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O&M Concession
Independent Engineering Report
Central Hidro Gas Mayagüez Plant

Prepared for

Puerto Rico Electric Power Authority

Report SL-015976.MG

Final

August 31, 2021

Project 14200.001

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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
API	American Petroleum Institute
Btu/kWh	British thermal unit per kilowatt hour
CAPEX	capital expenditures
CFR	United States Code of Federal Regulations
EAF	equivalent availability factor
ECHO	Enforcement and Compliance History Online
EFOR	equivalent forced outage rate
EPA	Environmental Protection Agency (United States)
EPCRA	Emergency Planning and Community Right to Know Act
EQB	Environmental Quality Board (Puerto Rico)
FY	fiscal year
GT	gas turbine
Mayagüez	Central Hidro Gas Mayagüez Plant
NCF	net capacity factor
O&M	operations and maintenance
OEM	original equipment manufacturer
OWS	oil/water separator
P&W	Pratt & Whitney
Phase I ESA	Phase I Environmental Site Assessment
Plant	Central Hidro Gas Mayagüez Plant
PRASA	Puerto Rico Aqueduct and Sewer Authority
PREB	Puerto Rico Energy Bureau
PREPA	Puerto Rico Electric Power Authority
PT	power turbine
RCA	root-cause analysis
REC	recognized environmental condition
SPCC	spill prevention, control and countermeasure

Acronym/Abbreviation	Definition/Clarification
TBC	thermal barrier coating

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 Central Hidro Gas Mayagüez Plant ("Mayagüez" or "Plant").

Mayagüez is located in the El Seco section, Mayagüez, on the western coast of Puerto Rico. At Mayagüez, eight Pratt & Whitney® (P&W) FT8-3 aero-derivative simple-cycle gas turbines went into service between 2008 and 2009 (in Fiscal Year 2009). The gas turbines (GTs) are configured in sets of two driving an electrical generator unit. The four electrical generating units in total have a nameplate capacity of 220 MW. As of April 25, 2021, Units 1A and 1B were out of service and in a forced outage. Additionally, Unit 4A was out of service due to cracks in the combustor area. Their return to service date was pending. The aero-derivative turbines at Mayagüez are part of PREPA's Central Hidro Gas organization.

This technical report includes an assessment of the plant design, operations and maintenance (O&M) activities, plant organization and personnel, technical performance, commercial arrangements and obligations, and provisions for environmental permitting. Sargent & Lundy completed this assessment with information provided from 2018–2020 and site visits performed in 2018 and 2019. The current operating status of the units are provided for reference. Sargent & Lundy understands that this review is being conducted in connection to the request for proposal 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 Mayagüez.

TECHNICAL REVIEW

The GT generators at Mayagüez are arranged in a TWINPAC™ configuration with two aero-derivative gas generators, each driving a free power turbine (PT), which are each direct-coupled to a single generator from opposite ends. The term "twin pack" or TWINPAC™ is a P&W term that describes two PTs connected to a single generator that includes a central shaft coupled and driven from both ends. The GTs are manufactured by P&W and were installed between 2008 and 2009. Each of the four TWINPACs has two PTs rated at 27.5 MW that are both coupled to a single 55-MW generator. Individually, the turbine units themselves are called SWIFTPAC® by the original equipment manufacturer (OEM) in reference to their drop-in-place arrangement that is easily installed and connected. 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.

EQUIPMENT CONDITION

The typical design life of a GT generator-based power plant is approximately 30 years when following the OEM's recommendations for operation and periodic maintenance. As of 2018, the GTs have accumulated 5500–8500 fired hours. Like many of PREPA's power generation plants, Mayagüez is exposed to the challenges of a coastal marine environment. The units at Mayagüez have weathered the operating conditions fairly well, and it is noted that the staff is diligent in maintaining the equipment.

Some signs of premature wear are evident, such as the recent replacement of all GT unit air compressor systems that had no enclosures and were not suitably configured for the operating conditions. Many of the GT air intake systems have permitted the ingress of salt fines through the combustion air filter and into the compressor sections of the GT as evident in the GT borescope reports. On the hot side of the turbines, some thermal barrier coating losses have been noted at the first-stage, high-pressure turbine blades across multiple units. A service bulletin from the OEM directs the use of more robust intake filtration for units serving in coastal environments like that of Mayagüez, and the Plant has implemented the prescribed resolution.

Issues with turbine blade degradation have forced outages for several units in recent years, but these issues have since been resolved with repairs performed at the OEM's shop in the mainland U.S., and the improved intake filters installed for the GT combustors should mitigate future blade degradation and other turbine wear issues.

The generator bearings for Units 2A, 2B, 4A, and 4B incurred damage during the January 7, 2020 earthquake that struck the island. Plant staff notes that repairs to these bearings have since been completed and that the affected units are back in service.

Of the eight turbine units, three were listed as unavailable as of the April 25, 2021 dispatch report. Units 1A and 1B went into a forced outage in September 2020 and underwent a combustion inspection while Unit 4A has been offline since late April 2021 with reported cracking in the combustor area. The offline units are undergoing the necessary inspections and repairs, but their return to service date has not yet been forecasted. With diligent monitoring, planned maintenance activities, and some corrective measures at the Plant, future turbine blade degradation issues can be mitigated, and the Plant can be expected to reach its full design life.

INFRASTRUCTURE AND INTERCONNECTIONS

The present-day Mayagüez facility consists of a suitable administration building that was remodeled and upgraded from the original plant installation in the 1950s. The building houses the main electrical rooms and control rooms as well as the water treatment plant for the site. An overhead crane from the original turbine house is available for maintenance activities in the demineralization plant. The main building also houses several maintenance bays and workshop areas. A separate warehouse is adjacent to the switchyard.

Currently, there is no natural gas supply for the facility, and the turbines are fired on No. 2 fuel oil; however, each gas turbine is provided with an OEM-designed fuel gas regulator valve skid. The external gas supply and regulation skids are currently blanked off at their supply point to the turbine, but the equipment could deliver natural gas to the turbines if gas were available at the site. Gas manifolds and other gas control equipment inside the turbine enclosure would still need to be adjusted. Gas supply piping and distribution piping inside the Plant are currently not in place.

Water for the Plant is from municipal supply from Puerto Rico Aqueduct and Sewer Authority (PRASA). Water is provided for multiple uses on site: potable water (including safety showers and eyewash stations), fire protection, and water for the water treatment/demineralizer system that is used for water injection for NO_X control. Water from the municipality is called the “raw water system.”

All water waste and sanitary streams, with the exception of the GT generator drains, are discharged to the PRASA system. The discharge is facilitated through a lift station. Water discharge is monitored for pH and contains a flow meter to monitor the overall flow from the Plant. Wastewater subject to oil contamination is processed through two separate oil-water separators (one on the either side of the facility), and the clean effluent is then delivered to the lift station for return to PRASA.

OPERATIONS & MAINTENANCE

The Plant was designed to be a fast-response power generating plant available as needed to provide peak power assistance to the base-loaded plants. The Plant is dispatched according to grid demands. It is manned during the day, typically responding to the grid peaking needs as required by dispatch control. For operation outside of the typical daytime hours, the staff plans accordingly to provide support during evening and night hours.

Each PREPA plant is mandated to perform an environmental outage at intervals of 12–18 months. During an environmental outage, the components are cleaned to meet the requirements of the air compliance preventative maintenance schedule contained in PREPA’s consent decree with the EPA. Each plant may

keep a unit in service for up to an 18-month limit, subject to the unit's compliance with the emissions criteria in the consent decree.

Corrective maintenance is primarily conducted on an as-needed basis. Due to the low dispatch of the units, corrective maintenance for redundant systems can be done online or as required when the unit is not dispatched. There are no service agreements with the OEM, and a site-monitored predictive maintenance program is used for the GTs. There is no formal program or process to track GT generator service bulletins (i.e., log the receipt of service bulletin and note applicability with priority, action required, responsible engineer or department, action taken, findings, and closure date). Plant staff noted that they are performing an audit of P&W combustion turbine service bulletins and technical alerts to identify and prioritize maintenance, but it is recommended that additional effort be given to obtain, disposition, and monitor these OEM notices as they are issued.

PERFORMANCE REVIEW

Sargent & Lundy reviewed Mayagüez's operational data from 2015 through 2020 as provided by PREPA, which is indicative of peaking units that are cycled and not base loaded. Generation data for the plants trended lower prior to the 2017 hurricanes. After the hurricanes, the Mayagüez facility was used as the black-start system for the south coast power plants and continued to generate power through the island's restoration efforts. The Plant has been providing additional generation due to the outage experienced at Costa Sur from the January 2020 earthquakes.

Prior to 2020, the limited use shows a low net capacity factor. The availability factor continued to be low throughout the past six years, and it is an indication that the noted turbine blade problems have driven usage lower as PREPA and the OEM resolve blade degradation and coating issues. It is Sargent & Lundy's opinion that these issues are a combination of fuel contamination and OEM coating design. The heat rates for the GTs are competitive and in the lower range (more efficient) for units of similar design and fuel type.

FINANCIAL REVIEW

Sargent & Lundy compiled the historical O&M and capital expenditures (CAPEX) for Mayagüez from reported PREPA data and fiscal plan forecasts, calculated fixed and variable O&M expenses, and compared these values with O&M and CAPEX for existing units in operation in North America of similar configurations and operating profiles. From the data, Sargent & Lundy determined that the Mayagüez 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 determine the compliance status for Mayagüez. Sargent & Lundy did not find any enforcement actions or compliance-related issues that would prevent renewal of the existing permits or impact near-term operation of the facility.

RECOMMENDATIONS AND CONCLUSIONS

The facility and generation units at Mayagüez are one of the newest in PREPA's power generation fleet. Sargent & Lundy found the site to be clean and well maintained. A recent overhaul of the turbine rotors at the OEM's facilities, along with improvements to the combustion air intake filters, is expected to extend the life of these units and reduce the turbine wear issues that have beleaguered the facility to date. To bring the issue to closure, Sargent & Lundy recommends that an independent third party conduct a full root-cause analysis (RCA) and provide conclusions and recommendations for PREPA and the OEM. The cost of these resolutions, including those already implemented, may be apportioned to each party, if claims are warranted, in accordance with each party's responsibility. Matters such as salt ingestion, fuel quality, suitability of the original design for purpose, subcontracted equipment and construction quality, OEM service bulletins, and similar matters are all aspects that may be evaluated as part of the RCA.

Mayagüez is a valuable asset to PREPA's generation fleet. Given the equipment's SWIFTPAC design, one should note that one, two, three, or all four TWINPAC units could easily be removed and quickly used as black-start units at any of the southern-coast or San Juan area power plant locations. The units are designed for fast startup, expected to be operable for many years, and can easily be redeployed as necessary to support black-start and peaking requirements at most of the PREPA power plants. Each unit is also capable of synchronous operation for power factor improvement. They are dual fuel (after installation of a fuel manifold) and may easily be redeployed at the Costa Sur Steam Plant or San Juan Power Plant to take advantage of the current and pending natural gas services for peaking and/or black-start duties; furthermore, there are four TWINPAC units, so it is possible to rapidly improve up to four existing locations with equipment that has a relatively low capacity factor; however, there are no existing plans for redeployment at other sites.

Mayagüez is in relatively good condition, but 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 balance-of-plant equipment are not well-suited for this type of operating environment. Any new equipment must be configured for the challenging conditions at Mayagüez. 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) use of 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. A summary of the Puerto Rico Energy Bureau's (PREB's) final resolution and order addressing PREPA's proposed integrated resource plan (Case No. CEPR-AP-2018-0001) published in August of 2020 indicated that PREB had rejected the plan's energy system management plan to add a new combined-cycle unit to Mayagüez and deliver natural gas supply to the facility.

PREPA continues to evaluate the need for additional grid support and generation throughout the island. Smaller, rapid-start GT equipment, such as those in place at Mayagüez, can be easily adapted to integrate purge credit, battery storage for instantaneous response, and other similar features to provide a quicker response for a future grid that is planned to integrate a larger amount of renewable power. Other Plant modifications that can provide faster starts and address the ongoing issues with coastal salt may all be integrated into the design, and—presuming the turbine blade issues are resolved with the OEM—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 Central Hidro Gas Mayagüez Plant ("Mayagüez" or "Plant").

1.1. PLANT DESCRIPTION

Mayagüez is located in the El Seco section, Mayagüez, on the western coast of Puerto Rico. At Mayagüez, eight Pratt & Whitney® (P&W) FT8-3 aero-derivative simple-cycle gas turbines (GTs) went into service between 2008 and 2009 (in Fiscal Year [FY] 2009). The aero-derivative turbines at Mayagüez are part of PREPA's Central Hidro Gas organization. They are located on Road #3341, Malecón Avenue, El Seco section, Mayagüez, Puerto Rico. The facility is centrally located on the western part of the island near high-demand areas; it is well placed for grid stabilization. Figure 1-1 shows Mayagüez's location on the western coast of Puerto Rico.

Figure 1-1 — Mayagüez Geographic Location

Source: Google Earth

The eight GTs are arranged in four-unit blocks. They are arranged in a TWINPAC™ configuration with two aero-derivative gas generators, each driving a free power turbine (PT); each PT is direct-coupled to a single generator from opposite ends. The term “twin pack” or TWINPAC™ is a P&W term that describes two PTs connected to a single generator that includes a central shaft coupled and driven from both ends. The GTs are manufactured by P&W and were installed between 2008 and 2009. Each of the four TWINPACs has two PTs rated at 27.5 MW; both are coupled to a single 55-MW generator. Individually, the GT units are called SWIFTPAC® by the original equipment manufacturer (OEM) in reference to their drop-in-place arrangement that is easily installed and connected. 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 four units in total have a nameplate capacity of 220 MW. These units replaced four 21-MW GTs that were previously located at the Mayagüez site. As of April 25, 2021, Units 1A and 1B were out of service and in a forced outage since September 2020. Additionally, Unit 4A was recently out of service due to a crack in the combustor area. Their return to service date is pending. The current Plant layout is shown in Figure 1-2.

Figure 1-2 — Mayagüez Overall Plant Layout

Source: Mayagüez Hidro Insurance Summary Presentation

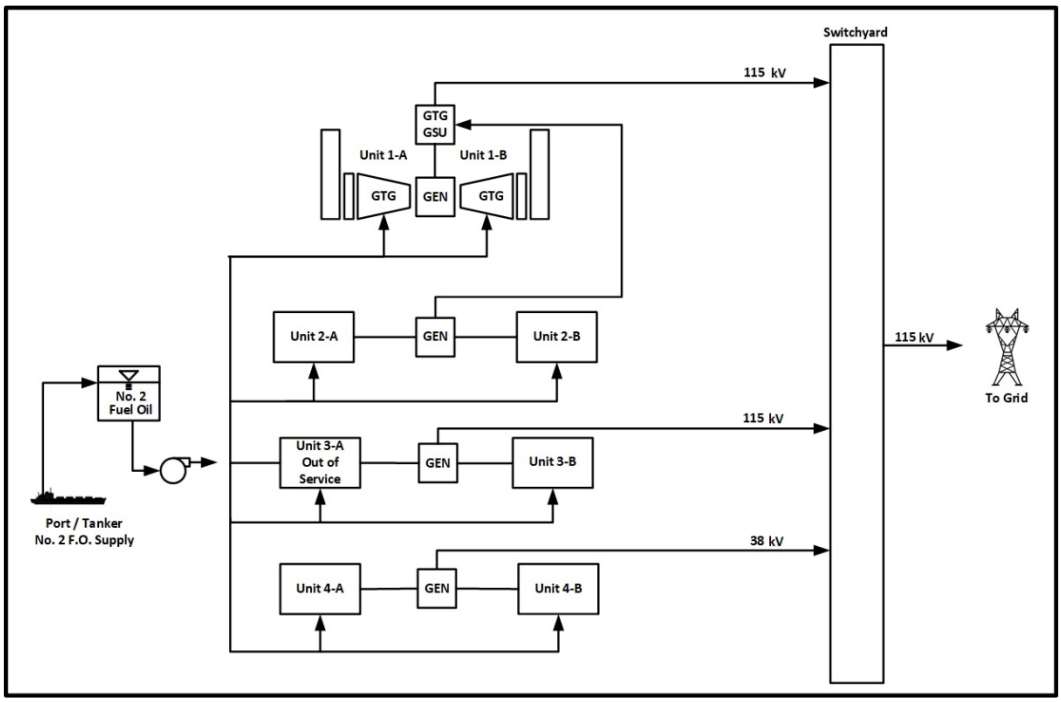
The units currently burn No. 2 fuel oil, but they have the capability of converting to operation on 100% natural gas. With a reserve of 95,000 barrels, the No. 2 fuel oil is stored across four storage tanks on site.

Barge deliveries are taken from the nearby port and pumped to the storage tanks. The Plant uses city water for domestic and service use as well as to produce demineralized water.

The electrical power from the Unit 1 and Unit 2 generators is connected to a 115-kV switchyard through a common step-up transformer. The generator for Unit 3 is connected through a dedicated transformer to the 115-kV switchyard, and the generator for Unit 4 is connected through a dedicated transformer to the 38-kV switchyard.

An overview schematic representation of the Plant is shown in Figure 1-3.

Figure 1-3 — Mayagüez Overall Plant Configuration



1.2. SCOPE OF REVIEW

This technical report includes an assessment of the Plant design, operations and maintenance (O&M) activities, Plant organization and personnel, technical performance, commercial arrangements and obligations, and provisions for environmental permitting. Sargent & Lundy's objective is to provide an overview of the condition of the asset, assess whether the facility has been operated and maintained in accordance with generally accepted industry practices, and identify significant challenges to continued successful operation. Recommendations for demolition, equipment upgrades, or operational improvements are also included within this report. Additionally, Sargent & Lundy performed a Phase I Environmental Site

Assessment (Phase I ESA) in May 2019 with the site visit in December 2018. Refer to Report SL-014468.MG.ESA [1] for the Sargent & Lundy's findings from this Phase I ESA.

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

- Documentation provided by PREPA's corporate operations and Plant personnel 2018 through the end of 2020
- Discussions with Plant personnel on the phone, via email exchange, and during several site visits of the facility 2018 through early 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 proposal 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 Mayagüez.

2. TECHNICAL DESCRIPTION

Mayagüez consists of eight simple-cycle GTs. The total nameplate capacity of the Plant is 220 MW. The characteristics of the generating units at Mayagüez are shown in Table 2-1.

Table 2-1 — Production Plant Overview

Plant Name	COD	Technology	Fuel	Capacity (MW)	Status (As of October 31, 2020*)
Mayagüez GT #1A	2008–2009	GT	Oil No.2	27.5	Non-Operational. Forced outage beginning September 19, 2020. Combustion inspection ongoing, return to service to be determined.
Mayagüez GT #1B	2008–2009	GT	Oil No.2	27.5	Non-Operational. Forced outage beginning September 19, 2020. Combustion inspection ongoing, return to service to be determined.
Mayagüez GT #2A	2008–2009	GT	Oil No.2	27.5	Operational
Mayagüez GT #2B	2008–2009	GT	Oil No.2	27.5	Operational
Mayagüez GT #3A	2008–2009	GT	Oil No.2	27.5	Operational
Mayagüez GT #3B	2008–2009	GT	Oil No.2	27.5	Operational
Mayagüez GT #4A	2008–2009	GT	Oil No.2	27.5	Non-Operational. Forced outage beginning April 19, 2021. Combustion inspection ongoing, return to service to be determined.
Mayagüez GT #4B	2008–2009	GT	Oil No.2	27.5	Operational

1. **Operational**—Functioning and suitable for power generation
2. **Non-Operational**—Out of service temporarily and not generating power

* As of April 25, 2021, Unit 3A has returned to service; Unit 4A is in a forced outage since April 19, 2021 due to a crack in the combustor area.

The modern Mayagüez facility consists of an administration building that houses the main electrical rooms and control rooms as well as the water treatment plant for the site. 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's main building includes: (i) mechanic and instrumentation workshops; (ii) two substations/switchyards at 38 kV and 115 kV; (iii) one demineralization plant; (iv) one emergency plant for unit black start; (v) 480-V load centers; (vi) support systems for fuel and water transfer and storage; and (vii) the following dedicated fire protection equipment and systems: CO_2 systems for generators and turbine

compartments, clean agent (FM-200) systems for the control console area, a foam agent for fuel tanks, and fire hydrants for Plant peripheral areas.

2.1. MECHANICAL SYSTEMS

This section describes the major mechanical equipment and systems in the Plant and their function in the generation of power.

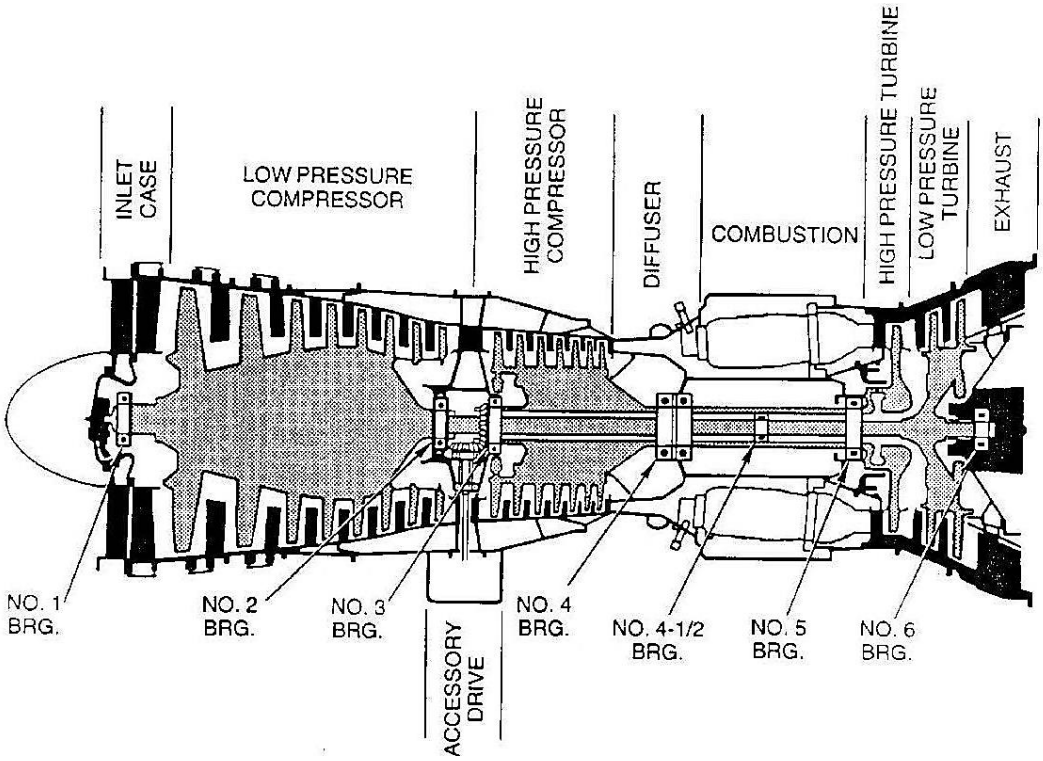
2.1.1. Gas Turbines

As mentioned, there are two FT8-3 GTs per generator. The turbines are designated as Turbine A and Turbine B. All eight gas turbines are of the same aero-dynamic design (noting except that the four A units rotate in one direction while the B units—those installed on the opposing end of common TWINPAC generator—rotate in the opposite direction when looking at the shaft ends of each free PT). The turbine units are each rated for 27.5 MW when firing low sulfur distillate oil No. 2. When two gas turbine units are fired and drive a single generator, the total TWINPAC is rated for a 55-MW electrical output; therefore, the Plant total output is a nominal 220 MW. All the GT generator units are contained within weather enclosures.

The major components of the FT8-3 are two compressor modules (low-pressure and high-pressure compressors), a combustion section, two turbine modules (high-pressure turbine drive and low-pressure turbine drive), and a PT assembly to drive the generator. Combustion air is filtered and drawn into the low-pressure compressor and then further compressed within the high-pressure compressor. The high-pressure air then enters a large plenum consisting of nine fuel nozzles and combustion cans. Most of the air enters the combustion cans through the fuel nozzles and combustion can walls that also cool the combustion chamber walls. A small portion of the air bypasses the combustion cans and is used to cool the GT section. The hot gases pass through the single-stage, high-pressure turbine and the two-stage, low-pressure turbine, which extract energy to drive the two compressor sections. The remainder of the hot gas energy is used for driving the free PT that is directly connected to the generator.

The free PT assembly consists of an annular transition duct connected to the electric generator via flexible coupling and drive shaft. The turbines are factory configured to rotate (either clockwise or counterclockwise) so that the generator shaft can be driven at both ends of the generator. Figure 2-1 illustrates the arrangement of the two-shaft GT coupled to the PT assembly that drives the generator. Figure 2-2 shows photographs of the four TWINPAC units at Mayagüez.

Figure 2-1 — Simplified FT8-3 Cross Section View and Power Turbine Rotor Assembly



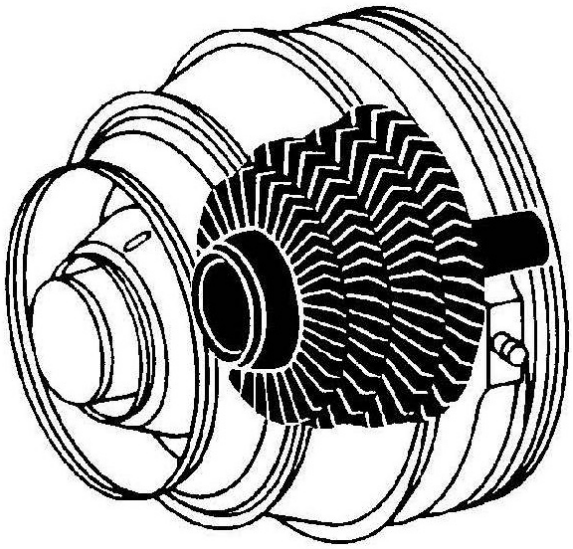


Figure 2-2 — Mayagüez Units 1A/B, 2A/B, 3A/B, and 4A/B

Unit 1A/B

Unit 2A/B

Unit 3A/B

Unit 4A/B

Figure 2-3 shows the fuel oil and gas skids. The gas turbines were supplied with combustors, which are dual-fuel capable. There are a few fuel gas train components in the enclosures that would need to be reinstalled to fire fuel gas, but the conversion to natural gas is not planned at this time. Water injection would still be required for nitrogen oxide control if the units were converted to firing natural gas.

Figure 2-3 — Fuel Oil Skid (Connected) and Gas Skid (Not Connected; Future Use)

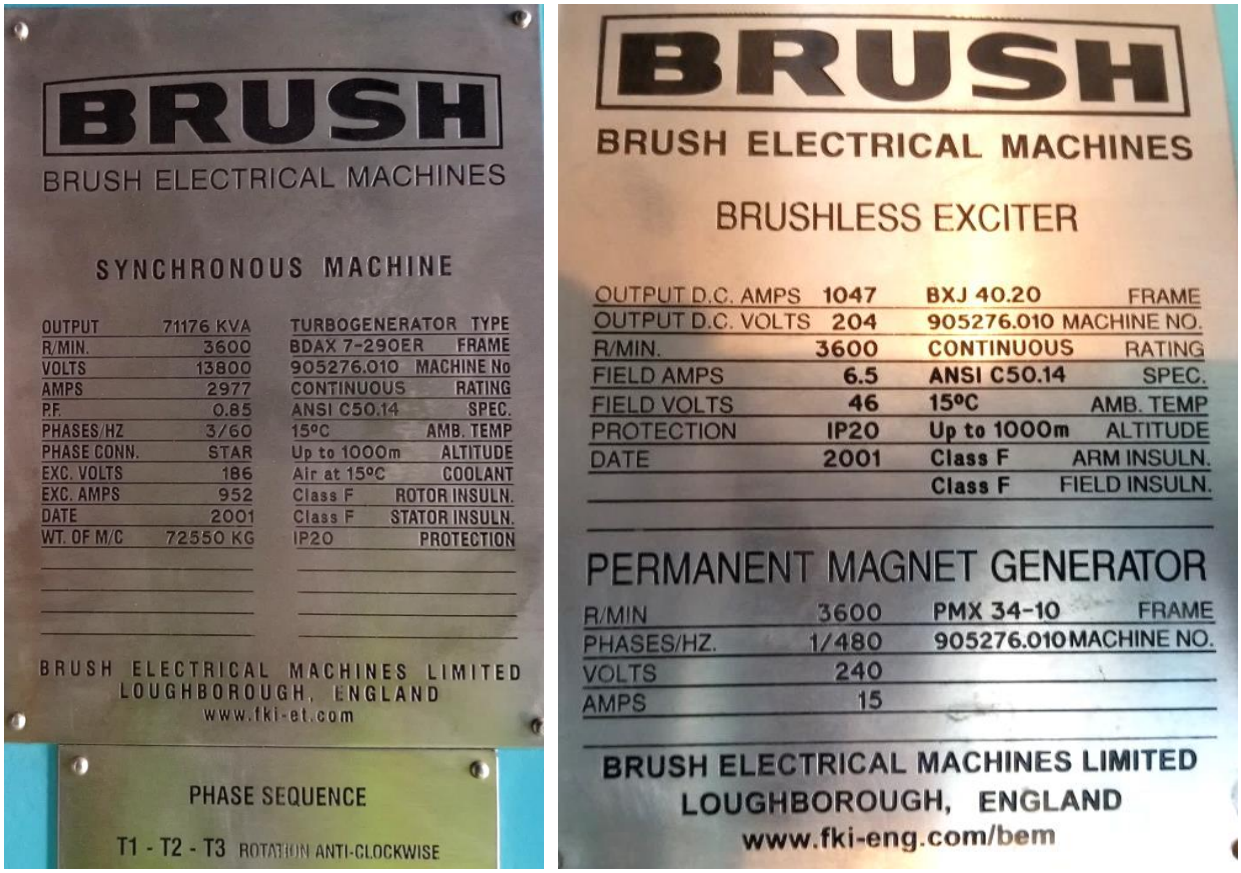
The original air compressors (Figure 2-4) were incorrectly sized and not configured for the marine operating environment; they have since been replaced for additional capacity and weather hardening. The Plant staff notes that all units have new compressors as of May 2019.

Figure 2-4 — Air Compressor (Typical) with Nameplate

2.1.2. Generators

All four generators are Brush BDAX 7-290 ER units, rated 71.176 MVA, 60.5 MW, 0.85 power factor, 13.8 kV, 60 Hz. They are the original generators from when the station was first built in 2008 and 2009.

Figure 2-5 — Generator and Exciter Nameplates (Typical of Four Units)



2.1.3. Water Systems

2.1.3.1. Water Treatment

The operation of the Mayagüez P&W GT generator units requires using water 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 water treating system at Mayagüez produces demineralized water per OEM requirements. The high-purity water leaves little or no traces of residue after it is injected into the gas turbine and vaporizes in the process.

The Plant's demineralized water production system has a rated capacity of 280 gallons per minute and uses a raw water supply stream of 366 gallons per minute to produce this high-quality water product. The

water treating system rejects suspended and dissolved solids out of the raw water stream, and this water is returned to the sewer lift station system. The demineralized water production rate is high enough to provide supply to each of the four TWINPAC units when running and provides extra capacity for demineralized water tank storage. Water quality from the equipment meets the required manufacturer limits for conductivity, silica, and sodium.

Figure 2-6 — Water Treatment System

The water treatment system consists of four main stages: the multimedia filtration system, pretreatment system (anti-scalant system and cartridge filters), reverse osmosis system, and electrodeionization module. Each stage accomplishes the following:

- **Multimedia Filtration System:** Reduces the raw water turbidity and removes suspended solids, chlorine, and organics (carbon)
- **Pretreatment System:** Adds anti-scalant chemicals and removes particulate matter from the raw water
- **Reverse Osmosis System:** Removes ionic impurities, turbidity, and organic carbon from water
- **Electrodeionization Module:** Removes dissolved ions and total organic carbon from water

After treatment, the water is stored in the demineralized water tank for the distribution system. The system equipment skid consists of manually operated suction and return isolation valves and two 100% Plant capacity pumps. The forwarding system draws water from one 491,000-gallon demineralized water storage tank that is located on site. This tank supplies water for nitrogen oxide water injection and water wash.

2.1.3.2. Raw Water Supply

Water is provided from the municipality (PRASA) for multiple uses on site: potable water (including safety showers and eyewash stations), fire protection, and water for the water treatment/demineralizer system. The water from the municipality is called the “raw water system.”

Raw water is supplied from the street connection to a header where it branches out to the users. Water for the demineralizer systems is typically fed from the raw-water tank. If the tank is out of service, feedwater to the demineralized water system can also be provided directly from the street connection. Demineralized water is forwarded to the 500,000-gallon deionized water tank. During GT operation, the deionized water is forwarded to the GT units to supply the water injection pump skid at each GT (two per unit). The forwarding skids contain two redundant pumps and manual valves.

2.1.4. Fuel Systems

The fuel currently used at Mayagüez is No. 2 (light oil/diesel). The system consists of storage tanks, pumps, piping, and associated valves to transfer No. 2 oil from the storage tank located approximately 200 meters northwest of the facility to the fuel oil service tanks at the main facility.

There are four storage and service capacities available:

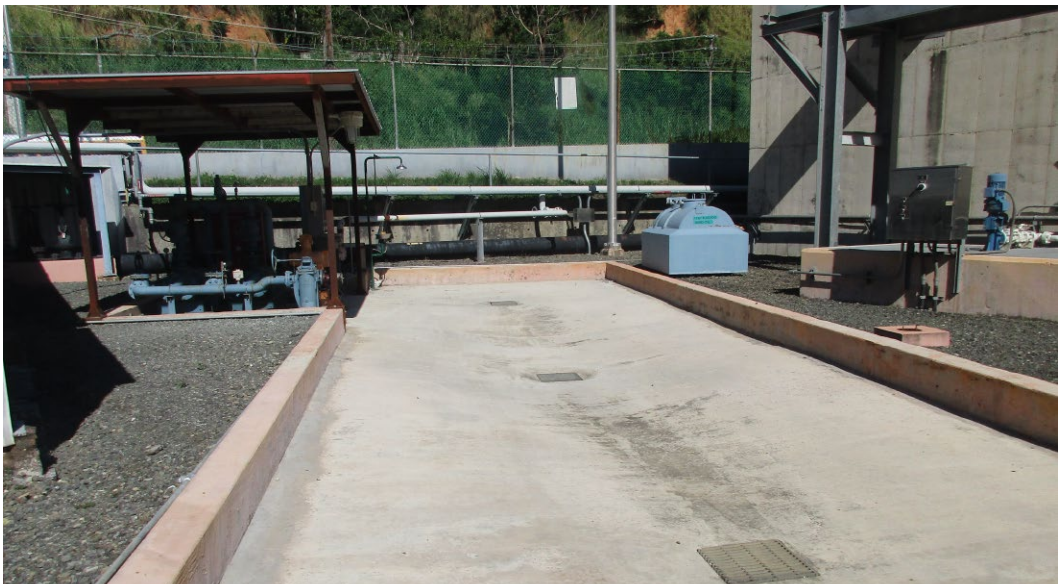
- **Tank #1**—Diesel reserve tank: 80,000 barrels capacity (Figure 2-7)
- **Tank #2**—Diesel service tank: 5,500 barrels capacity
- **Tank #3**—Diesel service tank: 7,600 barrels capacity
- **Tank #4**—Diesel service tank: 11,900 barrels capacity

Fuel is primarily received from the transfer station located at Mayagüez Port. The fuel is pumped from a docked tanker at the transfer station at Mayagüez Port to any of the four fuel oil storage tanks. From there, it can be pumped or (from Tank #1) gravity-fed to the respective service tanks.

Figure 2-7 — Tank #1 – 80,000 Barrel Capacity

Alternatively, if required, fuel can also be trucked into the site at the truck unloading station, which is located adjacent to Tank #3 and east of Unit 4. The truck connection allows fuel receipt at Tanks #2, #3, and #4.

Figure 2-8 — Fuel Oil Truck Fill Station



Tanks #2 and #3 each have forwarding pump skids and recirculation lines to accommodate fuel supply to the respective units. Tank #2 supplies Units 1A, 1B, 2A, and 2B, and Tank #3 supplies Units 3A, 3B, 4A, and 4B. The skid suction lines can be cross connected for additional operational flexibility. Each liquid fuel forwarding system is designed to provide fuel oil to support continuous operation of two TWINPAC units, or four total GT generators.

Figure 2-9 — Fuel Oil Tank #2, and Fuel Forwarding Skid to Unit 1A/B and Unit 2A/B

The GT generators are fired on fuel oil using water injection to assist with meeting emissions requirements for the Plant. The units are also designed and configured to accept gaseous fuel (also with water injection). The units are provided with local fuel gas control valve stations with supply pipes blanked. A component of the 2019 integrated resource plan's energy system modernization plan included the addition of a ship-based liquid natural gas terminal at Mayagüez to support the conversion of the units to fire natural gas instead of No. 2 fuel oil. This was, however, rejected by the Puerto Rico Energy Bureau (PREB), and the conversion of these units to natural gas is no longer anticipated.

Figure 2-10 — Fuel Forwarding Skid to Unit 1A/B and Unit 2A/B

Fuel oil transfer is primarily a manual operation. Fuel is delivered to fuel oil storage tanks that are not in operation. Once the online tank is low, pumps and valves are manually actuated and controlled to perform the fuel tank changeover. The forwarding pumps and ancillary equipment are integrated into and controlled by the balance-of-plant Allen Bradley control system located in the control building. The pumps can be controlled, and operational data displayed, on any of the four GT human-machine interface monitors located in each of the four GT control rooms as well as the remote human-machine interface located in the control building.

2.1.5. Fire Protection

Fire protection for the facility consists of two dedicated systems: gas systems—including CO_2 for generators and turbine compartments and FM-200 for the control console area—and water-based systems—including a foam agent for fuel tanks and fire hydrants for Plant peripheral areas.

2.1.5.1. Gas Suppression Fire Protection Systems

The OEM provided the CO_2 systems for the GT units. The bottles are located adjacent to each unit and are properly shaded within enclosures to shield the bottles from direct sunlight; in the event of fire, the CO_2 gas

floods the turbine enclosures (along with automatic shutoff of ventilation fans and closure of louvers) to provide an inert environment for extinguishing a fire hazard. FM-200 is provided in the dedicated control room for each unit. The Chemetron fire system holds 200 pounds of FM-200 fire suppressant. Traditionally, CO_2 has been used for areas of industrial facilities that are ordinarily unoccupied due to the risk associated with inadvertent discharge and suffocation. FM-200 is often used for occupied areas of plants and does not pose the same risk of suffocation to staff as CO_2. FM-200 also provides a better means to extinguish fires within sensitive control rooms versus wet sprinkler systems that would likely destroy most of the equipment contained within the room. As with any fire protection system, routine tests and certifications must be completed on a regular basis to ensure that the system is charged with suppressant and in working order.

Figure 2-11 — Gas Suppression Bottle FM-200 Fire Protection System

Figure 2-12 — Gas Suppression Bottles for the GT Fire Protection System

2.1.5.2. Water/Foam Fire Protection Systems

Water for the fire protection on site is provided through the diesel-driven pump. The diesel fire pump is in an enclosure adjacent to the raw-water tank. As a backup, water can be piped directly from the municipality. Water is supplied directly to the foam systems for fuel oil firefighting and to the 1.5-inch hose connection yard hydrants for manned firefighting operations.

Figure 2-13 — Foam Delivery Fire Protection System

Fire protection for the fuel oil tanks is provided by a foam system. The system is manually operated using a diesel-driven fire pump to provide the foam to one of the three fuel tanks (Tanks #2, #3, and #4) at the site as required.

2.2. ELECTRICAL SYSTEMS

2.2.1. Conceptual Design

Each of the four GT units at the plant has the same package design. The generators produce power at 13.8 kV and are connected to their respective 13.8-kV switchgear bus and the main power step-up transformer via generator circuit breaker. The switchgear buses for all of the packages are independent, and each feeds all electrical loads specific to the respective GT generator with no backup from other unit packages. The 13.8-kV bus is backed up by the emergency switchgear.

Each unit package includes a low-voltage auxiliary transformer that steps down the 13.8-kV generation voltage to the power consumption voltage of 480 V. This transformer feeds a dedicated motor control center, which in turn feeds all the GT auxiliary loads.

Balance-of-plant loads are fed from a 480-V double-ended switchgear lineup and two motor control centers. The switchgear has redundant incoming feeds: one from the switchgear of GT Unit 1 and the other from the switchgear of GT Unit 3.

There is also a 480-V emergency switchgear bus that derives power directly from the 38-kV substation through a step-down transformer and delivers it to any or all of the motor control centers at the station.

2.2.2. Switchyard and Interconnection

The 115-kV and 38-kV switchyards are located in the center of the Plant. The main power transformers are connected to the switchyard with underground feeder cables; Units 1–3 are connected to the 115-kV switchyard while Unit 4 is connected to the 38-kV switchyard.

Each GT of Units 1 and 2 is independently connected to a dedicated winding of a three winding step-up transformer via bus duct. The transformer is oil-filled, 90/120/150 MVA, OA/FA/FA,[1] 115 kV–13.8 kV. It is connected via underground cable to the 115-kV substation.

GT Unit 3 delivers its power via bus duct to a dedicated two-winding step-up oil-filled transformer. The transformer is rated 50/66.6/83.3 MVA, OA/FA/FA, 115 kV–13.8 kV. It is connected via underground cable to the 115-kV substation.

GT Unit 4 delivers its power via bus duct to a dedicated two-winding step-up oil-filled transformer. The transformer is rated 50/66.6/83.3 MVA, OA/FA/FA, 38 kV–13.8 kV. It is connected via underground cable to the 115-kV substation.

The revenue metering presently uses the current transformers and potential transformers located on the generator side of the main power transformer.

Currently, the demarcation points (Plant responsibility versus transmission responsibility) of the Plant's units are considered to be at the low-side termination of the main power transformers and the emergency station service transformers due to the division of responsibility on the maintenance of the large power transformers. Additionally, the switchyards' relays and controls are currently housed in the Mayagüez control room, which is located in a building within the Plant boundary. Engineering design is planned to identify and further separate the Plant from the PREPA transmission and distribution system. A high-level

[1] 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 with the first set of cooling fans on; the second FA rating is the rating when the second set of cooling fans kick on.

review of the separation required work is included in Sargent & Lundy Report TD-0003, “Demarcation of PREPA Generation Assets from the Transmission and Distribution System” [2].

2.2.3. Black Start Generator

The site is provided with a black-start generator capable of starting a unit if no outside source of power is available. The unit is a Caterpillar Model C32, rated at 1,000 kW, 480 V_{ac}; it is in a dedicated enclosure adjacent to the raw-water tank. The generator powers the station’s emergency switchgear bus.

2.3. STRUCTURES

The modern Mayagüez facility includes an administration building that was remodeled and upgraded from the original Plant installation. The administration building houses the main electrical rooms and control room as well as the water treatment plant for the site. An overhead crane from the original turbine house, which was built in the 1950s, is available for maintenance activities in the demineralization plant. The main building also houses several maintenance bays and workshop areas. A separate warehouse is adjacent to the switchyard. The main gate and administration building are easily accessible from the street, as seen in Figure 2-14.

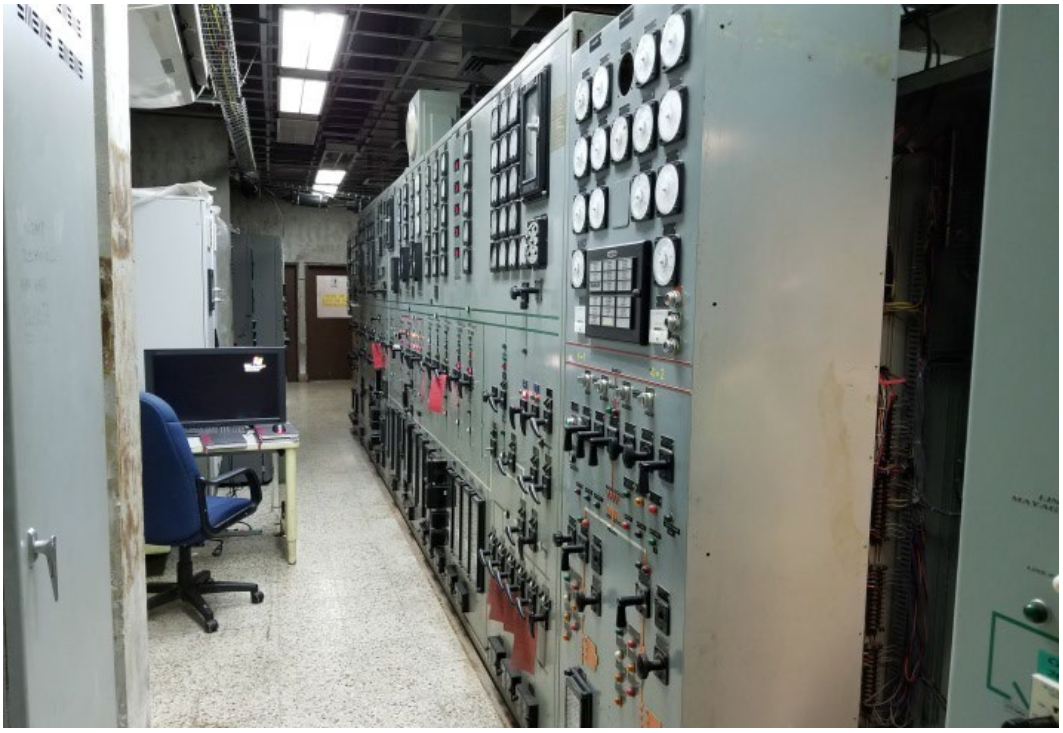
Figure 2-14 — Mayagüez Main Gate and Administration Building

2.4. CONTROL SYSTEM

Station personnel are able to operate all four GT generator units from either the main control room or at four local control panels located at each unit. Each local control panel has the capability to control the other GTs as well through the MicroNet™ Plus system. This provides flexibility so that operators are able to start and control units from any location while monitoring the status of other operating units. Each unit (pair of GTs and a single generator) is also able to operate as a synchronous condenser to improve system power factor.

In June 2020, the Plant began a project to upgrade the turbine control system with new hardware and software. This upgrade includes the addition of five new data servers and an upgrade of the Citec SCADA[2] software to the latest version. The project includes installation, configuration, and validation of the new systems and is scheduled for completion in the fall of 2020.

Figure 2-15 — Main Control Room



[2] supervisory control and data acquisition

Figure 2-16 — Typical Local Control Panel at Each Gas Turbine Unit

3. EQUIPMENT CONDITION

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

3.1. CONDITION ASSESSMENT 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 Sargent & Lundy walkdowns from experienced engineering staff
- **Corrosion Control**—Considers that, with most of the facilities near the coast, corrosion is 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 assessment, interviewing, and data review as indicated in the scoring tables. The high-level scoring system for this assessment is defined in Table 3-1.

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

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

As part of a consent decree with the EPA, each PREPA thermal production unit is mandated to take an environmental outage at intervals of 12–18 months. Sargent & Lundy has assumed that all required maintenance activities are conducted during each mandatory environmental outage except where progress is noted. This key assumption was used in Sargent & Lundy's evaluation of each of the six major condition assessment categories listed above.

3.2. UNIT CONDITION

Mayagüez Unit 3A was out of service (not operational) from July 2020 through March 2021 due to oil leakage in the bearing seals. Units 1A and 1B entered a forced outage on September 19, 2020 and are undergoing a combustion inspection. As of October 31, 2021, all other units—2A, 2B, 3B, 4A, and 4B—were operational; however, the Plant staff reports that all gas generators require repairs due to wear issues. As of April 25, 2021, Unit 3A had returned to service in March 2021; Unit 4A was out of service since April 19, 2021 due to a crack in the combustor area.

3.2.1. Blade Failures

As of 2018, the GTs had accumulated between 5500 and 8500 fired hours since initial installation (see Table 5-2). Several of the FT8-3 GTs experienced failure of the thermal barrier coatings (TBCs) and issues with the hot end of the PT section. Failure of the TBC may be an issue with fuel quality, water entrainment, fuel conditioning, or an issue with the OEM design. Vaporized liquid hydrocarbons or condensates are known to create localized thermal spots during the combustion process and may affect the integrity of coatings and erosion of base material. Significant loss of coatings, particularly accumulations, may affect the equipment's cooling systems and possibly the turbine rotor balance. On the cold end of the system, degradation of the compressor components may be linked to the ingestion of marine salt. P&W recognized this potential with the introduction of a new primary air inlet coalescing pre-filter for use at installation in coastal locations. P&W Service Bulletin No. 11M05 describes the service as mandatory for facilities within one mile of a coastal shoreline. The recommended filter modifications and media replacements have been completed at Mayagüez per the OEM recommendation, but Sargent & Lundy recommends that Plant staff consult the turbine OEM for approval of the modifications. Review of the installed system should be completed to ensure an effective solution is installed.

PREPA believes the issue experienced with the loss of TBC is due to poor manufacturing practices and that the PT issue is a design error, possibly with seals. The turbine OEM P&W noted that similar issues had been documented with other turbines in their fleet manufactured around the same time using the same blade surface preparation procedures prior to application of the high-temperature coating. P&W has since updated their surface preparation procedures for blade coating and furnished guidance for corrective

repairs; however, they have not acknowledged responsibility for the premature turbine blade coating degradation.

All eight PT sections have been cycled back through P&W's shop in Connecticut for repairs; however, further investigation is required to determine a root cause. Review of fuel oil laboratory analysis reports for recently delivered fuel shows that results are within the P&W liquid distillate fuel specification requirements; however, there may be issues with site-specific storage, fuel forwarding systems and equipment, or final fuel conditioning. It is recommended fuel samples are tested downstream of the fuel conditioning skid and final filters to ensure that salts and condensates that may accumulate during fuel storage are not at the root of the issue. Sargent & Lundy recommends a third-party root-cause analysis to conclude these blade discussions.

3.2.2. General Units Condition

The following photographs are included to convey the general condition of the GT units.

Static inlet air filters of the Mayagüez GTs incorporate a moisture-coalescing section, pre-filter stage, and final-filter stage. These filters are shown in Figure 3-1 and were observed to be in good condition.

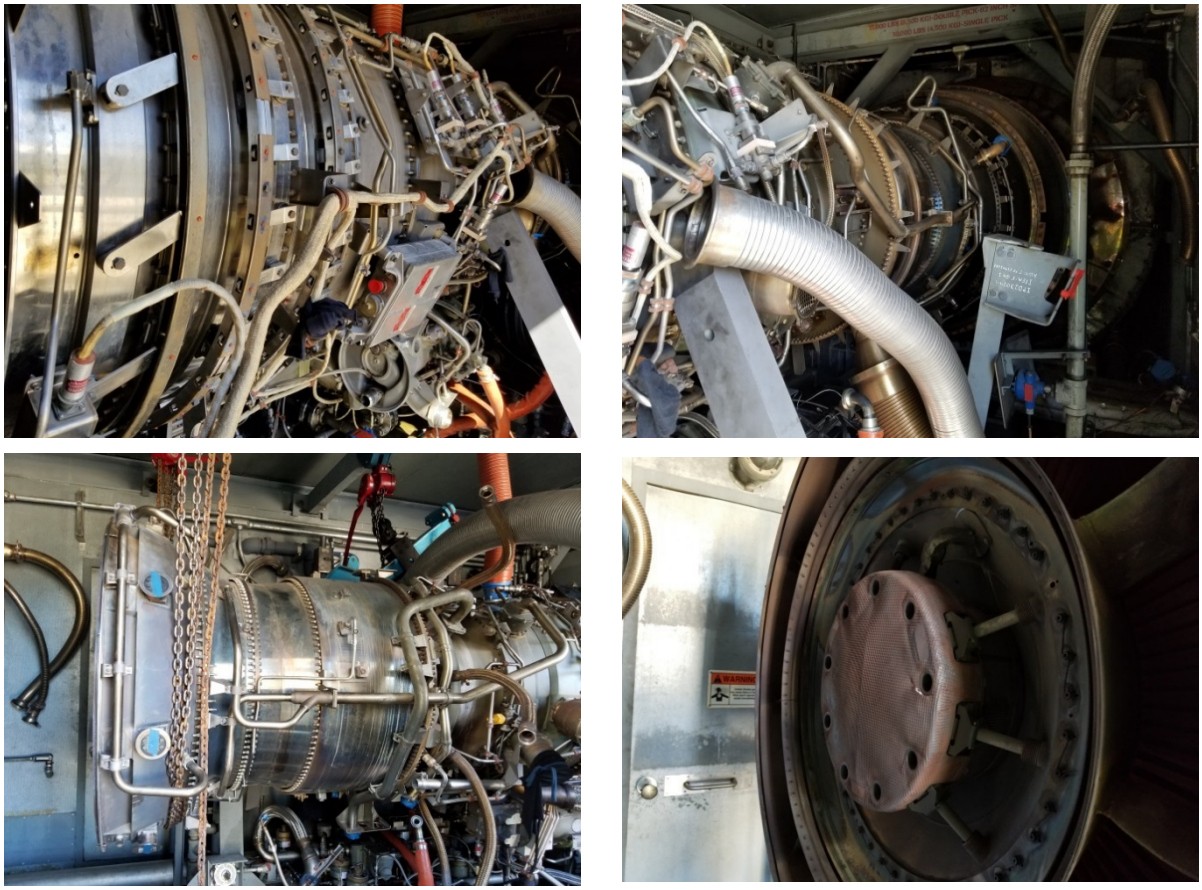
Figure 3-1 — Inlet Air Moisture Coalescing Section (Right) and Pre-Filter (Left)

Moisture Coalescing Section (Right) and Pre-Filter (Left)

Inlet Air Final-Filter

Figure 3-2 shows GT 2A out of service for blade repairs in 2019.

Figure 3-2 — Gas Turbine 2A Out-of-Service for Repairs



Mayagüez was generally in good condition and scored well in most categories of Sargent & Lundy's high-level condition assessment. The general condition of the facility is in line with average utilities built in the late 2000s. As a recommendation, an oil purifier could be used to ensure that lubricating oil is suitable for service across extended outage periods. Hot and cold cycles from day to night tend to permit condensation inside of the unheated lube oil system; it therefore collects water. Note that there are 1500-gallon underground holding sumps dedicated to pairs of GT Units 1 and 2 and of GT Units 3 and 4. An oil purifier would assist with ensuring that the lube oil is kept clear of condensation, which can lead to entrainment and other more serious bearing issues. The staff is currently studying possible solutions to improve the ability of the Plant to control condensation from within the tank and prevent it from entering the fuel oil delivery system.

3.2.3. Unit 1

Units 1A and 1B are currently in a forced outage and are undergoing a combustion inspection. The Plant staff is working toward immediate resolution of issues, but a return-to-service date for these units has not

yet been forecast. Turbine rotor upgrades at the OEM's facility in Connecticut were completed for Units 1A and 1B in 2019 that addressed vibration issues and the aforementioned turbine blade coating degradation issues. Plant staff notes that the turbine generators are worn and will need maintenance soon, but no immediate issues have been identified, and the generator output remains nominal.

Unit 1 is overall in good condition; however, several issues are discussed above and noted in the overall condition assessment summary in Table 3-2.

Table 3-2 — Mayagüez Unit 1 Overall Condition Assessment (as of Q4 2020)

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. The Plant recently repainted units to aid in corrosion control.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		No issues noted.
4	**Mechanical Assessment**								
4.1	Combustion Turbine	no	yes	no					Units 1A and 1B entered forced outage on September 19th, 2020. Combustion inspection is ongoing. Once repairs are completed Sargent & Lundy expects units will be back to operable condition.
4.2	Station Air System	yes	yes	no					No issues noted. Compressor units upgraded to units suitable for the environment.
4.3	Emission controls	no	no	no					Water is used for NOx emission control. This system is operable at any load above 10 MW.
4.4	Fuel Systems	no	no	no					No issues noted. Review of drawings indicate system can benefit from a floating suction.
4.5	Water Treatment	yes	yes	no					No issues noted.
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 notes that generators will need repair for wear issues.
5.2	Transformers	yes	yes	no					
5.3	Switchgear	yes	yes	no					
5.4	Protective Relays	yes	yes	no			*n/a*		
5.5	Black Start Engines	no	yes	no					
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		
6.2	Turbine Controls	yes	yes	no			*n/a*		
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no					No issues noted.
7.2	Structural Steel	no	no	no					No issues noted.
7.3	Tanks / Containment	no	no	no					No issues noted.
7.4	Cranes	no	no	no					Mobile cranes used. Crane in water treatment building is useable for that equipment.
8	**Overall Condition Assessment**								Deficiencies were noted

3.2.4. Unit 2

Units 2A and 2B are operational. Turbine rotor upgrades at the OEM's facility in Connecticut were completed for Units 2A and 2B in 2019 that addressed the aforementioned turbine blade coating degradation issues. Damage to the Unit 2A and 2B generator bearings incurred during the January 7, 2020 earthquake has also been repaired. Plant staff notes that the turbine generators are worn and will need maintenance soon, but no immediate issues have been identified, and the generator output remains nominal.

Unit 2 is overall in good condition; however, several issues are discussed above and noted in the overall condition assessment summary in Table 3-3.

Table 3-3 — Mayagüez Unit 2 Overall Condition Assessment (as of Q4 2020)

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. The Plant recently repainted units to aid in corrosion control.
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 2A and 2B have had their PT upgrades completed and are operational.
4.2	Station Air System	yes	yes	no					No issues noted. Compressor units upgraded to units suitable for the environment.
4.3	Emission controls	no	no	no					Water is used for NOx emission control. This system is operable at any load above 10 MW.
4.4	Fuel Systems	no	no	no					No issues noted. Review of drawings indicate system can benefit from a floating suction.
4.5	Water Treatment	yes	yes	no					No issues noted.
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 notes that generators will need repair for wear issues.
5.2	Transformers	yes	yes	no					
5.3	Switchgear	yes	yes	no					
5.4	Protective Relays	yes	yes	no			*n/a*		
5.5	Black Start Engines	no	yes	no					
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		
6.2	Turbine Controls	yes	yes	no			*n/a*		
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no					No issues noted.
7.2	Structural Steel	no	no	no					No issues noted.
7.3	Tanks / Containment	no	no	no					No issues noted.
7.4	Cranes	no	no	no					Mobile cranes used. Crane in water treatment building is useable for that equipment.
8	**Overall Condition Assessment**								Deficiencies were noted

3.2.5. Unit 3

Unit 3B is operational, but Unit 3A was out of service due to oil leakage in the bearing seals at the time of Sargent & Lundy's review. Plant staff was working toward immediate resolution of issues, and the unit was returned to service in March 2021. Turbine rotor upgrades at the OEM's facility in Connecticut were completed for Units 3A and 3B in 2020 and 2019, respectively. The upgrade overhaul also addressed the aforementioned turbine blade coating degradation issues. Plant staff notes that the turbine generators are worn and will need maintenance soon, but no immediate issues have been identified, and the generator output remains nominal.

Unit 3 is overall in good condition; however, several issues are discussed above and noted in the overall condition assessment summary in Table 3-4.

Table 3-4 — Mayagüez Unit 3 Overall Condition Assessment (as of Q4 2020)

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. The Plant recently repainted units to aid in corrosion control.
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 3A is not operational, currently in outage due to oil leak in bearing seals repair. Once repairs are completed Sargent & Lundy expects units will be back to operable condition.
4.2	Station Air System	yes	yes	no					No issues noted. Compressor units upgraded to units suitable for the environment.
4.3	Emission controls	no	no	no					Water is used for NOx emission control. This system is operable at any load above 10 MW.
4.4	Fuel Systems	no	no	no					No issues noted. Review of drawings indicate system can benefit from a floating suction.
4.5	Water Treatment	yes	yes	no					No issues noted.
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 notes that generators will need repair for wear issues.
5.2	Transformers	yes	yes	no					
5.3	Switchgear	yes	yes	no					
5.4	Protective Relays	yes	yes	no			*n/a*		
5.5	Black Start Engines	no	yes	no					
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		
6.2	Turbine Controls	yes	yes	no			*n/a*		
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no					No issues noted.
7.2	Structural Steel	no	no	no					No issues noted.
7.3	Tanks / Containment	no	no	no					No issues noted.
7.4	Cranes	no	no	no					Mobile cranes used. Crane in water treatment building is useable for that equipment.
8	**Overall Condition Assessment**								Deficiencies were noted

3.2.6. Unit 4

Units 4A and 4B were operational at the time of this review. Turbine rotor upgrades at the OEM's facility in Connecticut were completed for Units 4A and 4B that addressed the aforementioned turbine blade coating degradation issues. Damage to the Unit 4A and 4B generator bearings incurred during the January 7, 2020 earthquake has also been repaired. Plant staff notes that the turbine generators are worn and will need maintenance soon, but no immediate issues have been identified, and the generator output remains nominal. As of April 25, 2021, Unit 4A was out of service due to a crack in the combustor area.

Unit 2 is overall in good condition; however, several issues are discussed above and noted in the overall condition assessment summary in Table 3-5.

Table 3-5 — Mayagüez Unit 4 Overall Condition Assessment (as of Q4 2020)

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. The Plant recently repainted units to aid in corrosion control.
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 4A and 4B have had their PT upgrades completed and are operational.
4.2	Station Air System	yes	yes	no					No issues noted. Compressor units upgraded to units suitable for the environment.
4.3	Emission controls	no	no	no					Water is used for NOx emission control. This system is operable at any load above 10 MW.
4.4	Fuel Systems	no	no	no					No issues noted. Review of drawings indicate system can benefit from a floating suction.
4.5	Water Treatment	yes	yes	no					No issues noted.
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 notes that generators will need repair for wear issues.
5.2	Transformers	yes	yes	no					
5.3	Switchgear	yes	yes	no					
5.4	Protective Relays	yes	yes	no			*n/a*		
5.5	Black Start Engines	no	yes	no					
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		
6.2	Turbine Controls	yes	yes	no			*n/a*		
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no					No issues noted.
7.2	Structural Steel	no	no	no					No issues noted.
7.3	Tanks / Containment	no	no	no					No issues noted.
7.4	Cranes	no	no	no					Mobile cranes used. Crane in water treatment building is useable for that equipment.
8	**Overall Condition Assessment**								Deficiencies were noted

3.3. COMMON SYSTEMS

The original GT compressed-air systems were not well selected for use in the outdoor operating environment; as a result, the Plant was experiencing several reliability issues. To address this, replacement and upgrade of all air-compressor units was conducted and completed in May of 2019.

3.4. RECOMMENDATIONS

Recent overhaul of the turbine rotors at the OEM's facilities, along with improvements to the combustion air intake filters, are expected to extend the life of these units and reduce the turbine wear issues that have beleaguered the facility to date. To resolve these issues, Sargent & Lundy recommends that an independent third party conduct a full root-cause analysis (RCA) and provide conclusions and recommendations for both PREPA and the OEM. The cost of these resolutions, including those already

implemented, may be apportioned to each party, if claims are warranted, in accordance with each party's responsibility. Matters such as salt ingestion, fuel quality, suitability of the original design for purpose, subcontracted equipment and construction quality, OEM service bulletins, and other similar matters are all aspects of the analysis that may be evaluated as part of the RCA.

In addition, to rule out past or future blade problems originating with the liquid fuel supply, the fuel oil, transfer, and delivery system should be evaluated. The evaluation would start with the fuel specification, tank-suction type, water draw-off provisions and condensation control, and overall cleanliness, including filter sizing and media selection. Sargent & Lundy notes that no floating suction is in place for the fuel oil tanks at Mayagüez. Floating suction systems aid in the prevention of forward flow of water buildup to the GT generation equipment, particularly if water draw-off features are not used to routinely remove water that has collected and settled to the bottom of the fuel storage tank.

The three fuel oil tanks at the main facility are on the perimeter of the site, and the larger tank is offsite. The footprint and space available do not create a significant open area for repurposing the space currently dedicated to the fuel oil tanks; however, if fuel gas is provided to the site and fuel oil is not to be considered further, it is recommended that some of the tank areas may be evaluated for repurposing.

Corrosion may become a concern at this site if Plant staff is not diligent in keeping associated issues in check. As mentioned throughout this report, there are some indications that the equipment and material selections for the installation are not entirely adequate for the conditions at Mayagüez. The main enclosures of the GTs were repainted in 2019 (see Figure 3-3, right side for stack paint). Surface-level corrosion is generally not a concern; however, if left unattended, similar to the other sites across the island, corrosion rapidly progresses from simple cosmetic concerns to more serious issues that can affect safety and operability.

Figure 3-3 — Paint Touchup in Process

For plants such as Mayagüez that are often used for peaking services, it is even more important to ensure that idle equipment is protected from the elements, condensation, and salts. During normal operation, the equipment is kept hot, fluids are circulated, and fans are kept on for cooling. During idle time, moisture and corrosive salts are more apt to deposit onto the equipment. Repetitive deposition and evaporation of salt-laden moisture will lead to pitting, such as that found on the GT intake system; the results have been noted by the OEM and are now the subject of a service bulletin that is being addressed by Plant staff. Over extended periods, such as those for the four turbine units currently idle at Mayagüez, preservation measures, layup practices, and humidity control become increasingly more important to realize the full design life of the Plant and equipment.

4. INFRASTRUCTURE AND INTERCONNECTIONS

4.1. FUEL SUPPLY

No. 2 diesel fuel is received from the transfer station at Mayagüez Port adjacent to the facility. The fuel is then pumped to the storage tanks for use in the GTs or for the emergency generator. Fuel oil for Mayagüez is provided under a contract for multiple PREPA facilities.

PREPA receives No. 2 fuel under Contract #902-01-19 with Puma Energy Caribe, LLC that originally expired on November 20, 2020. The contract contains terms for fuel supply to five sites—San Juan, Palo Seco, Aguirre, Cambalache, and Mayagüez—together with the No. 2 fuel burning GT peaker stations. Provisions allow for alternate sources and cost savings. Additional provisions are agreed to for alternate sources and cost savings as agreed upon. PREPA and Puma Energy Caribe, LLC agreed to an extension of the contract until November 20, 2021. In 2021, PREPA will undergo a competitive process to secure its next No. 2 fuel oil supply agreement.

Currently, there is no natural gas supply for the facility, nor are there plans to provide natural gas to the site; however, each gas turbine is provided with an OEM-designed fuel gas regulator valve skid. The skid has a blanked off terminal point and is ready for receipt of gas if a pipeline is provided to the site. A plant metering and regulation station, along with distribution piping to each GT unit, would have to be put in place to enable the firing of natural gas.

4.2. WATER SUPPLY AND TREATMENT

Water for the Plant is from municipal supply (PRASA). Water is provided for multiple uses on site: potable water (including safety showers and eyewash stations), fire protection, and water for the water treatment/demineralizer system. The water from the municipality is called the “raw water system.”

All waste and sanitary, except for the GT generator drains, is discharged to the PRASA system. The discharge is facilitated through a lift station. Discharge is monitored for pH and contains a flow meter to monitor discharge from the Plant. Wastewater subject to oil contamination is processed through two separate oily water separators (one on the either side of the facility), and the clean effluent is then delivered to the lift station for return to PRASA. GT generator drains are managed separately due to the fact that the waste may contain heavy metals as the result of water-washing the GT equipment, which contains many tip seals and abradable systems that are washed out of the system during the cleaning process. GT generator drains are vacuum-pumped from the collection tanks and removed from the site.

5. OPERATIONS AND MAINTENANCE

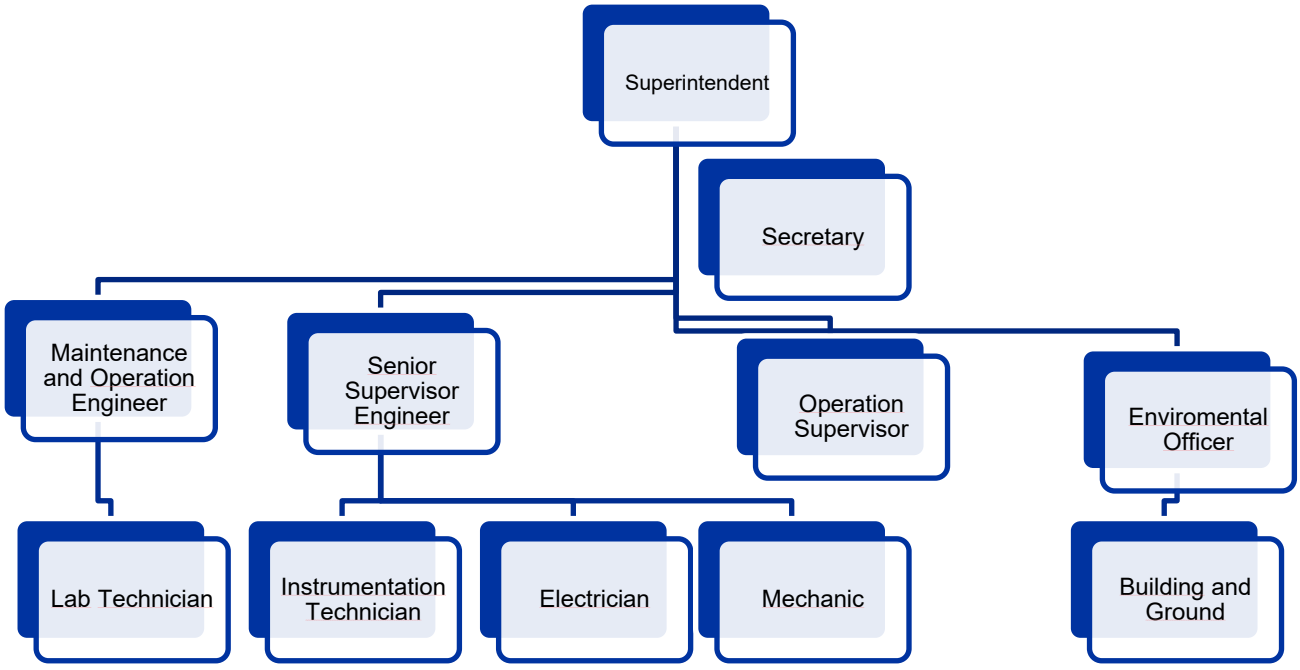
The Plant was designed to be a fast-response power generating plant available as needed to provide peak power assistance to the base-loaded plants. The Plant is dispatched according to grid demands and is manned during the day, typically responding to the peak highs during the day as needed. If response is needed outside of the typical time period of manned hours, the operations staff is recalled to the site.

5.1. STAFFING AND TRAINING

The Mayagüez site operates with a full complement of 13 staff for the site with the Plant superintendent heading the facility. Staff heads reporting to the superintendent are the maintenance and operation engineer, senior supervisor engineer, and environmental officer. In 2019, Plant staff noted that the operation supervisor position was vacant. Updated staffing information was requested but has not been received for this report.

The organization, containing administrative, operations, and maintenance staff, is as follows:

Figure 5-1 — Mayagüez Organization Chart



The facility is manned during normal and regular day working hours. If the site requires staffing after hours, staff is on call. To support outage work, staff augmentation is used, which is often drawn from PREPA personnel.

PREPA's commitment for a long-term maintenance program to support the significant number of facilities it operates has three main components: formal training for operators, comprehensive maintenance programs, and system upgrades.

Training for operators focuses on safety. Operations training also emphasizes running equipment and systems efficiently. A comprehensive maintenance plan includes preventative, corrective, and predictive maintenance programs. Each focus of the plan aims to ensure availability of the units. The preventative maintenance program uses regularly scheduled outage intervals for completing many of the required maintenance work defined by the OEM.

Design upgrades and modifications are completed as system life and demand requires. The upgrades are conducted to help improve the operation of the units with more efficient components and conversions. An example is the upgrade of the air compressors. Per the OEM's Service Bulletin 11M05 Revision A, coalescing air intake filters are now required and have been installed on all units to prevent the ingress and carryover of salt fines into the GT compression stages.

5.2. MAINTENANCE PROGRAMS

The Mayagüez units have low dispatch and are required to have regular outages for maintenance and environmental reasons per an EPA agreement and PREPA management requirements. In general, the frequent scheduled outages at Mayagüez provide time for much of the deferred maintenance items. Many maintenance items are delayed as necessary to the next scheduled outage as parts and supplies become available.

Routine maintenance activities are performed during the regular environmental outages. Larger scopes of work requiring a longer outage is also scheduled as needed. Upgrades and significant design modifications are planned during the major overhauls.

5.2.1. Mandatory Environmental Outage

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

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

- Fuel handling equipment is inspected, repaired, and recalibrated as necessary.

- Pumps and associated valves are inspected.
- Lubricating oil systems are inspected.
- Power transformers are inspected, and breakers tested and adjusted.
- Life extension inspections and nondestructive examination activities are completed on critical systems and components in preparation for future programmed outages.

5.2.2. Preventative Maintenance

Plant staff performs general preventative maintenance activities, which may be performed while the units are online (i.e., recoating of corroded steel) as needed. Many maintenance items are delayed as necessary to the next scheduled outage as parts and supplies become available.

5.2.3. Service Bulletins

Sargent & Lundy reviewed P&W service bulletins provided by PREPA. The bulletins are filed electronically in directories named as follows, consistent with P&W bulletin compliance designation:

- Replace As Required (qty. = 50)
- Replace At First Opportunity (qty. = 26)
- Replace If Desired (qty. = 15)
- Replace Mandatory (qty. = 7)

The manufacturer's recommendations for an issued service bulletin are categorized as follows:

- **Mandatory:** Incorporate prior to further unit operation
    - *Category I*: Disassemble unit at first opportunity to the extent necessary to incorporate highly recommended modification
    - *Category II*: Incorporation recommended whenever disassembly of unit provides accessibility
- **As Required:** Incorporate if the condition of existing part indicates compliance is required
- **If Desired:** Customer option

There is no formal program or process, however, at the Plant to track GT generator service bulletins (i.e., log the receipt of service bulletin and note applicability with priority, action required, responsible engineer or department, action taken, findings, and closure date). Sargent & Lundy therefore recommends that additional effort be given to obtain, disposition, and monitor P&W combustion turbine service bulletins and technical alerts as they are issued.

Sargent & Lundy's review notes that many service bulletins are not applicable due to the particular FT8-3 model, serial number, or technology of the Mayagüez units. Some were informational in nature, notifying owners about: (i) a replacement part that was discontinued, obsolete, prone to failure; (ii) recommend alternative supplier(s); (iii) alternative coatings and plating that are environmentally friendly; (iv) updated maintenance schedules; (v) more comprehensive inspection and tests of fluids for metal content and particulates; and (vi) generally prudent and good preventative maintenance practices.

There are other service bulletins that necessitate the owner to assess the current condition of the subject equipment/component and implement the change as required. Several of the more noteworthy service bulletins are related to the collector box and PT. Since service bulletins are not tracked, it is difficult to determine if a bulletin was acted upon by the Plant. Sargent & Lundy's review of inspection and maintenance reports did not reveal any upgrades to these components other than previously stated issues with the PT ongoing repairs.

More significant Service Bulletins in which compliance is mandatory are summarized in Table 5-1.

Table 5-1 — Service Bulletins Designated Compliance as Mandatory

Bulletin ID	Title	Summary	Remarks
ALERT BULLETIN NO. A10M11 (Oct. 15, 2010)	Gas Fuel System, Pipes – Cleaning	Informs customers against the use of natural gas to clean gas fuel pipes of unwanted material and other contaminations	Currently not applicable; will be mandatory if units are converted to fire natural gas
ALERT BULLETIN REVISION NOTICE NO. A11M04 REVISION A (June 15, 2011)	FT8 GT Fuel System Safety-Related Software Adjustments	Provides FT8 customers/operators with revised electric fuel mod valve position error limits that will help prevent a recent in-service incident that resulted in damage to the GT enclosure after alarms/trips indicated a problem with the fuel valve that was not investigated immediately after failed start attempts	Applicable to GTs firing fuel and should be addressed; may have limited applicability if units are converted to natural gas
ALERT BULLETIN NO. A10M05 (Sept. 10, 2010)	GT Enclosure Trolley	Alerts customers to the hazard of a GT trolley derailment when excessive force is applied to move an unloaded trolley; a trolley retainer (safety) clip is available to keep the trolley in its track if this procedure is not followed	N/A
ALERT BULLETIN REVISION NOTICE NO. A07M04 REVISION A (June 20, 2011)	GT Fuel System Safety-Related Maintenance and Inspection	Informs customers that some FT8 GT sites have experienced unintended ignition of fuel within the exhaust stacks and the GT enclosures that resulted in explosive concussions and the forcible separation of the enclosure doors from attaching hinges—such event can occur without warning	Applicable to GTs firing fuel oil and should be addressed; may have limited applicability if units are converted to natural gas

Bulletin ID	Title	Summary	Remarks
Alert Service Bulletin A07M04 Revision A (Mar. 31, 2010)	Fuel Valve Position Error During Light-Off; Safety Concerns and Recommended Procedures	Advises FT8 operators of recent in-service incident that resulted in damage to the FT8 GT enclosure after alarms/trips and indicated a problem with the fuel valve that was not investigated immediately following failed start attempts	Applicable to GTs firing fuel oil and should be addressed; may have limited applicability if units are converted to natural gas
SERVICE BULLETIN SB-FT8-A12M05 (Apr. 25, 2012)	High-Pressure CO_2 Discharge Hoses	Informs the customer that a specified number of high-pressure CO_2 hoses have been identified by the manufacturer as subject to early failure due to a manufacturing defect	N/A
SERVICE BULLETIN 11M05 Revision A	Inlet Filter House – Coalescing Pre-Filter	Alerts that FT8 applications within 1–10 miles of marine coastlines are suggested to modify intake filter systems; plants within one mile are stated as mandatory	Adjustments were completed; however, operations should address then with the OEM to confirm compliance

Service bulletins for the GT equipment are reviewed by staff for relevance and priority; however, there is no formal program or process to track GT generator service bulletins (i.e., log the receipt of service bulletin and note applicability with priority, action required, responsible engineer or department, action taken, findings, and closure date). Plant staff notes that they are in the process of identifying which service bulletin items to implement into their planned maintenance. Sargent & Lundy recommends that additional effort be given to obtain, disposition, and monitor P&W GT service bulletins and technical alerts in the future.

5.2.4. Corrective Maintenance

Corrective maintenance is primarily conducted on an as-needed basis. Due to the low dispatch of the units, corrective maintenance for redundant systems can be done online or as required when the unit is not dispatched.

5.2.5. Predictive Maintenance

A site-monitored predictive maintenance program is used for the GTs. The program reads and records the vibration recording for the main rotating equipment through an OEM-provided system. Plant staff use the predictive maintenance data to identify operational issues early in their development and prioritize maintenance activities for the monitored equipment.

5.3. MAINTENANCE AND OUTAGE SCHEDULES

The inspection and operational history for each unit at Mayagüez was provided to Sargent & Lundy in 2018, and a summary of the fired hours for each unit is included in Table 5-2. A more recent history and forecast

of the Plant's outage schedule was requested but has not been provided for review and inclusion in this report. Additionally, a listing of the number of starts for each turbine has not been provided. GT maintenance is based primarily on a "number of starts" regime.

Table 5-2 — Mayagüez Fired Hours by Unit November 2018

Unit	Fired Hours at end of November 2018
Mayagüez GT #1A	8252
Mayagüez GT #1B	8526
Mayagüez GT #2A	5771
Mayagüez GT #2B	4810
Mayagüez GT #3A	7568
Mayagüez GT #3B	5098
Mayagüez GT #4A	7369
Mayagüez GT #4B	5430

Furnished maintenance activity reports indicate that the units have undergone successive outages over the past several years to sequence their turbine rotor upgrades and repairs at the OEM's shop in Connecticut. The activities included shop disassembly, inspection and photo documentation of the damaged blades, carbon seals, gearbox assemblies, bearings, positioning ring bolts, vane actuators, and other miscellaneous subcomponents. Damaged items were refurbished or replaced, and the rotors were reassembled, balanced, and returned to site for reuse. Additionally, PREPA currently has a tank inspection program, per API code and SPCC compliance, planned in the next six years for all power plants. The detailed timing for Mayagüez was not provided. Sargent & Lundy will review historical and forecasted planned outages once available.

5.4. SPARE PARTS

A spare-parts list is kept on site and maintained by Plant staff. Sargent & Lundy reviewed a strategic spares list for Mayagüez during the 2018 visit. Spares on site are tracked by hand. The list was prioritized, showed requirements for majors, and indicated the minimum spares quantity suggested.

Part requisitions are routed through the main office in San Juan. As parts for the older and less used plants have been prioritized under other and newer plants, part and supply requests have been delayed or differed as deemed necessary.

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

In 2012, a supplier provided an updated energy management system 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 management system also incorporated cybersecurity compliance with the NERC's infrastructure standards. In addition to upgrading the energy management system, the supervisory control and data acquisition functionality was also updated to link the central energy management system with the generation plants and substations.

6. PERFORMANCE REVIEW

To evaluate the performance of the Plant, Sargent & Lundy reviewed historical operating performance provided by PREPA for each unit of the Plant and benchmarked it against a group of industry peer units where data was available. The primary performance indicators reviewed are as follows:

- Generation
- Equivalent Availability Factor (EAF)
- Equivalent Forced Outage Rate (EFOR)
- Net Capacity Factor (NCF)
- 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 period, including the impact of deratings (times when the unit is operating at a lower power output). EFOR is a measure of an electric generating unit's unreliability; it is the percentage of time that a unit is in a forced outage during a specified period, including the impact of forced derates on a unit.

PREPA provided operation data for 2015–2020. Sargent & Lundy also reviewed data cataloged by NERC within their Generating Availability Database System (GADS)[3] and established a peer group of units similar to Mayagüez Units 1–4 to compare reliability data.

Sargent & Lundy applied the selection criteria identified in Table 6-1 to the NERC GADS database[4] to establish the reliability peer group. The resulting peer group, which reflects these unit characteristics, included 10 units owned by 3 different operators, with the dataset including 88 operating years of annual reporting data. Although the units are similar, the units primarily are run on natural gas rather than No. 2 Fuel Oil as Mayagüez does. Additionally, 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 Mayagüez and the peer group.

[3] 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 GADS. Within 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, GADS can report reliability data reflective of a peer group of plants with specific characteristics and generating statistics. Sargent & Lundy filtered GADS to obtain reliability statistics that reflect a peer group of units similar to the Mayagüez units.
[4] Accessed via pc-GAR software on November 2, 2020. Version: PC-GAR v4.01.16.

Table 6-1 — Mayagüez Key Performance Data Summary

Mayagüez Units 1–4			Peer Group Characteristics			
Years in Service	COD	Unit Gross Capacity (MW)	Years in Service	COD	Unit Gross Capacity (MW)	Engine Cycle Type
12	2008–2009	55	5–20	2000–2015	35–75	Simple

Table 6-2 — Mayagüez Key Performance Data Summary

Key Performance Indicator	2015	2016	2017	2018	2019	2020	Peer Group (per unit)
Generation (MWh)	124,725	52,993	138,968	125,022	92,177	276,964	25,131
Availability (%)	81.65	72.14	61.53	50.11	65.67	53.93	85.49
Capacity Factor (%)	6.47	2.74	7.00	6.00	4.78	14.33	5.22
Equivalent Forced Outage Rate	6.22	4.14	12.45	50.73	14.86	39.70	43.24
Net Heat Rate (Btu/kWh)[1]	10,250	10,151	10,349	10,014	10,289	10,256	N/A

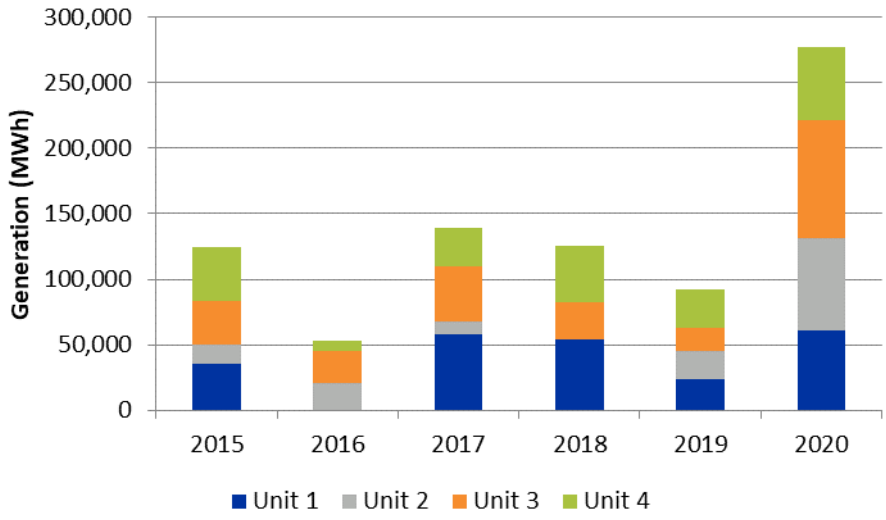
[1] Btu/kWh = British thermal unit per kilowatt hour

6.1. GENERATION

Generation for Units 1–4 is provided in Figure 6-1. Note that each unit consists of a single generator coupled to a pair of GTs. The individual GTs (example: 1A and 1B of Unit 1) are not separated out from the combined unit generation total.

The generation figure provides totalized information for the annual plant generation of power. Power output has remained relatively flat over the last few years, as the Plant is dispatched as needed as a peaker. Power output increased in 2020, mainly due to the outage at Costa Sur from earthquakes in January 2020. After the 2017 hurricanes, the available units were dispatched according to load demands and system requirements. Total power generation was at a high of 276,964 MWh in 2020 and a low of 52,993 MWh in 2016. The net generation in 2016 was lower because Unit 1 was offline for maintenance and repair for a significant portion of that year.

Figure 6-1 — Mayagüez Gas Turbine Generation



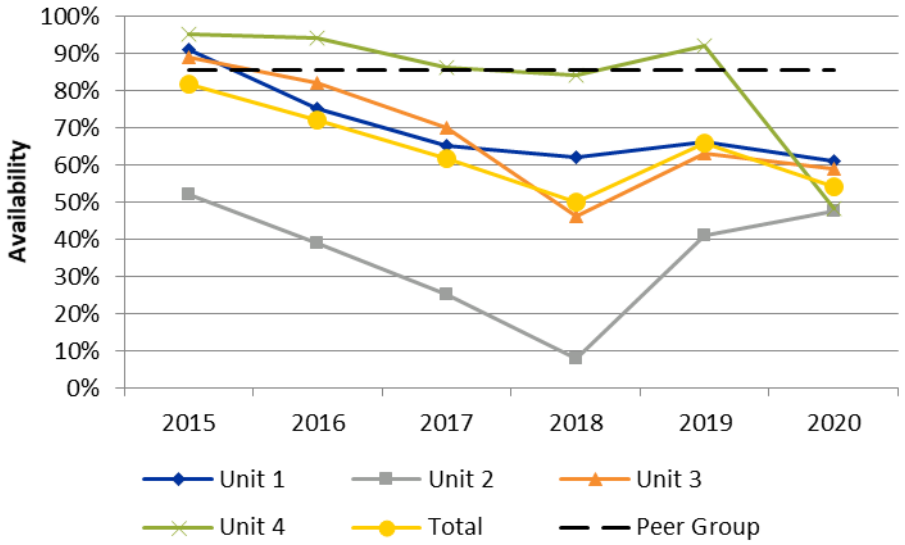
6.2. AVAILABILITY FACTOR

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

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

The availability of the Plant has been trending lower in recent years. The availability decreased from a high of 82% in 2015 to a low of 50% in 2018. This lower trend is indicative of the equipment issues (such as the blade coatings on Unit 2 and Unit 3) and reliability of the gas turbines; however, the deratings and issues with the units continue to be corrected on an ongoing basis. For 2020, the availability is lower than average, which mainly can be attributed to extended outages on Unit 2 and Unit 4 related to the January 7, 2020 earthquake. The units were returned to service.

Figure 6-2 — Mayagüez Gas Turbine Equivalent Availability Factor



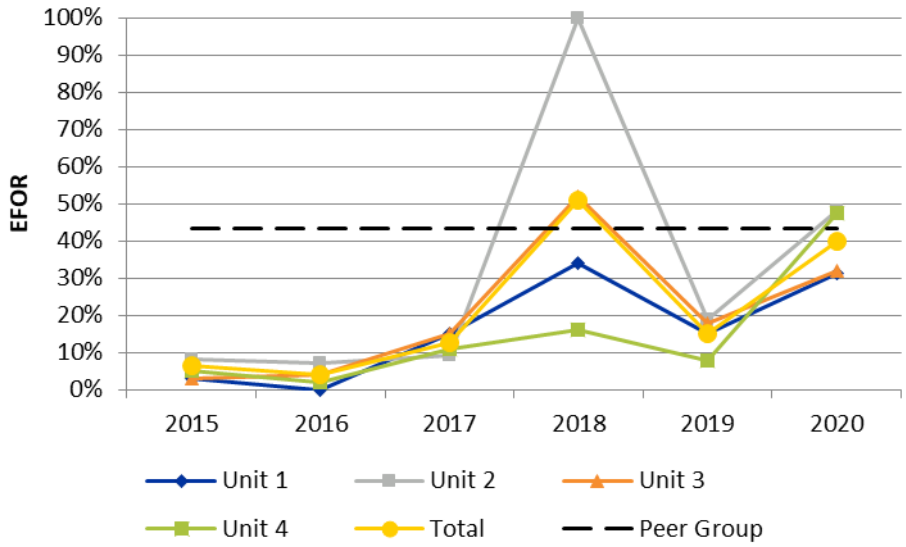
6.3. EQUIVALENT FORCED OUTAGE RATE

The EFOR is a measure of the probability that a generating unit will be unavailable due to forced outages or forced deratings; it excludes planned or maintenance outages. In other words, EFOR is a rating to indicate how the unit is unable to respond, irrespective of system need. It is calculated as follows:

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

As the availability of the Plant has trended lower, the EFOR rose in response to the extended outages of Unit 2 and Unit 4. Units 1 and 3 were largely derated with partial generation, and without half of the generating power available for those two units, the EFOR and related values will significantly increase. That skews the average higher and reflects the capital equipment importance of expediting repairs to maintain availability and capacity. The average EFOR has generally been below 15%; however, it increased to 51% in 2018 and was 40% in 2020 due to the outages and deratings previously discussed in the respective years. Overall, the EFOR is lower than other similar units, showing that Plant staff is addressing unit issues similarly or more quickly.

Figure 6-3 — Mayagüez Gas Turbine Equivalent Forced Outage Rate



6.4. NET 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:

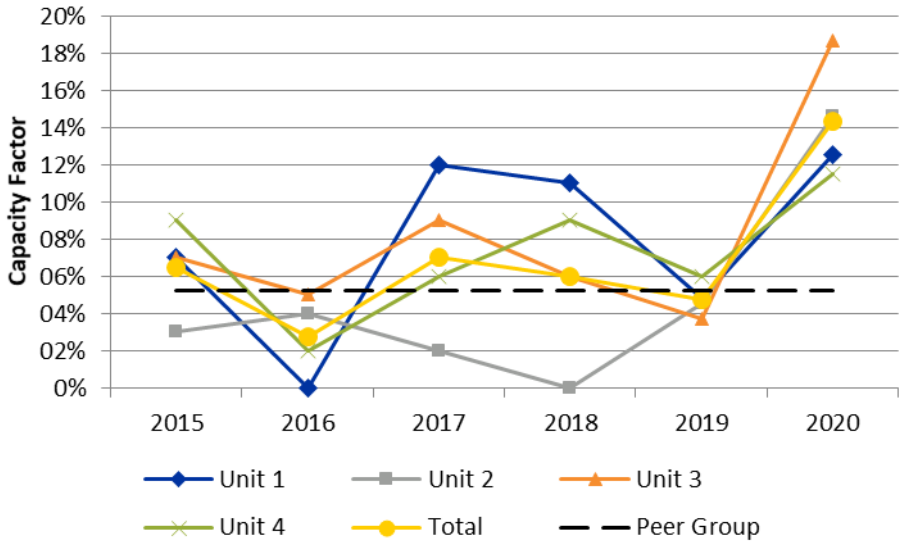
NCF = (Total Net Generation/[Net Capacity at Mean Ambient Temperature x Period Hours]) x 100

The capacity factor for peaking units is typically lower than cycling or base-loaded units, and interpreting information requires evaluating the availability and the market demands.

The Mayagüez units generally have capacity factors consistent with units used for peaking services. After the 2017 hurricanes, the available units were dispatched according to load demands and system requirements; however, the outage at Costa Sur has caused an increased demand for the Plant in 2020, which is expected to be reduced as Costa Sur returns to service.

The average capacity factor was at a low of 2.7% in 2016 and coincided with the lowest power generation during the selected range. The low capacity was due to maintenance outages and dispatch and not to forced outages, as the EFOR was at the lowest rate that year.

Figure 6-4 — Mayagüez Gas Turbine Capacity Factor

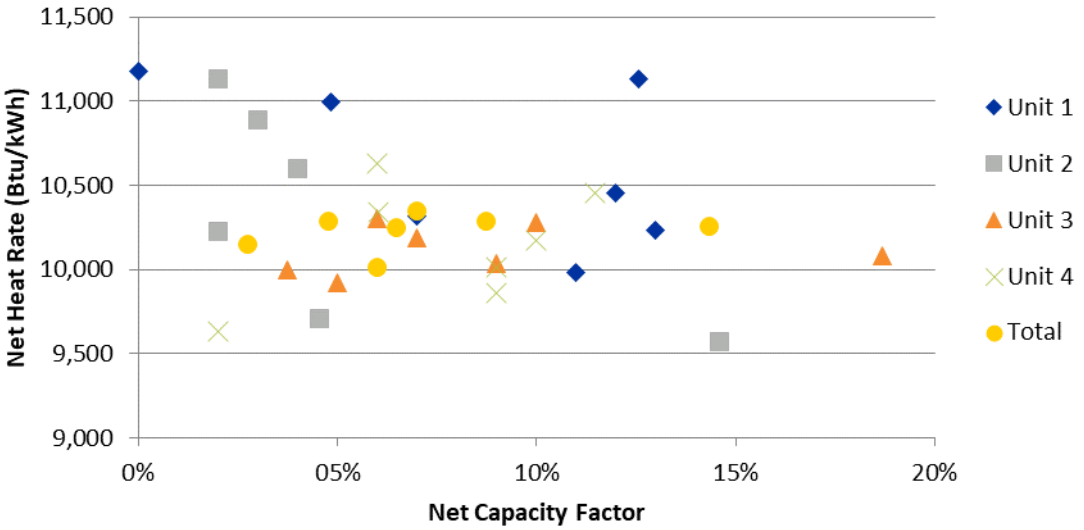


6.5. NET HEAT RATE

The heat rate is the amount of energy used by an electrical generator or power plant to generate one kilowatt-hour 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.

The units at Mayagüez indicate a competitive heat rate. In comparison to several other PREPA facilities with black-start or peaking units, the Mayagüez units have better heat rates and indicate higher efficiencies. On average, the heat rate range is from a low of 10,014 Btu/kW (2018) to a high of 10,349 Btu/kW (2017). Heat rate vs. capacity factor charts for Units 1–4 are provided in Figure 6-5.

Figure 6-5 — Mayagüez Gas Turbine Heat Rate vs. Capacity Factor



7. FINANCIAL REVIEW

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

Cost data for Mayagüez 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 below documents provided by Ankura.

- 725 OPER-CONST by Resp 2008-2020.xlsx
- Generation and Sales History.xlsx
- PREPA Ex 1.02 Part 1 Economic Analysis Report.pdf
- PREPA Ex 1.02 Part 2 Economic Analysis Report Appendices.pdf

Summaries of O&M costs and CAPEX for Mayagüez and comparisons with industry values are 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 Mayagüez are aggregated. Also, the costs for the four Mayagüez TWINPAC aero-derivative turbine units (each TWINPAC having a nominal capacity of 50 MW) are combined across all units (“Account 314”). The head office costs for Mayagüez (“Account 315”) are combined with head office costs for the Cambalache GT units (165 MW nominal capacity), the Culebra diesel plant (2-MW nominal capacity), and the hydroelectric units (59 MW nominal capacity).[5]

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

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

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

Mayaguez (200 MW) - Historical O&M Costs ($)	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Operating Labor						
314 - Central de Gas - Mayaguez	$ 1,033,576	$ 994,304	$ 822,393	$ 481,450	$ 980,260	$ 1,318,731
315 - Jefe de Central Hidro Gas	$ 2,579,710	$ 2,330,278	$ 2,214,552	$ 936,894	$ 1,101,324	$ 1,524,284
Operating Non-Labor						
314 - Central de Gas - Mayaguez	$ 235,535	$ 285,634	$ 448,723	$ 83,505	$ 434,114	$ 1,387,658
315 - Jefe de Central Hidro Gas	$ 763,796	$ 635,733	$ 562,771	$ 256,869	$ 503,779	$ 678,977
Total O&M Costs ($)	$ 4,612,617	$ 4,245,950	$ 4,048,438	$ 1,758,719	$ 3,019,477	$ 4,909,650
Total - Excluding Account 315 ($)	$ 1,269,112	$ 1,279,938	$ 1,271,116	$ 564,955	$ 1,414,374	$ 2,706,389

The aggregated O&M costs shown above correspond to the fixed and variable components estimated by PREPA in the aforementioned economic analysis report. Table 7-2 summarizes PREPA's estimate of the fixed O&M (in $/kW-year) and variable O&M (in $/MWh) for the Mayagüez aero-derivative turbine units in 2015. Note that variable O&M excludes fuel costs and assumes the 2015 generation of 125,000 MWh.

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

	Mayagüez Unit 1 (50 MW) | Unit 2 (50 MW) | Unit 3 (50 MW) | Unit 4 (50 MW)
Fixed O&M (2015 $)	$10.15/kW-year
Variable O&M (2015 $)	$6.11/MWh

Note: Variable O&M costs exclude fuel costs.

Sargent & Lundy compared these values with O&M costs for existing aero-derivative units in operation in North America of similar configurations and operating profiles. Fixed O&M costs, expressed in $/kW-year, do not vary with generating output and typically include routine labor costs, routine maintenance materials and services, and administrative and general costs (excluding property taxes, insurance, and home office expenses). Variable O&M costs, expressed in $/MWh, are proportional to generating output and typically include major maintenance, chemicals and consumables, and water. On the basis of these assumptions and comparisons with similar aero-derivative units in operation, we determined that the Mayagüez O&M costs are within the typical range of costs for similar units, considering that higher O&M expenditures are required for plants firing fuel oil as compared with natural gas.

7.2. CAPITAL EXPENDITURES

The provided historical CAPEX and expected future CAPEX reported by PREPA for Mayagüez 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.[6] It was determined that the annual CAPEX expenditures for Mayagüez are within the typical range of costs for similar units.

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

Mayaguez (200 MW) - Historical CAPEX ($)	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Construction/Maintenance Labor						
314 - Central de Gas - Mayaguez	$ -	$ -	$ -	$ -	$ -	$ -
315 - Jefe de Central Hidro Gas	$ 111,335.31	$ 15.08	$ -	$ -	$ 439,649.43	$ -
Construction/Maintenance Non-Labor						
314 - Central de Gas - Mayaguez	$ -	$ -	$ -	$ -	$ 434,114	$ 106,821
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
Total CAPEX ($)	$ 4,053,508	$ 1,835,837	$ 9,506,968	$ 3,756,882	$ 26,793,651	$ 6,738,308

[6] 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.

8. ENVIRONMENTAL AND REGULATORY

This section describes certain environmental requirements that currently apply to Mayagüez, and it includes a limited review of the station's current environmental compliance status as of November 2020. This section does not include a review of new and proposed regulatory initiatives that may have an impact on future operations at Mayagüez.

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

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

Permit/Approval Description	ID Number	Permit Expiration Date
Title V Operating Permit	PFE-TV-4911-63-1196-0014	November 9, 2006 (renewal application filed on November 4, 2005)
Industrial Discharge Permit – Commonwealth of Puerto Rico Aqueduct and Sewer Authority	AUA-E-09-309-002	September 19, 2020 (renewal application submitted on June 1, 2020)

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

8.1. AIR EMISSIONS

The Mayagüez Title V Operating Permit includes emission limits and monitoring, recordkeeping, and reporting requirements for Mayagüez. PREPA provided Sargent & Lundy with the facility's Title V operating permit that was issued on November 9, 2001 and expired on November 9, 2006. 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 Mayagüez's 2018 annual Title V compliance certification, a renewal application was submitted on November 4, 2005, and the EQB is in the process of reviewing the renewal application. PREPA installed four new turbines to replace the existing turbines, which was authorized under construction permit PFE-50-0307-0286-I-II-C, issued on October 15, 2007. The turbines have been operating under the terms and conditions of the construction permit. Sargent & Lundy was not provided any amendments to the Title V

application that included the new turbines; however, Sargent & Lundy reviewed a letter from August 21, 2014 indicating that PREPA had submitted a renewal application and obtained the protective cover of the permit. The emission units regulated under the construction permit include the following:

- Eight oil-fired simple-cycle gas turbines with a capacity of 27.5 MW each
- One oil-fired black-start generator with an output of 1,005.5 horsepower
- One 500,000-gallon fuel oil storage tank

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

8.1.1. Air Permit Compliance

Sargent & Lundy reviewed air compliance documents supplied by PREPA, including annual emissions reports, semiannual monitoring reports, and annual Title V compliance certifications. Sargent & Lundy also reviewed air compliance information included in EPA's ECHO database. ECHO does not indicate any records of noncompliance with regard to air emissions.

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

Table 8-2 — Mayagüez Power Plant Annual Emissions

Pollutant	Allowable Emissions (Ton/Year)	Actual Emissions (Ton/Year)						
		2013	2014	2015	2016	2017	2018	2019
PM	83.10	8.16	10.52	8.24	3.42	4.97	7.96	5.86
SO_X	304.82	20.60	10.63	8.32	1.15	2.04	12.70	6.80
NO_X	796.29	598.24	771.57	604.32	250.50	364.80	583.43	430.05
VOC	25.06	0.28	0.36	0.28	0.12	0.17	0.27	0.20
CO	93.93	2.24	2.89	2.27	0.94	1.37	2.10	1.61

Pollutant	Allowable Emissions (Ton/Year)	Actual Emissions (Ton/Year)						
		2013	2014	2015	2016	2017	2018	2019
Pb	0.017	0.010	0.012	0.010	0.004	0.006	0.009	0.007

PM = particulate matter | SO_X = sulfur oxides | NO_X = nitrogen oxide | VOC = volatile organic compounds | CO = carbon monoxide | Pb = lead

Sargent & Lundy reviewed annual Title V compliance certifications for 2013 and 2015–2019. PREPA did not provide Sargent & Lundy with the annual compliance certification for 2014; therefore, the 2014 compliance certification was not reviewed. For the years reviewed, there were no reported deviations from the facility's permit.

Sargent & Lundy also reviewed semiannual monitoring reports for 2017 through the first half of 2020. For the periods reviewed, there were no reported deviations from the facility's permit.

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

8.2. WATER AND WASTEWATER DISCHARGE

Wastewater from Mayagüez is a combination of sanitary water, sewage from the drains of the turbine system after it has passed through the oil/water separator system, and water treatment wastewater. Sources of water treatment wastewater include reverse-osmosis wash water, multimedia filters wash water, demineralized water system chemical cleaning wash water, reverse-osmosis reject water, and electro-ionization module reject water. Water treatment wastewater is discharged into two retention tanks with a capacity of 15,000 gallons each. Wastewater from Mayagüez is discharged directly to the Commonwealth of Puerto Rico sewer system.

The facility's discharges are authorized under an industrial discharge permit from PRASA, Permit Number AUA-E-09-309-002. The permit's expiration date was September 19, 2020. A renewal application was submitted on June 1, 2020, and issuance of the new permit is pending.

8.2.1. Water Discharge Permit Compliance

The Mayagüez industrial discharge permit includes discharge limits and sampling, recordkeeping, and reporting requirements for the Mayagüez Station. The facility is required to perform sampling for the parameters specified in the permit and submit monthly self-monitoring compliance reports, including certified lab reports.

Sargent & Lundy was provided with semiannual compliance reports submitted to PRASA for September 2015–August 2018. Sargent & Lundy was also provided with two notifications of noncompliance: The first, dated October 6, 2015, identified a pH limit deviation. PREPA explained that the deviation was due to the use of a disinfectant bowl cleaner and that corrective measures had since been implemented to prevent future deviations. The second, dated October 10, 2018, identified flow discharge exceedances that PREPA explained were related to reverse-osmosis system washes and heavy rain events. PREPA's corrective measures included adding a visual and auditory alarm that alerts when the discharge flow rate reaches 90% of the limit.

8.3. 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 Part 370)[7] requires facilities that maintain safety datasheets to report the quantity of certain 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 facilities that manufacture, process, or otherwise use listed toxic chemicals in excess of applicable thresholds to prepare and submit a toxic release inventory to federal and state agencies.

Sargent & Lundy was provided with a Tier 2 report for January–December 2017 for Mayagüez that was submitted in 2018. Based on review of the Tier 2 report, it appears that the facility is following the necessary reporting requirements. EPA's ECHO database confirms that PREPA has prepared and submitted toxic release inventory reports through 2019.

8.4. OIL STORAGE SPILL PREVENTION

Sargent & Lundy reviewed a copy of Mayagüez's spill prevention, control, and countermeasure (SPCC) plan, which was revised in May 2015. SPCC plans must be updated every five years. The SPCC plan, required by 40 CFR Part 112, identifies onsite oil storage containers and provides a plan for preventing the

[7] CFR = United States Code of Federal Regulations

discharge of oil into navigable waters or adjoining shoreline. The Mayagüez SPCC plan appears to be complete and generally meets the Part 112 requirements.

8.5. SUMMARY

Sargent & Lundy performed a limited environmental review of publicly available information and information provided by PREPA to determine the compliance status for Mayagüez. Sargent & Lundy did not find any enforcement actions or compliance-related issues that would prevent renewal of the existing permits or impact near-term operation of the facility.

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9. RECOMMENDATIONS AND CONCLUSIONS

The facility and generation units at Mayagüez are new compared to other units across PREPA's power generation fleet. Sargent & Lundy found the site to be clean and well maintained. The typical design life of a GT generator-based power plant is approximately 30 years when following the OEM's recommendations for operation and periodic maintenance. Like many of PREPA's power generation plants, Mayagüez is exposed to the challenges of a coastal marine environment. The units at Mayagüez have weathered the operating conditions fairly well, and it is noted that the staff is diligent in maintaining the equipment.

Recent overhaul of the turbine rotors at the OEM's facilities, along with improvements to the combustion air intake filters, is expected to extend the life of these units and reduce the turbine wear issues that have beleaguered the facility to date. To resolve the issues, Sargent & Lundy recommends that an independent third party conduct a full root-cause analysis (RCA) and provide conclusions and recommendations for both PREPA and the OEM. The cost of these resolutions, including those already implemented, may be apportioned to each party, if claims are warranted, in accordance with each party's responsibility. Matters such as salt ingestion, fuel quality, suitability of the original design for purpose, subcontracted equipment and construction quality, OEM service bulletins, and other similar matters are all aspects of the analysis that may be evaluated as part of the RCA.

The Mayagüez facility is a valuable asset to PREPA's generation fleet. Given the equipment's SWIFTPAC design, one, two, three, or all four TWINPAC units could easily be removed and rapidly used as black-start units or for synchronous operation at any of the southern-coast or northern-metro area power plant locations. The units are designed for fast setup, have a large amount of remaining useful life, and can easily be redeployed as necessary to support black-start and peaking requirements elsewhere. The units have been configured as TWINPACs, so they are well-suited and sized for black-start duty at most of the PREPA power plants. They are also dual fuel and may easily be redeployed at Costa Sur or San Juan to take advantage of the current natural gas services for peaking and/or black start duties. Furthermore, there are four TWINPAC units, so it is possible to immediately improve up to four existing locations with equipment that has a relatively low capacity factor. However, there are no existing plans to redeploy the Mayagüez units elsewhere.

Mayagüez is in relatively good condition, but 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 balance-of-plant equipment are not well-suited for this type of operating environment. This is illustrated in the air-compressor replacement as well as the necessitated media upgrades and improvements for the GT air

intake system to prevent salt fines from entering the compression section of the GT units (P&W Service Bulletin 11M05 Revision A). Any new equipment must be configured for the challenging conditions at Mayagüez. 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) use of 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.

The GT OEM issues service bulletins periodically. These bulletins notify users of new information and feedback, such as announcements of updated maintenance notifications and performance upgrade information. The current method at the Plant for service bulletin tracking is manual, with no job number or maintenance date of completion correlated for records. Sargent & Lundy recommends the service bulletins are formally tracked with a documented closeout procedure. The follow-up documentation of GT service notices, completed by Plant staff or by third parties, should be tracked with a formal list and recorded date of completion.

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 Summary of the Puerto Rico Energy Bureau's (PREB) final resolution and order addressing PREPA's Proposed integrated resource plan (Case No. CEPR-AP-2018-0001) published in August of 2020 indicated that PREB had rejected the integrated resource plan's energy system management plan to add a new combined-cycle unit to Mayagüez and deliver natural gas supply to the facility. In general, the PREB decision rejected most 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.

PREPA continues to study the need for additional grid support and generation throughout the island. Smaller, rapid-start GT equipment, such as those in place at Mayagüez, can be easily adapted to integrate purge credit, battery storage for instantaneous response, and other similar features to provide a quicker response for a future grid that is planned to integrate a larger amount of renewable power. The units currently have both liquid fuel and gas connections as well as controls for both fuels, but with the PREB

resolution, the Plant will not benefit from the multiple advantages that could be realized by switching from fuel oil to natural gas as the primary fuel.

Other Plant modifications that can provide faster starts and address the ongoing issues with coastal salt may all be integrated into the design, and—presuming the turbine blade issues are resolved with the OEM—provide years of future power generation service from the facility.

10. REFERENCES

1. Sargent & Lundy report, “Mayagüez Phase I Environmental Site Assessment,” SL-014468.MG.ESA, dated May 22, 2019.
2. Sargent & Lundy report, “Demarcation of PREPA Generation Assets from the Transmission and Distribution System,” TD-0003, Dated October 4, 2019.