repaired. Some storage buildings are still in need of repair, as are the STG enclosures of the STAG units.

Vegetation is trimmed and sprayed monthly by an outside contractor and generally appears effective.

3.1.6.1. Fuel Oil

The HFO and No. 2 fuel oil receiving, storage, forwarding, and heating systems are in good-to-moderate condition. Bunker C Reserve Tank 2 for HFO storage tank is out of service, as is light-oil Reserve Tank 5, which normally stores No. 2 fuel oil. Much of the impermeable liner around the Aguirre tank farm dikes has been damaged and degraded over time. The damaged liner should be removed and replaced with new geomembrane liner.

Figure 3-16 — HFO Forwarding Pump

Figure 3-17 — Unit 2 HFO Heating Skids

Figure 3-18 — HFO Reserve Tanks

13,000,000-gallon reserve tanks (each)

3.1.6.2. Process Water

The deep water wells that supply makeup water to the plant for steam-cycle makeup and Plant service water have experienced a decrease in historical water level. The cost of conditioning the well water for steam-cycle makeup has increased due to the additional burden on the demineralized production plant because the total dissolved solids level has raised over time to approximately 900 ppm. Plant staff indicates the well water total dissolved solids levels have risen to the point where demineralized water production has become more challenging to remove the higher levels of total dissolved solids to produce demineralized water. Upgrades should be made to either address the production capacity or the possibility of an alternate water source that is more in line with the original equipment design. A PREPA project to obtain plant water from Patillas Lake (owned by PREPA) is scheduled for completion in the fourth quarter of 2022. The final phase (Phase V) of the project is underway to repurpose two existing 1.8 M-gallon Aguirre No. 2 fuel oil storage tanks for raw water.

Sargent & Lundy recommends a review of the projected water system usage against the demineralizer system design and well water supply conditions to assess if there are water supply or usage conditions that might limit the Plant's power production prior to completion of the Patillas Lake project. The study should include onsite demineralized water storage capacity and the steam-cycle makeup requirement for a fully operational plant.

Figure 3-19 — Well Water Tanks

The two well water tanks are cross-tied and have a dedicated reserve as the fire water source. Corrosion repairs are needed on the southern tank.

The mixed bed system is located in the water treatment building at the thermal units. It has two trains that can each produce 600 gallons per minute. The Plant typically needs 450 gallons per minute of demineralized water. The building and equipment are in good-to-moderate condition, as seen in Figure 3-20.

Figure 3-20 — Water Treatment Building

STAGs 1 and 2 have a demineralizer below their control room; see Figure 3-21. In 2008, it was decided to obtain process water for operations from the Aguirre thermal facility. Some of the CC demineralizer equipment is used to apply necessary chemicals into the demineralized water received from Aguirre. The STAG chemical feed system is nearing its end of life. The feed tanks, pumps, and other items are likely to require replacement in the near future.

Figure 3-21 — Demineralizer at CC Unit

At the time of S&L's 2019 site visit, both condensate tanks at the CC unit were in service but noted to be in poor condition and approaching their end of life. As the tanks are essential to CC operation, this issue was identified as one of the top concerns for the Plant. Tank C-2 is in the worse condition of the two, along with its discharge pipe and its makeup pipe, and an RFP to refurbish its internal lining was pending at the time of writing this report. Condensate Tank C-1 was recently repaired and painted; a contract to apply an internal lining has recently been awarded. The Plant is also considering the conversion of the thermal units' unused demineralized water storage Tank 3 to condensate storage, but this project has not moved forward due to lack of funding. One or both CC Condensate Tanks C-1 and C-2 could then be retired.

Figure 3-22 — Demineralized Water and Condensate Tanks at CC Unit

Demineralized water tanks in foreground. Condensate Tank C-1 is shown on the far left (painted green).

3.1.6.3. Closed Cooling Water

The cooling tower for the thermal plant closed cooling water system has moderate corrosion on a small portion of its riser piping and supports and on the two pairs of pumps for each unit. During the 2018 site visit, Sargent & Lundy observed that over 50% of the tower fill was fouled to a moderate degree. At the time of this report, Plant staff reported that cooling tower repairs had been completed including the replacement of fill materials. The fiberglass tower is in good condition, including the fan stacks, the fan deck, and the gear box, including associated instrumentation and oil level indicators.

Figure 3-23 — Closed Cooling Tower, Units 1 and 2

Four-cell cooling tower for the Units 1 and 2 closed cooling water system. The two cells shown and the two closed cooling water pumps are for Unit 1. The tower extends to the right with the Unit 2 cells and pumps. The Unit 2 distribution header and risers have more corrosion than Unit 1.

Unlike the CC unit's seawater tower, the closed cooling tower did not receive any upgrades or replacements following Hurricane Maria. The seawater tower is discussed below in Section 3.1.6.5.3.

Figure 3-24 — Combined-Cycle Closed Cooling Water Tower

Makeup pumps and piping to the closed cooling tower. The ozone injection at the closed cooling tower has been abandoned in place, and the Plant plans to submit a request to have it removed.

3.1.6.4. Fire Protection

The fire protection underground loop is leaking at an undetermined location. While pressure can be maintained in the fire system, it requires use of the jockey pump at all times, which is not a normal industry practice. Plant personnel plans to hire a contractor to locate the leak. Both diesel fire pumps and the motor-driven fire pump were replaced in 2013.

There are plans to repaint the CC CO_2 lines used for fire protection. As noted in Section 3.1.4.2, all the GT enclosures are corroded with damaged or missing seals, which makes them unlikely to hold the carbon dioxide suppressant per NFPA requirements.

Figure 3-25 — Electrical-Fire Pump

3.1.6.5. Circulating Water System

3.1.6.5.1. Seawater Intake

There are five traveling screens, and PREPA plans to replace them for Clean Water Act Section 316(b) compliance. As of the end of 2020, two screens were out of service; Screen 3 was having corrective maintenance done on the deck, and Screen 1 had a major issue 3–4 years ago and has remained out of service. The concrete structure appears to be in good condition. A surface barrier was installed to keep seasonal sargassum seaweed from clogging the inlet screens. The Plant notes that there is an Engineering Department project currently underway to replace all five travelling screens with fine-mesh modified travelling water screens and a fish return system to bring them into compliance with Clean Water Act Section 316(b).

Figure 3-26 — Traveling Screens

3.1.6.5.2. Circulating Water Pumps

Following the traveling screens are five circulating water pumps for Aguirre Units 1 and 2. Two of the pumps serve Unit 1, two serve Unit 2, and one is a shared installed spare. Circulating water Pump 2-1 was refurbished in 2012.

Figure 3-27 — Circulating Water Pumps

3.1.6.5.3. Combined-Cycle Seawater Cooling Towers

The seawater cooling towers were severely damaged by Hurricane Maria, and the STAGs could only run in simple-cycle mode. The fill, louvers, mist eliminators, fans, and other components were replaced, though not the circulating water pumps or risers. These upgrades and replacements have improved the performance, reliability, and expected life of the towers.

Figure 3-28 — Seawater Cooling Tower – STAG 1

One of the two circulating water risers is shown. The risers and conduits are corroded.
The new fill is shown on the right.

3.1.6.5.4. Unit 1 & 2 Condensers

The waterboxes on both thermal units' condensers were replaced in 2011 and 2012. As seen in Figure 3-29, Sargent & Lundy observed some external corrosion on the circulating water flanges. This is being managed through surface preparation and recoating. The waterboxes and the condenser have minimal exterior corrosion. Corrosion on the interior of the waterboxes is resisted by coatings and a cathodic protection system. Plant staff reported in October of 2020 that the cathodic protection system is out of service and that no repair date has been identified. A contract for the refurbishment of the Unit 1 waterboxes is planned for auction within Fiscal Year 2020–2021. The waterbox sluice gates are operated 2–3 times weekly to minimize fouling and improve backpressure, which improves turbine performance.

Figure 3-29 — Corrosion on Circulating Water Condenser Connections, Units 1 and 2

Unit 1 on the left, Unit 2 on the right. There is minor-to-moderate corrosion on the exterior of the flanges.

Figure 3-30 — Corroded Drain Lines into Unit 2 Condenser

3.1.6.5.5. STAG 1 & 2 Condensers

The CC is implementing a plan to improve the condenser vacuum by increasing flow from the cooling towers. This will especially help when they run all four GTs on a unit. Circulating water Pump 2-2 was recently retrofitted with a new impeller, and its motor was rewound to yield 2200 hp from 2000 hp. Plant personnel is correcting some minor deficiencies and plans to bring the pump back into service in the fall of 2020. Similar upgrades are planned for the other three circulating water pumps and motors. To also help with condenser performance, one waterbox from each of the two Unit 2 condensers was sent off site to be refurbished with application of a ceramic-based coating in 2019. The other two waterboxes received a similar scope of work with the work being done on site. The refurbishment of the waterboxes has been completed, and they will be returned to service with the refurbished circulating water Pump 2-2 in the fall of 2020.

Figure 3-31 — Combined-Cycle STAG 1 Condenser

One of the STAG 1 condensers with waterboxes coated on the inside in 2017.

Figure 3-32 — Combined-Cycle STAG 2 Condenser

One of the STAG 2 condensers with its waterbox removed for refurbishment.

3.1.6.6. Controls

There is a common control room for Units 1 and 2 with separate controls for each unit. There is a similar arrangement for the CC units. The Plant uses Foxboro distributed control systems and has a contract agreement with Schneider Electric for maintenance of their boiler controls systems through August of 2021.

Figure 3-33 — Control Room Units 1-2

ABB's S90 Turbotrol turbine controls were installed for the Units 1 and 2 STGs in 2014 and 2015, respectively. In 2017, an upgrade to the Alstom BlueLine version was implemented for the Unit 2 turbine.

The HRSG controls upgrade by Foxboro for both units was completed in February 2019. The STAG 1 STG controls were upgraded from Mark V to Mark VI-E, with the project completed on June 27, 2020. The Plant intends the same upgrade for STAG 2 and, as of the end of 2020, was in contract negotiations with Baker Hughes/Nexus Controls for this work for targeted completion by May of 2021. The GE Mark V controllers for all eight GTs will be upgraded to Mark VI-E, at which time new EX-2100 model exciters will also be installed. Each of the communications rooms for the eight GTs has a new door with a safety window.

Figure 3-34 — HRSG Control Room – Foxboro Upgrade in Progress

3.1.6.7. Compressed Air

The instrument air compressors for both thermal units are in moderate-to-good visual condition, but there are issues with interstage cooling. Each unit has two 100%-capacity instrument air compressors, but all four are needed to meet demand. Instrument air dryer IAD 2-2 is out of service on maintenance, and the other three dryers remain in service. The air is conditioned adequately when all three of the remaining dryers are used. Each unit also has a full capacity service air compressor and dryer, and these pairs can be used to back up the instrument air system. The service air equipment is also in moderate-to-good visual condition. The plant staff notes that leaks in the instrument and service air systems have recently been addressed. Additional storage of instrument air is provided by three repurposed propane tanks adjacent to the Unit 1 HFO heating skid. New propane tanks were installed east of the plant for separation reasons. The CC compressed-air systems are working well.

Figure 3-35 — Thermal Units Instrument Air Compressor

Figure 3-36 — Combined-Cycle Compressed Air

3.1.6.8. Corrosion

Corrosion is an issue across Aguirre and is a safety concern. Plant personnel indicated that a unit would be drained when offline for extended periods, but dehumidification systems were seldom used. Limited nitrogen is used throughout the facility for inert blanketing and protection.

As with any coastal facility exposed to hot, humid, saline conditions, and particularly with windblown dust, corrosion control is an ongoing and expensive part of O&M planning and spending. Equipment and fabrication methods, as well as replacements for such installations, are more costly than non-coastal installations. Progress is being made, as Sargent & Lundy representatives saw many items that have been replaced or recoated/insulated. Corrosion-control painting of structural steel is performed under an outside contract for all the units.

3.1.6.8.1. Thermal Plant Corrosion & Recent Remediation

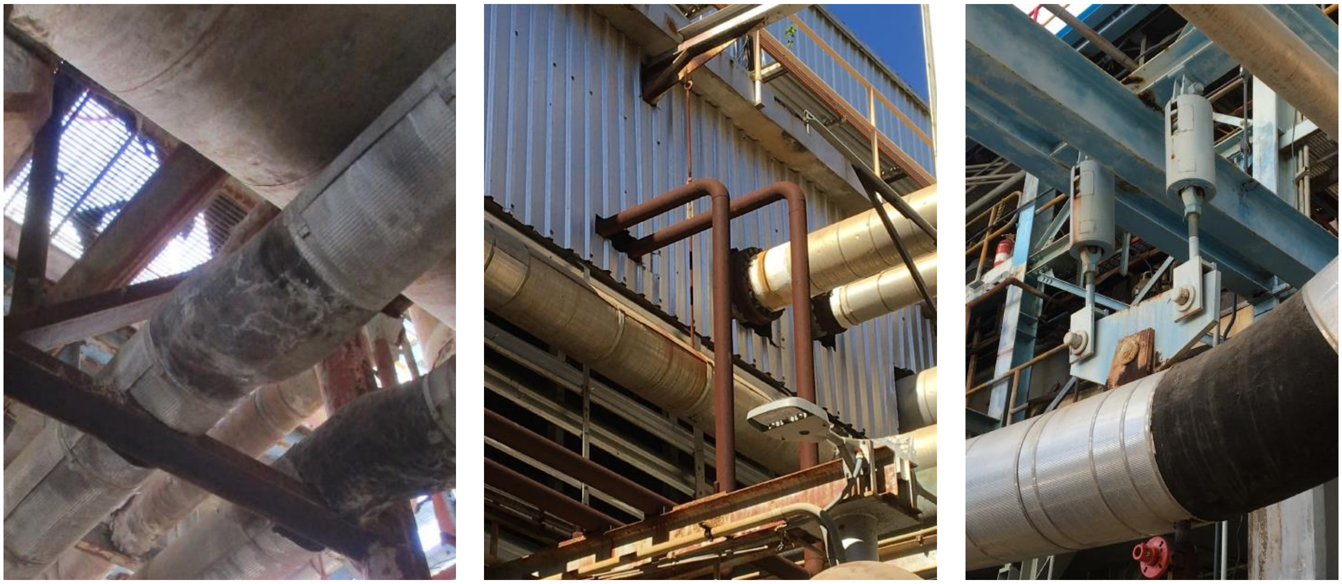
Figure 3-37 and Figure 3-38 illustrate some of the corrosion issues and remedial activities recently performed for thermal Units 1 and 2. Besides the items pictured below, Sargent & Lundy also notes the recent replacement of the BFP recirculation valves and actuators as well as the Unit 1 FW heater isolation valves due to corrosion issues.

Figure 3-37 — Examples of Replacements/Re-Coatings, Units 1 and 2

Unit 1 Propane tank, piping, and valves.

Unit 2 STG lube oil filtering skid.

Figure 3-38 — Corroded Pipe Hangers (and Pipes), Units 1 and 2



Note that many of the steam piping hangers were in good-to-moderate condition, as seen in the far-right photo.

3.1.6.8.2. Combined-Cycle Corrosion & Recent Remediation

The following are examples of ongoing corrosion repairs for STAGs 1 and 2 as well as corrosion issues yet to be addressed.

Figure 3-39 — Refurbishment of GT Generator Filter Cabinets

Original in brown (scheduled for refurbishment); refurbished in blue.

Valve preventive maintenance is done every month as an operational check, and components are replaced as needed. Several of the STAG feedwater control valves and HRSG steam valves have recently been replaced. Sargent & Lundy estimates the percentage of CC piping, tanks, structural steel, and enclosures with localized corrosion issues to be 30–40%, where small areas of corrosion are noticeable. In some instances, the corrosion is widespread on an uninsulated or uncoated item. Plant personnel periodically hires contractors to replace and/or coat corroded piping and steel structures at the CC facility, but some items have corroded beyond recovery and may represent safety issues if not addressed. Examples include the severely corroded footing of a valve platform near the HRSG 2-4 circulation pump and the abandoned gantry crane over the GT area. The crane's hoists and beam have been removed, but the remainder of the structure is continuing to deteriorate, as is illustrated in Figure 3-40.

Figure 3-40 — Corrosion of Gantry Crane Structural Steel at Combined-Cycle Plant

3.2. CONDITION OF NATURAL GAS COMPONENTS

3.2.1. Units 1 & 2

There are purchased modifications for the thermal units, and the gas conversion parts and fuel trains are currently being stored outdoors. The equipment appears in good condition, but a detailed assessment is recommended prior to putting any of the new equipment into service. According to the Puerto Rico Energy Board's (PREB) decision, no plans for natural gas delivery to Aguirre will be put into effect; however, there may be value in preserving the equipment for use at another PREPA facility that uses natural gas (e.g., Costa Sur) or for sale. Sargent & Lundy recommends long-term preservation, such as by relocating the equipment to indoor storage, for all purchased equipment for natural gas firing to preserve its value and functionality if an opportunity for reuse is identified. Figure 3-41 provides an example of the storage condition of the natural gas conversion components for the thermal units.

Figure 3-41 — Storage of Natural Gas Conversion Components for the Thermal Units

3.2.2. STAGs 1 & 2

Similar to the thermal units, operation on natural gas would extend the life of the STAG units but is no longer being considered for Aguirre. The components are installed and in good visual condition, and the final filter skid and control valve enclosure are typical for each GT. They are seen in Figure 3-42.

Figure 3-42 — Natural Gas Delivery Components Installed at CC Units

The natural gas final filter is shown on the left (yellow); on the right is the gas control valve station inside the grey enclosure.

3.3. RECOMMENDATIONS & CONCLUSIONS

Overall, the thermal units were found to be in good condition and are consistent with comparable units of similar vintage; however, the CC units and black-start GTs were found to be in moderate condition and have experienced more wear than like units of similar age. The thermal and CC units at Aguirre are nearing the end of their useful life and have been approved for retirement over the next five years according to

PREB's recent resolution addressing PREPA's proposed integrated resource plan (Case No. CEPR-AP-2018-0001). The retiring thermal units will be repurposed as synchronous condensers to provide dynamic reactive support and stability to PREPA's grid with the addition of new solar generation directed by the resolution. Despite the approaching retirement, it is important that efforts are made to preserve existing generating units to maintain grid reliability until sufficient new generation is brought online.

The recommendations based on the above condition assessments are split into two categories: improvements and expected activities. Items considered under recommended improvements are items that may not be under consideration or have been deferred. Sargent & Lundy recommends they be given a high priority. Expected activities includes items that PREPA will likely execute as part of their normal operations. The recommendations are, in general, arranged by items applicable to the Plant, followed by thermal unit recommendations, and then those for the CC units.

3.3.1. Improvements

Based on the walkdowns and discussions with the Plant staff, Sargent & Lundy recommends the following actions for improvement throughout the Plant:

- Pursue long-term preservation for all purchased equipment for natural gas firing, such as relocating the equipment to indoor storage.
- Implement layup procedures for equipment and systems that include draining, dehumidifying, protecting, and, when needed, nitrogen-blanketing.
- Conduct a water study to be sure a temporary source of process water will not be needed before the Patillas Lake water is delivered. Monitor the progress of the Patillas Lake project and expedite the process as needed.
- Install HRSG stack dampers.
- Upgrade the protection of components being stored outdoors (in addition to the natural gas components).
- Implement a database to allow documentation to be more easily located and distributed. Many of the CC unit maintenance records were not provided for review because they are difficult to track and retrieve.

3.3.2. Expected Activities

Based on the walkdowns and discussions with Plant staff, Sargent & Lundy understands that the following recommended actions are under consideration or are actively being pursued.

- Accelerate mitigation efforts while corrosion mitigation efforts at the Plant are ongoing, especially at the CC facility. Some of the corrosion is decreasing unit output and reliability and some of it is a safety risk (as identified in Section 3.1.6.8).

- Repair, and in some instances replace, the boiler internals on Units 1 and 2 per the GE boiler inspection reports. Schedule the next inspections.
- Rewind the stator of the Unit 2 generator. Plant staff notes that this project is planned for 2021.
- Complete the interchange of HP and IP rotors for Unit 1. Plant staff notes that they have solicited quotes for this work.
- Requalify the spare LP rotors for Units 1 and 2. Plant staff notes that a proposal for this work is under review.
- Replace or upgrade the Unit 2 generator voltage regulators. A proposal for this work has been received and the contract terms and conditions are being finalized.
- Repair or replace the Units 1 and 2 air preheat coils and inspect the drain traps. Plant staff notes that this work has not been completed and that no plans have been made to address it.
- Schedule CC ST and generator inspections. Plant staff notes that these inspections have not yet been scheduled.
- Continue the HRSG internal and external repairs, including the pressure parts, insulation, valves, ductwork, and removal of the soot-blowers on the remaining two HRSGs for CC Units 1-3 and 2-2.
- Continue upgrading the exciters and the ST and GT controls for STAG 2. Plant staff notes that the contract for this work is in negotiation and expected to be signed in the fall of 2020.
- Replace damaged liner in fuel oil tank farms.
- Continue to address the need for reliable condensate storage at the CC plant due to excessive corrosion of both existing tanks and their adjacent piping. Plant staff notes that repairs and recoating to Condensate Tank 1 have been made and that a contract to apply an internal lining has recently been awarded.

4. INFRASTRUCTURE & INTERCONNECTIONS

4.1. FUEL SUPPLY

4.1.1. Heavy Fuel Oil

HFO is delivered to the coastal port by tankers and forwarded via pipelines to onsite storage tanks. On July 31, 2015, PREPA entered a fuel oil purchase contract (Contract 902-02-15) with Freepoint Commodities for the supply of HFO to the Aguirre Steam, Costa Sur, Palo Seco Steam, and San Juan Steam plants. The contract has been extended for additional years through various amendments. PREPA and Freepoint Commodities executed the fifth amendment to the contract, which extended the term until October 30, 2021.

In 2021, PREPA will undergo a competitive process to secure its next HFO supply agreement.

4.1.2. No. 2 Fuel Oil

No. 2 fuel oil is delivered to the coastal port by tankers and forwarded via pipelines to onsite storage tanks. On November 21, 2019, PREPA entered a contract (Contract 902-01-19) with Puma Energy Caribe for the supply of No. 2 fuel to all the PREPA plants that operate with this fuel. The original term of the contract was for one year, but the contract includes a provision for an automatic extension upon mutual agreement. PREPA and Puma Energy Caribe extended the contract until November 20, 2021.

In 2021, PREPA will undergo a competitive process to secure its next No. 2 fuel oil supply agreement.

4.1.3. Propane

Liquefied propane gas is delivered by truck to the existing PREPA tanks on site. Propane is used to ignite the burners on the boilers when natural gas is not available, as is the case at Aguirre. PREPA entered a fuel purchase contract for liquefied propane supply (Contract 902-08-15) with the Liquilux Gas Corporation. The contract began in March of 2016 and was extended to March of 2019. Current contract information for Aguirre’s propane procurement has not been provided.

4.2. WATER SUPPLY & TREATMENT

Water for the plant is obtained from five local wells that are also shared with the community. PREPA is pursuing water system improvements where water will be sourced from Patillas Lake, currently scheduled for completion in the fourth quarter of 2022. The new water supply project is underway and includes a phased approach; the current Phase V work includes rehabilitation of two 1,800,000 gallon tanks—the final effluent tank and water retention tank—with sandblasting and recoating.

A capped amount of well water is provided under a franchise agreement with the Department of Natural Resources and Environmental. The franchise contains rules that the Plant has agreed to follow; in return, there is no charge for the water. A two-year renewal of the agreement is currently in process. The franchise number is unchanged: R-FA-FAID6-SJ-00222-02102015.

5. OPERATIONS & MAINTENANCE

The Plant is generally producing power 24 hours a day, 7 days a week. The Plant cycles as directed by dispatch and it is rarely at full load. The operations department works three shifts, staffing the plant 24 hours a day, 7 days a week. The staff uses the control rooms as their centers of operation. Daily meetings are used to direct activities and coordinate efforts among the staff. During each shift, the shift engineer is in charge of the Plant operations and management.

Normally, the thermal units operate at 230–430 MW continuously for grid frequency control, and the CC component operates as a peaker in either simple-cycle mode or in CC mode. In recent operation, only STAG 1 has operated in CC mode, typically with steam from only one or two of the GT HRSGs. The Plant is finalizing repairs to STAG 2 and expects it to be available for CC service in the fall of 2020.

5.1. STAFFING & TRAINING

Aguirre and the CC each have three main departments that respond to their respective plant manager. These departments are Operations, Administration, and Maintenance. A staffing organization chart from 2018 indicated that there were 223 people on staff at Aguirre with 144 at the thermal units and 79 at the CC units. At the thermal plant, 84 people are in maintenance, 53 are in operations, and 7 are in administration and other roles. At the CC facility, 34 people are in maintenance, 39 are in operations, and 6 are in administration and other roles. A generation employee roster from September 9, 2020 indicated a total Plant staff of 207 people, but a more recent organization chart has not been received.

New staff is mentored by the experienced personnel on site. Units 1 and 2 have an operator training simulator located at the Costa Sur plant. It is used for refresher type courses and for new hires. The CC does not have a simulator.

During normal operations, maintenance staff is on site for one shift daily, Monday through Friday. This includes staffing of the precision machine shop on the premises. Extended hours and additional personnel are used during outages.

5.2. MAINTENANCE PROGRAMS

5.2.1. Mandatory Environmental Outage

Each PREPA thermal production plant is mandated to perform an environmental outage at intervals of 12–18 months. During an environmental outage, the boiler and other components are cleaned to meet the requirements of the air compliance preventative maintenance schedule contained in PREPA's consent decree with the EPA. Each plant may keep a unit in service for up to an 18-month limit, subject to the unit's compliance with the emissions criteria in the consent decree.

Several areas are inspected, cleaned, and replaced (if necessary) during each environmental outage:

- Slag is removed from the boiler and the water walls are cleaned.
- The superheater, reheater, air heater, economizer areas, and the exhaust gas ducts and the stack are washed and inspected.
- Air heater components, seals, baskets, casing, and sector plates are inspected and replaced as necessary. Ductwork is repaired.
- Hoppers are emptied and cleaned; expansion joints are inspected for corrosion and leakage.
- Fuel handling equipment is inspected, repaired, and recalibrated as necessary.
- The forced- and induced-draft fans and the gas recirculation fan are cleaned, noise and vibration levels are monitored, adjustments are made, and repairs are completed.
- Motors for fans and main boiler pumps are cleaned and inspected.
- Dampers are inspected and adjusted.
- The windbox, burners, combustion air instrumentation, combustion controls, and soot-blowers are inspected; damaged or worn components are either repaired or replaced.
- Monitors for opacity, oxygen, and furnace pressure are cleaned, recalibrated, or, as necessary, replaced.
- Pumps, feedwater heaters, the deaerator, and associated valves are inspected.
- Lubricating oil systems are inspected.
- Power transformers are inspected, and breakers are tested and adjusted.
- If a pressurized part of the boiler has been replaced, the boiler part will be pressure tested before the unit returns to service. Life extension inspections and non-destructive examination activities are completed on critical systems and components in preparation for future programmed outages.

Plant personnel indicated that all of these maintenance activities are conducted during each Unit 1 and Unit 2 environmental outage, and Sargent & Lundy has confirmed this by reviewing outage summary reports. The CC units are not required to have environmental outages.

5.2.2. Preventative Maintenance

Routine maintenance activities are performed during environmental outages and planned major outages. Major outages are of a longer duration and allow for more involved overhauls, upgrades, and changes. Each PREPA thermal production unit is mandated to perform an environmental outage at intervals of 12–

18 months. During an environmental outage, the boiler and other equipment and systems are cleaned and inspected. Components are replaced if necessary.

The Plant's steam turbine valves are inspected regularly, and the scope includes the cleaning, non-destructive examination, and adjustment of HP stop and control valves, reheat stop valves, and intercept valves. Major inspections of the steam turbine are generally performed every 50,000 equivalent service hours. PREPA is considering a calendar-based inspection of the CC STGs because of their low capacity factor.

Major outages are now on eight-year spacing instead of six years. Maintenance activities in these outages include major boiler/HRSG and turbine inspections and refurbishments as well as inspecting, refurbishing, or replacing pipe hangers, valves, valve actuators, damper actuators, condenser cleaning, and drain traps. Requisitions are routed through the main office in San Juan, where parts and supply requests have been delayed or deferred as deemed necessary.

5.2.3. Corrective Maintenance

Maintenance and operational issues are recorded in logs by the operations staff, prioritized by plant and PREPA corporate management, and dealt with when possible during forced and scheduled outages. The 2017 and 2018 equipment balancing reports were provided and reviewed for the thermal units' ID fans and condensate pumps. The results were within industry norms.

5.2.4. Predictive Maintenance

A predictive maintenance program is used that is mainly based on the vibration recording and trending over time for the main equipment.

5.3. MAINTENANCE & OUTAGE SCHEDULES

As noted in Section 5.2.1, unit maintenance is often performed during the mandatory environmental outages. The outage schedule is extended to accommodate a larger maintenance scope when necessary. A summary of recent or ongoing outage dates, as provided by PREPA, and brief descriptions of any maintenance outside the standard environmental outage activities for Fiscal Years 2019–2020, and 2020–2021, can be found in Table 5-1. No recent or planned outage work was indicated for CC GTs 1-1, 1-4, 2-1, 2-3, or 2-4, STAG ST 1 or black-start BSGT 2-2.

Table 5-1 — Plant Maintenance Outage Activities

Plant Name	Start	Finish	Reason	Description
Aguirre ST 1	Sept 2020	Oct 2020	Maintenance Outage	Fixed issues with the ID Fan 1-2 and repaired a broken tube in the condenser.
	Jan 2021	Feb 2021	Env. Inspection	Environmental inspection included work to repair the Unit 1 MPT.
Aguirre ST 2	Dec 2019	May 2020	Env. Inspection	Environmental inspection included work to replace the Unit 2 MPT, replace the air heater basket, and repair the HP Water Heater 7.
	Mar 2021	April 2021	Env. Inspection	Environmental inspection will include work to repair the Unit 2 generator.
Aguirre Black-Start Turbine 2-1	Jan 2019	TBD	Maintenance Outage	Repairs to holes in the transition pieces.
Aguirre CC GT 1-2 (commercial operation date [COD] 1977 as a “B” model)	Sept 2020	TBD	Maintenance Outage	Unit was brought offline on September 30, 2020 with synchronization issues.
Aguirre CC GT 1-3 (COD 1977 as a “B” model)	Sept 2020	TBD	Maintenance Outage	Unit was brought offline on September 30, 2020 for a problem with the transmission gear.
Aguirre CC GT 2-2 (COD 1977 as a “B” model)	Sept 2016	TBD	Major Inspection	Unit has been offline since 2016 for a major inspection. Over this period, the GT 2-2 rotor was sent to the mainland United States for repairs, but it was poorly protected during the return shipment, rejected on site, and sent back for remediation. The rotor returned to site again in the spring of 2019. Unit is in the final stages of reassembly.
Aguirre CC ST 2	June 2017	TBD	Maintenance Outage	Unit offline for correction of various deficiencies.

The Plant staff also performs regular inspection and maintenance of the auxiliary systems that are shared by multiple units. As is good industry practice, many of these auxiliary systems were designed to include sufficient redundancy such that they can be maintained without the need for an outage. Some upcoming common system maintenance includes the following:

- PREPA currently has a tank inspection program, per the API Code and the spill prevention, control, and countermeasure (SPCC) plan, planned in the next six years for all power plants.
- As part of Phase V of the new water supply project, rehabilitation of the final effluent and water retention tanks began in July of 2019 and is scheduled for completion in January of 2021.
- Soot-blower and stairway removals have been completed on HRSGs 1-1, 1-2, 1-4, 2-1, 2-3, and 2-4; they should be completed on the remaining two HRSGs (1-3 and 2-2) by the fall of 2022 as outage schedules permit.

- Fire protection system testing is conducted per NFPA requirements, but no recent or planned maintenance issues have been identified.
- A fuel line inspection program is planned for all PREPA power plants in the next six years for code compliance, maintenance, and life extension; however, the detailed timing of the program for Palo Seco was not provided.
- Condition assessment programs for the boilers and high-energy piping are also planned in the next six years. The detailed timing of the program has not been provided.

Details of the recent outage history and forecast outage dates for the Plant were requested by PREPA. The information above includes data from a general maintenance activities report for the PREPA fleet and from September and October of 2020 daily availability dispatch reports. More detailed information was not received at the time of this report.

5.4. SPARE PARTS

A spares list for the thermal units was provided by PREPA, and it identified a multitude of small parts as well as air heater baskets, generator rotor, pump impellers, and capital valves. Tracking for local spares is done by hand and through the corporate asset management program.

Figure 5-1 — Warehouse

A spare generator stator for the thermal units is on site and should be installed in 2020. There is one set of spare ST rotor sections for the thermal units, but they are in various locations and stages of repair. The Unit 2 ST's HP and IP rotors were sent to Virginia for analysis in 2017 because they had operational issues. The site's spare HP and IP rotors were installed. It was determined the ST experienced HP impulse wheel damage from fatigue and/or excess hours. Pending a contract from PREPA Technical Services, the HP rotor will be repaired or replaced, and the IP section will have its blades changed and be high-speed balanced. There are two spare LP rotors on site; as of October 2020, the plant was evaluating proposals to have these rotors requalified prior to use.

A spare ID fan rotor and a spare FD fan rotor are on site. In the laydown yard with the boiler natural gas conversion parts is a replacement deaerator (DA) and DA storage tank. There is significant expense associated with installing the replacement DA due to access issues. The replacement DA and DA storage tank are uncovered but appear to be in good condition. During the 2019 site visit, Sargent & Lundy noted that the bearing journals of the FD rotors appeared to be well-protected, but other areas of the fan shaft should be cleaned and better protected. Plant staff reports that this cleaning was performed, and better protection has been provided.

Figure 5-2 — Replacement DA and DA Storage Tank

Figure 5-3 — Spare ID and FD Rotors

Outdoor storage—the bearing journals appear to be well-protected.

5.5. ENERGY MANAGEMENT SYSTEM

PREPA, at the corporate level, employs numerous automated control applications to ensure safe and reliable operation of its system. These applications coordinate with or are integrated into larger systems that support PREPA's routine technical and commercial operations. PREPA uses an energy management system (EMS) to regulate the supply-side generation of electricity to match real-time electric power demand-side from the users. This section addresses selected automated systems employed by PREPA for control and operation of its generation, transmission, and distribution systems.

In 2012, a supplier provided an updated EMS to replace the older system employed at the time. The 2012 system updated the generation mixture to include intermittent and renewable generation to reflect the new supply-side resources becoming available due to mandated legislation. The EMS also incorporated cyber-security compliance with NERC infrastructure standards. In addition to upgrading the EMS, the supervisory control and data acquisition functionality was also updated to link the central EMS with the generation plants and substations.

6. PERFORMANCE REVIEW

To evaluate the performance of the Plant, Sargent & Lundy reviewed historical operating performance provided by PREPA of CC Units 1 and 2, thermal Units 1 and 2, and GT Units 2-1 and 2-2 of the Plant and benchmarked it against a group of industry peer units where data was available. The primary performance indicators were as follows:

- Generation
- Net capacity factor (NCF)
- Equivalent availability factor (EAF)
- Equivalent forced outage rate (EFOR)
- Net heat rate

NCF is the annual net energy production as a fraction of the energy that would be produced if a plant operated at its rated capacity 100% of the time. EAF is a measure of an electric generating unit's availability where it is a percentage of time that the unit has been available during a specified time period, including the impact of deratings (times when the unit is operating at a lower power output). EFOR is a measure of an electric generating unit's unreliability; it is the percentage of time that a unit is in a forced outage during a specified time period, including the impact of forced unit derates.

PREPA provided operation data for the past six full years of operation, 2015–2020. Sargent & Lundy also reviewed data cataloged by NERC within their generating availability database system (GADS)[5] and established peer groups of units comparable to those of the Plant to compare reliability data.

Sargent & Lundy applied the selection criteria identified in Table 6-1 to the NERC GADS database[6] to establish separate reliability peer groups for the GTs and STs for CC Units 1 and 2, as the data was reported separately by both PREPA and NERC for the CC units, thermal units, and GT units. The resulting peer groups that reflects these unit characteristics included: (i) 11 units, owned by 7 different operators, with the dataset including 58.50 operating years of reporting data for the STs; (ii) 16 units, operated by 3 utilities, with 118.50 operating years of reporting data for the GTs; and (iii) 11 units by 10 owners, with 38.83

[5] NERC maintains records of reliability information for generating stations within the United States and Canada based on data provided by the station owners and operators. These data are compiled within the GADS. Within the GADS, filters can be applied to review reliability data by plant characteristics, such as plant prime mover, nameplate capacity, fuel type, and age. Filters can also be applied for plant generating statistics, such as plant capacity factor. In this way, the GADS can report reliability data reflective of a peer group of plants with specific characteristics and generating statistics. Sargent & Lundy filtered the GADS to obtain reliability statistics that reflect a peer group of units similar to the Aguirre units.

[6] Accessed via pc-GAR software on November 11, 2020. Version: PC-GAR v4.01.16

operating years for the thermal units. Note that heat rate is not reported to NERC, and therefore peer group data is not presented in this report. Table 6-2 provides a summary of the key performance data for Aguirre. Although the GT units and CC ST and GT units are similar, the units in the peer groups primarily run on natural gas rather than No. 2 fuel oil as the GT units do.

Table 6-1 — Aguirre Units Peer Group

Aguirre Unit Characteristics				Peer Group Characteristics			
Technology	**COD**	**Unit Gross Capacity (MW)**	**Operating Fuel**	**COD/Age**	**Unit Gross Capacity (MW)**	**Operating Fuel**	**Additional Criteria**
CC Gas Turbine	1977	50	No. 2	35–50 years	30–70	Not Specified	–
CC Steam Turbine	1977	96	No. 2	COD 1960–1985	25–175	Not Specified	–
Thermal Units	1971–1972	450	HFO	COD 1970–1980; 40–55 years	350–550	Distillate Oil(DI) or Oil	–
GT Units	1972	21	No. 2	COD 1965–1980; 40–60 years	15–25	Not Specified	Black-Start Capable 0–20% Capacity Factor

Table 6-2 — Aguirre Overall Key Performance Data Summary

Plant/ Unit	Key Performance Indicator	2015	2016	2017	2018	2019	2020	Peer Group
Aguirre Steam	Generation (MWh)	3,846,975	2,384,165	2,790,835	3,141,255	2,410,820	3,305,240	–
	Equivalent Availability (%)	65.8	44.8	73.1	81.1	49.4	61.4	85.1
	Net Capacity Factor (%)	48.8	30.2	35.4	39.8	30.6	41.8	2.3
	Equivalent Forced Outage Rate	24.0	53.5	21.2	14.0	45.5	31.7	34.1
	Net Heat Rate (Btu/kWh)[1]	10,486	10,452	10,800	10,684	10,774	11,158	–

Plant/ Unit	Key Performance Indicator	2015	2016	2017	2018	2019	2020	Peer Group
Aguirre CC I	Generation (MWh)	361,577	502,347	285,734	155,864	485,915	731,485	–
	Equivalent Availability (%)	62.5	79.6	73.1	75.3	80.1	59.8	GT: 88.8 ST: 81.7
	Net Capacity Factor (%)	13.9	19.3	11.0	6.0	18.7	28.1	GT: 12.2 ST: 32.0
	Equivalent Forced Outage Rate	5.6	15.7	25.7	22.7	14.5	35.1	GT: 12.6 ST: 9.0
	Net Heat Rate (Btu/kWh)	13,856	11,686	12,149	12,934	12,616	13,517	–
Aguirre CC II	Generation (MWh)	255,986	133,659	211,584	66,595	256,035	541,681	–
	Equivalent Availability (%)	52.3	52.3	54.9	41.8	43.5	39.8	GT: 88.8 ST: 81.7
	Net Capacity Factor (%)	9.9	5.1	8.0	3.0	9.9	20.8	GT: 12.2 ST: 32.0
	Equivalent Forced Outage Rate	29.1	33.5	26.7	32.3	13.0	23.2	GT: 12.6 ST: 9.0
	Net Heat Rate (Btu/kWh)	13,811	12,224	13,202	13,879	13,224	14,132	–
Aguirre CT	Generation (MWh)	11,866	4,597	3,749	1,644	121	12,081	–
	Equivalent Availability (%)	49.4	44.6	35.1	40.6	4.3	18.4	89.1
	Net Capacity Factor (%)	3.2	1.3	1.0	0.0	0.0	3.3	0.5
	Equivalent Forced Outage Rate	44.7	56.1	65.4	57.8	95.8	81.7	88.6
	Net Heat Rate (Btu/kWh)	15,981	17,101	16,286	16,874	17,612	13,409	–

[1] Btu/kWh = British thermal unit per kilowatt hour

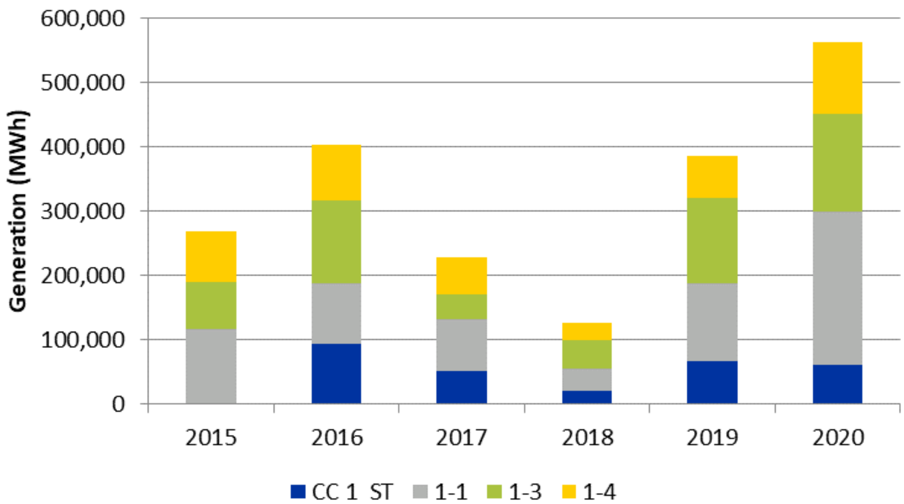
6.1. GENERATION

Figure 6-1 through Figure 6-4 show the annual power output to the grid in MW-hours for the CC units, the steam units, and the black-start GTs. The 2017 hurricanes caused various limitations on the units. Note that the scale of generation is different in each graph.

The two CC units, STAG 1 and STAG 2, are generally used to meet peaking demands, sometimes operating in simple-cycle mode and sometimes in CC mode, with any number or combination of their GTs in service. ST use was greatly curtailed in 2017 when Hurricane Maria severely damaged the cooling towers of the CC unit's circulating water systems. The towers were recently repaired.

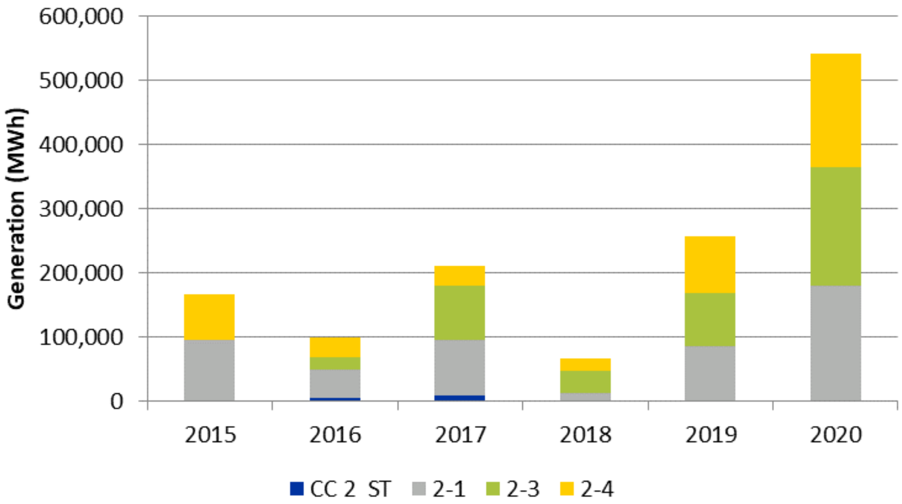
STAG 1's annual generation peaked in 2016 at 92,581 MWh and declined to 19,775 MWh in 2018. The Plant took advantage of this reduction to make several much-needed repairs by rotating through each GT–HRSG train. STAG 1 has generally been operational since 2018.

Figure 6-1 — Aguirre STAG 1 Generation



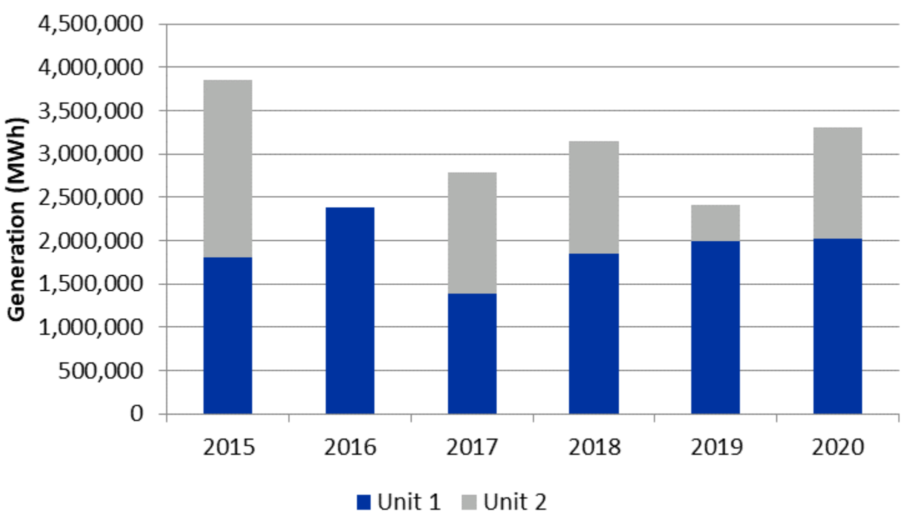
STAG 2 also has a decline in output to 2018, and like STAG 1, it is having several repairs and upgrades made, especially to the HRSGs. In addition, GT 2-2 has been out of service for repairs since 2016. The ST was idle since 2018 while the condenser waterboxes were being refurbished.

Figure 6-2 — Aguirre STAG 2 Generation



The data show that the thermal plant output has risen slightly in recent years. In 2016, Unit 2 was offline, with ST troubleshooting and repairs. Site personnel explained the thermal units have generally been operating between 230 MW and 430 MW for grid frequency control. Their nameplate full load capacity is 450 MW (gross).

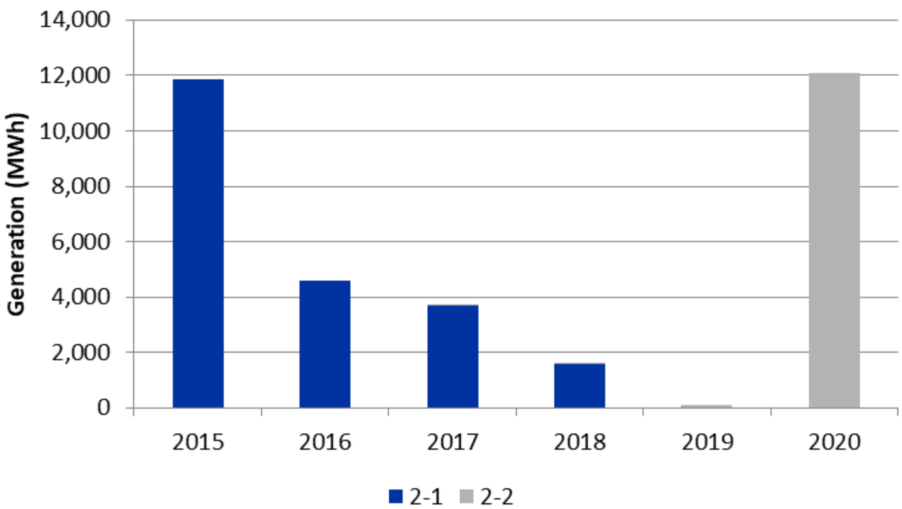
Figure 6-3 — Aguirre Thermal Plant Generation



As seen in Figure 6-4, the use of the black-start GTs was declining through 2019. GT 2-1 was the preferred unit; it went into an outage for a combustor inspection in mid-January 2019. GT 2-2 is limited to four hours of operation before it trips on high oil temperature in the lubricating oil tank. The generation of GT 2-2 in

2017 and 2018 is not high enough to register in the graph shown in Figure 6-4. Additional details on the condition of the black-start GTs can be found in Section 3.1.5.

Figure 6-4 — Aguirre GT Units Generation



6.2. AVAILABILITY FACTOR

The EAF is the fraction a facility is available to generate electricity at net dependable capacity less derated conditions. EAF is calculated as follows:

EAF =([Available Hours - (Equivalent Unplanned Derated Hours + Equivalent Planned Derated Hours + Equivalent Seasonal Derated Hours)]/Period Hours] x 100

The notes above in Section 6.1 explain some of the major outage events for individual units at the Plant over the last five years. When a unit is in an outage, it is not available to add power to the grid, and this is reflected in the "Available Hours" in the above formula. This is seen in Figure 6-7, for example, when the Unit 2 STG was offline in 2016 for extended repairs. The hours are considered "equivalent" because they equate a unit's derate to outage hours. A unit is derated when it cannot produce its rated capacity.

Availability is one of the best single metrics for the condition of a plant. It indicates if the plant is available to generate power. Whether the plant is dispatched to operate has to be correlated with the net capacity factor for relevance. The average EAF for STAG 1 in Figure 6-5 was a low of 59.8% in 2020 and a high of 79.6% in 2016. The unavailability of the STAG 1 ST in 2015 was due to an extended planned outage. There appear to be some discrepancies in the PREPA data. In Figure 6-5, the STAG 1 STG availability is high in 2018, but its EFOR is also high (80% in Figure 6-9). Sargent & Lundy would expect to see low EAF at times of high EFOR.

The availability for the PREPA fleet will include a deduct for the required EPA environmental maintenance outages. The deduct significantly impacts the ratings in the system; therefore, the availability has an upper limit, and higher availabilities in other systems cannot be directly compared with the PREPA fleet. STAG 1, however, has been able to achieve a lower but similar availability to the peer group. Note that availability of the STG in the peer group is typically lower than that of the GTs.

Figure 6-5 — Aguirre STAG 1 Equivalent Availability Factor

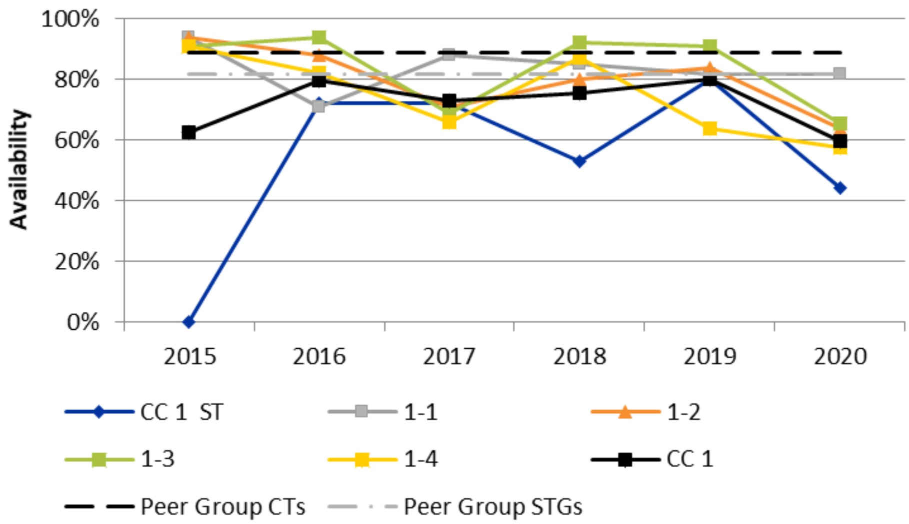
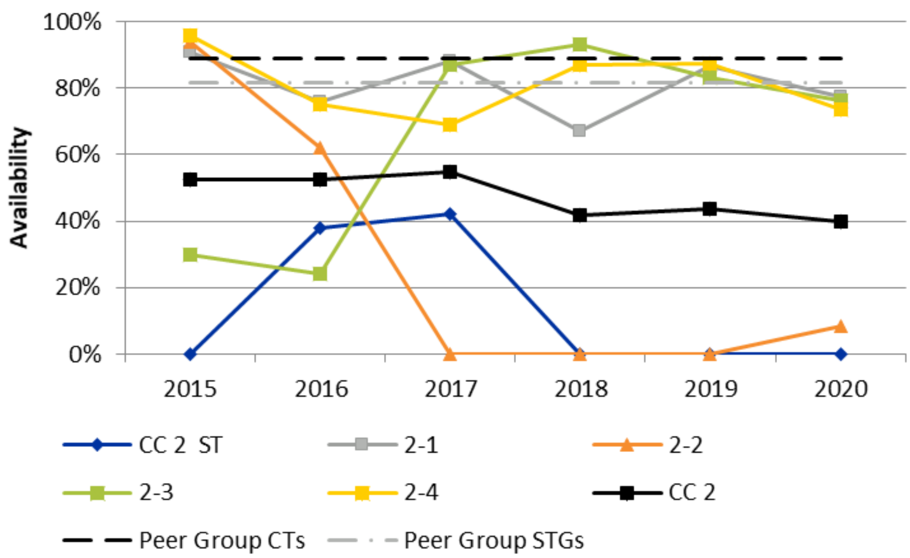


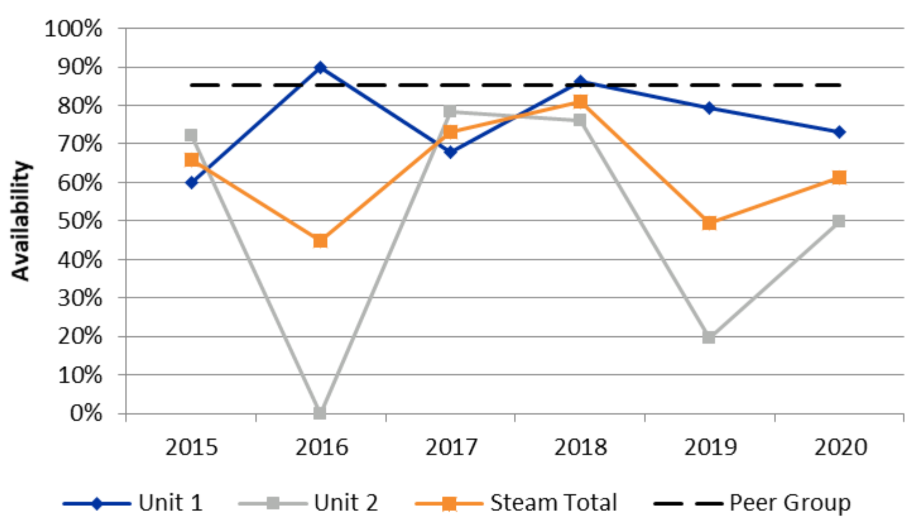
Figure 6-6 and Figure 6-10 for the STAG 2 STG also show a discrepancy in the PREPA data in 2016 and 2017 with approximately 40% availability but an approximately 90% forced outage rate. Sargent & Lundy recommends PREPA revisit the inputs and calculations. The average STAG 2 (total) EAF has been decreasing from around 50% to 40% within the last five years.

Figure 6-6 — Aguirre STAG 2 Equivalent Availability Factor



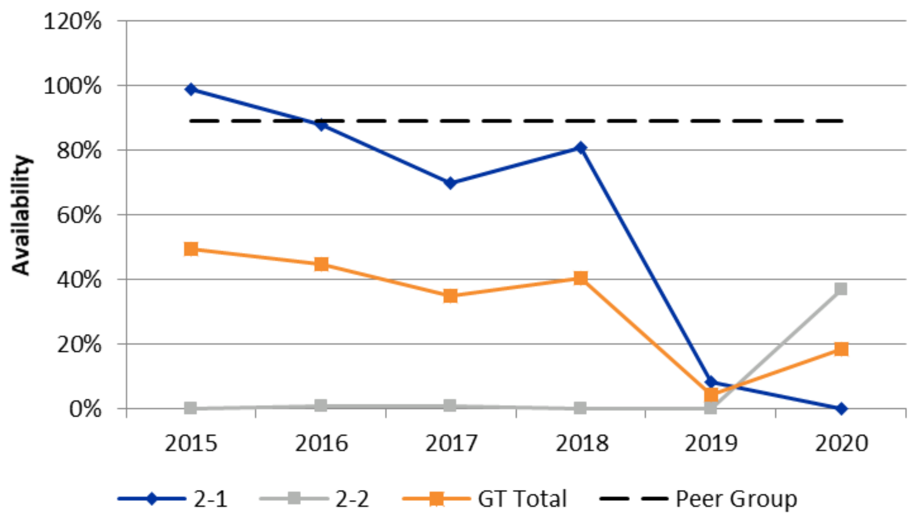
The availability of the thermal units is around 70% and higher on average, which is good considering their age, the fuel burned, and the coastal environment. The average availability factor for the thermal units was a low of 44.8% in 2016 and a high of 81.1% in 2018. The thermal units EAF is provided in Figure 6-7:

Figure 6-7 — Aguirre Thermal Plant Equivalent Availability Factor



Until 2019, GT 2-1 had high availability while GT 2-2 has generally been unavailable (emergency use only). The availability factor for GT 2-1 has ranged from 70% to 99% from 2015 through 2018, which is consistent with the availability of its peers, but it dropped when it went into an outage for a combustor inspection in mid-January 2019. For 2015–2019, the GT 2-2 EAF was below 1%; however, it has increased over the last year.

Figure 6-8 — Aguirre GT Unit Equivalent Availability Factor



6.3. EQUIVALENT FORCED OUTAGE RATE

EFOR is a measure of the probability that a generating unit will not be available due to forced outages or forced deratings, which does not include planned or maintenance outages. In other words, EFOR is a rating to indicate how often the unit is unable to respond, irrespective of system need.

EFOR = (Forced Outage Hours + Equivalent Forced Derated Hours)/(Service Hours + Forced Outage Hours + Equivalent Reserve Shutdown Forced Derated Hours) x 100

Figure 6-9 and Figure 6-10 show the GTs with relatively low forced outage rates (similar to the peer group) and the STGs with high forced outage rates. The maintenance and planned outage factors (not shown) are also low for the GTs, except for GT 2-2, which has been undergoing a major inspection as discussed in Section 3.1.4.2; however, STGs have experienced several outages, as discussed in Section 3.1.4.5. The Aguirre EFOR for STAGs 1 and 2 is provided in Figure 6-9 and Figure 6-10, respectively.

Figure 6-9 — Aguirre STAG 1 Equivalent Forced Outage Rate

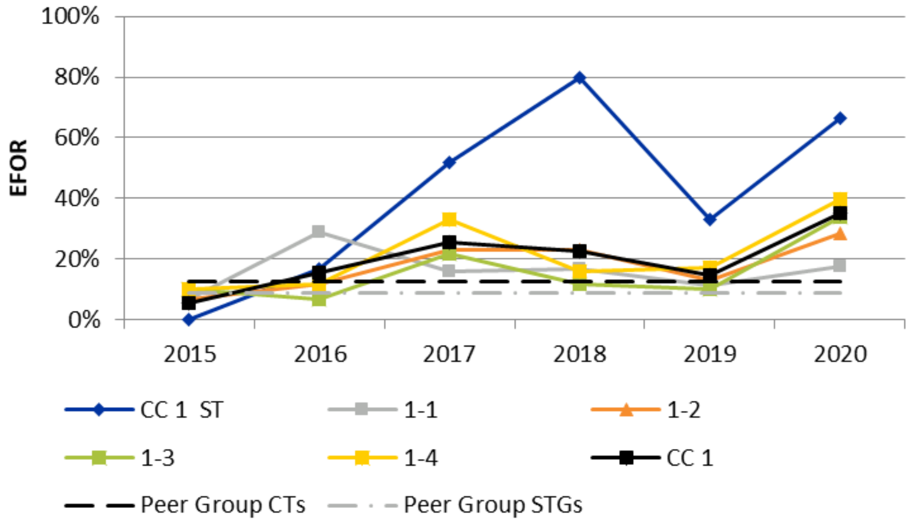
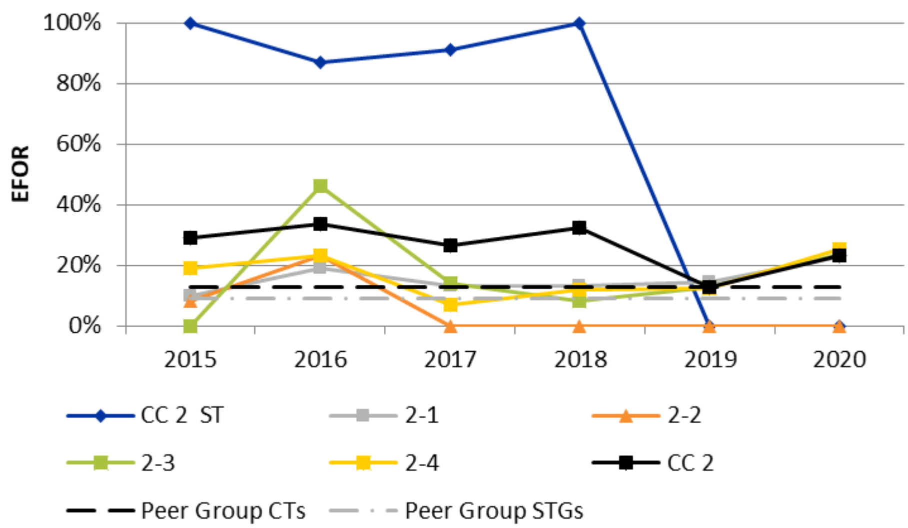
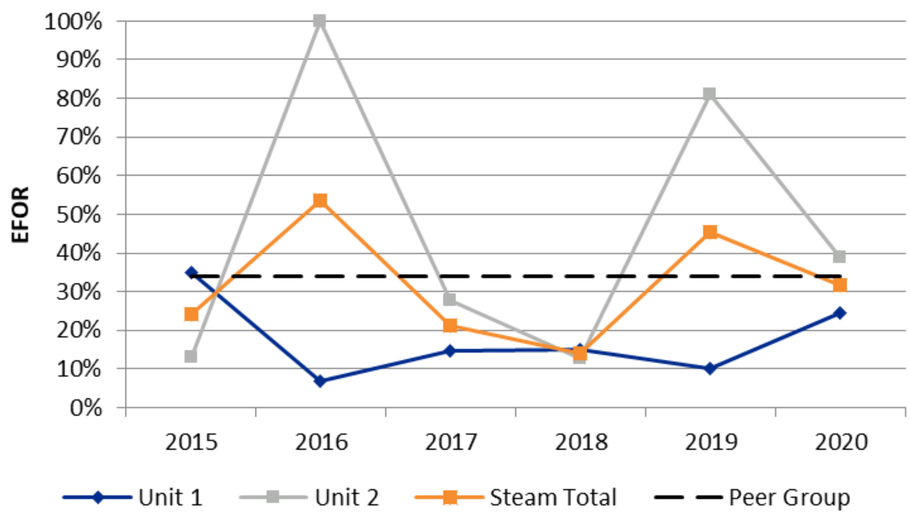


Figure 6-10 — Aguirre STAG 2 Equivalent Forced Outage Rate



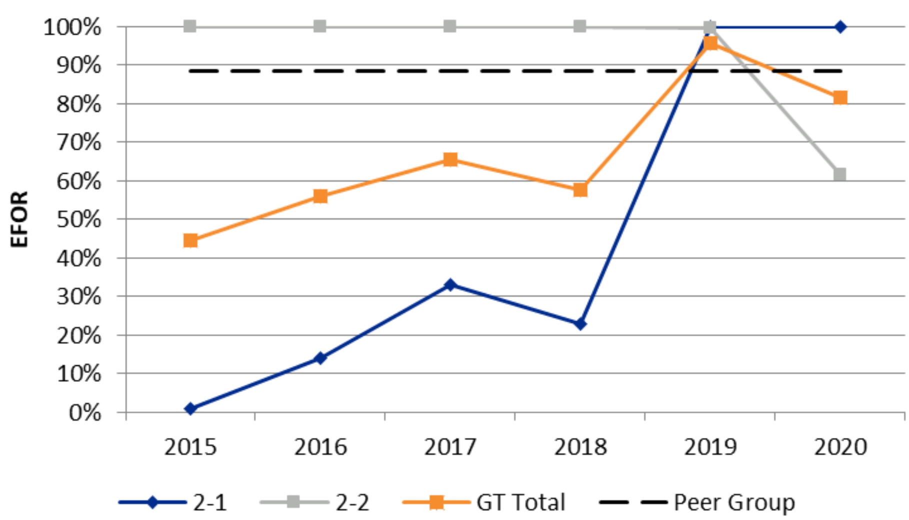
For the thermal units, Figure 6-11 shows an elevated (35%) Unit 1 EFOR in 2015, which is a result of the generator replacement at the end of 2015. Unit 2 was addressing extended STG issues in 2016 and underwent a major outage in 2019, which is also reflected in Figure 6-11. Unit 1 has generally had lower (better) EFORs than the peer group while Unit 2 has experienced higher EFORs than the peer group in 2016 and 2019, as noted above.

Figure 6-11 — Aguirre Thermal Plant Equivalent Forced Outage Rate



The black-start GTs generally have had lower EFORs than their peer group; however, as noted previously, GT 2-1 has been out of service since it went into an outage for a combustor inspection in mid-January 2019, and GT 2-2 has limited use due to high oil temperatures.

Figure 6-12 — Aguirre GT Units Equivalent Forced Outage Rate



6.4. CAPACITY FACTOR

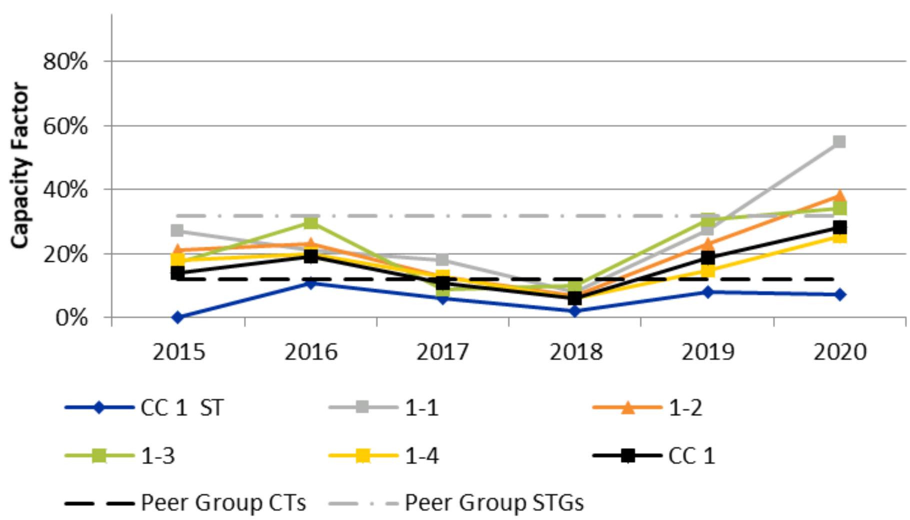
When reviewing changes in availability and forced outage values, it is important to identify if the unit was being dispatched differently; in a gross fashion, the NCF provides insight into this. NCF is a percentage representing the average output of the facility during the time it was active (declared operational). The net capacity factor is calculated as follows:

NCF = (Total Net Generation/[Net Capacity at Mean Ambient Temperature x Period Hours]) x 100

An important driver for the capacity factors and the annual generation is the dispatch demand for power, which appears to be decreasing based on the NCF and availability plots below; however, the NCF has increased in 2020, likely due to an extended outage at Costa Sur since the January 7, 2020 earthquake. Other governing factors for the low NCF, such as those caused by the 2017 hurricanes and 2020 earthquakes, are disruptions to fuel and water supplies and damage to transmission and distribution systems.

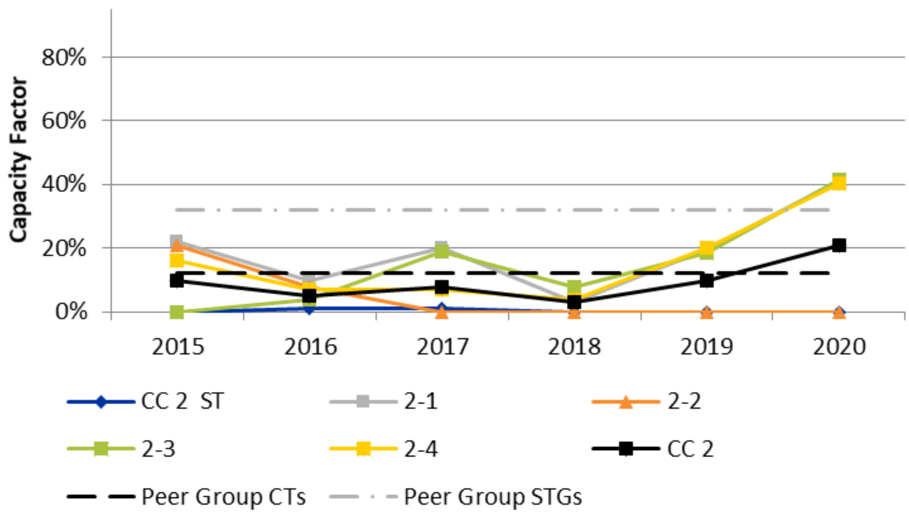
The NCF of STAG 1 is shown in Figure 6-13. The 0% capacity factor and 0% availability for the STAG 1 STG in 2015 was due to an extended planned outage. The severe hurricane damage to the cooling towers explains why the STG capacity factor decreases in 2017 and 2018. The average NCF of the GT generators and STG is included in the plot; it ranges from a low of 6% in 2018 to a high of 33% in 2020. This is generally in line with similar units.

Figure 6-13 — Aguirre CC Unit 1 Capacity Factor



The NCF on STAG 2 is shown in Figure 6-14. In 2017, the STG came offline for high bearing vibration, and in 2018 the condenser waterboxes were refurbished. The effect of these outages on the capacity factor is seen below and in the following plots for EAF and EFOR. The plots also indicate there were STG-related issues in 2015, but the Plant staff was unable to provide information for review. As explained above for the STAG 1 STG, hurricane damage caused limited CC operation in 2017 and 2018. The GTs were available for simple-cycle operation. GT 2-2 remains out of service from a rebuild beginning in 2016. The average NCF depicts a recovery from a low of 3% in 2018 to 21% in 2020, which is generally in line with similar units.

Figure 6-14 — Aguirre CC Unit 2 Capacity Factor



The NCF plots for Aguirre thermal Units 1 and 2 are provided in Figure 6-15. The NCF for Units 1 and 2 follows the same trend seen in the generation information above. The NCF is high in the same year that the unit has high generation, and it is low when the generation is low. In 2016, Unit 2 has 0% NCF because it was out of service with extended STG issues. With Unit 2 out of service in 2016, Unit 1 had its highest NCF over the past five years at 60%. Unit 1's lowest capacity factor in the past five years was 35% in 2017 (likely due to the hurricanes of that year). Unit 2 was at its high in 2015 at 52%. These capacity factors are significantly higher than its peer group and shows the Aguirre thermal units are used generally for base load while the peer group is used for peaking operations.

Figure 6-15 — Aguirre Thermal Plant Capacity Factor

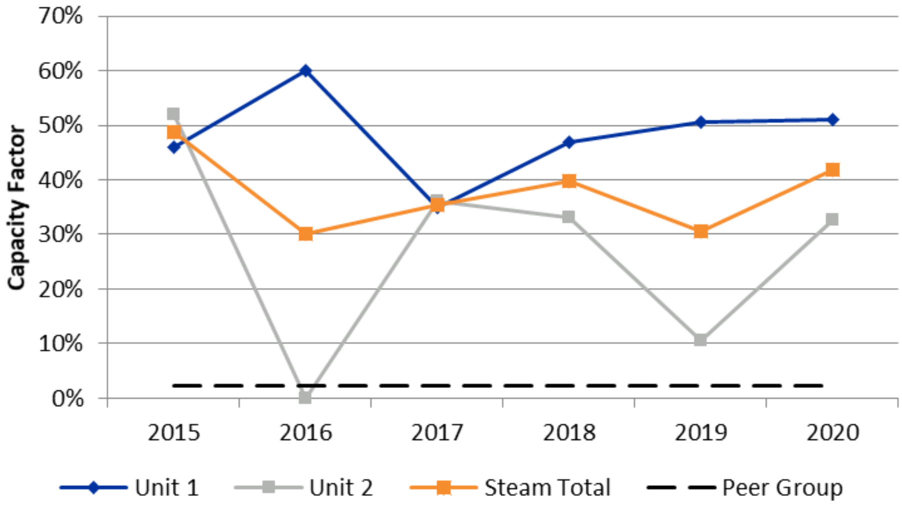
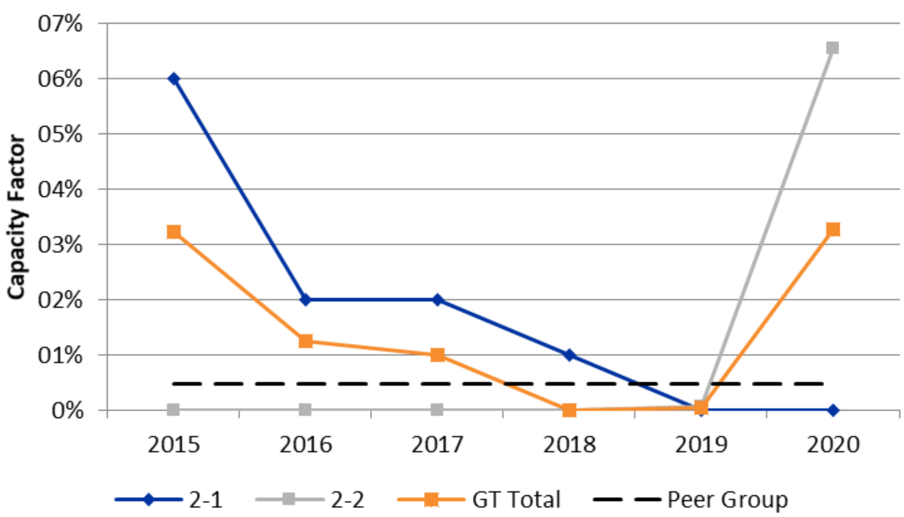


Figure 6-16 shows that the black-start GT net capacity factor over the last five years has generally been above that of its peer group. The peer group shows an NCF indicative of black-start units while the Aguirre units are used for peaking generation at times. As noted previously, GT 2-2 is used for emergency generation due to the high oil temperature; GT 2-1 has been out of service since January 2019.

Figure 6-16 — Aguirre GT Units Capacity Factor



6.5. NET HEAT RATE

The heat rate is the amount of energy used by an electrical generator or power plant to generate one kWh of electricity. Heat rate shows in general the efficiency of the unit and to an extent represents the units to be considered in a dispatch hierarchy. The heat rate is slightly degraded through service.

Heat rate also can be used to determine expected fuel requirements necessary for generation. As fuel represents the largest variable cost, having a lower heat rate than that of other similar units is a competitive advantage. Lower heat rates are indicative of a generating unit that is efficient at converting fuel into electricity; if two generating units of similar design and vintage are compared, the unit with the lower heat rate will have lower variable fuel costs than the other unit.

The net heat rates below for the CC units show the GTs separately, while the contribution from the STG is seen in the “Total” category. The total heat rate is the sum of the GT fuel input in Btu divided by the sum of the GT and ST net power output in kWh. The heat rates are high (unfavorable) for both STAG units, which is to be expected considering their high percentage of simple-cycle dispatch.

Figure 6-17 — Aguirre CC Unit 1 Heat Rate v. Capacity Factor

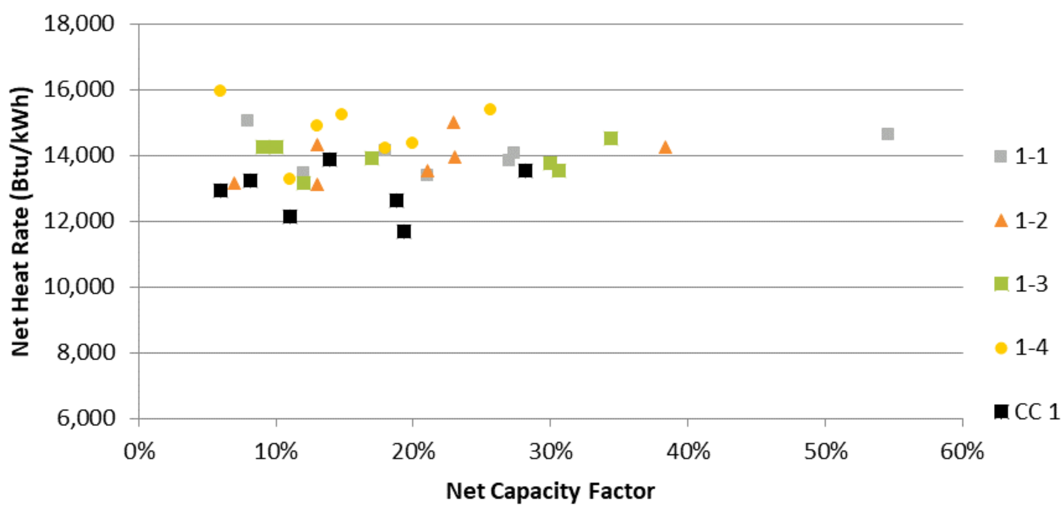
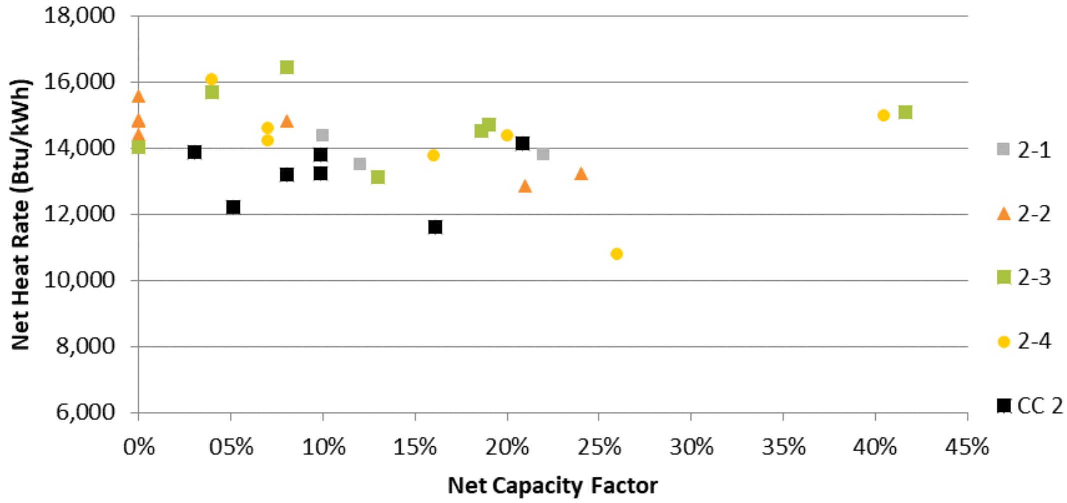
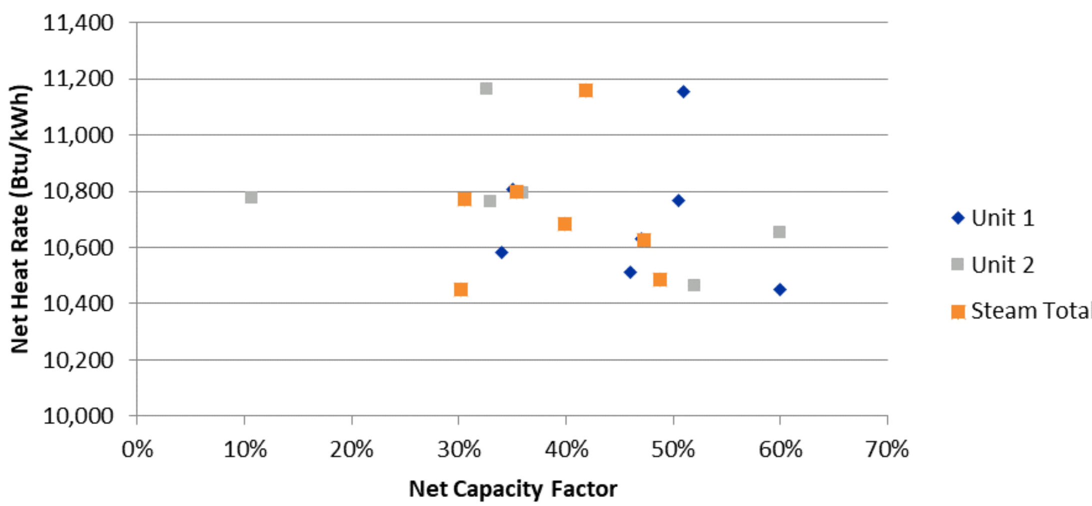


Figure 6-18 — Aguirre CC Unit 2 Heat Rate v. Capacity Factor



The thermal units have similar heat rates to each other. An analysis of the data shows their heat rates are fairly steady as the unit's capacity factor decreases. This may indicate a unit is operating at a similar load at all capacity factors but is operating there for shorter durations at the lower capacity factors. If it were operating at lower loads at lower capacity factors, a higher heat rate would be expected, as units typically lose efficiency at reduced loads. The Aguirre thermal plant heat rates are shown in Figure 6-19 (note the scale of the heat rate numbers on the left axis).

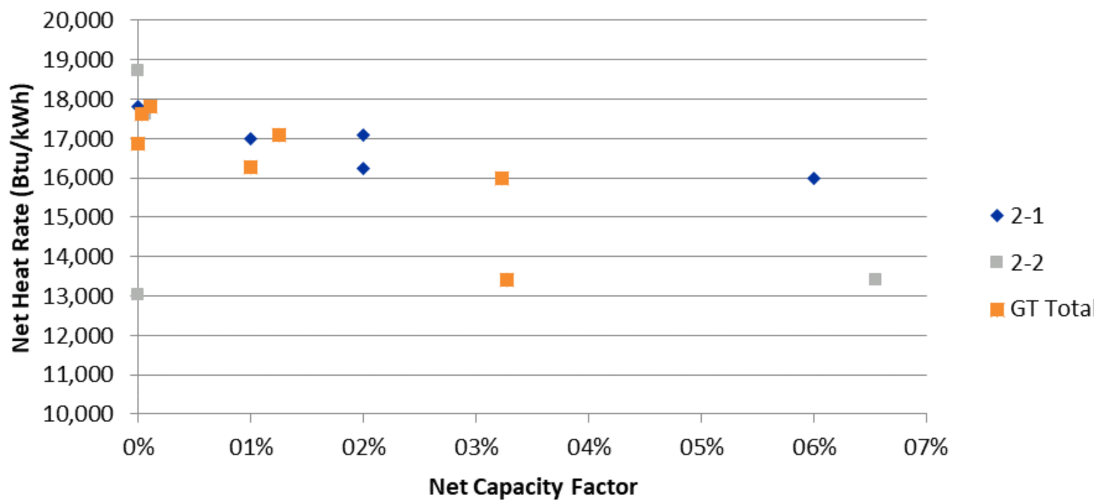
Figure 6-19 — Aguirre Thermal Plant Heat Rate v. Capacity Factor



Compared to other PREPA steam units operating on HFO, Units 1 and 2 have some of the best heat rates in the fleet; however, the CC units are dominated by inefficient simple-cycle use; therefore, they have higher heat rates. The Aguirre plant staff looked at some short-term data in predominately CC mode from October 2011, and the heat rates for CT-HRSG Trains 1-3 and 2-4 were 9198 Btu/kWh and 9275 Btu/kWh, respectively. These are significantly better than the 12,772 and 13,879 Btu/kWh CC heat rates illustrated in the figures above.

The heat rate of the black-start GTs is fairly high, which is expected due to their low operation; however, the heat rate declines consistently at higher capacity factors.

Figure 6-20 — Aguirre GT Units Heat Rate v. Capacity Factor



7. FINANCIAL REVIEW

Sargent & Lundy compiled the historical O&M and capital expenditures (CAPEX) for Aguirre from reported PREPA data and fiscal plan forecasts for FY 2015 through FY 2020.

Cost data for Aguirre is reported under the Generation Directorate, which is one of the five historical PREPA directorates (Generation, Transmission, Distribution, Customer Service, and Administrative & General). Historical O&M and CAPEX costs were obtained from the following data files and reports:

- *725 OPER-CONST by Resp 2008-2020.xlsx*
- *Generation O&M by RESP.xlsx*
- *PREPA Ex 1.02 Part 1 Economic Analysis Report.pdf*
- *PREPA Ex. 1.02 Part 2 Economic Analysis Report Appendices.pdf*

Summaries of O&M costs and CAPEX for Aguirre and comparisons with industry values are presented in the subsections below.

7.1. FIXED & VARIABLE O&M

Fixed O&M costs are independent of the amount of the plant generating output, such as fixed labor, materials, and administrative and general costs. Variable O&M costs are directly proportional to plant generating output, such as chemicals and consumables. The reported fixed and variable O&M costs for Aguirre are aggregated. Also, the costs for Aguirre CC Unit 1 (260 MW) and Unit 2 (260 MW) are combined with the Aguirre Steam Unit 1 (450 MW) and Unit 2 (450 MW).[7]

Table 7-1 summarizes the historical O&M costs at Aguirre. This does not include corporate costs for the Generation Directorate that is common with other plants, such as administrative, technical support, and fuel contracting.

[7] MW capacity values shown in this report section are nominal values reported by PREPA for cost reporting and do not necessarily reflect the latest tested capacity.

Table 7-1 — Aguirre Historical O&M Costs (FY 2015–FY 2020)

Aguirre (Steam: 900MW; CC: 520MW) Historical O&M Costs $)	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Operating Labor						
342 - Jefe Div. Central Gen. Aguirre	$ 17,269,779.18	$ 15,693,190.83	$ 14,635,156.99	$ 12,105,651.29	$ 11,563,480.32	$ 11,224,222.72
304 - Jefe Central Ciclo Combinado	$ 7,968,368.73	$ 8,067,818.61	$ 7,311,843.54	$ 5,177,706.92	$ 6,322,141.78	$ 6,276,877.95
343 - Proyectos Conservacion Aguirre	$ -	$ -	$ -	$ -	$ -	$ -
Operating Non-Labor						
342 - Jefe Div. Central Gen. Aguirre	$ 5,193,226.27	$ 5,265,508.15	$ 6,997,360.70	$ 5,009,734.39	$ 5,455,056.49	$ 5,264,458.21
304 - Jefe Central Ciclo Combinado	$ 891,326.65	$ 1,145,288.74	$ 999,258.98	$ 735,752.22	$ 771,715.03	$ 1,231,824.99
343 - Proyectos Conservacion Aguirre	$ -	$ -	$ -	$ -	$ -	$ -
Total O&M Costs ($)	$ 31,322,700.83	$ 30,171,806.33	$ 29,943,620.21	$ 23,028,844.82	$ 24,112,393.62	$ 23,997,383.87

FY = Fiscal Year, July 1–June 30

The aggregated O&M costs shown above correspond to the fixed and variable components estimated by PREPA in the aforementioned economic analysis report. Table 7-2 summarizes PREPA's estimate of the fixed O&M (in $/kW-year) and variable O&M (in $/MWh) for the Aguirre CC and steam units. Sargent & Lundy compared these values with O&M costs for existing units in operation in North America of similar configurations and operating profiles. From the data, Sargent & Lundy determined that the Aguirre O&M costs are within the typical range of costs for similar units, considering that higher O&M expenditures are required for plants firing HFO and No. 2 fuel oil as compared with natural gas.

Table 7-2 — Aguirre Fixed and Variable O&M Cost Breakdown

Category	Aguirre Combined-Cycle Unit 1 (260 MW) and Unit 2 (260 MW)	Aguirre Steam Unit 1 (450 MW) and Unit 2 (450 MW)
Fixed O&M (2015 $)	$21.60/kW-year	$30.57/kW-year
Variable O&M (2015 $)	$6.48/MWh	$2.15/MWh

7.2. CAPITAL EXPENDITURES

Historical CAPEX, reported by PREPA, for Aguirre for FY 2015 through FY 2020 are summarized in Table 7-3. Sargent & Lundy compared these values with CAPEX for existing units in operation in North America of similar ages and configurations.[8] From the data, Sargent & Lundy determined that the annual CAPEX expenditures for Aguirre are within the typical range of costs for similar units.

[8] "Generating Unit Annual Capital and Life Extension Costs Analysis – Final Report on Modeling Aging-Related Capital and O&M Costs," prepared by Sargent & Lundy for the U. S. Energy Information Administration, May 2018.

Table 7-3 — Aguirre Historical CAPEX (FY 2015–FY 2020)

Aguirre (Steam: 900MW; CC: 520MW) Historical CAPEX $)	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Construction/Maintenance Labor						
342 - Jefe Div. Central Gen. Aguirre	$ 99,987.29	$ -	$ -	$ -	$ -	$ -
304 - Jefe Central Ciclo Combinado	$ -	$ -	$ -	$ -	$ -	$ -
343 - Proyectos Conservacion Aguirre	$ -	$ -	$ -	$ -	$ -	$ -
Construction/Maintenance Non-Labor						
342 - Jefe Div. Central Gen. Aguirre	$ 7,357,426.80	$ 11,093,170.28	$ 15,972,034.84	$ (2,686,903.04)	$ 3,544,326.54	$ 8,719,150.84
304 - Jefe Central Ciclo Combinado	$ 3,332,910.61	$ 5,412,511.65	$ 4,530,986.82	$ 86,828.64	$ 7,526,533.29	$ 8,570,935.40
343 - Proyectos Conservacion Aguirre	$ -	$ -	$ -	$ -	$ -	$ -
Total CAPEX ($)	$ 10,790,324.70	$ 16,505,681.93	$ 20,503,021.66	$ (2,600,074.40)	$ 11,070,859.83	$ 17,290,086.24

8. ENVIRONMENTAL & REGULATORY

This section describes some of the major environmental requirements that currently apply to Aguirre and includes a limited review of the station's current environmental compliance status. This section does not include a review of new and proposed regulatory initiatives that may have an impact on future operations at Aguirre.

Aguirre operates under the key permits and approvals identified in Table 8-1. Based on review of permits and documentation provided by PREPA or publicly available information, all major environmental permits for the Aguirre facility are current or in the process of being renewed.

Table 8-1 — Aguirre Power Plant Key Permits and Approvals

Permit/Approval Description	ID Number	Permit Expiration Date
Title V Operating Permit	PFE-TV-4911-63-0212-0244	April 15, 2020 (renewal application has been filed, see Section 8.1)
National Pollution Discharge Elimination System (NPDES)	PR0001660	May 31, 2024
Resource Conservation Recovery Act (RCRA) – Industrial and Hazardous Waste	PRD980644470	N/A
Safe Drinking Water Act	PR563065, PR563105	N/A
Franchise for the use of Waters of Puerto Rico	R-FA-FAID6-SJ-00222-02102015	N/A

Sargent & Lundy reviewed environmental compliance information provided by PREPA and information obtained from U.S. EPA's Enforcement and Compliance History Online (ECHO) database to determine the current environmental status of the facility. Provided below is a review of the facility's status for following areas: air emissions, water and wastewater discharge, emergency planning reporting, oil storage spill prevention, and recent enforcement actions.

8.1. AIR EMISSIONS

The Aguirre Title V Operating Permit includes emission limits and monitoring, recordkeeping, and reporting requirements for Aguirre. The facility's current permit was issued on April 15, 2015 and expired on April 20, 2020. The facility is required to submit a renewal application to the Puerto Rico Environmental Quality Board (EQB) at least 12 months prior to the expiration date. According to PREPA, the renewal application was filed on April 15, 2019. The emission units regulated under the Title V operating permit include the following:

- Two HFO-fired boilers with steam turbogenerators with a capacity of 4180 MMBtu/h each
- Eight oil-fired gas turbines with HRSG and steam turbogenerators, each turbine having a capacity of 607.5 MMBtu/h
- Two oil-fired gas turbines with a capacity of 301.5 MMBtu/h each
- Two 13,482,000-gallon No. 2 fuel oil storage tanks
- Four 1,152,060-gallon No. 2 fuel oil storage tanks
- Two 1,807,050-gallon No. 2 fuel oil storage tanks

The facility is required to retain all required monitoring and supporting information for a period of five years. Recordkeeping and reporting requirements are as follows:

- Semi-annual monitoring reports/sampling
- Deviations due to emergencies
- Deviation reporting for hazardous air pollutants
- Annual emissions report
- Annual Title V compliance certification
- Monthly or quarterly reports to provide fuel consumption, fuel sulfur content
- (EPA) Mercury Air and Toxic Standards (MATS) compliance

8.1.1. Air Permit Compliance

Sargent & Lundy reviewed air compliance documents supplied by PREPA, including annual emissions reports, semiannual monitoring reports, and annual Title V compliance certifications. Sargent & Lundy also reviewed air compliance information included in EPA's ECHO database.

PREPA's annual emissions reports for 2013 to 2019 show that the Aguirre's facility-wide emissions have been well below allowable levels (see Table 8-2).

Table 8-2 — Aguirre Power Plant Annual Emissions

Pollutant	Allowable Emissions (Ton/Year)	Actual Emissions (Ton/Year)						
		2013	2014	2015	2016	2017	2018	2019
PM Total	2,194.9	1,040.1	979.6	1,011.1	631.7	667.9	447.5	674.7
SO_2	30,608.6	10,512.3	9,596.2	9,888.1	5,979.9	6,578.7	4,387,2	6,381.3
NO_X	28,867.8	5,427.4	7,086.2	7,856.6	5,826.2	5,313.7	3,138.6	6,835.2

Pollutant	Allowable Emissions (Ton/Year)	Actual Emissions (Ton/Year)						
		2013	2014	2015	2016	2017	2018	2019
Volatile Organic Compounds	195.3	102.6	95.2	97.5	60.6	65.1	43.8	63.6
CO	1,299.5	675.6	628.5	643.7	401.3	430.4	289.1	421.6
Pb	0.63	0.22	0.24	0.25	0.17	0.17	0.11	0.19
CO_2e	10,093,497	—	—	—	2,558,716	2,558,716	2,558,716	2,558,716
Nickel	20.7	—	—	—	6.59	6.59	6.59	6.59
Manganese	19.6	—	—	—	3.05	3.05	3.05	3.05
Formaldehyde	14.8	—	—	—	3.56	3.56	3.56	3.56
Chlorides	84.7	—	—	—	27.00	27.00	27.00	27.00
Total Hazardous Air Pollutants	177.7	—	—	—	24.40	24.40	24.40	24.40

PM = particulate matter | SO_2 = sulfur dioxide | NO_X = nitrogen oxides | CO = carbon monoxide | Pb = lead | CO_2e = carbon dioxide equivalent

The ECHO database does not identify any violations or enforcement actions with regard to air emissions; however, the compliance monitoring history (five years) reported on EPA's ECHO database indicates that there were Title V permit deviations as part of the annual certification for 2015. The reported deviations are described in the following paragraphs:

Sargent & Lundy reviewed annual Title V compliance certifications for 2013 and 2015–2019. PREPA did not provide Sargent & Lundy with the annual compliance certification for 2014; therefore, the 2014 compliance certification was not reviewed. In 2013, there were no reported deviations from the facility's Title V permit. In 2015, PREPA reported deviations related to late submittal of quarterly monitoring reports; PREPA noted that visible emissions reporting requirements were "under the Title V reconsideration process between PREPA and PREQB since May 5, 2015." The 2016–2019 reports identified deviations related to MATS compliance. PREPA noted in the annual compliance certifications that MATS compliance efforts had been affected by causes outside its control, including permitting processes and legal challenges related to the Aguirre Offshore Gasport construction and the Aguirre 1 and 2 generating units conversion project. Additional review of MATS compliance is included in Section 8.1.2.

In 2015–2018, PREPA reported excess emissions for opacity. The excess opacity emissions are explained in the reports as being due to startup/shutdown, control equipment problems, process problems, and other known causes. Equipment was adjusted as needed or taken out of service. Note that during portions of 2017 and 2018, PREPA was operating under a "No Action Assurance" granted by the EPA in the aftermath of Hurricanes Irma and Maria for relief from certain Title V permit requirements, including emission limitations.

Sargent & Lundy also reviewed semi-annual monitoring reports for 2017, 2018, and second half 2019. Sargent & Lundy was not provided semi-annual reports for any other periods. The semi-annual reports for 2017 and second half 2018 identified deviations related to MATS compliance. Additional review of MATS compliance is included in Section 8.1.2. Semi-annual monitoring reports for all periods reviewed identified deviations related to opacity levels. Deviations are explained in the reports as being due to startup/shutdown, control equipment problems, process problems, and other known causes. Equipment was adjusted as needed or taken out of service. The "No Action Assurance" granted by the EPA was effective starting October 2017 and was extended through April 2018, covering portions of the second half 2017 and first half 2018 periods.

Semi-annual monitoring reports for the second half 2017, first half 2018, second half 2018, and the 2017 annual Title V compliance certification were not submitted according to the normal reporting schedule. Emergency conditions related to Hurricanes Irma and Maria prevented PREPA from preparing and submitting the required reports; therefore, under the "No Action Assurance," the EPA extended reporting deadlines for all reports covered under the No Action Assurance to May 30, 2018. According to PREPA, the EPA gave PREPA until July 30, 2018 to submit the reports, and the EQB informally extended the deadline consistent with the "No Action Assurance." According to PREPA, the first half 2018 semi-annual report was submitted in February 2019. In March 2019, PREPA submitted the second half 2017 semi-annual report and the 2017 and 2018 annual Title V compliance certifications.

8.1.2. Mercury & Air Toxics Standards

The two HFO fired boilers at Aguirre, Units 1 and 2, are subject to MATS. The MATS compliance date was April 16, 2015, but Aguirre obtained a one-year extension to April 16, 2016 for Units 1 and 2. PREPA had originally planned to comply with MATS by converting the affected boilers to fire natural gas and had requested a one-year extension to provide time necessary for the conversion, but the natural gas infrastructure has not been installed at the facility; therefore, the Aguirre boilers are required to comply with the applicable MATS standards for oil-fired boilers. The units, however, had not complied with MATS between 2016 and 2018 because they did not conduct the required quarterly testing for particulate matter (PM) from the compliance date in April 2016 up until November 2018. PREPA's compliance with the hydrochloric acid and hydrofluoric acid limits is demonstrated based on fuel moisture content being less than 1.0%.

The aftermath of Hurricanes Irma and Maria in September 2017 further delayed the facility from demonstrating compliance with the MATS PM requirements through the required quarterly testing. Following the hurricanes, PREPA obtained a “No Action Assurance” from the EPA for delays in testing that resulted from the hurricanes, as well as other MATS compliance requirements. PREPA was also granted “No Action Assurance” for reporting deadlines, including reporting related to MATS compliance testing; however, according to PREPA, this expired on July 31, 2018 for MATS testing at Aguirre Unit 1 and on August 31, 2018 for MATS testing at Aguirre Unit 2. The “No Action Assurance” expired on different dates for the various reporting requirements, but the latest deadline for reports was October 1, 2018. The coverage provided by the “No Action Assurance” expired prior to PREPA conducting the required MATS testing and submitting the associated reports; moreover, the “No Action Assurance” did not cover the delays in testing and reporting that occurred prior to the hurricanes.

Sargent & Lundy reviewed MATS PM stack test reports for Units 1 and 2. The reports include results of testing performed on Unit 1 in November 2018 and April 2019 and Unit 2 in November 2018. The Unit 1 test results indicate that the unit is in compliance with the MATS PM limit. Test results for Unit 2 shows exceedances of the MATS PM limit.

8.1.3. One-Hour SO_2 NAAQS

The Clean Air Act (CAA) requires the EPA to establish National Ambient Air Quality Standards (NAAQS). Areas that do not meet the NAAQS are designated as “non-attainment areas” for that particular air pollutant, while areas meeting the NAAQS are designated as “attainment areas.” NAAQS standards are established by EPA to be protective of public health and welfare, and EPA is required to periodically review and update the NAAQS, as necessary.

The one-hour SO_2 NAAQS was published on June 2, 2010. The Aguirre site is located in the Municipality of Salinas, which is currently designated non-attainment for the one-hour SO_2 NAAQS. A plan will need to be developed by the EPA/EQB for bringing the area into attainment with the one-hour SO_2 NAAQS. At this time, Sargent & Lundy cannot predict what the plan will require regarding SO_2 reductions from Aguirre’s boilers and turbines; however, since the boilers and turbines primarily combust No. 6 fuel oil and No. 2 fuel oil that are not classified as ultra-low sulfur, it is expected that some reductions may be required. Potential options for reducing SO_2 emissions, if deemed necessary by the EPA/EQB, include firing lower sulfur content fuels and installation of post-combustion SO_2 controls.

8.2. WATER AND WASTEWATER DISCHARGE

Sources of wastewater from Aguirre include once-through cooling water, cooling tower blowdown, hydrostatic test waters, seawater intake screen wash water, fuel heater condensate, floor and equipment drains, wastewater treatment plant effluent, and stormwater. Wastewater is discharged to Jobos Bay via five separate outfalls.

The facility's discharges are authorized under NPDES Permit Number PR0001660. The permit's expiration date is May 31, 2024, and the facility will be required to submit a renewal application on December 3, 2023.

8.2.1. NPDES Permit Compliance

Sargent & Lundy reviewed the EPA ECHO database to evaluate the facility's NPDES permit compliance status. The ECHO database identifies unresolved Clean Water Act (CWA) violations for the Aguirre facility dating back to the fourth quarter 2015. The listed violations include failures to submit required discharge monitoring reports (DMRs). PREPA explained that the facility's DMRs have been submitted but are being submitted to EPA via paper format instead of through the EPA's web-based Net-DMR, because EPA's electronic reporting system does not conform with the Aguirre facility's NPDES permit reporting requirements. In May 2019, PREPA expected that DMR submittals could be performed electronically following issuance of the renewed NPDES permit, which was issued on March 28, 2019.

EPA's ECHO database also identifies discharge flow rate exceedances from Outfalls 002 and 004, along with isolated violations of oil and grease, dissolved oxygen, temperature, copper, and pH limits. Sargent & Lundy reviewed DMRs and addendum reports that PREPA submitted to the EPA for 2016, 2017, and 2018.

The ECHO database lists flow rate exceedances from Outfalls 002 and 004 in 2015, 2016, 2017, 2019, and 2020. Based on discussion with PREPA in early 2019, flow rates at Outfalls 002 and 004 exceeded flow rate limitations due to rainfall but did not constitute violations because the daily maximum flow limitations did not include stormwater. It appears that this issue had been resolved with the EPA, as the renewed NPDES permit includes revised flow rate limitations, allowing higher maximum daily flow at Outfalls 002 and 004. Nevertheless, ECHO identifies flow exceedances from second quarter 2019 to the present.

During the third quarter 2016, first quarter 2017, and second quarter 2017, the ECHO database identified violations related to pH. In early 2019, PREPA reported that the pH range was exceeded due to fissures on various equipment and noted that the equipment would be repaired. ECHO identifies additional pH violations in 2020.

During the third quarter 2017, the ECHO database identifies violations related to oil and grease, temperature, and pH. PREPA reported that the temperature was exceeded due to failure of a heater recovery system and subsequently implemented corrective measures; however, PREPA did not report oil and grease or pH outside of permitted values. It therefore appears that these ECHO violations are in error.

Sargent & Lundy reviewed DMRs for 2018. During the second and third quarter 2018, PREPA paid stipulated penalties for pH levels that were below the allowable range and temperature exceedances (both requirements of the NPDES permit and PREPA's 1999 Consent Decree with the United States). It appears that these issues have been resolved, as PREPA did not report any violations during the fourth quarter 2018.

8.2.2. 316(b) Cooling Water Intake Structure Requirements

On August 15, 2014, the EPA published a final rule implementing Section 316(b) of the federal Clean Water Act. The purpose of the rule is to reduce impingement and entrainment of fish and other aquatic organisms at cooling water intake structures used by certain existing power generation and manufacturing facilities.

The two 450-MW oil-fired units use a once-through cooling system. The two 300-MW CC units (four GTs, four HRSGs, and one ST per unit) include a condenser cooling system employing mechanical draft cooling towers. Aguirre withdraws approximately 654 million gallons per day of seawater from Jobos Bay for use in the cooling systems. The intake structure consists of five intake channels with five bar screens, five dual flow traveling screens, and five intake pumps.

PREPA has negotiated a 316(b) compliance strategy for Aguirre. Per the NPDES permit, an alternative schedule has been granted by the EPA for submitting necessary studies concerning impingement mortality and entrainment. The permit says, "EPA has granted this alternate schedule and is requiring all application materials to be submitted by [(Effective Date of Permit) + 4.5 years]." In addition, the permit requires that "[b]y [(Effective Date of Permit) + 6 Months], the permittee shall submit an anticipated schedule of submittals required by the permit." The effective date of the permit is June 1, 2019. A status report indicating PREPA's preferred impingement mortality compliance method is due December 1, 2023 (four and a half years after the effective date of the NPDES permit).

In the short term, PREPA is to operate all existing technology and operational measures, which include closed-cycle condenser cooling for the CC units, smooth one-fourth inch square mesh dual-flow traveling screens with fish return, and cooling water intake structure designed with low approach velocities. PREPA's long-term compliance strategy is to install new traveling screens for compliance with impingement mortality and entrainment provisions.

8.3. EMERGENCY PLANNING REPORTING

The Emergency Planning and Community Right to Know Act (EPCRA) provides national public disclosure of emergency information in order to protect the public from chemical emergencies and dangers. EPCRA Section 312 (40 CFR Part 370) requires certain facilities that maintain safety data sheets to report the quantity of chemicals that are present on site for the previous year; the submittals are known as Tier 2 reports. EPCRA Section 313 (40 CFR Part 372) requires certain facilities that manufacture, process, or otherwise use listed toxic chemicals in excess of applicable thresholds to prepare and submit a toxic release inventory (TRI) to federal and state agencies.

Sargent & Lundy was provided with the Tier 2 report for the reporting period from January 2017 to December 2017 prepared for Aguirre and submitted in 2018. Based on review of the Tier 2 report, it appears that the facility is following the necessary reporting requirements.

PREPA provided Sargent & Lundy with TRI reports for Calendar Years 2016 and 2017. The reports provided by PREPA and EPA's ECHO database confirms that PREPA has prepared and submitted TRI reports; however, PREPA originally failed to file TRI Form R reports for hydrochloric acid for the Aguirre facility in 2010, 2011 and 2012; the reporting violation led to enforcement action (see Section 8.5.2).

8.4. OIL STORAGE SPILL PREVENTION

Sargent & Lundy reviewed a copy of Aguirre's spill prevention, control, and countermeasure (SPCC) plan. The SPCC plan, required by 40 CFR Part 112, identifies onsite oil storage containers and provides a plan for preventing the discharge of oil into navigable waters or adjoining shoreline. The Aguirre SPCC plan follows the Part 112 requirements and appears to complete.

Sargent & Lundy also reviewed correspondence related to SPCC inspections provided by PREPA. Inspections took place in April 2012 and December 2013, and the EPA noted various deficiencies and made an information request in November 2014. In January 2014, PREPA's responded to the 2013 inspection, which indicated that PREPA had a schedule to perform maintenance and repair of two of its tanks, R-2 (December 2016) and R-1 (January 2019). In December 2014, PREPA responded to the information request, referencing their previous letter from January 2014 with the schedule for repairs, and providing some additional details. No further correspondence was provided to Sargent & Lundy for review.

8.5. ENFORCEMENT ACTIONS

8.5.1. PREPA Consent Decree

On March 19, 1999, the U.S. District Court for the District of Puerto Rico entered a consent decree between the United States and PREPA (Civil Action No. 93-2527) ("1999 Consent Decree"). The 1999 Consent Decree includes detailed requirements to promote compliance with the Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act, Comprehensive Environmental Response, Compensation, and Liability Act, and EPCRA. Specific requirements for the Aguirre facility included implementing a CAA compliance program, CWA compliance program, and preparing a SPCC plan, among other requirements. A consent decree modification, lodged on June 21, 2004, included additional objectives for monitoring and reducing air emissions such as methods for opacity readings, reducing fuel sulfur content, and reducing nitrogen oxide (NO_X) emissions.

It is Sargent & Lundy's understanding through discussion with PREPA that PREPA is generally complying with the requirements of the consent decree; however, PREPA paid stipulated penalties under the CAA and CWA compliance programs in 2017 and 2018.

8.5.2. TRI Violation

On December 2, 2013, EPA conducted an inspection at Aguirre to determine compliance with TRI Form R reporting requirements. TRI Form R reports are due July 1 of each year for each listed TRI chemical that exceeds the manufactured, processed, or otherwise used threshold. Subsequent to the inspection, it was determined that PREPA should have filed TRI Form R reports for hydrochloric acid for PREPA's Aguirre, Palo Seco, and Costa Sur facilities during Reporting Years 2010, 2011, and 2012. The case was settled for $37,500.

8.5.3. Safe Drinking Water Act Violations

The ECHO database identifies four Safe Drinking Water Act (SWDA) violations that occurred between 2008 and 2013; the violations are listed as archived and resolved. The ECHO database also identifies a violation of the "Total Coliform Rule" during the first quarter 2016. ECHO does not show recurring violations from the second quarter 2016 through the first quarter 2019; therefore, Sargent & Lundy assumes this has been resolved.

The reported Safe Drinking Water Act violations from 2008, 2010, and 2011 were related to coliform levels and monitoring and reporting. Based on discussion with PREPA, the violations were resolved, and subsequent verification of compliance was demonstrated.

The 2013 violation was related to missing monitoring parameters (Trihalomethanes, haloacetic acids, and nitrate). PREPA communicated to the Puerto Rico Health Department that the missing parameters were not required to be monitored during that quarter per Aguirre's chemical monitoring program approved by the Puerto Rico Health Department.

PREPA also received notices of violation during the first and second quarter 2018, but according to PREPA this was due to an inadvertent reporting issue.

8.6. SUMMARY

Sargent & Lundy performed a limited environmental review of publicly available information and information provided by PREPA to evaluate the compliance status for Aguirre. Sargent & Lundy did not find any compliance-related issues that would prevent renewal of the existing permits or impact near-term operation of the facility; however, the items listed below were identified as having unknown or potential compliance implications for Aguirre:

- Air Emissions
  - Unit 2 PM emissions exceed the MATS limit.
  - Salinas is currently designated non-attainment for the one-hour SO_2 NAAQS. EPA/EQB's forthcoming plan for bringing the area into attainment with the one-hour SO_2 NAAQS may require SO_2 reductions from Aguirre.
- Water and Wastewater
  - Violations are identified in ECHO as "reportable noncompliance" and "significant Category 1 noncompliance." Sargent & Lundy has not been provided information concerning violations from 2019 and 2020.

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9. RECOMMENDATIONS AND CONCLUSIONS

Overall, the thermal units were found to be in good condition and are consistent with comparable units of similar vintage; however, the CC units and black-start GTs were found to be in moderate condition and have experienced more wear than like units of similar age. The thermal and CC units at Aguirre are nearing the end of their useful life and have been approved for retirement over the next five years according to the recent resolution of the Puerto Rico Energy Bureau (PREB) addressing PREPA's proposed integrated resource plan (Case No. CEPR-AP-2018-0001). The retiring thermal units may be repurposed as synchronous condensers (although new equipment may be required) to provide dynamic reactive support and stability to PREPA's grid with the addition of new solar generation directed by the resolution. Despite the approaching retirement, it is important that efforts are made to preserve existing generating units in order to maintain grid reliability until sufficient new generation is brought online.

PREPA currently is completing a load demand and resource study to evaluate the need of new generation assets as older assets are retired and to study the effects of intermittent generation on the system. Sargent & Lundy recommends that this study be completed before retiring any of the units at Aguirre. If the study determines repowering efforts or other operating features are desired for capacity or flexibility, then a third-party feasibility study is encouraged to ensure that proper planning and selections are made to avoid the operating challenges that Aguirre has seen during its service.

Due to its proximity to Ponce, Aguirre—especially with the availability of seawater supply for cooling, nearby port services, and future water supply from the PREPA owned Patillas Lake—is a strategic location for power generation on the island. With the removal of Units 1, 2, 1-1 through 1-4, and 2-1 through 2-4, a modern repowered design—one that uses efficiency, environmental, and emissions advancements currently available from original equipment manufacturers—could be considered. The new design can have additional operational flexibility in response to load demands and the shifting generation of renewable sources of power like wind and solar. A redesign must include better ambient protection for the coastal equipment and hardening of the facilities to enable command and control of power production during emergency conditions, such as harsh weather events.

Smaller, rapid-start GT equipment with integrated synchronous condensing options, such as those in place at Mayagüez, could be planned for the reclaimed space at Aguirre. New fast-start generation equipment that integrates purge credit, battery storage components for instantaneous response, integrated/clutched synchronous condensing, and similar features could provide quicker support and flexibility for a future grid that is planned to integrate a larger amount of less stable renewable power. These new units can also provide black-start capability for Aguirre. The diminished capacity of the existing black-start GTs can no longer start a thermal unit. Reciprocating engine plants provide even faster startups than GT equipment and also can be configured to operate on natural gas and in CC configurations and provide black-start capability.

Care must be taken to ensure that replacements or upgrades to the Plant are suitable for an aggressive, salt-laden marine environment exposed to coastal winds. Typically, competitively priced original equipment manufacturer standards for power generation and balance-of-plant equipment are not well-suited for this type of operating environment. New equipment must be configured for the challenging conditions at Aguirre. Failure to make allowances for suitable materials, equipment selection, buildings/enclosures, and other aspects of the facility design to protect the Plant from the coastal operating environment will result in excessive future O&M costs and a shorter plant design life for any new installation. Suitable design specifications appropriate for this location include: (i) corrosion-resistant material requirements; (ii) marine-specific coatings; (iii) appropriate welding selections and special treatment of metal seams and stitched connections; (iv) fastenings with sealants, gaskets, and coatings; and (v) increased use of protective equipment enclosures. Due to these requirements, coastal power generation sites are inherently more expensive than those installed in less aggressive operating environments.

Ongoing proposals for Plant replacements, upgrades, and new generation should consider the guidelines provided herein. Any new operating regimes and other comparisons at the Plant must be made so equipment is selected to suit the future direction of the power generation and distribution system planned for Puerto Rico.

The Plant may continue to operate until such conversions or repowering projects take place. Units 1 and 2 and the Plant’s common systems are in a condition to support near-term operation; however, degradation and eventual failure of aging turbine and boiler components will contribute to increased maintenance and down time as these units approach their end-of-life. The two CC units are in moderate condition, and ongoing maintenance and improvements are expected to keep them serviceable as well. Mobile generation units may be put in place to temporarily support generation until the repowering projects are completed. Future repowering work should be carefully planned, and a third-party feasibility study is suggested to ensure the design includes attention to corrosion protection, integrated unit sizing and selection, and a sensible method of phased replacement is carried out for the next era of power generation at Aguirre.

Until repowering projects can be completed:

- Evaluate the condition of all gas equipment that is on site for future use. Long-term preservation should be pursued for all purchased equipment for natural gas firing such as relocating the equipment to indoor storage, assessing the equipment’s design conditions, and evaluating how the equipment may be useful for future conversion efforts.

- Implement layup procedures for idled equipment and systems that include draining, dehumidifying, protecting, and ,when needed, nitrogen-blanketing.
- Conduct a water study to confirm that a temporary source of process water will not be needed before the Patillas Lake water is delivered. Monitor and, if necessary, expedite the timeline for completion of the Patillas Lake pipeline project.
- Install HRSG stack dampers to preserve heat for cycling operations.
- Upgrade the protection of components being stored outdoors (in addition to the natural gas components).

10. REFERENCES

1. Sargent & Lundy report, "Aguirre Phase I Environmental Site Assessment," SL-014468.AG.ESA, dated May 31, 2019.
2. Sargent & Lundy report, "Demarcation of PREPA Generation Assets from the Transmission and Distribution System," TD-0003, dated October 4, 2019.
3. Alstom Power Inc. Boiler Inspection Final Report, "Condition Assessment of Selected Components for Aguirre Unit 1," dated October 2013.
4. GE Power Co. Boiler Inspection Final Report, "Condition Assessment of Selected Components for Aguirre Unit 2," dated December 2016.