CONFIDENTIAL

Independent Engineering Report

Cambalache Power Plant

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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ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition/Clarification
ABB	Asea Brown Boveri
AFFF	aqueous film-forming foam
BOP	balance of plant
CAPEX	capital expenditures
Cambalache	Cambalache Power Plant
CFR	United States Code of Federal Regulations
COD	commercial operation date
EAF	equivalent availability factor
ECHO	(EPA) Enforcement and Compliance History Online
EFOR	equivalent forced outage rate
EMS	energy management system
EOH	equivalent operating hour
EPA	(United States) Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
EQB	(Puerto Rico) Environmental Quality Board
FY	fiscal year
GADS	generating availability database system
GE	General Electric
GT	gas turbine (operating on natural gas or No. 2 fuel oil)
gpm	gallons per minute
HMI	human–machine interface
HTS	Hughes Technical Services LLC
LTSA	long term service agreement
MPT	main power transformer
NAAQS	National Ambient Air Quality Standards
NCF	net capacity factor
NERC	North American Electric Reliability Corporation

Acronym/Abbreviation	Definition/Clarification
NFPA	National Fire Protection Association
NPDES	National Pollution Discharge Elimination System
O&M	operations and maintenance
OEM	original equipment manufacturer
Plant	Cambalache Power Plant
PREB	Puerto Rico Energy Bureau
PREPA	Puerto Rico Electric Power Authority
PSD	prevention of significant deterioration
psig	pounds per square inch, gage
SPCC	spill prevention, control, and countermeasure
Spectron	Spectron Caribe, Inc.
TRI	toxic-release inventory
UAT	unit auxiliary transformer
Vibra	Vibra Inc.

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 Cambalache Power Plant ("Cambalache" or the "Plant").

Cambalache is located in the northern part of Puerto Rico in the Arecibo municipality and is owned and operated by PREPA. The Plant consists of three simple-cycle Alstom (now General Electric [GE] Power) gas turbines (GT), each with a nameplate capacity of 82.5 MW; it began operation between 1997 and 1998.

This technical report includes an assessment of the Plant design, operations and maintenance (O&M) activities, organization and personnel, technical performance, commercial arrangements and obligations, and provisions for environmental permitting. The review was based on information provided by PREPA and its advisors through January 2021 and onsite visits conducted in 2018 and 2020.

Sargent & Lundy understands that this review is being conducted in connection to the request for proposals 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 Cambalache.

TECHNICAL REVIEW

The three Alstom (now GE Power) Model GT11N1 GTs at Cambalache are arranged in parallel simple-cycle units. Each turbine is coupled to a dedicated generator and is rated for 82.5 MW when firing low-sulfur distillate oil No. 2. The units were commissioned in 1997–1998 to improve the quality and reliability of PREPA's electrical system and can operate base loaded or with up to 60% rapid spinning reserve. The GT equipment and facilities are dedicated to support the operation of the simple-cycle plant with redundancy and unit-specific systems for independent operation as required.

The units receive No. 2 diesel fuel oil from three 3,878,000-gallon fuel oil storage tanks that are cross-tied in a combined suction line to three fuel oil forwarding pumps. The forwarding pumps discharge into a combined header that serves the three GT fuel skids and the two diesel day tanks for the 1.5-MW black-start diesel generators on site. Fuel is received on site via an underground pipeline from Arecibo Port, or it may be delivered by truck. The GTs use steam injection for power augmentation and NOx reduction.

Demineralized water for the GT steam injection is created from treated raw water on site. Three process trains in the Plant's demineralization system provide a maximum of 270,000 gallons per day to fill the shared 2,380,000-gallon demineralized-water storage tank. The water for this process is supplied by the three raw water transfer pumps that draw water from the 1,280,000-gallon raw-water storage tank. Raw water is supplied to this tank from four local well pumps located outside the plant boundary, and half of the raw-water storage tank is dedicated to the fire protection system. Process waste water from the Plant passes through a neutralization system and is stored in the 150,000-gallon wastewater tank prior to being pumped back to the storm sewer.

The three GTs are each connected to a dedicated generator. The generators for each unit are connected through dedicated main power transformers (MPTs) to the 115–230-kV switchyard. Two 1.5-MW diesel generators provide the Plant with black-start capabilities. Cambalache is connected to the PREPA electrical system through three 230-kV transmission lines and one 115-kV transmission line. The MPTs are connected to the switchyard with overhead conductors.

EQUIPMENT CONDITION

Depending on the total factored fired hours and the number of starts, the typical design life of a GT generator-based power plant is approximately 30 years when following the original equipment manufacturer's (OEM's) recommendations for operation and periodic maintenance. Unit 1 has been out of service since September 2011 after the GT sustained catastrophic damage due to combustion failure and reignition. The Unit 1 GT enclosure subsequently sustained significant damage from Hurricane Maria in 2017. There are currently no plans to return Unit 1 to service; however, the Plant has received a recovery plan from the turbine OEM (GE) that is being considered along with other options for the unit's reuse. For the time being, it remains out of commission due to the high estimated capital costs for repairs that would be necessary to bring it back online. Units 2 and 3 have been well maintained under a long-term service agreement (LTSA) with GE and are in generally good condition. The filter house louvers on the Unit 2 and 3 GT air intake weather hood that were damaged in the 2017 hurricane were replaced by new ones fabricated on site.

The Plant's common systems are also in generally good, serviceable condition. The Plant staff performs regular inspections and preventative maintenance to ensure the continued reliability of these systems, and many of these systems are well protected in weatherproof enclosures. The acid injection skid in the demineralized water plant was recently replaced, and an ongoing project to replace the plant's ionic exchange resin was expected to be completed in the fourth quarter of 2020. A proposal to refresh the demineralized-water tank's external anticorrosive coating is in the final stages of approval. The fuel pump shelters, which had been damaged in the 2017 hurricane, have since been repaired, and the interior and

exterior of Fuel Storage Tank R1 were recently refurbished. The Puerto Rico Energy Bureau (PREB) decision in response to PREPA's 2019 integrated resource plan designated many of PREPA's fossil fuel burning units for retirement in by 2025, but the Cambalache units were not included in this list. The PREB "Modified Action Plan" is focused primarily on the addition of renewable resources and battery storage; it is expected that Cambalache will provide crucial grid support during the repowering transition.

INFRASTRUCTURE AND INTERCONNECTIONS

The units operate on No. 2 fuel oil, of which 277,000 barrels are on reserve across three storage tanks on site. Barge deliveries are taken from the nearby Arecibo Port and pumped to the storage tanks via an underground pipeline to the site. Fuel may also be delivered via tanker trucks and unloaded into the storage tanks using the onsite truck unloading pump.

The Plant uses a municipal potable water supply for domestic use in the facility buildings and for the eyewash and safety showers on site. Well water pumps near the site fill the 1,280,000-gallon raw-water storage tank. This raw water is used for fire protection and service-water applications as well as the production of demineralized water for use in the Plant processes.

OPERATIONS & MAINTENANCE

The main objective of PREPA's maintenance plan is to use preventative maintenance in conjunction with predictive techniques developed at the Plant level. Maintenance is performed using the OEM's specifications, Plant experience, Plant routine inspections, equipment monitoring, and O&M manuals as applicable. The Plant has an ongoing LTSA contract, TSM-23-03, with the GT OEM (GE) through December 31, 2023 that covers regular inspections and preventative maintenance of the GT units at the prescribed equivalent operating hour (EOH) intervals. Other inspections are generally done by Plant staff, with contractors hired for further analysis and repairs as needed.

Cambalache has a robust maintenance program supported by regular preventative maintenance of the GTs under the LTSA with GE and a variety of predictive maintenance strategies employed with the help of other specialty subcontractors. With the exception of Unit 1's disablement in 2011 from a catastrophic combustion failure event—and the subsequent damage to the GT enclosure and filter house due to the force majeure event of the 2017 hurricane—the Plant staff has successfully maintained the generating units and ancillary systems in good working order and appears prepared to continue their operation and care for this critical asset for years to come.

PERFORMANCE BENCHMARK

PREPA provided Cambalache's operational data for the last six years. The generation and net capacity factors are consistent with peak capacity fired units that are cycled and not base loaded. Units 2 and 3 have had high availability consistent with its peers and low forced-outage rates, demonstrating that the units are generally well maintained. The heat rates provided are some of the lowest for the GT units owned by PREPA and are in line with other peaking units.

FINANCIAL REVIEW

Sargent & Lundy compiled the historical fixed and variable O&M costs and capital expenditures (CAPEX) for Cambalache from reported PREPA data and fiscal plan forecasts. Then, Sargent & Lundy compared these values with O&M costs and CAPEX for existing units in operation in North America of similar configurations and operating profiles. From the data, Sargent & Lundy determined that the Cambalache costs are within the typical range of costs for similar units considering that higher expenditures are required for plants firing fuel oil as compared to natural gas.

ENVIRONMENTAL AND REGULATORY

Sargent & Lundy performed a limited environmental review of publicly available information and information provided by PREPA to evaluate the compliance status for Cambalache. Based on a review of permits and documentation provided by PREPA or publicly available information, major environmental permits for the Cambalache facility are current or are in the process of being renewed. 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.

RECOMMENDATIONS AND CONCLUSIONS

Cambalache is in good condition considering its age. The GTs are regularly inspected and maintained under the LTSA with the OEM, and the Plant staff employs a robust maintenance program that ensures balance-of-plant (BOP) equipment is monitored, repaired, and replaced as needed. While corrosion is a concern in similar oceanic coastal environments, the visual appearance of much of the Plant's exposed equipment indicates that the staff is appropriately rigorous in their corrosion mitigation efforts. Even so, equipment protected by enclosures has been observed to fare much better in this harsh environment, and it would be advisable to continue to locate critical components indoors and provide enclosures for new or replaced equipment on site wherever practical. Furthermore, the correction of enclosures that have been compromised (like the GT enclosure of Unit 1) should be prioritized to protect equipment from the accelerated degradation that will be caused by exposure to the elements.

As with other PREPA facilities, 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 OEM standards for power generation and BOP equipment are not well suited for this type of operating environment. Any new equipment must be configured for the challenging conditions at Cambalache. Failure to make allowances for suitable materials, equipment selection, buildings/enclosures, and other aspects of the facility design to protect the Plant from its 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 operating environment include: (i) corrosion-resistant material specifications; (ii) appropriate welding selections, including special treatment of all metal seams, stitched connections, and fastenings with sealants, gaskets, and coatings; (iii) protective equipment enclosures; (iv) proper system selections; and (v) marine coatings systems. 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. New operating regimes and other comparisons must be made so that equipment is selected to suit the future direction of the power generation and distribution system planned for Puerto Rico. The final resolution and order of PREB addressing PREPA's proposed integrated resource plan (Case No. CEPR-AP-2018-0001), published in August of 2020, did not issue a retirement date for the Cambalache units; however, the PREB decision did reject most of the plan's proposed improvements or additions to PREPA's fossil fuel generation fleet in favor of adding more renewable generation and battery storage capacity to Puerto Rico's grid infrastructure. It is expected that existing fossil fuel powered generation facilities, with several years of remaining useful life like Cambalache, will be relied upon to maintain grid stability throughout this repowering transition.

PREPA continues to study the need for additional grid support and generation throughout the island. The GT units at Cambalache, with 60% rapid spinning reserve, will be relied upon to provide grid stability until sufficient battery storage has been installed. If PREPA does not move forward with the full recovery of Unit 1, the unit may still be considered as a candidate for repurposing as a synchronous condenser (although this is not currently being considered). This would also offer grid stabilization benefits during the repowering period. In either scenario, prioritizing the recovery of the Plant's damaged overhead crane would be beneficial to support these activities.

Other Plant modifications that can sustain or improve unit operation or reliability may be integrated into the design and provide years of future power generation service from the facility.

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 Cambalache Power Plant ("Cambalache" or the "Plant").

1.1. PLANT DESCRIPTION

Cambalache is located near the northern coast of Puerto Rico in the Arecibo municipality and is owned and operated by PREPA. The Plant consists of three simple-cycle Alstom (now General Electric [GE] Power) gas turbines (GT), each with a nameplate capacity of 82.5 MW; it went into operation between 1997 and 1998. The Plant is centrally located between San Juan and the western tip of the island and connects to the grid via three 230-kV transmission lines and one 115-kV transmission line.

The northern end of Cambalache includes an administration building and three No. 2 fuel oil storage tanks. Fuel is delivered to the facility by an underground pipeline from Arecibo Port. The site can also receive fuel by tank trucks. South of the administration building, the three GT power blocks are arranged in a parallel configuration from east to west, and the raw-water and demineralized-water storage tanks are located to their west. The control room building is directly south of the power blocks, flanked by the diesel generators to the east and the demineralization plant and maintenance shop building across the road to the west. The warehouse is the southernmost major structure on the site, and the 115–230-kV outdoor switchyard sits across the ravine off the southern tip of the unpaved ring road that circles the plant. An annotated satellite photo of the site is shown in Figure 1-1.

Figure 1-1— Cambalache Overall Plant Layout

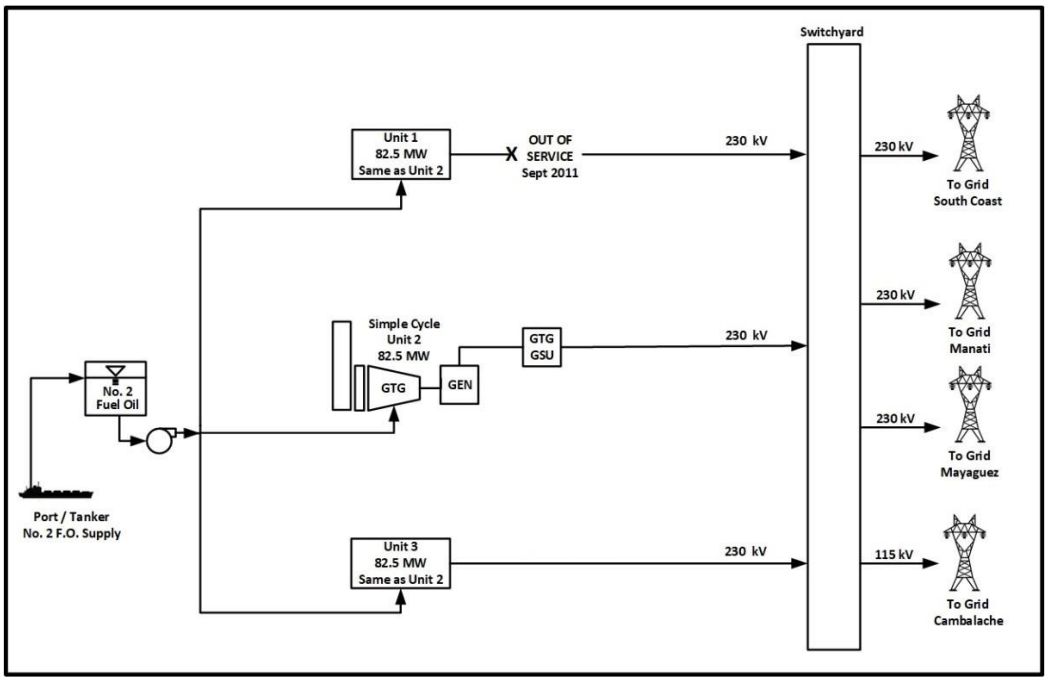
A standalone fire pump enclosure sits directly north of the raw-water tank, from which the pumps draw their suction. The enclosure houses an electric motor pump, a diesel pump, and a jockey pump to maintain water pressure in the fire protection loop. The fire water loop feeds fire hydrants and hose stations around the site as well as the building sprinkler systems. Pressurized water from the fire protection loop also feeds into the aqueous film-forming foam (AFFF) injection system, which provides foam fire protection to the fuel storage tanks and forwarding pumps.

A CO_2 injection system provides fire suppression to the sensitive equipment at the GT units and their auxiliary enclosures. The Plant's control room includes a clean-agent FM-200® fire suppression system, and a Fike® ECARO-25 clean-agent suppression system is installed at the switchyard control building.

The three GTs are each connected to a dedicated generator. The generators for each unit are connected through dedicated transformers to the 115–230-kV switchyard. Two 1.5-MW diesel generators provide the Plant with black-start capabilities.

An overview schematic representation of the plant, including out-of-service GT units, is shown in Figure 1-2.

Figure 1-2 — Cambalache Overall Plant Configuration



1.2. SCOPE OF REVIEW

This technical report includes an assessment of the Plant design, operations and maintenance (O&M) activities, 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 the report. Additionally, Sargent & Lundy performed a Phase I Environmental Site Assessment, dated February 28, 2021.

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

- Documentation provided by PREPA's corporate operations and Plant personnel through January 2021
- Discussions with Plant personnel on the phone, via email exchange, and during site visits in May 2018 and November 2020
- 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 proposals 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 Cambalache.

2. TECHNICAL DESCRIPTION

Cambalache consists of three simple-cycle GTs. The total nameplate capacity of the Plant is 247.5 MW with a current capacity of 165 MW due to Unit 1 being out of service. There is currently no project underway to recover Unit 1. The characteristics of the generating units at Cambalache are shown in Table 2-1:

Table 2-1 — Cambalache Plant Overview

Unit Name	Commercial Operation Date (COD)	Technology	Fuel	Nameplate Capacity (MW)	Status as of November 2020
Cambalache Unit 1	1997	CT	Oil No. 2	82.5	Irreparable Unit has been out of commission since incurring hurricane damage in 2011. Unit recovery and repurposing proposals are being considered by PREPA.
Cambalache Unit 2	1997	CT	Oil No. 2	82.5	Operational
Cambalache Unit 3	1997	CT	Oil No. 2	82.5	Operational

1. Operational—Functioning and suitable for power generation

2. Irreparable—Equipment requires major expenditures to restore for power generation

The Cambalache facility includes separate administration and control buildings. The control building houses the main electrical rooms and control rooms. The water treatment and general services building houses the Plant's water treatment equipment and a maintenance shop. Additional equipment and facilities are dedicated to the function of the simple-cycle units with redundancy and unit-specific systems for independent operation as required.

The site includes two substations/switchyards at 115 kV and 230 kV, one demineralization plant, two diesel generators for unit black start, support systems for fuel and water transfer and storage, and dedicated fire protection equipment: CO_2 protection equipment for generators and turbine compartments, clean agent (FM-200) equipment for the control console area, foam agent equipment for fuel tanks, and fire hydrants for Plant peripheral areas.

2.1. MECHANICAL SYSTEMS

The mechanical systems at Cambalache include three simple-cycle Alstom (now GE Power) GT units with fuel storage and delivery, raw-water, water treatment, demineralized-water, once-through steam generator, fire protection, stormwater, and wastewater systems. The technical details of these systems and their comprising equipment are provided below.

2.1.1. Combustion Turbines

The three Alstom (GE Power) GT11N1 simple-cycle GT units at Cambalache are each rated for 82.5 MW when firing low-sulfur distillate oil No. 2. Each unit drives a dedicated generator, and the Plant's total output is a nominal 247.5 MW; however, with Unit 1 out of service (as indicated in Table 2-1), the current capacity is approximately 165 MW. All of the GT generator units are contained within weather enclosures.

The GT11N1 model is designed to be a robust generator for demanding service environments. The unit includes a solid welded rotor with a five-stage turbine and an 18-stage compressor; it is outfitted with single-burner combustors designed for high-output peaking and steam injection.

Figure 2-1 — Alstom GT11N1 Unit

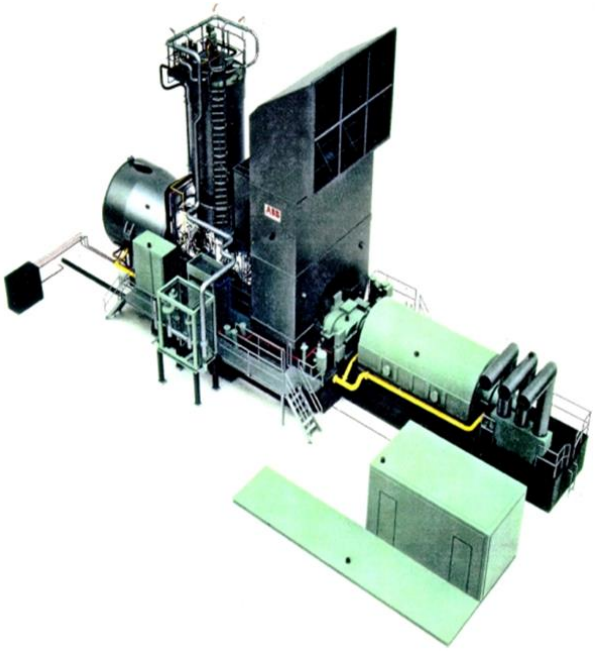
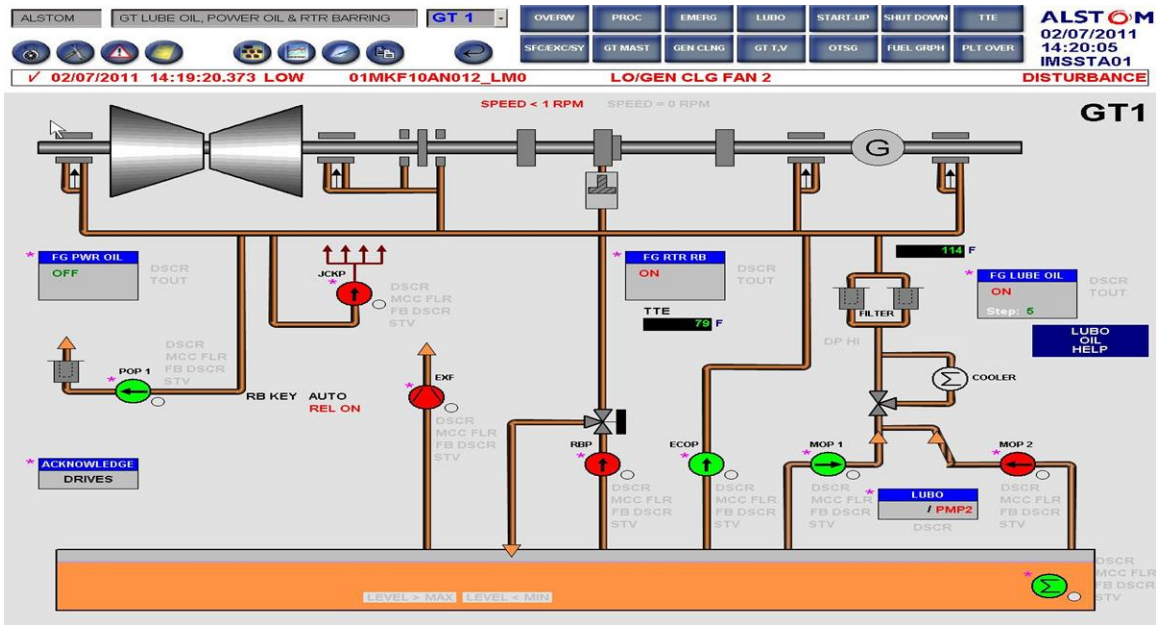


Image provided by Cambalache staff

Each unit includes a dedicated lube oil system with redundant pumps and filters. For each unit, the lube oil system is contained in an auxiliary enclosure adjacent to the GT enclosure. Figure 2-2 illustrates the configuration of the lube oil system and critical components as displayed in the control room HMI[1] graphics.

[1] human–machine interface

Figure 2-2 — HMI Graphic – GT and Generator Lube Oil System



2.1.2. Generators

Each of the three power blocks at Cambalache includes a 119.2-MVA, 82.5-MW, 0.8-power factor, 13.8-kV, 60-Hz air-cooled Asea Brown Boveri (ABB) generator equipped with a synchronous motor for the static starting system. Figure 2-3 shows the Unit 3 generator as installed inside a climate-controlled enclosure.

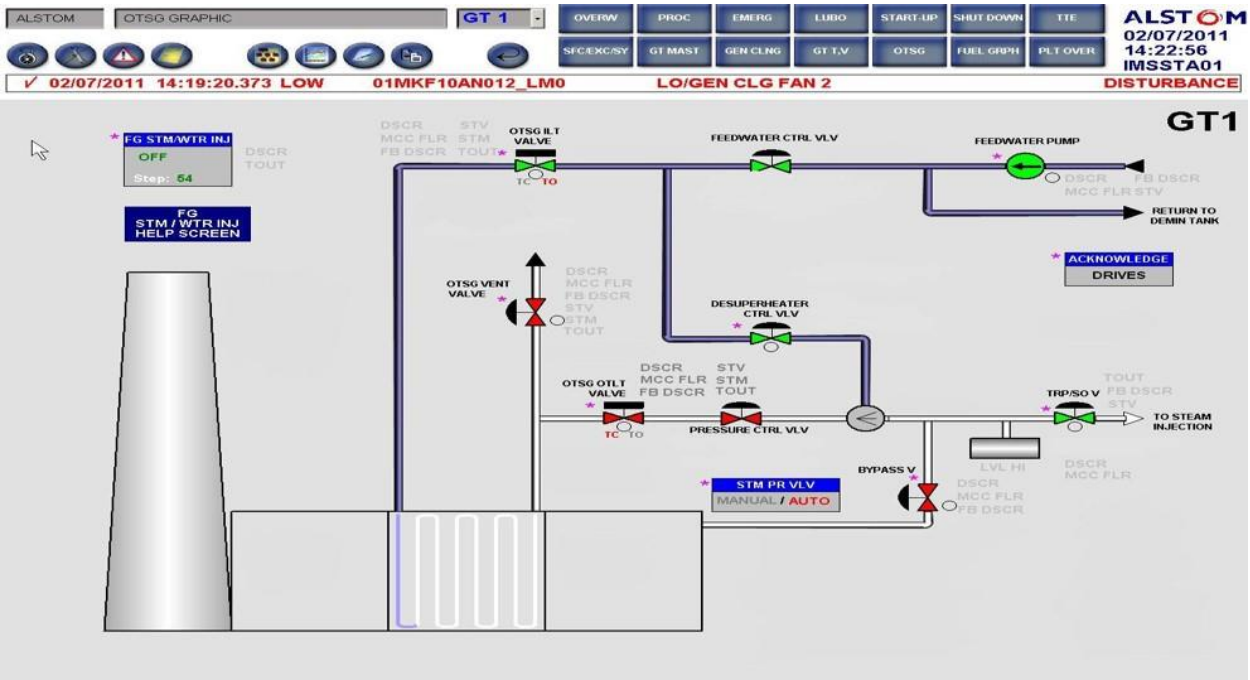
Figure 2-3 — Generator for GT Unit 3

2.1.3. Water Systems

The operation of the Cambalache GT generator units requires the use of steam injection in the GT gas path for emissions control and, to a lesser extent, power augmentation. Demineralized water (per the manufacturer's requirements) is needed for these services. The steam for this process is supplied by once-through steam generators located in the exhaust duct of each GT. Each power block has a dedicated 285-gpm[3] feedwater pump that draws suction from the demineralized-water tank and supplies feedwater at 695 psig[4] to the boiler. Figure 2-4 shows the HMI graphical illustration of the once-through steam generator and steam injection system, which is typical for all three units. Note that critical temperature information and operational status of the control valves is visible at the control room and that each steam injection system includes only one feedwater pump without redundancy.

[3] gallon/minute
[4] Pounds per square inch, gage

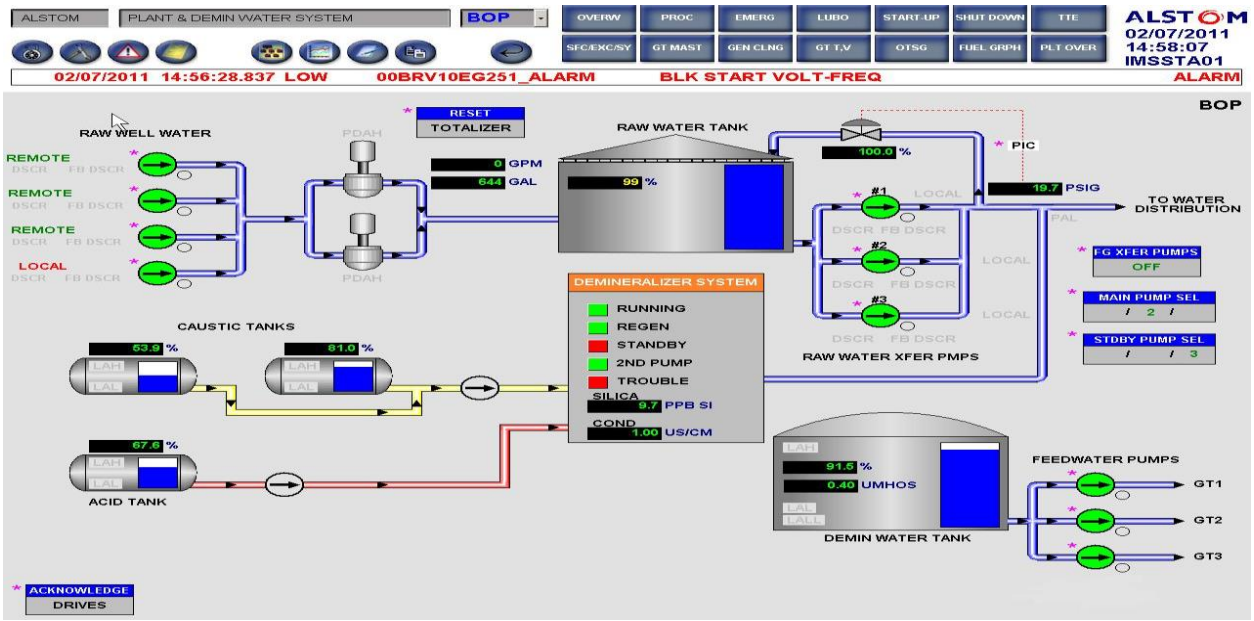
Figure 2-4 — HMI Graphic for GT1 – Once-Through Steam Generator



The water treating system at Cambalache produces demineralized water per OEM requirements. The high-purity water is necessary so that the steam will leave minimal traces of residue after it is injected into the GT combustion process.

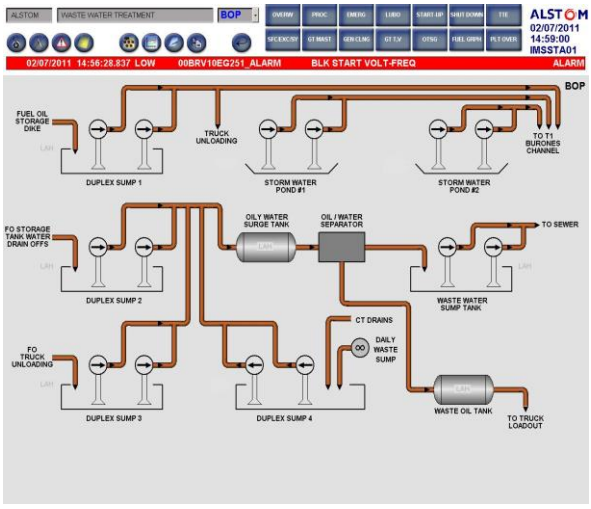
The Plant's 1,280,000-gallon raw-water tank (66 ft in diameter by 50 ft in height) is filled by four well pumps with two parallel self-cleaning strainers that provide the initial filtration and send backwash to the Plant sewer drain system. Three raw-water transfer pumps draw suction from the tank and supply the service water to hose stations at the water storage area, demineralized-water Plant building, and all three GT units as well as process water for the demineralized-water production system. The demineralized-water production system provides the rest of the filtration and chemical treatment necessary to produce the high-quality water product required by the GT OEM for steam injection. The demineralized-water system has three process trains, each with a rated capacity of 270,000 gallons per day, high enough to provide supply each of the three units when running and extra capacity for the 2,380,000-gallon (90 ft in diameter by 50 ft in height) demineralized-water tank storage. Figure 2-5 shows the HMI graphic screen representation of this system. Water quality from the equipment meets the required manufacturer limits for conductivity, silica, and sodium.

Figure 2-5 — HMI Graphic – Raw and Demineralized Water



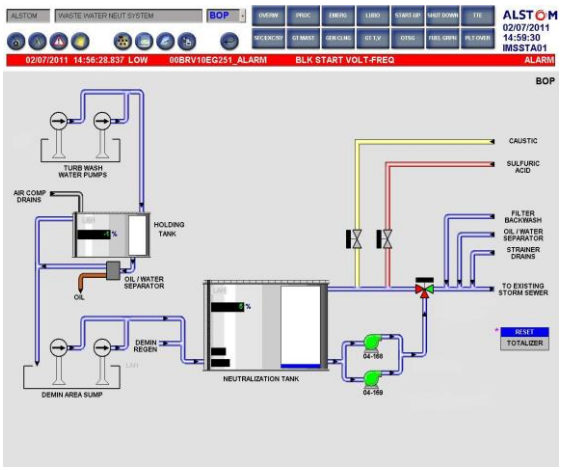
The storage tanks for the caustic and acid dosing in the demineralized-water production system are shown in Figure 2-6. These tanks also provide the treatment chemicals for the wastewater neutralization system. Water drainage from areas that may contain oil spillage, like the fuel tank containment dike and fuel forwarding pump containment, is routed to an oil/water separator to remove oil from these waste streams. Figure 2-6 also includes the HMI graphic illustration of the wastewater system, showing the various containments and redundant sump pumps located throughout the system. Note that operators may select to send water from the fuel oil tank dike containment through the oil water separator if an oil spill has occurred or pump directly off site to the Tiburones channel if only rainwater has been collected.

Figure 2-6 — HMI Graphic and Photo – Acid and Caustic Bulk Tanks and Wastewater



The wastewater neutralization system provides final treatment of the Plant's process wastewater prior to discharge. Process wastewater is collected in the demineralization area's wastewater lift station and delivered to the 150,000-gallon neutralization tank. The water is recirculated via the 2 x 100% 700-gpm neutralization pumps in a loop where it is analyzed and treated with caustic and sulfuric acid as necessary before being discharged to the storm sewer system via the dump/recirculation valve. Figure 2-7 shows the neutralization tank and the HMI graphic illustration of the neutralization system.

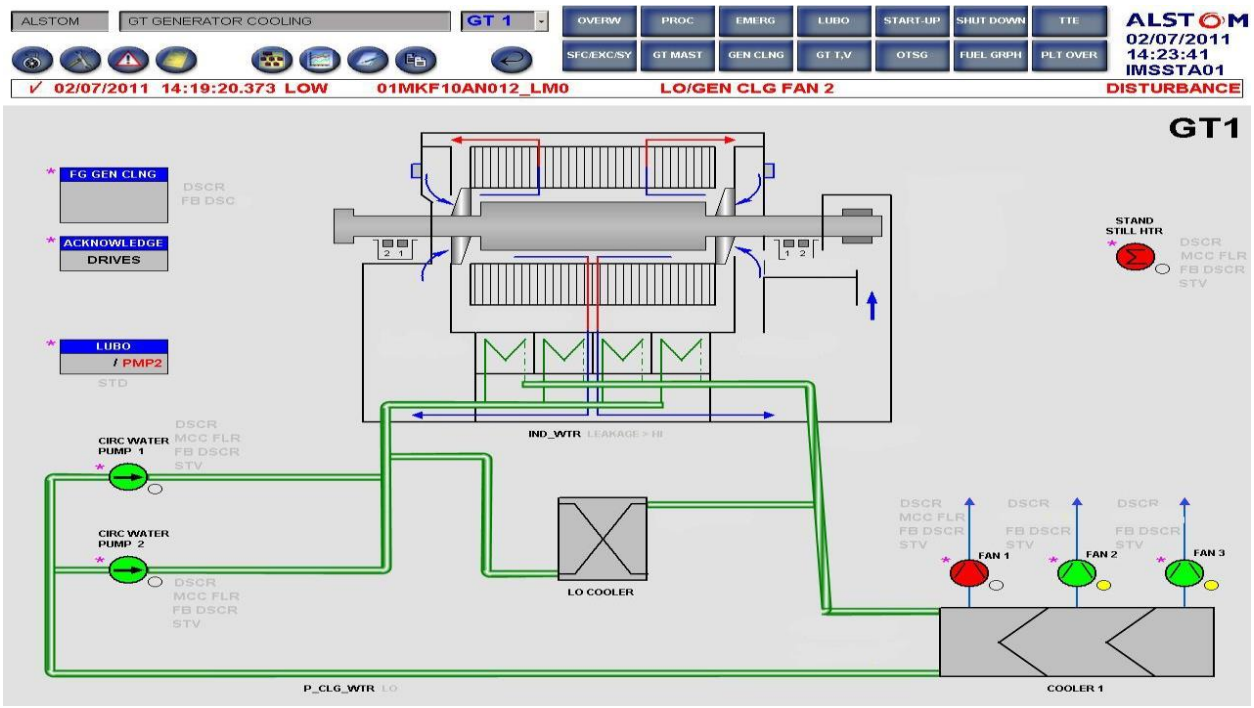
Figure 2-7 — HMI Graphic and Photo – Neutralization Tank and System



A municipal potable-water source supplies the Plant's 3000-gallon potable-water storage tank. The 2 x 100% potable-water pumps draw suction from the potable-water storage tank and supply pressurized water to the building domestic facilities and assorted eyewash and safety shower stations around the site.

Each GT generator has its own dedicated closed cooling water system. For each unit, two pumps circulate the cooling water to collect heat from the air-cooled generator and lube oil system and reject the heat in a dedicated three-fan air-cooled heat exchanger. Figure 2-8 shows the basic arrangement of the closed cooling water system, including the operating status of the system's pumps and fans as would typically be displayed on the HMI graphic screen in the Plant's control room.

Figure 2-8 — HMI Graphic – Closed Cooling Water System



2.1.4. Fuel Systems

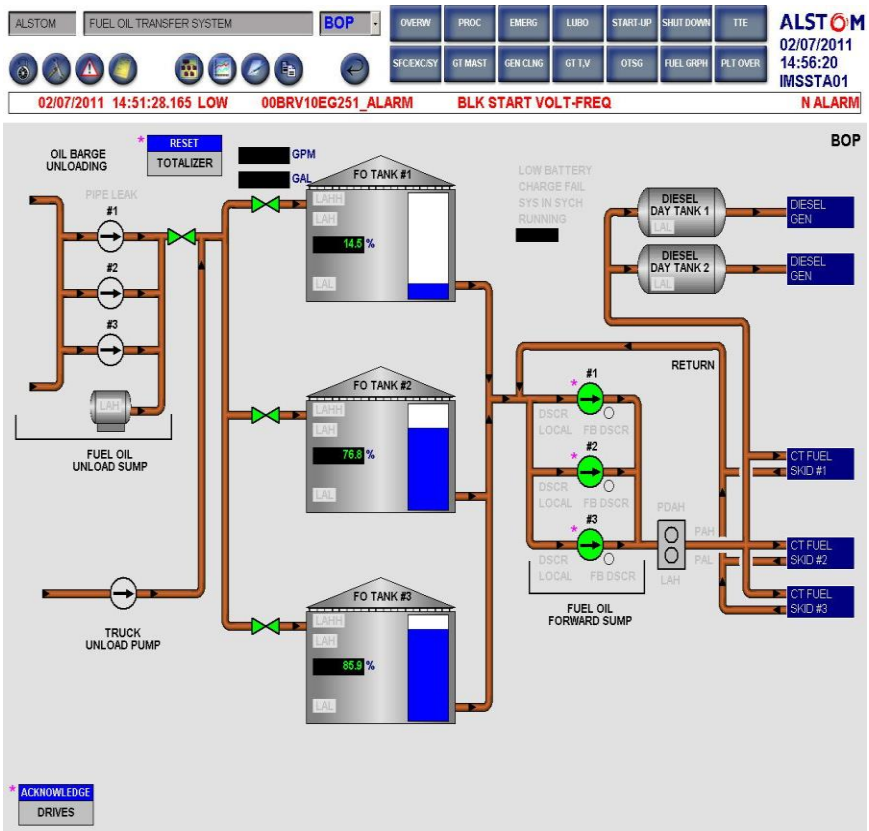
The fuel currently used at Cambalache is No. 2 (light oil/diesel). On site, the fuel is stored in three 122-ft diameter, 50-ft tall fuel oil storage tanks that are cross-tied to provide fuel to any of the three GT units. The storage tanks each have a capacity of approximately 92,300 barrels. This fuel storage capacity is sufficient to provide for 23 days of baseload operation for all three GT units.

Fuel is primarily received from the transfer station located at Arecibo Port. The fuel is pumped from a docked tanker via a double-walled underground pipeline (12-in. carrier and 16-in. containment) from the transfer station at Arecibo Port to any of the three fuel oil storage tanks. The transfer station includes 3 x 50% single-stage centrifugal pumps, each with a capacity of 1150 gpm at 185 ft of head. Alternatively, fuel can be trucked into the site and unloaded into any of the storage tanks at the truck unloading station. Discharge nozzles from these three tanks combine into a single header to the suction of the 3 x 50% fuel forwarding

pumps. Each forwarding pump has a capacity of 425 gpm at 205 ft of head, and the discharge of these pumps combines into a pressurized header to supply fuel to the three GTs and to fill the diesel day tanks for the black-start generators and the diesel fire pump tank as needed. A combined recirculation header returns to the fuel oil storage tanks.

Fuel oil delivery is primarily a manual operation. Tank fuel levels are monitored with level transmitters, and manual valves are opened and shut to select which tank will receive fuel from the barge or truck unloading operation. Limit switches on the tank fill lines indicate whether a valve is open or closed, and pumps at the barge and truck unloading areas are locally operated. The forwarding pumps and ancillary equipment are integrated into and controlled by the balance-of-plant (BOP) control system located in the control building. The graphic for this system, shown in Figure 2-9, illustrates the signals and controls available at the Plant control room's HMI.

Figure 2-9 — HMI Graphic – Fuel Oil Transfer System



2.1.5. Fire Protection

The fire pumps draw their suction from the 1,280,000-gallon raw-water tank, 50% of which is reserved for use by the firewater system. The fire pump enclosure houses a 100% electric motor pump, a 100% diesel

pump, and a jockey pump to maintain water pressure at approximately 160–170 psig in the fire protection loop. The 2 x 100% main electric and diesel fire pumps are each designed to provide 2000 gpm at 150 psig. Firewater is distributed to the hydrants, hose stations, transformer deluges, and building sprinkler systems via the aboveground and belowground firewater loop shown in Figure 2-10.

Figure 2-10 — Cambalache Aboveground and Belowground Firewater Loop

The red lines denote the approximate route of fire water piping throughout the site, some of which travels in covered trenches or below grade.

Pressurized water from the fire protection loop also feeds into the foam injection system. Inside the foam house, the firewater feeds a sprinkler system and is then dosed with foam concentrate by manually operated rotary gear pumps supplying 3% aqueous film-forming foam (AFFF) from the 2700-gallon AFFF storage tank. Four foam injection valves outside the foam house provide isolation for the foam lines to the three fuel storage tanks, each of which is equipped with three foam chambers. The fourth valve isolates the line supplying the foam hose stations and foam monitors. A separate branch off the fire foam system provides protection for the fuel oil forwarding skid area.

A CO_2 injection system provides fire suppression to the sensitive equipment at the GT units and their auxiliary enclosures. The 14-ton CO_2 tank (Figure 2-11) is located in the southwest area of the power block, and the actuation of the suppression system is controlled by a fire control panel located in the GT and motor control center's module enclosure. Finally, the plant's control room includes a clean-agent FM-200® fire

suppression system, and a Fike® ECARO-25 clean-agent system provides protection for the 4.16-kV switchgear bus module control building.

Figure 2-11 — CO_2 Storage Tank

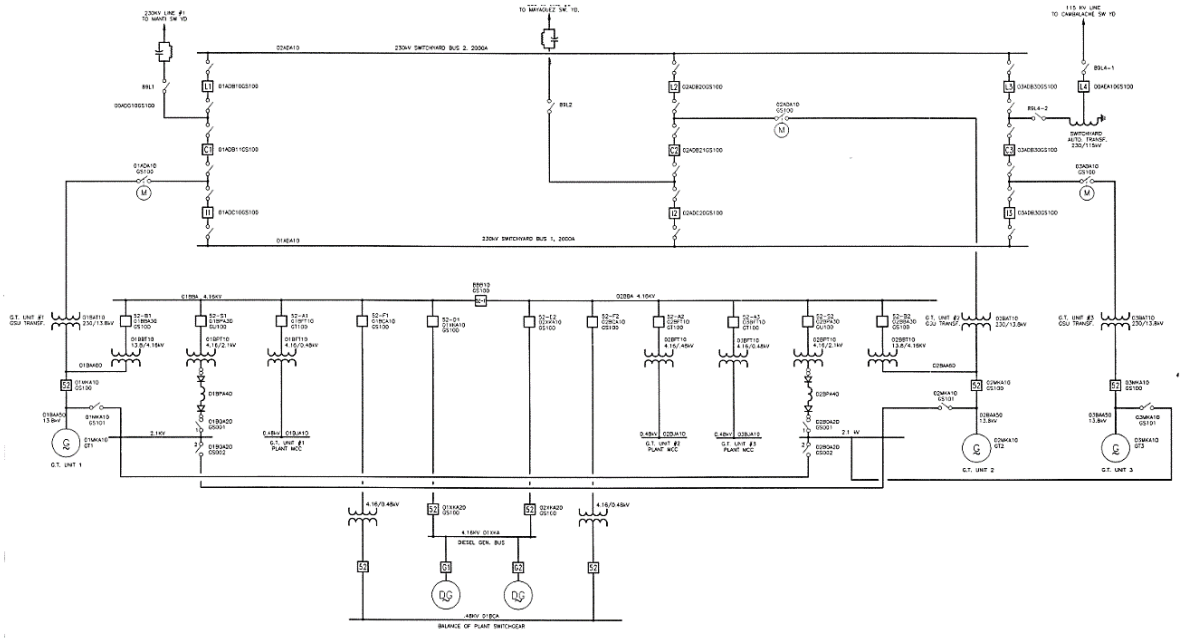
2.2. ELECTRICAL SYSTEMS

2.2.1. Conceptual Design

Each of the three GT units has a dedicated main power transformer (MPT) stepping up the voltage to 230 kV. GT1 (which is out of service) and GT2 each have a step-down transformer that connects to a common 4.16-kV switchgear bus. The 4.16-kV switchgear buses provide power to the Plant's auxiliary loads, including the 480-V switchgear and motor control center through step-down transformers. The 4.16-kV bus is also connected to the emergency switchgear, which has two 1.5-MW black-start diesel generators.

Each GT is connected to a common 2.1-kV bus to provide power for starting the GTs. The 2.1-kV bus is fed from the 4.16-kV switchgear via two low-voltage auxiliary transformers. BOP loads are fed from the 480-V double-ended switchgear line-up connected to the BOP 480-V substation. The 480-V switchgear is a doubled-ended switchgear with redundant incoming feeds from the common 4.16-kV switchgear.

Figure 2-12 — Cambalache Plant Simplified Single-Line Diagram



2.2.2. Switchyard and Interconnection

Cambalache is connected to the PREPA electrical system through three 230-kV transmission lines and one 115-kV transmission line. The 115–230-kV outdoor switchyard sits across the ravine off the southern tip of the unpaved ring road that circles the Plant.

Each GT is independently connected to a dedicated winding of a two-winding step-up transformer via isolated phase bus duct. The transformer is oil-filled, 60/80/100 MVA, OA/FA/FA,[5] and 230–13.8 kV. It is connected via overhead conductor to the 230-kV substation.

The existing demarcation point for Cambalache is on the low side of the MPT and the unit auxiliary transformer (UAT) due to the division of responsibility of 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, UATs, and the startup transformers.

Engineering design is planned to identify and further separate controls and protection between the Plant and the PREPA transmission and distribution system. A high-level review of the separation required work

[5] The OA rating is the self-cooled MVA rating of an oil-filled transformer. The FA rating is the forced-air cooled MVA rating. The first FA rating is the rating in the first stage of cooling; the second FA rating is the rating in the second stage of cooling.

is included in Sargent & Lundy's Report TD-0003, "Demarcation of PREPA Generation Assets from the Transmission and Distribution System" [1].

Figure 2-13 — 115–230-kV Switchyard

2.3. STRUCTURES

Cambalache includes an administration building near the main gate on the northern end. The control room building is located directly south of the three GT power blocks (Figure 2-14).

Figure 2-14 — Cambalache Administration Building and Control Room

Pictured is the entrance on the west side of the administration building (left) and the entrances on the north side of the control room building (right).

The demineralization plant and maintenance shop building (one structure) is across the road from the control building to the west. The warehouse is the southernmost major structure on the site, located at the end of the main road that bisects the Plant. Photos of these buildings are shown in Figure 2-15.

Figure 2-15 — Cambalache Maintenance Shop and Warehouse

Pictured is the overhead door access on the east side of the maintenance shop and demineralization plant (left) and the loading dock entrances on the north side of the warehouse (right).

2.4. CONTROL SYSTEM

The Cambalache and Aguirre facilities share a “control systems and power plant maintenance consulting services” contract (PO 83244) with Envirecs—a local representative of Hughes Technical Services LLC (HTS)—for general maintenance and support with their controls systems. The agreement provides both stations with several benefits:

- Full software and hardware assistance and support for P400, ProControl
- BlueLine (Now ABB P13), automatic voltage regulator, static frequency converter, Proficy, and iFix HMI control systems
- Full parts repair/replacement for the above-mentioned systems
- 24/7 dedicated engineers/specialists for phone, VPN, TeamViewer, email, and onsite assistance
- Improvements and upgrades options for obsolete equipment and systems
- Expedited solutions for unexpected issues
- A complete maintenance program and related services, including commissioning and training for the plant controls hardware and software

The Cambalache controls were recently upgraded under Contract 83004 with HTS. The project included the upgrade of eight HMI servers from Windows XP to Windows 10, including new servers, monitors, keyboards, network switches, hard drives, and necessary software. Work also included a new Windows 10 engineering station laptop with all software, Microsoft® IFix, and an update of all associated devices with the latest P400 and BlueLine/P13 licenses and applications. Plant staff notes that they are seeking funding for upgrades to the static frequency converter and automatic voltage regulator as advised by HTS.

3. EQUIPMENT CONDITION

The condition assessment of the Plant is a summary of the main equipment, facilities, BOP, 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:

- **Safety Hazards**—Based on visual observations during walkdowns from experienced engineering staff
- **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
- **Mechanical Assessment**—A high-level review of all major mechanical equipment and systems
- **Electrical Assessment**—A high-level review of all major electrical equipment and systems
- **Instrumentation and Controls Assessment**—A high-level review of all major instrumentation and controls equipment and systems
- **Civil and Structural Assessment**—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 assessments, 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 Scoring System

	System like new (replaced or refurbished within the past 5 years)
	System maintained with general O&M on a routine basis; no major issues noted
	Deficiency noted or components out of service
	Major issues noted causing a safety, reliability, or unit output issue
	Not in operation due to end of life

Unlike several of PREPA's generation facilities, Cambalache is not subject to an environmental consent decree with the EPA; therefore, it does not have mandated environmental outages at intervals of 12–18 months. Per the OEM's recommendations, outages for the GTs at Cambalache are taken every 4,000 EOH, with major outages every 16,000 EOH, and Sargent & Lundy has assumed that all required maintenance activities are conducted during these outages except where in progress or otherwise planned in the maintenance schedule (see Table 5-1). This key assumption was used in the evaluation of each of the six major condition assessment categories.

3.1.2. Condition

Cambalache Unit 1 has been out of service since 2011 due to a catastrophic combustion failure event. Units 2 and 3 remain operational and are in generally good condition. GE has submitted a proposal for the recovery of Unit 1, but the funding for this project has not been approved and there are currently no plans to bring the unit back online. The PREB resolution concurred with the 2019 integrated resource plan prepared by Siemens Power Technologies, which indicated that Cambalache Units 2 and 3 should remain in service beyond the 2025 suggested retirement date for much of the existing PREPA fleet. The general condition of the plant, with the exception of Unit 1, is keeping with similar utility installations built in the late 1990s.

3.1.3. Unit 1

As noted above, the Unit 1 GT enclosure and intake louvers sustained hurricane damage in 2017; the unit has been out of service since a catastrophic combustion failure that occurred in 2011. The unit enclosure interior was cleaned ahead of a recent recovery assessment that took place in 2020. GE has submitted a proposal for this recovery project, but this would represent a significant capital expenditure, and the funding has not been approved. Unit 1 is also being considered for synchronous condensing use as a part of PREPA's ongoing grid repowering efforts, and the generator heater remains energized to prevent condensation and corrosion. A third consideration would involve installing GT3 in place of the GT1, but this would only be enacted if the Unit 1 recovery and synchronous condenser options were rejected. Sargent & Lundy's overall condition assessment summary of Cambalache Unit 1 and the common systems can be found in Table 3-2. Note that additional discussion of the common systems' condition is covered in Section 3.1.6.

Table 3-2 — Cambalache Unit 1 and Common Systems Overall Condition Assessment

Plant Name: Cambalache Unit 1 and Common Systems									
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*		No issues noted.
2	**Corrosion Control**	yes	no	no			*n/a*		No issues noted.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		No issues noted.
4	**Mechanical Assessment**								
4.1	Combustion Turbine	no	yes	no					Unit 1 turbine was damaged in 2011 and has been out of service since. Enclosure was recently cleaned and Unit was inspected for potential recovery effort. GE has submitted a proposal for this work but the funding has not been approved.
4.2	Station Air System	yes	yes	no					No issues noted.
4.3	Emission controls	no	no	no					Water is used for NOx emission control and power augmentation. This system is operable at any load above 10 MW. Recently upgraded CEMS server and analyzers.
4.4	Fuel Systems	no	no	no					No issues noted.
4.5	Water Treatment	yes	yes	no					Plant acid injection skid was replaced. Demin plant ionic exchange resin replacement project is pending resin delivery. Demin water tank external anticorrosive coating contract is in final approval.
4.6	Underground Piping	no	yes	no					No issues noted.
4.7	Fire Protection Systems	no	yes	no					No issues noted.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					Plant staff notes that the generator heater remains energized to prevent condensation.
5.2	Transformers	yes	yes	no					No issues noted.
5.3	Switchgear	yes	yes	no					No issues noted.
5.4	Protective Relays	yes	yes	no			*n/a*		No issues noted.
5.5	Black Start Engines	no	yes	no					One of the two 1.5 MW black start diesels was recently repaired and returned to service. Two BSDGs are required to black start Cambalache.
6	**Instrument and Controls Assessment**								
6.1	Plant Controls	no	yes	yes					Staff notes recent upgrades to BlueLine/P13 Plant controls system under controls system maintenance support contract with Envirecs (HTS).
6.2	Turbine Controls	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no					2017 hurricane damage has been repaired. No further issues have been noted.
7.2	Structural Steel	no	no	no					No issues noted.
7.3	Tanks / Containment	no	yes	no					Fuel storage tank R1 was refurbished and returned to service. Tanks R2 and R3 were recently inspected, and Plant staff notes the inside of R2 will be cleaned in Q4 of 2020.
7.4	Cranes	no	yes	no			*n/a*	*n/a*	OH crane was damaged in 2017 hurricane. Plant staff notes that recovery project is still pending.
8	**Overall Condition Assessment**								Major issues were noted.

3.1.4. Unit 2

Unit 2 is overall in good condition, and the GT undergoes regular inspections by the OEM (GE) as part of the Plant's long-term service agreement (LTSA). During the last major (Class C) inspection, several issues were identified, including high bearing temperatures and vibrations. These issues were addressed after the completion of the overhaul as warranty claims with the turbine OEM. In 2020, the GT2 had a scheduled combustion (Class A) inspection in February and an intermediate (Class A) inspection in June. The next

minor (Class B) inspection will be after 8000 EOH from the last major (Class C) inspection and was expected to be started in November 2020 after completion of the major (Class C) inspection on GT3. Plant staff notes that the filter house louvers on the GT2 air intake weather hoods, which were damaged in the 2017 hurricane, were replaced by new ones fabricated on site. The inspection types and schedules are detailed in Section 5. Sargent & Lundy's overall condition assessment of Cambalache Unit 2 is summarized in Table 3-3:

Table 3-3 — Cambalache Unit 2 Overall Condition Assessment

Plant Name: Cambalache 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*		No issues noted.
2	**Corrosion Control**	yes	no	no			*n/a*		No issues noted.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		No issues noted.
4	**Mechanical Assessment**								
4.1	Combustion Turbine	no	yes	no					Unit 2 had a class A inspection in February and intermediate inspection in June of 2020. Next inspection will be a minor class B scheduled for November 2020 after the major class C inspection of GT3. Weather hood filter house louvers were replaced by Plant personnel. GT exhaust duct rebuild project is expected to be completed Q1 of 2021.
4.2	Station Air System	yes	yes	no					No issues noted.
4.3	Emission controls	no	no	no					Water is used for NOx emission control and power augmentation. This system is operable at any load above 10 MW. Recently upgraded CEMS server and analyzers.
4.4	Fuel Systems	no	no	no					No issues noted.
4.5	Water Treatment	yes	yes	no					Plant acid injection skid was replaced. Demin plant ionic exchange resin replacement project is pending resin delivery. Demin water tank external anticorrosive coating contract is in final approval.
4.6	Underground Piping	no	yes	no					No issues noted.
4.7	Fire Protection Systems	no	yes	no					No issues noted.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					Plant is seeking funding for upgrades to the generator SFC and AVR.
5.2	Transformers	yes	yes	no					No issues noted.
5.3	Switchgear	yes	yes	no					No issues noted.
5.4	Protective Relays	yes	yes	no			*n/a*		No issues noted.
6	**Instrument and Controls Assessment**				*n/a*	*n/a*	*n/a*	*n/a*	
6.1	Turbine Controls	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	
7	**Civil / Structural Assessment**								
7.1	Structural Steel	no	no	no					No issues noted.
8	**Overall Condition Assessment**								No major issues noted.

3.1.5. Unit 3

Unit 3 is overall in good condition, and the GT underwent a major inspection performed by the OEM (GE) as part of the Plant's LTSA in November 2020. GT3 had a Class A combustion inspection in December 2019 and an extra Class A inspection in June 2020 at 16,000 EOH instead of the Class C major inspection due to delays in part delivery. The recent major (Class C) inspection of GT3 was completed in November

2020, and the GT was scheduled to have an intermediate (Class B) inspection in December of 2020. Plant staff notes that the filter house louvers on the GT3 air intake weather hoods, which were damaged in the 2017 hurricane, were replaced by new ones fabricated on site. The inspection types and schedules are detailed in Section 5. Sargent & Lundy's overall condition assessment of Cambalache Unit 3 is summarized in Table 3-4:

Table 3-4 — Cambalache Unit 3 Overall Condition Assessment

Plant Name: Cambalache Unit 3

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*		No issues noted.
2	**Corrosion Control**	yes	no	no			*n/a*		No issues noted.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		No issues noted.
4	**Mechanical Assessment**								
4.1	Combustion Turbine	no	yes	no					Unit 3 had class A inspection @ 16,000 EOH in June 2020, and a major C class inspection and overhaul starting in October of 2020. Weather hood filter house louvers were replaced by Plant personnel.
4.2	Station Air System	yes	yes	no					No issues noted.
4.3	Emission controls	no	no	no					Water is used for NOx emission control and power augmentation. This system is operable at any load above 10 MW. Recently upgraded CEMS server and analyzers.
4.4	Fuel Systems	no	no	no					No issues noted.
4.5	Water Treatment	yes	yes	no					Plant acid injection skid was replaced. Demin plant ionic exchange resin replacement project is pending resin delivery. Demin water tank external anticorrosive coating contract is in final approval.
4.6	Underground Piping	no	yes	no					No issues noted.
4.7	Fire Protection Systems	no	yes	no					No issues noted.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					Plant is seeking funding for upgrades to the generator SFC and AVR.
5.2	Transformers	yes	yes	no					No issues noted.
5.3	Switchgear	yes	yes	no					No issues noted.
5.4	Protective Relays	yes	yes	no			*n/a*		No issues noted.
6	**Instrument and Controls Assessment**				*n/a*	*n/a*	*n/a*	*n/a*	
6.1	Turbine Controls	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	
7	**Civil / Structural Assessment**								
7.1	Structural Steel	no	no	no					No issues noted.
8	**Overall Condition Assessment**								No major issues noted.

3.1.6. Common Systems

The common systems for Cambalache remain in generally good serviceable condition. Plant staff performs regular inspections and preventative maintenance to ensure the continued reliability of these systems. A brief assessment of these common systems is provided in the subsections below.

3.1.7. Water Systems

The raw-water system is in generally good condition for a system of this vintage. Based on visual appearance, Plant staff has been diligent with their maintenance of tank coatings for corrosion protection,

but substantial corrosion was noted on exposed systems like the raw-water strainers and piping shown in Figure 3-1.

Figure 3-1 — Raw Water Tank and Raw Water Strainers

Like the raw-water tank, the demineralized-water tank appears to be well maintained, and the weather shroud over the raw-water transfer pumps appears to be helping to mitigate weather-related corrosion of the equipment beneath it (see Figure 3-2).

Figure 3-2 — Demineralized Water Tank and Raw Water Transfer Pumps

Plant staff recently replaced the acid injection skid for the demineralized-water production system, and the new skid is now in service. An ongoing project to replace the demineralization plant's ionic exchange resin is pending the resin delivery to the site and was expected to be completed in the fourth quarter of 2020. Finally, a proposal to refresh the demineralized-water tank's external anticorrosive coating is in the final stages of approval.

The potable water tank and pumps are in an outdoor area exposed to the elements. The tank appears to be in good condition, but the valves and pump casings show considerable corrosion, as is the case with many unprotected systems on site.

Figure 3-3 — Potable Water Storage Tank

The closed cooling water systems show evidence of some minor corrosion, but they generally appear to be in good serviceable condition (see Figure 3-4). The circulating water pumps are contained in an enclosure that appears to have preserved the equipment better than exposed systems on site of the same vintage.

Figure 3-4 — Water Circulation Pumps and Fin Fan Cooler

3.1.8. Fuel Systems

The fuel transfer station located at Arecibo Port (Figure 3-5) is in good condition, thanks largely to the weather-proof enclosure housing the pumps. Based on recent interviews, Plant staff did not make note of any recent maintenance issues or concerns with the system.

Figure 3-5 — Barge Unloading Area and Barge Unloading Pumps

Several of the fuel storage tanks have begun to show rust streaks, indicating that their coating systems are no longer providing complete corrosion protection. The fuel forwarding pumps, however, appear to be well

maintained and well protected by a weatherproof enclosure. Figure 3-6 includes a photograph of two of the three fuel storage tanks from August 2020 as well as a photo of the three fuel forwarding pumps in their enclosure and the truck unloading pump obscured at the far end of the row.

Figure 3-6 — Fuel Oil Storage Tanks (1 and 2) and Fuel Oil Forwarding Pumps

Plant staff recently completed repairs to the fuel forwarding pump shelter, which had been damaged in the 2017 hurricane. The interior and exterior of Fuel Storage Tank R1 were also recently refurbished, and the tank has been returned to service. Figure 3-7 provides a visual of the Fuel Storage Tank R1 roof before and after this work was performed.

Figure 3-7 — Fuel Storage Tank R1 Roof

Pictured is the Fuel Storage Tank R1 roof before (left) and after refurbishing (right).

Exterior inspections of Fuel Storage Tanks R2 and R3 were recently completed, and Plant staff notes that operations have begun to draw down for Tank R2 for interior cleaning, which is scheduled to begin before the end of 2020. Plant staff has not reported any other issues with the fuel systems.

3.1.9. Fire Protection

Inspection of the Plant's fire protection systems during the 2018 walkdown did not reveal any outstanding operational or maintenance concerns. Figure 3-8 shows the electric and diesel motor-driven firewater pumps in their enclosure. These photos are from 2010, but Plant staff notes that the system remains in working order and that the enclosure provides good protection from the elements.

Figure 3-8 — Electric and Diesel Firewater Pumps

The fire foam system that protects the fuel oil tanks and fuel oil forwarding pumps also appears to be in serviceable condition. The photo on the left in Figure 3-9 shows minor chalking of the pipe coating system; this is not uncommon for systems that remain exposed to the elements. Over time the coatings degrade, releasing the binder's hold on the pigment and resulting in the chalky white appearance. These and other coatings on outdoor equipment and piping should be monitored for further degradation and regularly recoated to protect the substrate from corrosion.

Figure 3-9 — Foam System Isolation Valves and Foam Chamber

3.1.10.Miscellaneous Equipment and Structures

The Cambalache power blocks share a common overhead crane, which was damaged in the 2017 hurricane. A project to recover the overhead crane and replace damaged equipment was planned, but Plant staff notes that this work is still pending. Sargent & Lundy recommends that this crane recovery be prioritized in the near term so that the crane can be used to support any Unit 1 recovery or repurposing work.

The site perimeter fencing was severely damaged by erosion and flooding caused by the 2017 hurricane, as shown in Figure 3-10. The fence was repaired as part of the Hurricane Maria Recovery Project.

Figure 3-10 — Cambalache Perimeter Fence Damage and Repair

Pictured are portions of the perimeter fence that were damaged (left) in 2017 and repaired (right) as part of the Hurricane Maria Recovery Project.

The major occupied structures on site, like the administration building, control building, and maintenance shop/demineralization plant building appear to be in good serviceable condition. Plant staff reported recent replacements and repairs to the HVAC systems, and no outstanding issues with these structures were identified in recent interview responses. The Unit 1 main GT enclosure remains severely damaged from the 2017 hurricane destruction, and temporary measures have been taken to protect the interior with a temporary roof while the GT intake duct and enclosure superstructure are removed (see Figure 3-11). The same figure shows a 2018 photo of the old oil storage shelter on site. Plant staff reports that a new oil storage structure has since been constructed in the diked area, which was previously designated for the ammonia storage tank near the truck unloading area. Completion of this structure with rolling doors was still pending as of December 2020.

Figure 3-11 — Unit 1 Main GT Enclosure and Oil Storage Shelter

Pictured are portions of the Unit 1 GT enclosure that were damaged in 2017 (left) and a 2018 photo of the old oil storage shelter (right), which has since been replaced.

3.1.11. Black-Start Diesel Generators

One of the 1.5-MW black-start diesel generators was out of service in 2018 due to damaged valves and rocker arms. Since the GT units require power from both generators for black start, the Plant was reliant upon grid power for startup while this generator was down. Plant staff notes that the damaged generator has been repaired and thus the Plant's black-start capabilities have been restored.

3.2. RECOMMENDATIONS

Cambalache is in good condition considering its age. The GTs are regularly inspected and maintained under the LTSA with the OEM and Plant staff employs a robust maintenance program that ensures BOP equipment is monitored, repaired, and replaced as needed. While corrosion is a concern in similar oceanic coastal environments, the visual appearance of much of the Plant's exposed equipment indicates that the staff is appropriately rigorous in their corrosion mitigation efforts. Even so, equipment protected by enclosures has been observed to fare much better in this harsh environment and it would be advisable to continue to locate critical components indoors and provide enclosures for new or replaced equipment on site wherever practical. Furthermore, correction of enclosures that have been compromised, like the GT enclosure of Unit 1, should be prioritized to protect equipment from the accelerated degradation that will be caused by exposure to the elements.

As with other PREPA facilities, 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 OEM standards for power generation and BOP equipment are not well suited for this type of operating environment. Any new equipment must be configured for the challenging conditions at

Cambalache. Failure to make allowances for suitable materials, equipment selection, buildings/enclosures, and other aspects of the facility design to protect the Plant from its 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 operating environment include: (i) corrosion-resistant material specifications; (ii) appropriate welding selections, including special treatment of all metal seams, stitched connections, and fastenings with sealants, gaskets, and coatings; (iii) protective equipment enclosures; (iv) proper system selections; and (v) marine coatings systems. Due to these requirements, coastal power generation sites are inherently more expensive than those installed in less aggressive operating environments.

Ongoing proposals for plant repairs, replacements, and upgrades should consider the guidelines provided herein. New operating regimes and other comparisons must be made so that equipment is selected to suit the future direction of the power generation and distribution system planned for Puerto Rico. The final resolution and order of PREB addressing PREPA's proposed integrated resource plan (Case No. CEPR-AP-2018-0001), published in August of 2020, did not issue a retirement date for the Cambalache units; however, the PREB decision did reject most of the integrated resource plan's proposed improvements or additions to PREPA's fossil fuel generation fleet in favor of adding more renewable generation and battery storage capacity to Puerto Rico's grid infrastructure. It is expected that existing fossil fuel-powered generation facilities with several years of remaining useful life, like Cambalache, will be relied upon to maintain grid stability throughout this repowering transition.

PREPA continues to study the need for additional grid support and generation throughout the Island. The GT units at Cambalache, with 60% rapid spinning reserve, may be relied upon to provide grid stability until sufficient battery storage has been installed. If PREPA does not move forward with the full recovery of Unit 1, the unit may still be considered as a candidate for repurposing as a synchronous condenser, which would also offer grid stabilization benefits during the repowering period. In either scenario, prioritizing the recovery of the Plant's damaged overhead crane would be beneficial to support these activities.

Other Plant modifications that can sustain or improve unit operation or reliability may be integrated into the design and provide years of future power generation service from the facility.

4. INFRASTRUCTURE AND INTERCONNECTIONS

4.1. FUEL SUPPLY

The units operate on No. 2 fuel oil, of which 277,000 barrels are on reserve across three storage tanks on site. Barge deliveries are taken from the nearby Arecibo Port and pumped to the storage tanks via an underground pipeline to the site. Fuel may also be delivered via tanker trucks and unloaded into the storage tanks using the onsite truck unloading pump.

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.

4.2. WATER SUPPLY AND TREATMENT

The plant uses a municipal potable water supply from PRASA for domestic use in the facility buildings and for the eyewash and safety showers on site. Potable water is stored on site in a 3000-gallon tank, and 2 x 100% potable-water pumps pressurize the station's potable-water system. There are also four raw-water well pumps located outside of the Cambalache facility that are used to fill the 1,280,000-gallon raw-water storage tank. Half of this water is reserved for use by the fire protection system. The remaining water is used for service-water applications as well as the production of demineralized water for use in Plant processes. Plant wastewater is processed through a neutralization system and stored in a 150,000-gallon tank prior to being discharged to the storm sewer system.

5. OPERATIONS AND MAINTENANCE

The Cambalache GT units were designed to provide rapid-response spinning reserve to ensure system stability in the event of the unanticipated loss of a large generating unit, thereby improving the reliability of service to PREPA's customers. Unlike several of PREPA's older fossil fuel combustion generation units, the GTs at Cambalache are not subject to periodic environmental outages. Instead, fuel deliveries are sampled and analyzed for quality, and a continuous emissions monitoring system (CEMS) logs the emissions of CO, NOx, and O_2 from each unit. Quarterly reports submitted to the Chief Air Compliance Branch of the EPA verify PREPA's compliance with their prevention of significant deterioration (PSD) permit for this generation facility.

During the site visit, Sargent & Lundy visually inspected the facility and met with key managerial personnel at Cambalache to discuss recent, ongoing, and planned O&M activities. Key components of PREPA's maintenance strategy at Cambalache are detailed below.

5.1. STAFFING AND TRAINING

Cambalache is staffed with 35 personnel responsible for the regular operation, maintenance, and administration of the facility. Nine of these employees are responsible for the regular operation of the GTs and perform in shifts from 7:00 a.m. to 11:00 p.m., seven days a week. The staff, maintenance, and operation organization charts in Figure 5-1 through Figure 5-3 were shared with Sargent & Lundy in December of 2020 to illustrate the staffing breakdown..

Figure 5-1 — Cambalache Plant Staff Organization Chart

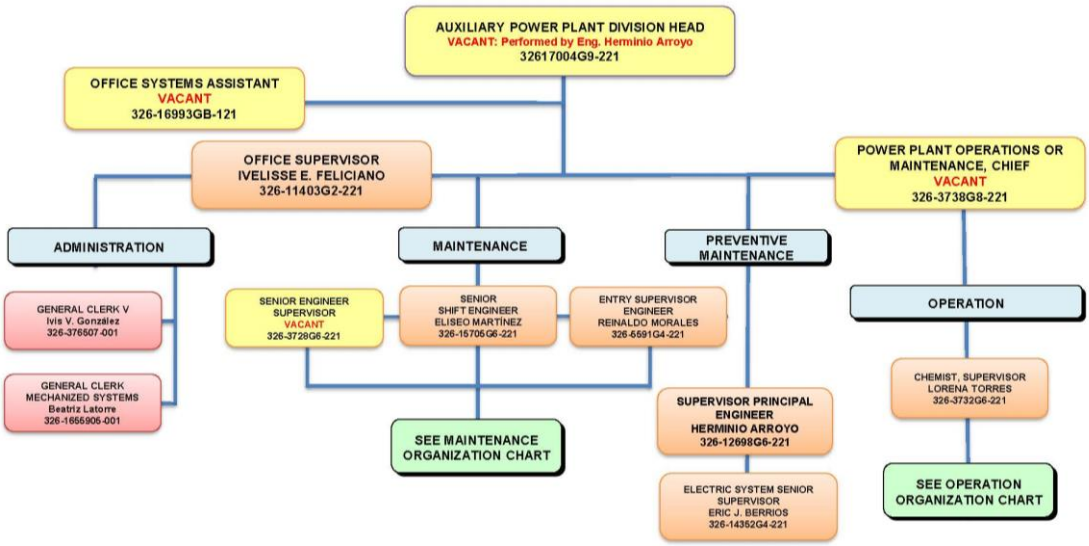


Figure 5-2 — Cambalache Plant Maintenance Organization Chart

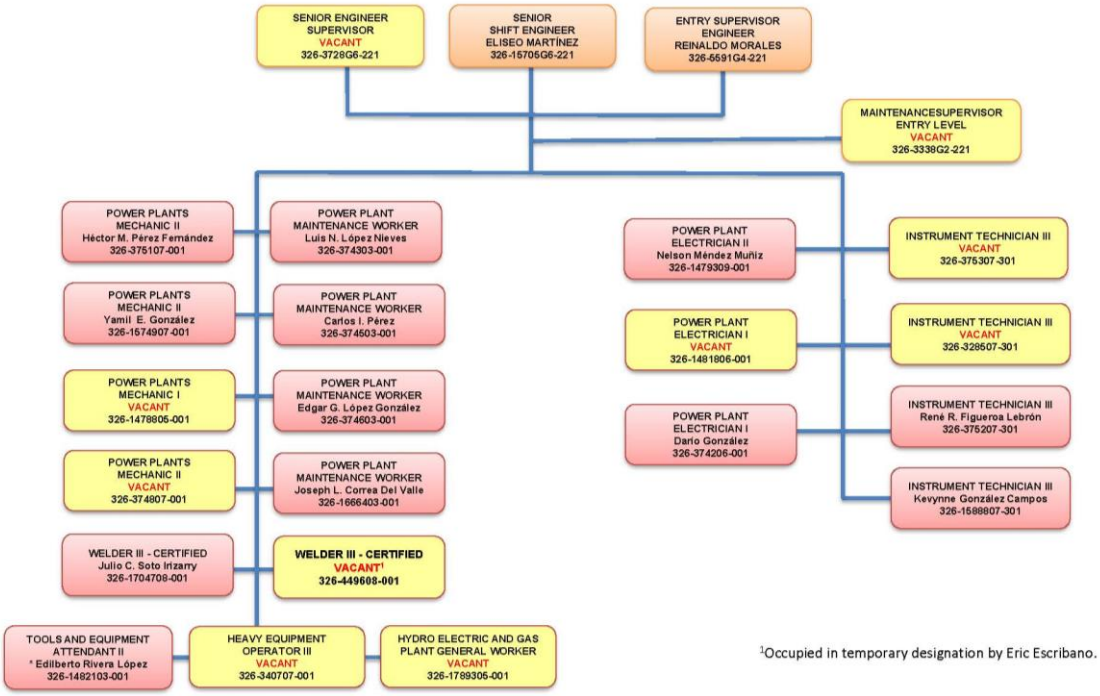
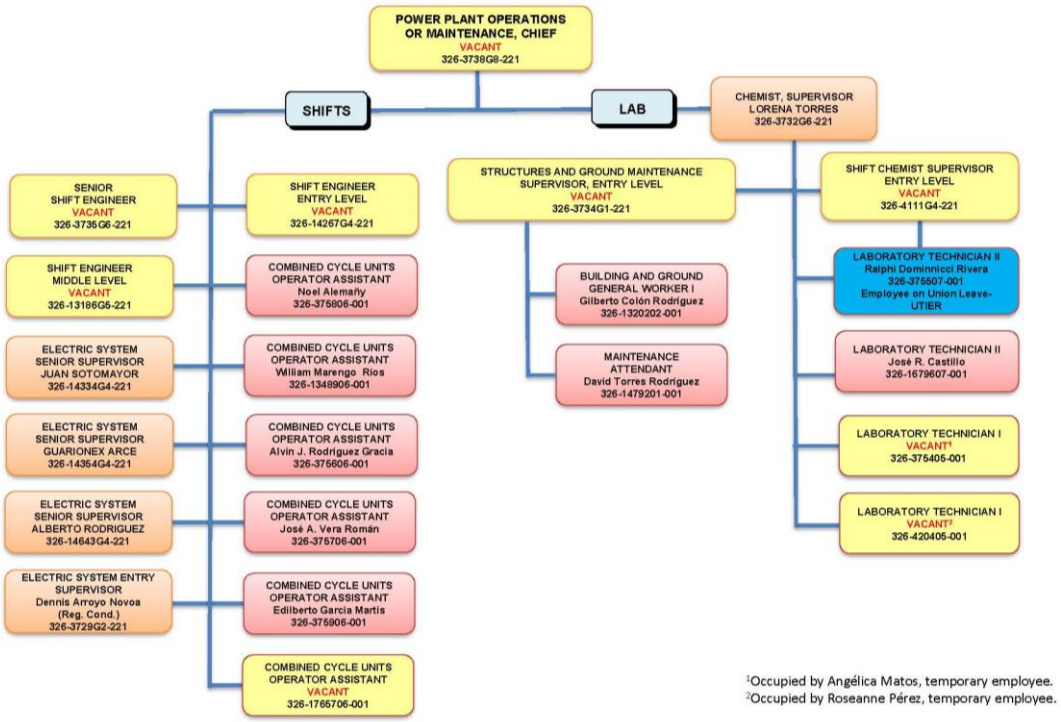


Figure 5-3 — Cambalache Plant Operation Organization Chart



5.2. MAINTENANCE PROGRAMS

The main objective of PREPA's maintenance plan is to use preventative maintenance in conjunction with predictive techniques developed at the plant level. Maintenance is performed using the OEM specifications, Plant experience, Plant routine inspections, equipment monitoring, and O&M manuals as applicable. Rotors and motors are sent to contractors to be rebuilt. The Plant has an ongoing LTSA contract, TSM-23-03, with the GT OEM (GE) through December 31, 2023, which covers regular inspections and preventative maintenance of the units at the prescribed equivalent operating hour (EOH) intervals. Other inspections are generally done by Plant staff with contractors hired for further analysis and to make repairs as needed.

5.2.1. Preventative Maintenance

The Plant staff follows the applicable preventative maintenance guidance for the GT units provided by the manufacturer, GE, in the O&M manual and in technical information letters issued periodically. Routine maintenance activities are performed during planned outages for the operating units. Major inspection outages are of a longer duration and allow for more involved overhauls, upgrades, and changes, while shorter inspection outages are used for more frequent inspections concentrated on the high-wear elements. Under the current LTSA, GE provides technical field assistance on site to support these inspections and their inclusive maintenance activities. The types of inspections performed on the GTs are as follows:

- **Combustion Inspection (Class A)—**The combustion inspection is a relatively short disassembly inspection of fuel nozzles, liners, transition pieces, crossfire tubes and retainers, spark plug assemblies, flame detectors, and combustor flow sleeves. This inspection concentrates on the combustion liners, transition pieces, fuel nozzles, and end caps, which are often the first to require replacement and repair. The inspection also includes a borescope inspection of the turbine buckets and compressor to mark progress of wear and help establish the schedule for the hot-gas path inspection. Proper inspection, maintenance, and repair of these items helps to ensure a longer life of the downstream parts, such as the turbine nozzles and buckets.
- **Hot-Gas Path Inspection (Class B)—**The purpose of a hot-gas path inspection is to examine those parts exposed to high temperatures from the hot gases discharged from the combustion process. The inspection includes the full scope of the combustion inspection and, in addition, a detailed inspection of the turbine nozzles, stator shrouds, and turbine buckets. To perform this inspection, the top half of the turbine shell must be removed.
- **Major Inspection (Class C)—**The purpose of the major inspection is to examine all of the internal rotating and stationary components from the inlet of the machine through the exhaust. Major inspections are scheduled in accordance with the recommendations in the owner's O&M manual or as modified by the results of previous borescope and hot-gas path inspections. The work scope involves inspection of all of the major flange-to-flange components of the GT, which are subject to deterioration during normal turbine operation. This inspection includes previous elements of the combustion and hot-gas path inspections and requires laying open the complete flange-to-flange GT to the horizontal joint.

The typical order of these inspections will be a repeating sequence of "A-B-A-C" at 4,000-EOH intervals such that a major (Class C) inspection occurs every 16,000 EOH and between each there is a combustion (Class A), minor (Class B), and second combustion (Class A) inspection at 4,000-EOH intervals.

5.2.2. Corrective Maintenance

Maintenance and operational issues are recorded in logs by the operations staff, prioritized by Plant and PREPA corporate management, and addressed when possible during forced and scheduled outages. To the greatest extent possible, corrective maintenance requiring an outage is performed during the planned outages for the GTs in parallel with the GT inspection and maintenance activities. Recent, ongoing, and upcoming corrective maintenance activities are described in Section 5.3.

5.2.3. Predictive Maintenance

The Plant employs three types of condition monitoring technologies to inform their predictive maintenance decisions:

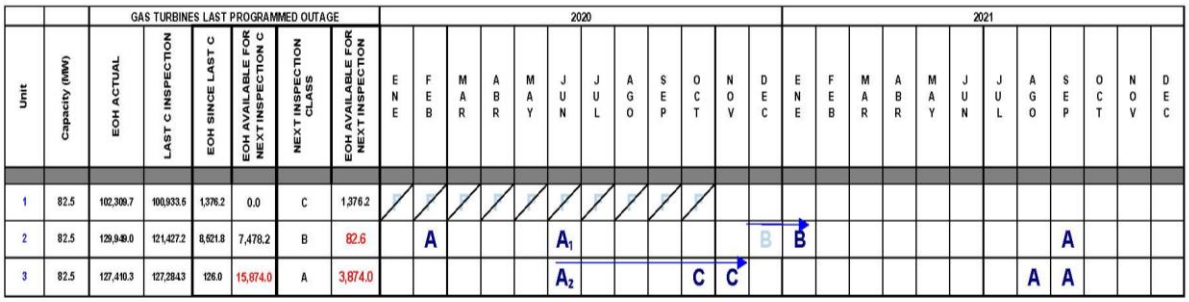
- **Vibration Monitoring—**Vibration data is recorded for the main rotating equipment through an OEM-provided system. The Plant contracts with Vibra Inc. (Vibra) for data analysis and uses their analysis to identify operational issues early in their development and prioritize maintenance activities for the monitored equipment.
- **Thermography—**Vibra also provides the Plant with thermographic data collection and analysis and uses this analysis to identify hot-spot issues that are invisible to the naked eye but may require maintenance, repair, or further monitoring.
- **Oil Analysis—**Oil sampling performed by PREPA staff is furnished to Spectron Caribe, Inc. (Spectron) for analysis. Spectron maintains a monitor control list of equipment included in this program to track trends and issue individual component condition reports, corrective action instructions, and other information pertaining to mechanical and lubricant integrity to the Plant staff.

Issues identified with the predictive maintenance program are used to elevate preventative maintenance priority on equipment and systems showing more prominent warning signs or rapid deterioration.

5.3. MAINTENANCE AND OUTAGE SCHEDULES

The 2020–2021 inspection plan itinerary for Cambalache was provided to Sargent & Lundy in December of 2020, which shows actual and planned outages by month for that period along with a summary of the EOH for each unit (see Table 5-1).

Table 5-1 — Cambalache Inspections Planned Itinerary – 2020 and 2021



EOH Inspections Schedule based on LTSA: TSM-23-03									
EOH Data date:	Gas Turbine	EOH Schedule since the last class C Inspection					EOH Usage Since Last Schedule Inspection		
		Last C Insp	Class A	Class B	Class A	Class C	Performed @	Class	Actual USAGE(EOH)
	GT1	100,933.5	**104,933.5**	108,933.5	112,933.5	116,933.5	100,933.5	C	**1,376.20**
	GT2	121,427.2	125,427.2	**129,427.2**	133,427.2	137,427.2	126,031.6	A	**3,917.40**
11/30/20	GT3	127,284.3	131,284.3	135,284.3	139,284.3	**143,284.3**	127,284.3	C	**126.00**

Inspection outages are scheduled according to the EOH of each unit based on the OEM's recommended intervals.

In response to interview inquiries, Plant staff provided several details of recent and upcoming inspection outages and maintenance work, which is summarized in Table 5-2:

Table 5-2 — Plant Maintenance Outage Activities

Plant Name	Start	Finish	Reason	Description
Cambalache Unit 2	Feb 2020	Feb 2020	Combustion Inspection	Class A inspection performed under LTSA with GT OEM (GE).
	June 2020	June 2020	Minor Inspection	Class A inspection performed under LTSA with GT OEM (GE).
	Nov 2020	Dec 2020	Minor Inspection	Class B inspection performed under LTSA with GT OEM (GE).
Cambalache Unit 3	Dec 2019	Dec 2019	Combustion Inspection	Class A inspection performed under LTSA with GT OEM (GE).
	June 2020	June 2020	Combustion Inspection	Additional Class A inspection performed under LTSA with GT OEM (GE) to install parts that were received too late for the previous Class A inspection outage.
	Oct 2020	Nov 2020	Major Inspection	Class C inspection performed under LTSA with GT OEM (GE).

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. Much of the recent corrective maintenance at Cambalache has been focused around repairs to the damage inflicted upon the site by Hurricane Maria in 2017. A brief summary of recently completed, pending projects, and ongoing maintenance programs is provided below:

Projects Completed

- Fence restoration
- Building repairs
- HVAC system replacement and repairs
- GT fuel-pump shelter repairs
- Stormwater and fuel oil dike water drain-off pump upgrade
- GT filter house replacement
- Emergency generators repairs and maintenance
- Sanitary lift station repairs

Projects Pending

- GT1 Enclosure Repair—pending funds assignment and contingent upon approval of Unit 1 recovery project
- Cambalache Site Dike Integrity Assessment—pending funds assignment

Ongoing Maintenance Programs

- PREPA currently has a tank inspection program, per compliance with the API Code and SPCC[6] plan, planned in the next six years for all power plants.
- 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 Cambalache was not provided.
- Fire protection system testing is conducted per NFPA requirements, but no recent or planned maintenance issues have been identified.

5.4. SPARE PARTS

The plant staff notes that several of the commonly replaced hot-gas path parts are included under the LTSA with the GT OEM, but major equipment spares are not kept on site, and parts are typically acquired as needed depending upon available funds and criticality to plant operation.

5.5. ENERGY MANAGEMENT SYSTEM

PREPA, at the corporate level, employs numerous automated control applications to ensure the safe and reliable operation of its system. These applications coordinate with or are integrated into larger systems

[6] spill prevention, control, and countermeasure

that support PREPA's routine technical and commercial operations. PREPA uses controls and an energy management system (EMS) to regulate the supply-side generation of electricity to match real-time electric power on the demand side from the users.

In 2012, a supplier provided an updated EMS to replace the older system then employed. 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 cybersecurity compliance with NERC's 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 Cambalache, Sargent & Lundy reviewed historical operating performance indicators provided by PREPA for each unit and benchmarked them against a group of industry peer units where data was available. There were five primary performance indicators:

- 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 de-ratings (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.

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)[7] and established a peer groups to compare reliability data.

Sargent & Lundy applied the selection criteria identified in Table 6-1 to the NERC GADS database[8] to establish a reliability peer group for the units. The resulting peer groups that reflect these unit characteristics included 58 units owned by 15 different operators, with the dataset including 489.83 operating years of reporting data. Note that heat rate is not reported to NERC; therefore, peer group data is not presented in this report.

Table 6-2 provides a summary of the key performance data for Cambalache. Note that the peer group identified is for units operating primarily on natural gas, while Cambalache operates on No. 2 fuel oil.

[7] 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 Cambalache units.

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

Table 6-1 — Cambalache Units Peer Group

Cambalache Unit Characteristics			Peer Group Characteristics			
COD	Unit Gross Capacity (MW)	Operating Fuel	COD	Unit Gross Capacity (MW)	Operating Fuel	Black-Start Capable
1997	82.5	No. 2	1990–2005	70–95	No. 2/Natural Gas/Heavy Fuel Oil	No

Table 6-2 — Cambalache Overall Key Performance Data Summary[2]

Key Performance Indicator	2015	2016	2017	2018	2019	2020	Peer Group
Generation (MWh)	166,263	106,772	191,435	83,992	145,032	301,523	–
Equivalent Availability (%)	66.2	61.4	62.0	56.9	93.2	88.2	94.1
Net Capacity Factor (%)	7.7	4.9	8.8	3.9	10.0	20.8	2.3
Equivalent Forced Outage Rate	34.3	36.2	38.1	40.5	36.7	37.1	18.5
Net Heat Rate (Btu/kWh)[1]	12,887	12,627	12,922	13,135	12,600	12,162	–

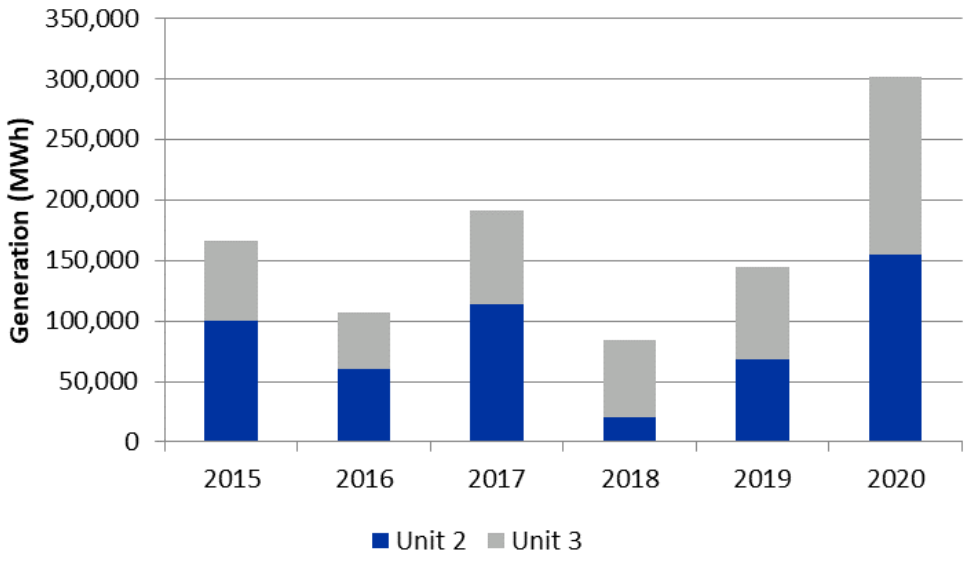
1. Btu/kWh = British thermal unit per kilowatt hour
2. Values include Units 1–3; however, Unit 1 has not operated since 2011 and is considered a GT in forced outage.

6.1. GENERATION

Generation for Units 2 and 3 is provided in Figure 6-1. The generation figures provide totalized information for the annual plant generation of power.

The units' generation and net capacity values correspond to units that are run primarily as peaking units. After the 2017 hurricanes, the available units were dispatched according to load demands and system requirements. Total power generation was at a high of 301,523 MWh in 2020 and a low of 83,992 MWh in 2018. The net generation in 2018 can be attributed to lower demand, as the availability and EFOR of the units remained relatively flat.

Figure 6-1 — Cambalache Generation – Units 2 and 3



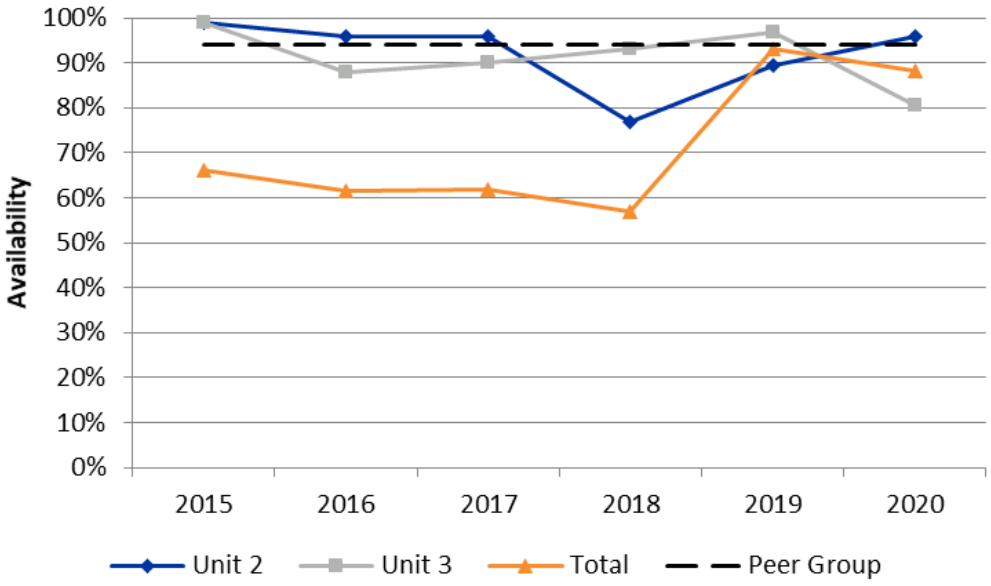
6.2. AVAILABILITY FACTOR

The EAF is the fraction a facility is available to generate electricity at net dependable capacity subtracted by de-rated conditions. EAF is calculated as follows:

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

The availability of Cambalache has remained relatively high and in line with other similar units. The availability of Unit 2 was lower in 2018 due the major Class C inspection in that year. The average availability of the plant, as shown in Figure 6-2, is considerably lower than Units 2 or 3, as Unit 1 is included in the average until 2019. Note that Unit 1 is not included on the plot, as the unit has been out of service since 2011.

Figure 6-2 — Cambalache Equivalent Availability Factors



Unit 1 is included in the Plant total average until 2019.

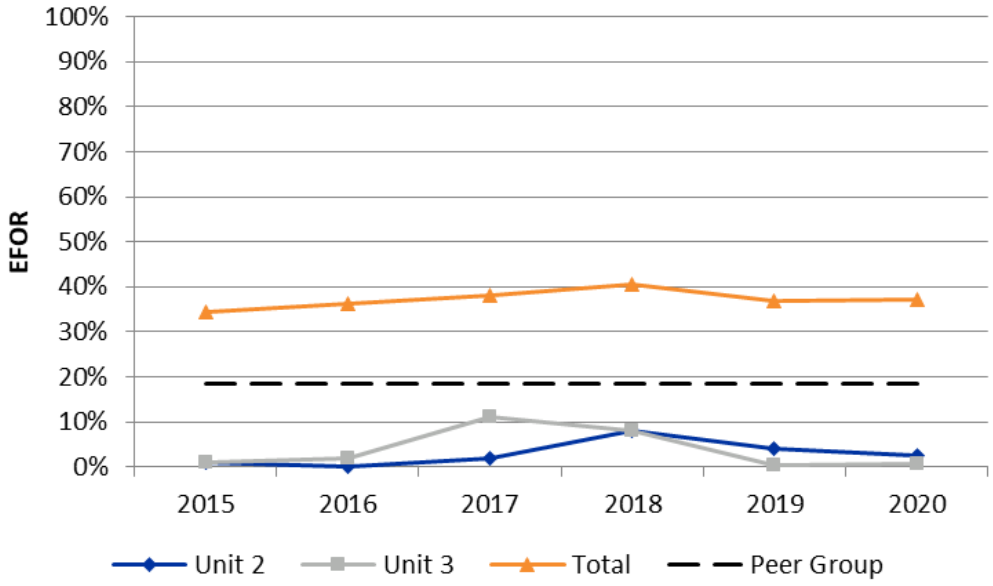
6.3. EQUIVALENT FORCED OUTAGE RATE

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

EFOR = (Forced Outage Hours + Equivalent Forced De-Rated Hours)/(Service Hours + Forced Outage Hours + Equivalent Reserve Shutdown Forced De-Rated Hours) x 100

The EFOR of Units 2 and 3 has averaged to be less than 10% over the last five years and is better than its peer group EFOR, showing that the units are maintained with more care than their peer group and have experienced less unexpected failures than similar units. Cambalache's forced outage factor is provided in Figure 6-3. The Unit 1 EFOR is not included on the plot, as it has been 100% since 2011. Note that the Plant average includes the Unit 1 EFOR.

Figure 6-3 — Cambalache Equivalent Forced Outage Rates



Unit 1 is included in the Plant total average.

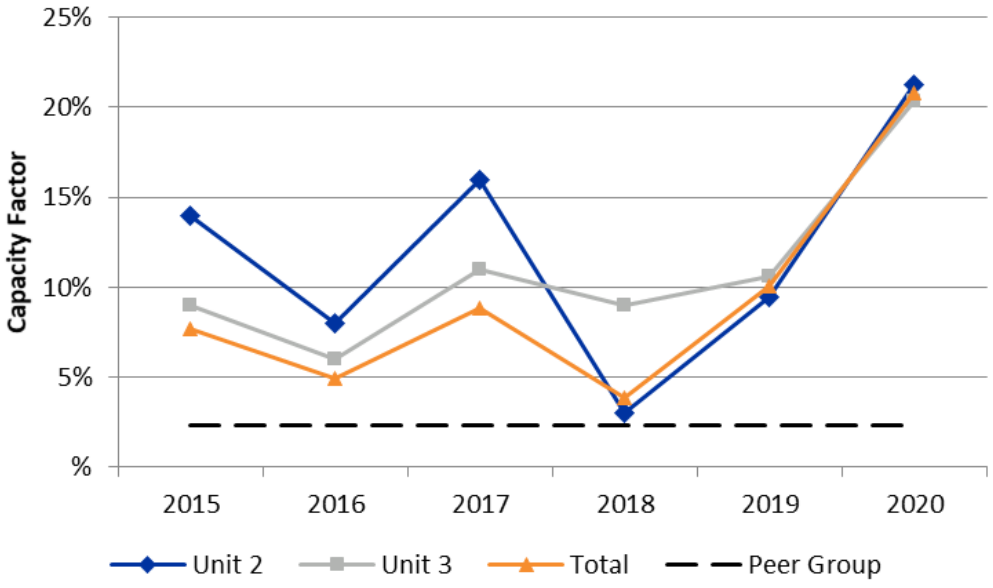
6.4. CAPACITY FACTOR

When reviewing availability and forced outage value changes, 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

The capacity factors for the Cambalache units has been increasing since 2018, when it reached a low of 3.9%. In the aftermath of Hurricane Maria in 2017, demand on the Island decreased; however, the increased usage in recent years shows an increase in demand. Additionally, while still being dispatched for peaking needs, the Plant is used on a more frequent basis than other similar units that are fired infrequently and only as peakers.

Figure 6-4 — Cambalache Capacity Factors



Unit 1 is included in the Plant total average until 2019.

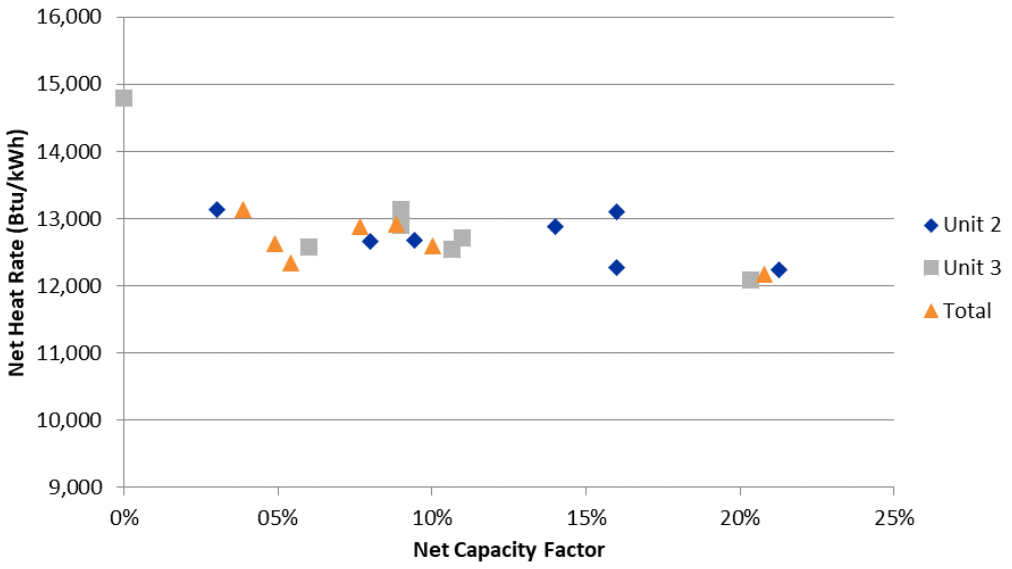
6.5. NET HEAT RATE

The heat rate is the amount of energy used by an electrical generator or power plant to generate 1 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 the 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.

Cambalache's heat rates are on the lower end of PREPA's peaking generation fleet; however, they are in a typical range for GT peaking units. The heat rates for Units 2 and 3 are similar and decrease, as expected, as their capacity factor increases. A limitation on fuel flow imposed by the plant's EPA Title V permit forces these units to operate at approximately 5 MW below their rated capacities, which is also deleterious to the operating heat rates. The heat rates for Units 2 and 3 and the average are shown in Figure 6-5.

Figure 6-5 — Cambalache Units – Heat Rate vs. Capacity Factor



7. FINANCIAL REVIEW

Sargent & Lundy compiled the historical O&M costs and capital expenditures (CAPEX) for Cambalache from reported PREPA data and fiscal plan forecasts for Fiscal Years (FY) 2015–2020.

Cost data for Cambalache 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 capital costs were obtained from the following data files and reports:

- *725 OPER-CONST by Resp 2008-2020.xlsx*
- *Generation O&M by RESP.xlsx*
- *IRP2019 - Main Report REV2 06072019 (002).pdf*

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

7.1. FIXED AND 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 Cambalache are aggregated.

Additionally, the costs for the three Cambalache GT units (each having a nominal capacity of 83 MW for 165 MW total when considering only Units 2 and 3) are combined across all units (“Account 305”). The head office costs for Cambalache (“Account 315”) are combined with head office costs for the Mayagüez TWINPAC aero-derivative turbine units (200-MW nominal capacity), the Culebra diesel plant (2-MW nominal capacity), and the hydroelectric units (59-MW nominal capacity).[9]

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

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

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

Cambalache (165MW) Historical O&M Costs ($)	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Operating Labor						
315 - Jefe de Central Hidro Gas	$ 2,579,709.60	$ 2,330,278.05	$ 2,214,551.55	$ 936,894.06	$ 1,101,324.03	$ 1,524,283.72
305 - Jefe Central - Cambalache	$ 3,276,382.80	$ 3,301,175.93	$ 2,738,643.74	$ 2,425,888.06	$ 2,139,366.65	$ 2,637,047.80
Operating Non-Labor						
315 - Jefe de Central Hidro Gas	$ 763,795.68	$ 635,733.47	$ 562,770.74	$ 256,869.04	$ 503,778.79	$ 678,977.35
305 - Jefe Central - Cambalache	$ 638,101.70	$ 821,346.75	$ 990,695.35	$ 720,857.91	$ 676,048.14	$ 1,345,344.08
Total O&M Costs ($)	$ 7,257,990	$ 7,088,534	$ 6,506,661	$ 4,340,509	$ 4,420,518	$ 6,185,653

FY = July 1–June 30
Costs are normalized, excluding Unit 1, which has been out of service since September 2011.

The aggregated O&M costs correspond to the fixed and variable components estimated by PREPA in the integrated resource plan of 2018–2019.[10] Table 7-2 summarizes PREPA's estimate of the fixed O&M ($/kW-year) and variable O&M ($/MWh) costs for the Cambalache 82.5-MW GT turbine units. Sargent & Lundy compared these values with O&M costs for existing units in operation in North America of similar configurations and operating profiles and determined that the Cambalache O&M costs are within the typical range of costs for similar units considering that higher O&M expenditures are required for plants firing No. 2 fuel oil as compared to natural gas.

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

	Cambalache Units 2–3 (165 MW)
Fixed O&M (2015 $)	$24.44/kW-year
Variable O&M (2015 $)	$5.52/MWh

7.2. CAPITAL EXPENDITURES

Historical CAPEX reported by PREPA for Cambalache 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.[11] From the data, Sargent & Lundy determined that the annual CAPEX for Cambalache are within the typical range of costs for similar units, considering that higher expenditures are required for plants firing No. 2 fuel oil as compared to natural gas.

[10] "Puerto Rico Integrated Resource Plan 2018-2019 – Draft for the Review of the Puerto Rico Energy Bureau," *IRP2019 - Main Report REV2 06072019 (002).pdf*, June 2019.
[11] "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 — Cambalache Historical CAPEX (FY 2015–FY 2020)

Cambalache (165MW) Historical CAPEX ($)	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Construction/Maintenance Labor						
315 - Jefe de Central Hidro Gas	$ 111,335.31	$ 15.08	$ -	$ -	$ 439,649.43	$ -
305 - Jefe Central - Cambalache	$ -	$ -	$ (353.88)	$ -	$ 793,659.66	$ -
Construction/Maintenance Non-Labor						
315 - Jefe de Central Hidro Gas	$ 3,942,172.81	$ 1,835,821.61	$ 9,506,967.73	$ 3,756,882.09	$ 25,919,886.82	$ 6,631,487.48
305 - Jefe Central - Cambalache	$ 4,714,273.78	$ 2,612,886.70	$ 3,347,495.28	$ 8,895,535.25	$ 1,736,103.50	$ 8,246,238.74
Total CAPEX ($)	$ 8,767,782	$ 4,448,723	$ 12,854,109	$ 12,652,417	$ 28,889,299	$ 14,877,726

8. ENVIRONMENTAL AND REGULATORY

This section describes some of the major environmental requirements that currently apply to Cambalache 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 Cambalache.

Cambalache 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, most major environmental permits for the Cambalache facility are in the process of being renewed or expired.

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

Permit/Approval Description	ID Number	Permit Expiration Date
Title V Operating Permit	PFE-TV-4911-07-0897-0043	May 31, 2010 (renewal application submitted on May 29, 2009)
Industrial Discharge Permit	GDA-99-201-057	August 31, 2021
Operation Permit for Used Water Treatment Systems	C-AG 96-07-0008	December 31, 2021 (permit renewed on February 14, 2020)
Resource Conservation Recovery Act – Industrial and Hazardous Waste	PRD000007211	N/A
Franchise for the Use of Waters of Puerto Rico	R-FA-FAID6-SJ-00243-20092016	N/A

Sargent & Lundy reviewed environmental compliance information provided by PREPA and information obtained from the EPA's ECHO[12] 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 Cambalache Title V Operating Permit includes emission limits and monitoring, recordkeeping, and reporting requirements for Cambalache. The facility's most recent permit was issued on May 31, 2005 and expired on May 31, 2010. 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 May 29, 2009, and additional information was submitted to EQB on

[12] Enforcement and Compliance History Online

December 13, 2013. In addition, it is PREPA's understanding that no confirmation of the application shield was received from the Puerto Rico Department of Natural and Environmental Resources (PRDNER).

The emission units regulated under the Title V operating permit include the following:

- Three oil-fired combustion turbines with a capacity of 847 MMBtu/h[13] each
- Two emergency diesel generators at 1500 kW each for a total of 3000 kW
- Three 4.2 MM-gallon No. 2 fuel storage tanks

In 1995, a PSD permit was issued by the EPA approving Cambalache. The permit was subsequently revised on December 5, 1996 and July 5, 2006. The facility produces electricity from three ABB GT 11 N distillate oil-fired combustion turbines, each with a power output of 83 MW. Each combustion turbine consists of a compressor, combustor, and turbine. Energy is generated at each of the combustion turbines by drawing in ambient air with the compressor, heating the air by means of burning fuel oil and expanding the hot combustion gases in a five-stage turbine. Each combustion turbine burns No. 2 fuel oil having a maximum sulfur content of 0.15% by weight. In addition, the facility is allowed to operate in a spinning reserve mode (60% load) for up to 6000 hours/ for 365 days for the entire powerplant. The combustion turbines are required to meet the limits included in Table 8-2:

Table 8-2 — PSD Emissions Limits

Pollutant	PSD Significant Emission Rate (tons/year)	Projected Facility Emission Rate (tons/year)
CO	100	713
VOC	40	180
NO_X	40	1,801
SO_2	40	1,800
H_2SO_4	7	420
PM	25	263
PM_{10}	15	670

The facility is required to retain all required monitoring and supporting information for a period of five years. Recordkeeping and reporting requirements include the following:

- Semiannual monitoring reports/sampling
- Deviations due to emergencies

[13] Million British thermal units per hour

- Deviation reporting for hazardous air pollutants
- Annual emissions reports
- Annual Title V compliance certification
- Monthly or quarterly reports to provide fuel consumption and fuel sulfur content

8.2. 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 2015–2019 show that the Cambalache's facility-wide emissions have been well below allowable levels (see Table 8-3).

Table 8-3 — Cambalache Power Plant Annual Emissions

Pollutant	Allowable Emissions (tons/year)	Actual Emissions (tons/year)				
		2015	2016	2017	2018	2019
PM_{10}	670	114.28	68.54	79.97	68.86	99.17
SO_x	1800	307.00	184.12	214.82	184.99	266.39
NO_X	1801	143.20	84.92	182.01	152.46	10.28
Volatile Organic Compounds	180	27.63	16.62	18.02	16.44	23.92
CO	713	11.07	7.94	31.74	27.62	1.57
Pb	0.30	0.05	0.03	0.03	0.03	0.04

PM = particulate matter | SO_x = sulfur oxides | NO_X = nitrogen oxides | CO = carbon monoxide | Pb = lead

The ECHO database does not identify any violations or enforcement actions with regard to air emissions.

Sargent & Lundy reviewed annual Title V compliance certifications for the 2015–2019. During these years, there were no reported deviations from the facility's Title V permit. 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 semiannual monitoring reports for January 2017 to June 2017, July 2017 to December 2017, January 2018 to June 2018, July 2018 to December 2018, January 2019 to June 2019,

and July 2019 to December 2019. Sargent & Lundy was not provided semiannual reports for any other periods. Semiannual monitoring reports for all periods reviewed did not identify any deviations.

8.3. ONE-HOUR SO2 NAAQS

The Clean Air Act requires the EPA to establish the 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 the EPA to be protective of public health and welfare, and the 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 Cambalache site is located in the Municipality of Arecibo, which is currently designated as an attainment area for the one-hour SO_2 NAAQS.

8.4. WATER AND WASTEWATER DISCHARGE

According to PREPA, Cambalache does not have an NPDES[14] permit; however, it does have an industrial discharge permit and an operation permit for used water treatment systems.

The industrial discharge permit is associated with Permit Number GDA-99-201-057. The permit became effective on September 1, 2016 and expires August 31, 2021. Under the industrial discharge permit, Cambalache is permitted to discharge wastewater into regional waste water treatment plant (PRTAR) of Arecibo.

The operation permit for used water treatment systems is associated with Permit Number C-AG 96-07-0008. This permit became effective on February 14, 2020 and expires on December 31, 2021. Under the operation permit, Cambalache is permitted to operate a pretreatment system of used water without discharge to surface water.

8.5. 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 the impingement and entrainment of fish and other aquatic organisms at cooling-water intake structures used by certain existing power generation and manufacturing facilities.

[14] National Pollution Discharge Elimination System

According to PREPA, Cambalache does not have an NPDES permit. Based on this information, the facility is not subject to 316(b); therefore, cooling-water intake structure requirements do not apply.

8.6. EMERGENCY PLANNING REPORTING

The Emergency Planning and Community Right to Know Act (EPCRA) provides national public disclosure of emergency information to protect the public from chemical emergencies and dangers. EPCRA Section 312 (40 CFR[15] 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 prepare and submit a toxic-release inventory (TRI) to federal and state agencies. Applicable reports are submitted to the environmental division of PREPA based on the reportable periods.

Sargent & Lundy was provided with a Tier 2 report for the reporting period from January 2017 to December 2017 prepared for Cambalache and submitted in 2018; based on a review, 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. The ECHO database does not identify any violations or enforcement actions with regard to TRI violations.

8.7. OIL STORAGE SPILL PREVENTION

Sargent & Lundy reviewed a copy of Cambalache's spill prevention, control, and countermeasure (SPCC) plan, dated March 2015 and updated December 2015. 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 Cambalache SPCC plan follows the Part 112 requirements and appears complete.

Sargent & Lundy was provided a copy of an SPCC plan inspection report, noting violations associated with an SPCC field inspection performed by the EPA in December 2014. The letter references the following violations: failure to prepare a SPCC plan in accordance with 40 CFR Part 112.7 and failure to implement a SPCC plan in accordance with 40 CFR Part 112.8. The letter also requests an updated schedule for the implementation of necessary changes within 30 days. In a letter dated October 2, 2015, PREPA responded

[15] United States Code of Federal Regulations

to the EPA's violations and provided comments on their course of action. Sargent & Lundy has not independently verified the implementation of these comments. No further correspondence was provided for review.

According to Part 112.5 requirements, the SPCC plan shall be amended when there is a change in the facility design, construction, operation, or maintenance that materially affects its potential for a discharge or once every five years. Sargent & Lundy was not provided a status on the SPCC update from PREPA.

8.8. ENFORCEMENT ACTIONS

The ECHO database does not identify any violations or enforcement actions for Cambalache.

8.9. SUMMARY

Sargent & Lundy performed a limited environmental review of publicly available information and information provided by PREPA to evaluate the compliance status for Cambalache. Based on review of permits and documentation provided by PREPA or publicly available information, major environmental permits for Cambalache are current or are in the process of being renewed. 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.

9. RECOMMENDATIONS AND CONCLUSIONS

Cambalache is in good condition considering its age. The GTs are regularly inspected and maintained under the LTSA with the OEM, and Plant staff employs a robust maintenance program that ensures BOP equipment is monitored, repaired, and replaced as needed. While corrosion is a concern in similar oceanic coastal environments, the visual appearance of much of the Plant's exposed equipment indicates that the staff is appropriately rigorous in their corrosion mitigation efforts. Even so, equipment protected by enclosures has been observed to fare much better in this harsh environment, and it would be beneficial to continue to locate critical components indoors and provide enclosures for new or replaced equipment on site wherever practical. Furthermore, correction of enclosures that have been compromised, like the GT enclosure of Unit 1, should be prioritized to protect equipment inside from the accelerated degradation that will be caused by exposure to the elements.

As with other PREPA facilities, 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 OEM standards for power generation and BOP equipment are not well suited for this type of operating environment. Any new equipment must be configured for the challenging conditions at Cambalache. Failure to make allowances for suitable materials, equipment selection, buildings/enclosures, and other aspects of the facility design to protect the Plant from its operating environment will result in excessive future O&M costs and a shorter design life for any new installation. Suitable design specifications appropriate for this operating environment include: (i) corrosion-resistant material specifications; (ii) appropriate welding selections, including special treatment of all metal seams, stitched connections, and fastenings with sealants, gaskets, and coatings; (iii) protective equipment enclosures; (iv) proper system selections; and (v) marine coatings systems. 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. New operating regimes and other comparisons must be made so that equipment is selected to suit the future direction of the power generation and distribution system planned for Puerto Rico. The final resolution and order of PREB addressing PREPA's proposed integrated resource plan (Case No. CEPR-AP-2018-0001), published in August of 2020, did not issue a retirement date for the Cambalache units; however, the PREB decision did reject most of the plan's proposed improvements or additions to PREPA's fossil fuel generation fleet in favor of adding more renewable generation and battery storage capacity to Puerto Rico's grid infrastructure. It is expected that existing fossil fuel-powered generation facilities with several years of remaining useful life, like Cambalache, will be relied upon to maintain grid

stability throughout this repowering transition, but aging components, like the turbine rotors for GT2 and GT3, may require significant capital investment for continued operability.

PREPA continues to study the need for additional grid support and generation throughout the island. The GT units at Cambalache, with 60% rapid spinning reserve, may be relied upon to provide grid stability until sufficient battery storage has been installed. If PREPA does not move forward with the full recovery of Unit 1, the unit may still be considered as a candidate for repurposing as a synchronous condenser, which would also offer grid stabilization benefits during the repowering period. In either scenario, prioritizing the recovery of the Plant's damaged overhead crane would be beneficial to support these activities.

Other Plant modifications that can sustain or improve unit operation or reliability may be integrated into the design and provide years of future power generation service from the facility.

10. REFERENCES

1. Sargent & Lundy Report TD-0003, “Demarcation of PREPA Generation Assets from the Transmission and Distribution System,” dated October 4, 2019.