CONFIDENTIAL

Independent Engineering Report

Palo Seco Steam Plant

Prepared for

Puerto Rico Electric Power Authority

Report SL-015976.PS

Final

October 8, 2021

Project 14495.001

55 East Monroe Street
Chicago, IL 60603-5780 USA
312-269-2000
www.sargentlundy.com

Sargent & Lundy

LEGAL NOTICE

This deliverable was prepared by Sargent & Lundy, L.L.C. (S&L) expressly for the sole use of Puerto Rico Electric Power Authority (Client) in accordance with the contract agreement between S&L and Client. This deliverable was prepared using the degree of skill and care ordinarily exercised by engineers practicing under similar circumstances. Client acknowledges: (1) S&L prepared this deliverable subject to the particular scope limitations, budgetary and time constraints, and business objectives of Client; (2) information and data provided by others, including Client, may not have been independently verified by S&L; and (3) the information and data contained in this deliverable are time-sensitive and changes in the data, applicable codes, standards, and acceptable engineering practices may invalidate the findings of this deliverable. Any use or reliance upon this deliverable by third parties shall be at their sole risk.

Sargent & Lundy is one of the oldest and most experienced full-service architect engineering firms in the world. Founded in 1891, the firm is a global leader in power and energy with expertise in grid modernization, renewable energy, energy storage, nuclear power, and fossil fuels. Sargent & Lundy delivers comprehensive project services—from consulting, design, and implementation to construction management, commissioning, and operations/maintenance—with an emphasis on quality and safety. The firm serves public and private sector clients in the power and energy, gas distribution, industrial, and government sectors.

55 East Monroe Street • Chicago, IL 60603-5780 USA • 312-269-2000

VERSION LOG

Version	Issue Date	Sections Modified
Draft	November 13, 2020	Issued for PREPA comment
Final	October 8, 2021	For use

ISSUE SUMMARY AND APPROVAL PAGE

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.

Contributors

Prepared by:

Name	Title	Section(s) Prepared	Signature	Date
Joshua Junge	Project Associate	E.S., 1, 2, 3, 4, 5, 6, 9		10/8/2021
Nathan Adams	Energy Consultant	7		10/8/2021
David Helm	Senior Environmental Consultant	8		10/8/2021

Reviewed by:

Name	Title	Section(s) Reviewed	Signature	Date
Kevin Hopkins	Principle Energy Consultant	Overall Report		10/8/2021
Lara Bledin	Senior Energy Consultant	6, 7		10/8/2021
Kenneth Snell	Senior Environmental Manager	8		10/8/2021

Approved by:

Thomas Cavalcante Principal Consultant	October 8, 2021 Date

TABLE OF CONTENTS

FIGURES AND TABLES

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition/Clarification
Btu/kWh	British thermal unit per kilowatt hour
CAPEX	Capital expenditures
CE	combustion engineering
CFR	United States Code of Federal Regulations
DMR	discharge monitoring report
EAF	equivalent availability factor
ECHO	Enforcement and Compliance History Online (EPA's database)
EFOR	equivalent forced outage rate
EMS	energy management system
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
EQB	Puerto Rico Environmental Quality Board
ESST	emergency station service transformers
FEMA	Federal Emergency Management Agency
FY	fiscal year
GE	GE Power/General Electric
GIS	gas-insulated switchyard
gpm	gallons per minute
GT	gas turbine
HFO	heavy fuel oil
HP	high pressure
IP	intermediate pressure
IRP	integrated resource plan
MATS	Mercury and Air Toxics Standards
MMBtu/h	Million British thermal units per hour
MPT	main power transformer
NAAQS	National Ambient Air Quality Standards

Acronym/Abbreviation	Definition/Clarification
NCF	net capacity factor
No. 2	diesel
NFPA	National Fire Protection Association
NPDES	National Pollution Discharge Elimination System
O&M	operations and maintenance
Palo Seco	Palo Seco Steam Plant
Plant	Palo Seco Steam Plant
PM	particulate matter
PRASA	Puerto Rico Aqueduct and Sewer Authority
PREB	Puerto Rico Energy Bureau
PREPA	Puerto Rico Electric Power Authority
PS1	Palo Seco Steam Turbine #1
PS2	Palo Seco Steam Turbine #2
PS3	Palo Seco Steam Turbine #3
PS4	Palo Seco Steam Turbine #4
PSGT1-1	Palo Seco Gas Turbine #1-1
PSGT1-2	Palo Seco Gas Turbine #1-2
PSGT2-1	Palo Seco Gas Turbine #2-1
PSGT2-2	Palo Seco Gas Turbine #2-2
PSGT3-1	Palo Seco Gas Turbine #3-1
PSGT3-2	Palo Seco Gas Turbine #3-2
PSMP1	Palo Seco FT8 MOBILEPAC #1
PSMP2	Palo Seco FT8 MOBILEPAC #2
PSMP3	Palo Seco FT8 MOBILEPAC #3
psi	Pounds per square inch
psig	Pounds per square inch, gage
PWPS	Pratt & Whitney Power Systems
REC	recognized environmental condition
SPCC	spill prevention, control, and countermeasure

Acronym/Abbreviation	Definition/Clarification
TRI	toxic release inventory
TSS	total suspended solids

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 Palo Seco Steam Plant ("Palo Seco" or the "Plant").

Palo Seco is located on the northern coast of Puerto Rico in the Cataño municipality near San Juan. The Plant consists of four thermal steam units, six Hitachi-GE gas turbines (GTs), and three Pratt & Whitney Power Systems (PWPS) FT8 MOBILEPAC GTs with a total nameplate capacity of 809 MW. Palo Seco has been a major generator in the PREPA fleet and continues to serve on a limited basis as current power distribution challenges face the island.

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. The review was based on information provided by PREPA and its advisors through January 2021 and onsite visits conducted in 2018 through 2020. Sargent & Lundy understands that this review is being conducted in connection to the request for proposal to manage, operate, maintain, asset manage, 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 Palo Seco.

TECHNICAL REVIEW

Palo Seco Steam Plant Units 1 and 2 are tangentially fired Combustion Engineering ("CE," now GE Power), heavy fuel oil-fired (HFO-fired) boilers with reheat and a nameplate capacity of 85 MW each. The units are rated 1450 psi,[1] 1000°F, and the boilers are 857.7 MMBtu/h.[2] Unit 1 began commercial operation in 1960, and Unit 2 began commercial operation in 1961.

Palo Seco Steam Plant Units 3 and 4 are tangentially fired CE HFO-fired boilers with a nameplate capacity of 216 MW each. The steam turbines are rated 1800 psi, and the boilers are 1971 MMBtu/h. Additional details about the boilers and turbines were not provided for review. The units began commercial operation between 1967 and 1968.

[1] pounds per square inch
[2] one million British thermal units per hour

There are also three blocks of diesel-fueled gas turbine generators that began commercial operation in 1972 and 1973. Each block is composed of two 21-MW (nominal) Hitachi-GE (PB5341) GT generators. In total, the three blocks have a nameplate capacity of 126 MW.

Each steam turbine generator is connected to the 115-kV switchyard through a dedicated transformer. The gas units are connected in pairs, where each pair shares a step-up transformer connecting them to the 115-kV switchyard.

Three mobile GT units were added to the facility in 2019. The units are trailer-mounted 27-MW (nominal, approximate) PWPS FT8 MOBILEPAC GTs. The units were installed adjacent to the main road and the gas-insulated switchyard (GIS) building and tied into the primary side of the Unit 2 main power transformer. In total, the three mobile GT units have a nameplate capacity of 69 MW.

EQUIPMENT CONDITION

Palo Seco has been updated with newer controls and electrical switchyard infrastructure in recent years; however, most of the major equipment related to power generation—with the exception of the three new FT8 MOBILEPAC GTs—is at or nearing the end of its design life. Anticipated infrastructure maintenance and repair would not be cost effective for continued service, largely due to the current extended disuse of much of the thermal equipment, extensive coastal corrosion impact across the Plant and equipment, and safety concerns associated with the end-of-life operation. The Plant has seen much lower use since the September 2017 hurricanes.

Of the four HFO-fired thermal units, Unit 4 was operating at reduced capacity, Unit 3 was out of service in an environmental outage, expected to return by the end of 2020 and Unit 1 was undergoing repairs for air infiltration in the boiler but did not have a return-to-service date forecast as of October 2020. Unit 2 has been out of service since December 2016, and the Plant has no plans to bring the unit back online.

As of October 2020, only one of the six original GE diesel-fired GT units, PSGT1-1, was available, with the remaining units constrained by ongoing corrective maintenance activities or environmental restrictions. No return-to-service date was forecasted for the five non-operational GE units (PSGT1-2 through PSGT3-2). The three PWPS FT8 MOBILEPAC GTs (PSMP1, PSMP2, and PSMP3) are operational with some environmental restriction since they do not currently have the water supply necessary to inject for NO_X reduction. PSMP1 had its air prefilters replaced in early October 2020.

The site has inherent potential for a repowering project due to its proximity to the high electrical demand of the San Juan metropolitan area and the Plant's existing infrastructure and interconnection points that could be reused. PREPA is studying the need for additional grid support and generation throughout the island.

There are currently no plans to install new generation at Palo Seco; however, the final resolution and order from the Puerto Rico Energy Bureau (PREB) addressing PREPA's proposed integrated resource plan ("IRP," Case No. CEPR-AP-2018-0001) grants a budget for preliminary economic, siting, permitting and planning analysis of a new fossil-fuel-powered unit and/or energy storage at the site. The PREB decision also confirms the IRP's projected retirement[3] of the HFO thermal and GE GT units by 2025. To help offset this loss in generating capacity, Palo Seco is also being considered as a site for 3 of 11 new peaker GT units that will be added to PREPA's fleet with recently approved funding from FEMA.

The infrastructure that could be suitable for reuse includes the following:

- **115-kV GIS:** The facility is connected to the grid through an existing GIS that was recently installed (2012), is in good condition, and can be used as part of a new Plant design. The indoor GIS is protected from the saline environment and is far better suited than outdoor switchyards that are prevalent across the island. It is in excellent condition and could provide a valuable interface to the grid for new generation projects.
- **Existing Seawater Intake and Outfall:** The Plant has an existing permitted seawater intake and outfall system that is used for cooling and other Plant services that require seawater (the permit is expected to expire in 2021, unless otherwise extended). With new equipment and modifications and improvements to the existing intake system, the same intake locations could be reused to supply a new seawater cooling system. A seawater cooling tower may be considered preferable to the current once-through system if new thermal units added with the repowering project require more cooling capacity than the existing system was designed to supply. A seawater cooling loop with a cooling tower could yield the same or greater heat rejection with less water usage in makeup and blowdown flows. The reduced inflow and outfall from a cooling tower system would also be a benefit to the sensitive environmental areas that surround the Plant.
- **Existing Buildings:** The existing site buildings can be used for a control room, administrative offices, warehouses, and maintenance shops related to new generating unit(s).
- **Existing Fuel Oil Storage Facilities:** While some corrosion-related repairs could be anticipated, the existing fuel oil system could be used to support new generating units either as a source of primary fuel or backup fuel.
- **Miscellaneous:** The site has existing potable water and sewage connections that could support new generation facilities. The potable water connection has a high capacity; currently, the Plant can use up to about 620 gallons per minute (gpm), which is sufficient to support domestic usage and makeup to the demineralized water system via the water treatment system located in the administration/demineralization Plant building. Other existing items that could support a new plant include: (i) security walls, fencing, and gates; (ii) oil water separators; and (iii) an existing network of site roads with interconnection to Avenue El Caño.

[3] Removal from service and not considered for future generation

INFRASTRUCTURE AND INTERCONNECTIONS

The site building infrastructure is dated but serviceable. The steam plant administration building has older offices but ample room for many uses. The building also interfaces with the Plant to provide easy access to the steam turbine deck and control room of the current facility. The location of the administration building is central to the Plant on the eastside, and due to the size and shape of the space, it can be repurposed without impacting the ability to install a new power generating unit.

The warehouses and mechanical shops are also serviceable, with the locations on the periphery of the main Plant enabling a clear-space allowance for consideration. The GT administration building and main and miscellaneous workshop areas are to the western side of the facility. The workshops are well maintained and have extensive capability to service the units.

The Plant has several interconnections with services outside the Plant boundary. The site receives fuel oil, both heavy and diesel oil (No. 2), from two separate pipelines entering in at the southeastern side near the street. Fuel delivered to Palo Seco is from San Juan Harbor. Municipal water and sewer are provided on the southern side at the street. Seawater is used as circulating water. The intake is centered in the northern side of the Plant with the discharge to the southeast at the former Bayamón River.

OPERATIONS & MAINTENANCE

The operable units generate power as directed by PREPA dispatch. The Plant is manned with three shifts of operations personnel. The staff uses the control room as the center of operations; it is manned continuously for 24-hour operation, 7 days a week. Daily meetings in the mornings are used to direct activity and coordinate efforts among the staff. During each shift, the shift engineer oversees the Plant operations and management. There are typically 10 workers per each operations shift. Extended hours and additional personnel are used during outages.

The units have regular outages every 12–18 months for maintenance and environmental reasons, per an EPA consent decree and PREPA direction. There are no service agreements with manufacturers. The Plant has extensive workshop capability and is mostly self-reliant for repairs of equipment. Rebuilds of motors, generators, and rotors are done by specialty shops. Onsite simulators for the boilers, steam turbines, and demineralized water system are used for training and troubleshooting.

PERFORMANCE BENCHMARK

Sargent & Lundy reviewed the operational performance data that PREPA provided. The data is consistent with aging oil-fired power generation units that are cycled and not base loaded. Generation data for the

plants trended lower prior to the 2017 hurricanes. After the hurricanes, the units were entered back into service and used occasionally as required by dispatch. The limited use of Palo Seco is illustrated by the low net capacity factor (NCF). The average availability factor has fallen over the past six years and it is indicative of older plants that have maintenance and reliability issues. The heat rates provided for the steam units are competitive in the market and are in the range for units of similar design and fuel type; however, the Plant performance testing results were not available, and the peer group comparison to Palo Seco would also, on average, be at the end of useful life and outdated.

There are inconsistencies between the operational data provided for this report and the data shown in the PREPA monthly reports. Sargent & Lundy recommends PREPA review the data provided with the monthly reports and verify the data is the same. Inconsistencies include heat rate, net MWh, and capacity factors. Plant performance testing could be performed to reestablish the facility's current capability.

FINANCIAL REVIEW

Sargent & Lundy compiled the historical fixed and variable O&M and capital expenditures (CAPEX) for Palo Seco from reported PREPA data and fiscal plan forecasts for comparison with O&M and CAPEX for existing units in operation in North America of similar configurations and operating profiles. This data was for the period FY 2015 – FY 2020. From the data, Sargent & Lundy determined that the Palo Seco costs are within the typical range of costs for similar units considering that higher expenditures are required for plants firing HFO 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 Palo Seco. Sargent & Lundy did not find any compliance-related issues that would prevent renewal of the existing permits or impact near-term operation of the facility; however, the items listed below were identified as having unknown or potential compliance implications for Palo Seco:

- **Air Emissions**
  - Sargent & Lundy was not provided MATS[4] compliance reports for the second half of 2017 through 2020.
  - Particulate matter (PM) emissions from Unit 3 exceeded the MATS standard for all compliance periods reviewed by Sargent & Lundy.

[4] Mercury and Air Toxics Standards

  - Toa Baja, the municipality where the Plant is located, is currently designated as nonattainment for the one-hour SO_2 NAAQS.[5] EPA/EQB's forthcoming plan for bringing the area into attainment with the one-hour SO_2 NAAQS may require SO_2 reductions from Palo Seco.

- **Water and Wastewater**
  - From the second quarter of 2016 through the third quarter of 2020, PREPA reported exceedances for various parameters.

RECOMMENDATIONS AND CONCLUSIONS

Palo Seco's nameplate capacity is 809 MW; however, the operating capacity as of October 2020 was approximately 237 MW. A decline in Plant performance and reliability should be expected during the operating life of a thermal power generation plant, and it is evident in the case of Palo Seco. The Plant has provided power generation service since the 1960s and is at the end of its design life. It has been recommended that Palo Seco be phased out of service and replaced by a plant with capacity and flexibility as determined by a separate load demand and resource study which is ongoing.

Since its initial siting, Palo Seco—due to its proximity to the large San Juan population, the availability of seawater supply for cooling, and the nearby port services—has always been an ideal location for power generation on the island. PREPA is studying the need for additional grid support and generation throughout the island. The 2020 PREB decision confirms the IRP's projected retirement of the original HFO thermal and GE GT units by 2025 but grants a budget for preliminary economic, siting, permitting, and planning analysis of a new fossil fuel-powered unit and/or energy storage at the site. To help offset this loss in generating capacity, Palo Seco is also being considered as a site for 3 of the 11 new peaker GT units that will be added to PREPA's fleet with recently approved funding from FEMA. Ongoing and future repair of the original GE GTs and HFO thermal units is expected to continue as needed to maintain base-load availability during PREPA's repowering efforts; however, maintenance decisions should focus on minimizing capital expenditures, since these units are projected to retire by 2025 in accordance with the 2019 IRP.

For new generation equipment, a modern design should be considered for any new generation—one that uses best available technologies for improved efficiency and environmental and emissions controls. The new generation units can have additional operational flexibility designed for rapid response to support shifting load demands and a greater penetration of renewable sources of power like wind and solar. The redesign must include better protection and material selection than currently in place for this coastal

[5] National Ambient Air Quality Standards

installation as well as hardening of the facilities to enable command and control of power production during emergency conditions such as harsh weather events.

Care must be taken to ensure that replacements or upgrades to the Plant are suitable for an aggressive, salt-laden marine environment exposed to coastal winds. Typically, competitively priced original equipment manufacturer standards for power generation and balance-of-plant equipment are not well-suited for this type of operating environment. New equipment must be configured for the challenging conditions at Palo Seco. Failure to make allowances for suitable materials, equipment selection, buildings/enclosures, and other aspects of the facility design to protect the Plant from the operating environment will result in excessive future O&M costs and a shorter design life for any new installation. Suitable design specifications appropriate for this operating environment include: (i) corrosion-resistant material specifications; (ii) appropriate welding selections, including special treatment of all metal seams 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 at Palo Seco 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. Additional features other than location to consider for reusing the site include the GIS facility, intake and discharge structures, existing buildings, and ample site space. The balance-of-plant systems are tied to the existing layout and equipment sizes; their reuse for the air, cooling water, fuel, or fire protection is very limited. Altering and attempting to reuse the underground piping will be problematic for most new design layouts. The underground piping placement may not lend itself well for different, new power block sizes and foundation requirements and may need significant changes and modification. Due to age, Sargent & Lundy does not recommend reusing these systems.

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 Palo Seco Steam Plant ("Palo Seco" or the "Plant").

1.1. PLANT DESCRIPTION

Palo Seco is located on the northern coast of Puerto Rico in the Cataño municipality near San Juan. The Plant consists of four thermal steam units, six Hitachi-GE gas turbines (GTs), and three Pratt & Whitney Power Systems (PWPS) FT8 MOBILEPAC GTs with a total nameplate capacity of 809 MW. Palo Seco has been a major generator in the PREPA fleet and continues to serve on a limited basis as current power distribution challenges face the island.

Figure 1-1 — Palo Seco Geographic Location

Source: Google Earth

Palo Seco Steam Plant Units 1 and 2 are tangentially fired Combustion Engineering ("CE," now GE Power) heavy fuel oil-fired (HFO-fired) boilers with reheat and a nameplate capacity of 85 MW each. The units are rated at 1450 psi,[6] 1000°F, and boilers at 857.7 MMBtu/h.[7] Unit 1 began commercial operation in 1960, and Unit 2 began commercial operation in 1961.

Palo Seco Steam Plant Units 3 and 4 are tangentially fired CE HFO-fired boilers with a nameplate generation capacity of 216 MW each. The steam turbines are rated at 1800 psi, and the boilers are 1971 MMBtu/h. Additional details about the boilers and turbines were not provided for review. The units began commercial operation between 1967 and 1968.

There are also three blocks of diesel-fueled GT generators that began commercial operation in 1972 and 1973. Each block is composed of two 21-MW (nominal) Hitachi-GE (PB5341) GTs with a single step-up transformer. The three blocks have a total nameplate capacity of 126 MW.

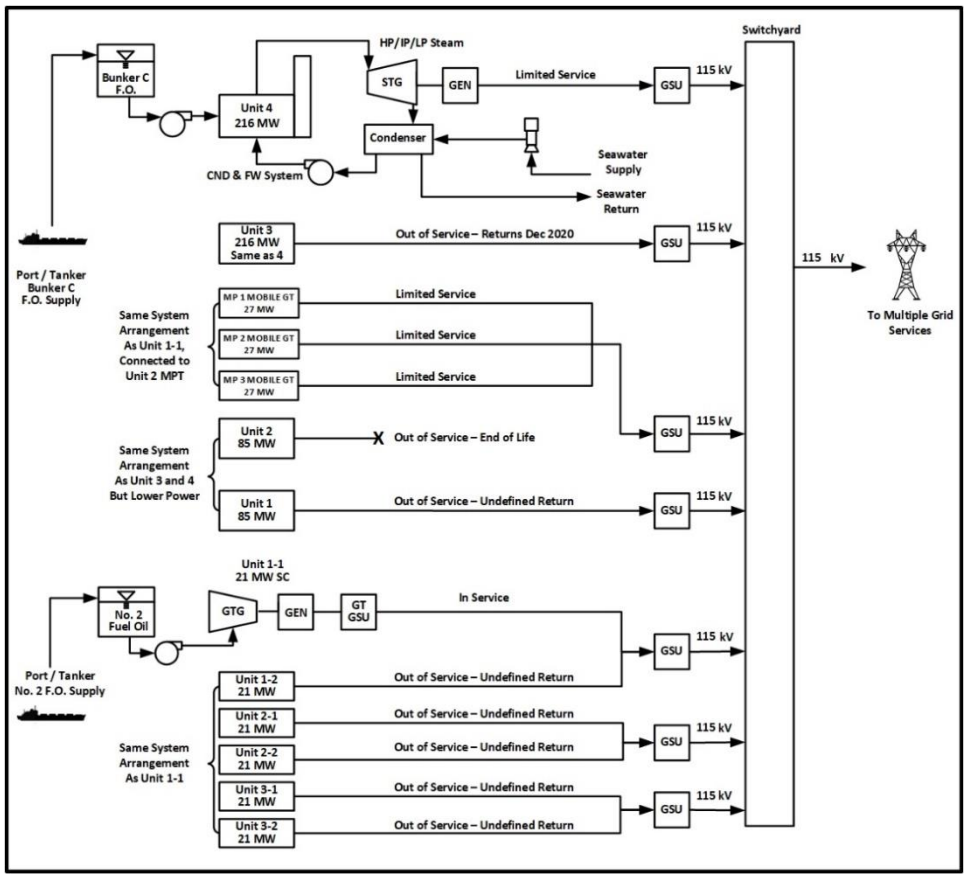
In 2019, the Plant added three new MOBILEPAC FT8 GT units made by PWPS, each rated to approximately 27 MW. The units are designed to operate on liquid fuel or natural gas, and each unit consists of two trailers: one with the turbine, generator, and exhaust system, the other containing the 15-kV switchgear, control system, protective relays, motor control center, and hydraulic start package. At the Palo Seco site, these units are located adjacent to the gas-insulated switchyard (GIS) building and are tied into the primary side of the Unit 2 main power transformer (MPT).

Each steam and GT unit includes a separate MPT. The four MPTs associated with the steam plant are connected to the 115-kV GIS through overhead conductor and GIS bus. Each GE GT block contains two generators and one MPT. The MPTs are connected to the 115-kV GIS substation via underground cables. Freshwater for the Plant is from the Puerto Rico Aqueduct and Sewer Authority (PRASA) municipal supply. Seawater is used for circulating water cooling.

An overview schematic representation of the plant facilities is provided in Figure 1-2 with outages as reported at the end of October 2020.

[6] pounds per square inch
[7] one million British thermal units per hour

Figure 1-2 — Palo Seco 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 in May 2019 with the site visit in December 2018. Please see report SL 014468.PS.ESA [1] for the Sargent & Lundy's findings of from the assessment.

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

- Documentation provided by PREPA's corporate operations and Plant personnel through January 2021.

- Discussions with Plant personnel on the phone and during several site visits of the facility from 2018 to early 2020.
    - Due to recent travel restrictions related to the 2020 global pandemic, no further visits to the site were made to support this report update. Updates of current equipment conditions and Plant activities were solicited from PREPA via an exchange of interview questions with Plant personnel in the fall of 2020.
- 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, asset manage, 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 Palo Seco.

2. TECHNICAL DESCRIPTION

Palo Seco includes four steam units, six diesel-fueled Hitachi-GE GT generators in three blocks, and three PWPS MOBILEPAC units. The total nameplate capacity of the Plant is 809 MW. The characteristics of the generating units at Palo Seco are shown in Table 2-1. Noting that recent dispatch data indicated that a number of units are classified as "Non-Operational," the aforementioned total breakdown of Plant capacity requires a reduction to reflect the recently reported conditions. The operational capacity of the plant as of October 2020 was approximately 237 MW.

Table 2-1 — Production Plant Overview

Plant Name	COD	Technology	Fuel	Nameplate Capacity (MW)	Status as of October 2020
Palo Seco Steam Turbine #1 (PS1)	1960	Steam	HFO	85	Non-Operational; End of Life; Out of service since August 2020 due to excessive air infiltration in the boiler
Palo Seco Steam Turbine #2 (PS2)	1961	Steam	HFO	85	Irreparable; Out of service since December 2016 due to failure of boiler feedwater Pump 2-1; parts from Unit 2 are scavenged to repair and maintain Unit 1
Palo Seco Steam Turbine #3 (PS3)	1967–1968	Steam	HFO	216	Non-Operational; End of Life; Environmental outage scheduled to be complete in December 2020.
Palo Seco Steam Turbine #4 (PS4)	1967–1968	Steam	HFO	216	Operational; End of Life; Unit is limited by 66- to 150-MW output with air infiltration into the boiler and high-pressure differential across air heaters; boiler feedwater Pump 4-1 is out of service
Palo Seco Gas Turbine (PSGT1-1)	1972–1973	GT	No. 2	21	Operational; End of Life
Palo Seco Gas Turbine (PSGT1-2)	1972–1973	GT	No. 2	21	Non-Operational; End of Life; Repairs underway on stack
Palo Seco Gas Turbine (PSGT2-1)	1972–1973	GT	No. 2	21	Non-Operational; End of Life; Unit is out of service with reported ground fault issues
Palo Seco Gas Turbine (PSGT2-2)	1972–1973	GT	No. 2	21	Non-Operational; End of Life; Unit is restricted per EPA permit
Palo Seco Gas Turbine (PSGT3-1)	1972–1973	GT	No. 2	21	Non-Operational; End of Life; Unit is restricted per EPA permit

Plant Name	COD	Technology	Fuel	Nameplate Capacity (MW)	Status as of October 2020
Palo Seco Gas Turbine (PSGT3-2)	1972–1973	GT	No. 2	21	Non-Operational; End of Life; Unit is restricted per EPA permit
Palo Seco Gas Turbine (PSMP1)	2019	GT	No. 2	27	Operational Limited by 5- to 22-MW output due to lack of water available for NO_X control
Palo Seco Gas Turbine (PSMP2)	2019	GT	No. 2	27	Operational Limited by 5- to 22-MW output due to lack of water available for NO_X control
Palo Seco Gas Turbine (PSMP3)	2019	GT	No. 2	27	Operational Limited by 5- to 22-MW output due to lack of water available for NO_X control

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

Palo Seco consists of the following major components:

- Four steam turbines and generators
- Six diesel-fired GE GT generators
- Three diesel-fired PWPS GT generators
- Two emergency station service transformers
- Four normal station service transformers
- One 115/38-kV gas-insulated substation for grid interconnection
- One 4160/480-V switchgear room
- One machine/mechanical room
- Fuel oil lines
- Four reserve and four service HFO tanks
- Three diesel (No. 2) fuel oil tanks
- Four lube oil tanks
- Propane gas tanks (light-off fuel)
- Boilers – burner levels
- Demineralization water treatment system

- Sulfuric acid tanks
- Caustic soda tanks
- Industrial gas storage area
- Control room

2.1. MECHANICAL SYSTEMS

A brief description of the facility's main equipment and systems is provided herein. Where appropriate, systems and equipment have been grouped together by units or kept separately. In general, legacy documentation of original equipment is missing or only exists as hard copy in the information library. Most of the information presented in this report is relayed through the knowledge of the staff on site or by walkdown observations by Sargent & Lundy staff during the 2018 site visits.

2.1.1. Steam Generators

2.1.1.1. Units 1 and 2

Palo Seco Units 1 and 2 (PS1 and PS2) are tangentially fired CE HFO-fired boilers with reheat and a nameplate capacity of 85 MW each. The units are rated 1450 psi, 1,000°F boilers at 857.7 MMBtu/h. Additional details about the boilers and steam turbines were not available for review. Unit 1 began commercial operation in 1960, and Unit 2 began commercial operation in 1961.

Figure 2-1 — Palo Seco Boilers, Units 1 and 2

2.1.1.2. Units 3 and 4

Palo Seco Units 3 and 4 (PS3 and PS4) are tangentially fired CE HFO-fired boilers with a nameplate capacity of 216 MW each. The steam turbines are rated 1800 psi, and the boilers are 1971 MMBtu/h. Additional details about the boilers and turbines were not provided for review. The units began commercial operation between 1967 and 1968.

Figure 2-2 — Palo Seco Boilers, Units 3 and 4

2.1.1.3. Units 1–4

Palo Seco Units 1–4 use similar overall system designs, but the designs are scaled according to their ratings. The similar slide-along design aids in uniform equipment layout for access and location. The units are arranged from east to west, Units 1–4. Units 1 and 2 are each single stack, and Units 3 and 4 each have two stacks. The units are fired with HFO through tilting burners and are started with propane gas. Propane gas for ignition is provided to lighters prior to admitting No. 2 fuel oil for additional warmup of the boiler before firing heavy fuel.

Boiler-specific equipment includes forced-draft fans—with Windbox East and Windbox West—induced-draft fans, recirculation fans, air heaters, and a deaerator (located at EL. 74´ and 84´ for Units 1 and 2 and Units 3 and 4, respectively).

The last condition assessment was provided for Unit 3, undertaken in 2013. The assessment examined the upper steam drum, water wall headers, economizer, and portions of the main steam line. The report summarized a few findings, including wall thinning, and indicated additional recommended examinations for follow-up and monitoring. No subsequent inspections or reports were provided for Sargent & Lundy's review, and the unit is currently in operable condition.

2.1.2. Steam Turbines

There are four steam turbines on site. Units 1 and 2 have similar turbines, and Units 3 and 4 have similar turbines. All four are outdoor installations with weather shelters for the turbine and generator. The units are located on the turbine deck above the condenser with adjacent maintenance walkways and work platforms.

A common gantry crane, with a main hook rated at 50 tons and an auxiliary hook rated at 15 tons, is available for servicing the units. The turbine deck is conveniently located adjacent to the control rooms for access to the capital equipment and the engineering offices in the administration building. The gantry crane has access to the bays between the units for equipment laydown.

Figure 2-3 — Palo Seco Unit 1 Steam Turbine

The turbines are a down discharge configuration. The condenser is located below the exhaust discharge duct with the turbines above the auxiliary spaces and equipment rooms. The turbine deck is wide and unobstructed, with some deterioration shown in the walkways and catwalks at an approximate elevation of 42 ft. (30 ft. above grade).

Extraction steam is used for feedwater heaters. There are nine extractions total: two extractions for the low-pressure (LP) Turbine A, two extractions for the low-pressure Turbine B, three extractions for the intermediate-pressure (IP) turbine, and two extractions for the high-pressure (HP) turbine. The nine extractions feed six feedwater heaters. The HP and IP turbine steam feeds from the boiler split into two connections at the steam chests. The low-pressure feed is direct from the IP steam turbine exhaust.

Units 1 and 2: The steam turbines for Units 1 and 2 are GE, 22-stage units in three pressure sections. The HP and IP sections are opposed flow. The low-pressure section is dual flow, down exhaust.

Each turbine has a nominal inlet pressure of 1450 psig[8] at 1000°F with a nominal rating of 85 MW per the net capacity factor formula and 82,500 kW per the generator nameplate. The generators are hydrogen cooled.

Units 3 and 4: The steam turbines for Units 3 and 4 are Westinghouse and provided with three pressure sections. The HP and IP sections are opposed flow. The low-pressure section is dual flow, down exhaust configuration.

Figure 2-4 — Palo Seco Unit 3 Steam Turbine

[8] Pounds per square inch, gage

Each turbine has a nominal inlet pressure of 1850 psig, at 1000°F, with a nominal rating of 216 MW per the net capacity factor (NCF) formula; the generator nameplates are 269,000 kilovolt-ampere at 0.85 power factor. The generators are hydrogen cooled.

2.1.3. Generators

The generators for all four thermal boiler units are hydrogen cooled (60 psig) with nominal ratings of Units 1 and 2 both at 85 MW and Units 3 and 4 both at 216 MW. The generators are located outdoors on the turbine deck at a nominal elevation of 42 ft. The generators feed into the 115-kV GIS that was newly installed in 2012.

2.1.4. Steam and Condensate Cycle

Units 1–4 use similar overall steam and condensate system designs, but the designs are scaled according to their ratings. Steam is provided to the steam turbine as HP and IP. The HP steam pipe exits the boiler from the superheater, and the flow is divided into two feeds with stop valves prior to connection to the steam chest and nozzle block. The IP system is also split into two flows prior to admittance to the intercept, stop valves, and IP turbine. The IP turbine discharges to the low-pressure turbine, and the flow path is divided through opposing rotors.

No turbine bypass dump system to the condenser is provided for cycling or to aid in startup, and the unit is brought up using the vents on the boiler side.

The turbine is down exhaust, resulting in a high turbine deck; the condenser is mounted below it. Condensate is pumped from the condenser hotwell via redundant pumps, rated at 2420 gpm and 175 feet for Units 3 and 4 and a nominal 900 gpm for Units 1 and 2. The condensate pumps discharge to the suction side of deaerator booster pumps for delivery to the condensate polisher, feedwater heaters, and deaerator.

Boiler feed pumps take suction from the deaerator for delivery through the remaining feedwater heaters to the steam drum. From the observable nameplates at site, Allis-Chalmers boiler feed pumps are used. Each unit's boiler feed pumps are 2 x 100% and deliver flow to Feedwater Heaters 5 and 6 before entering the respective boiler.

2.1.5. Circulation Water Systems

Circulating water is drawn from the ocean as primary cooling water for the condensers. It is a once-through cooling system with the discharge water channeled through a mangrove (the former flowing Bayamón River mouth, now diverted upstream offsite) for release back to the ocean. Due to the environmental restrictions, no biocides may be used with this cooling water system, which create challenges in controlling biological

fouling and maintaining adequate cooling water system flow and heat transfer. Maintenance outages usually include cleaning of hard marine buildup in the system.

Figure 2-5 — Palo Seco Water Intake, Unit 1

2.1.5.1. Unit 1 & 2 Circulation Water Systems

The Unit 1 and Unit 2 circulating water system consists of an oceanside intake structure, screenwell chambers, three traveling intake screen assemblies, screen wash pumps, and one Byron Jackson vertical pump for each unit with a shared spare pump for redundancy. The intake is located on the Boca Vieja Bay.

The pumps are mounted to the concrete deck above the water intake basin. A service platform is provided at the motor level for servicing and inspection of the units. An overhead crane is available for maintenance removal and access.

The pumps discharge to the condenser intake tunnel, and the circulating water flow is then headered to either side of the condenser for heat rejection. After cooling the condenser, the circulating water is piped to the circulating water discharge channel and enters the mangrove for release to the ocean.

2.1.5.2. Units 3 & 4 Circulation Water Systems

The Unit 3 and Unit 4 circulating water system consists of an oceanside intake structure, screenwell chambers, seven traveling intake screens, screen wash pumps, and two Byron Jackson vertical pumps for each unit with a spare pump that is shared for redundancy.

The pumps are mounted to the concrete deck above the water intake basin. A service platform is provided at the motor level for servicing and inspection of the units. An overhead crane is available for maintenance removal and access.

Figure 2-6 — Palo Seco Unit 3 and Unit 4 Circulating Water Pumps

The pumps discharge to the intake tunnel, and the circulating water flow is split to either side of the condenser for heat rejection. After cooling the condenser, the circulating water is piped to the circulating water discharge channel, which returns water through adjacent mangroves for release to the ocean.

Separate seaweed trenches are also provided to aid in the clearance of debris from the traveling intake screens. The seaweed channels bypass the Plant and are directed into the discharge tunnel for release into the ocean.

Due to the environmental restrictions associated with the return path to the adjacent mangroves, biocide cannot be used within the circulation water system; therefore, frequent maintenance is required to keep the system clean.

2.1.6. Fuel Systems

Fuel storage and transfer systems on site include HFO and No. 2 for the thermal units and the GTs, respectively. No. 2 is received into three tanks that feed the GT units. These tanks can be arranged to receive fuel directly from fuel delivery trucks or by pipeline. Palo Seco receives HFO and No. 2 fuel oil from ships and barges unloaded at the station's oil discharge docks in the San Juan Bay. The HFO and No. 2 are stored in onsite tanks prior to being forwarded to the thermal and GT units, respectively, for firing to generate electricity.

Figure 2-7 — Palo Seco Diesel Oil Tank #1 and Transfer Pump Skid

2.1.6.1. HFO System

The HFO system consists of four reserve tanks, four service tanks, pumps, heaters, and a pipeline connection to fill with fuel from off site. The offsite fuel loading station is the Puerto Nuevo Fuel Oil Docking Station located nearby, and it provides two fuel oil pipelines: one for HFO and one for No. 2.

The four combined reserve tanks hold a nominal 450,000 barrels total. The R-1 and R-2 reserve tanks are both a nominal 89,000-barrel capacity each. The R-3 and R-4 reserve tanks are both a nominal 135,000-barrel capacity each. The reserve tanks allow for continuous operation for 21 days at the nameplate capacity of the thermal boilers.

Fuel is forwarded from the reserve tanks to four service tanks that have a nominal storage capacity of 26,590 barrels. From the service tanks, fuel is provided through transfer and delivery pumps and heaters to the respective thermal units for firing.

2.1.6.2. No. 2 Oil Systems

The No. 2 fuel oil systems are dedicated to the GT generation units on the west side of the Plant. The three tanks have a total capacity of 40,000 barrels. The tanks have fuel pumps to forward fuel to the GTs; the piping is arranged to deliver fuel to the turbines via a trench so that fuel piping condition and leakage may be monitored.

2.1.7. Gas Turbines

2.1.7.1. General Electric Gas Turbines

There are three blocks of No. 2-fired GT generators, which began commercial operation in 1972 and 1973. Each block is composed of two 23.25-MW General Electric (PB5341) GTs (six in total) with a common step-up transformer manufactured under license by Hitachi. The three blocks have a total nameplate capacity of 139.5 MW with a current nominal output rating of 126 MW. The unit numbers are as follows: PSGTI-1, PSGTI-2, PSGT2-1, PSGT2-2, PSGT3-1, and PSGT3-2.

The units can be used for black start of the Plant (two GTs are needed for capacity requirements of the large horsepower pumps for the thermal units).

Figure 2-8 — Palo Seco Gas Turbines

The turbines are a GE design that was first available for delivery in 1961. The units are each rated at 23,450 kW for 6,000 hours of use a year. The model also has an available peak rating of 25,300 kW for limited (2,000 hours/year) usage. The nominal (new) heat rate is 12,370 Btu/kWh. The compressor has a compression ratio of 10.2, with a combustion turbine inlet temperature of 1805°F and exhaust temperature of 958°F. The output turbine shaft has a speed of 5105 revolutions per minute and a gear box reduces the speed for the generator to 3600 revolutions per minute. The design is licensed to Hitachi and John Brown Engineering for manufacture and delivery. The GT is self-contained, described as a packaged unit with only a fuel source required for operation.

2.1.7.2. MOBILEPAC Gas Turbines

In 2019, the Plant added three new PWPS MOBILEPAC FT8 units rated 30.941 MW at standard ISO conditions. The units are designed to operate on liquid fuel or natural gas, and each unit consists of two trailers: one with the turbine, generator, and exhaust system, the other containing the 15-kV switchgear, control system, protective relays, motor control center, and hydraulic start package. Figure 2-9 shows an example of one trailer in transit. The three units were procured to meet the needs of a fast-response generation source and can be brought online during power shortage emergencies like those that resulted during the 2017 hurricane season. The mobile design allows the units to be transported by road and redeployed in a matter of days wherever additional generation is needed. At the Palo Seco site, these units are located adjacent to the GIS building and are tied into the primary side of the Unit 2 MPT.

The three MOBILEPAC units require the injection of high-quality demineralized water into their combustors for NO_X control to meet their emissions standards. The operation of these units is currently restricted until a connection to the necessary water source is provided. A project is underway to add the pumps and piping to deliver demineralized water to these units from the Plant's existing demineralized water system and is expected to be completed in the first quarter of 2021.

Figure 2-9 — PWPS FT8 MOBILEPAC Gas Turbine in Transit

Source: pwps.com

2.1.8. Compressed Air

The compressed air systems are adjacent to each respective unit in the auxiliary building and headered together for the block. The system is a mixture of different units and contains Atlas Copco compressor units, Pneumatic Products (SPX) dryers, and air receivers for the instrument and service air systems. Additional backups include compressor units in shelters outside the auxiliary building.

2.1.9. Fire Protection

The fire protection system consists of a dedicated firewater storage tank, a Fairbanks Morse diesel-operated pump (in an enclosure with a jockey pump), two Aurora (Pentair) electric pumps (both in a shelter), and two separate foam application shelters (one each for the HFO and GT areas). The main control cabinet is in the control room on the turbine deck of the auxiliary building. The main fire protection cabinet was manufactured by Fike Corporation.

The main pumps (electric and diesel) are rated at 1500 gpm each. The firewater storage tank is adjacent to the electric pump shelter and provides the water for the system. The pumps discharge to an underground loop system supplying the turbine areas, fuel tank areas, buildings, and other sprinkler loads.

2.2. ELECTRICAL SYSTEMS

2.2.1. Overall Electrical Scheme

The generators for all four steam units are each connected to a dedicated step-up transformer. Taps from the generators' main leads of Units 1 and 2 also provide power to station service transformers, which step down the generation voltage to 4.16 kV, and each feeds a switchgear bus that is dedicated to the respective

unit. In addition to the unit switchgear buses, there is an additional 4.16-kV bus, which is common to both units and provides power to balance-of-plant loads as well as backup power to the unit buses in case of a loss of its normal source of power. The common bus receives its power directly from the 38-kV substation through a step-down transformer.

The 4.16-kV switchgear buses power the low-voltage switchgear through low-voltage auxiliary transformers, which in turn feed motor control centers located throughout the Plant.

2.2.2. Switchyard and Interconnection

Each steam turbine generator for thermal Units 1, 3, and 4 is connected to the 115-kV GIS through a dedicated MPT. The connection is through overhead conductor and GIS bus. The original GE gas units are connected in pairs, three pairs total, where each pair shares a step-up transformer connecting them to the 115-kV switchyard via underground cables. The new FT8 MOBILEPAC GT generators are connected to the 115-kV switchyard via the MPT previously dedicated to thermal Unit 2.

Additionally, the four thermal steam units also have two common emergency station service transformers (ESSTs), one ESST per two units, that connect to the 38-kV and 115-kV switchyards via underground cable.

The 115-kV and 38-kV switchyards are located just south of the power block. The existing demarcation point for Palo Seco is on the low side of the MPT due to the division of responsibility on the maintenance of the MPTs. All maintenance on the large power transformers is performed by the conservation group within PREPA's substation group; the maintenance includes the MPTs, ESSTs, and normal station service transformers. Additionally, the GIS local control cabinets have controls of the PREPA transmission center breakers.

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

2.2.3. GIS Building

The GIS replaced the old 38-kV and 115-kV open-air switchyard in 2012. The energized parts are contained using gas-insulated technology and are divided into two buildings based on the voltage level. The GIS facility review is out of the scope of this document but is included here for information only.

Figure 2-10 — New Palo Seco Gas GIS Building

2.2.4. Emergency Generators

Two 500-kW electric generators (GE-PS-1 and GE-PS-2) are provided for emergencies. The generator sets are Detroit Diesel Model 8V2000-R083K36. Both run on diesel fuel and are model year 2005.

The GIS is also provided with a separate 250-kW emergency generator. The genset is a Kohler model with a John Deere 6090HF484 diesel engine; the model year is 2007.

The GE GTs provide black-start capabilities to the Plant.

2.3. STRUCTURES

There are multiple structures on site to support the facility; however, only a few will be described herein. Structures range in age from the recently added GIS building to the original administration building. The main structures include the following:

- Administration/demineralization plant building

- Mechanical building; warehouses
- GT administration and support buildings
- Maintenance shops
- Pneumatic building
- GIS building
- Auxiliary building

The Administration/demineralization plant building is a multistory structure. The main offices are located here and have an elevator, conference rooms, support staff offices, and library. A separate area houses the demineralization plant equipment including the pumps, tanks, and water treatment skids.

Figure 2-11 — Palo Seco Main Administrative Building

The GT administration and support buildings house the workshops and offices for the six GT units on site. The building is located on the west side of the facility adjacent to the outdoor storage area for the GTs.

Figure 2-12 — Palo Seco Gas Turbine Administrative Building

Figure 2-13 — Palo Seco Pneumatic Workshop

The GIS building houses the GIS equipment and electrical connections from the electrical generators to the grid. The building is located on the south side of the plant adjacent to the access road and the old 115-kV switchyard.

The auxiliary building is adjacent to the boilers and interconnects the boilers to the control room and the steam turbine deck for all four units. It is a multistory structure that houses support functions for each of the

main steam plants, Units 1–4. The building contains most of the plant equipment, including pumps and electrical switchgear, and provides access from the administration offices, steam turbine deck, steam units, and control room areas of the plant.

2.4. CONTROL SYSTEMS

An upgrade of the Units 1–4 existing Foxboro® boiler control system with the I/A Series® system upgrade began in June of 2020. The upgrade includes the replacement of 5 servers, 15 workstations, and 14 switches with modern hardware. Two new servers will be added to implement cybersecurity compliant with modern industry standards and corporate policies.

Key elements of the I/A system upgrade include the following tasks:

- Replace and exchange engineering workstations with new rack-mounted servers H90 with (no raid) hard drives and monitors.
- Replace the operator workstations with new H92 tower model computers standard hard drives and monitors.
- Port the existing FoxView HMI displays to the latest version of FoxView installed for the Units 1-4 boilers.
- Port the Aim*Historians to new workstations.
- Include a server mounting enclosure i for the secure primary and secondary domain servers.
- Replace the existing “mature” switches.

These upgrades are expected to improve the functionality, performance, and control capabilities of the Unit 1–4 boiler control system and are scheduled for completion in February 2021.

The new FT8 MOBILEPAC GT units come standard with an integrated control system as part of the MOBILEPAC package. These include modern Woodward MicroNet™ Plus hardware platforms and Citect HMI software.

Additional information concerning the control systems for the GE GT units was requested but has not been furnished for review and discussion in this report.

3. EQUIPMENT CONDITION

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

3.1. CONDITION ASSESSMENT

3.1.1. Methodology

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

- **Safety Hazards**—Based on visual observations during walkdowns from experienced engineering staff
- **Corrosion Control**—With most of the facilities located near the coast, 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. It should be noted that the GIS review was not in this scope and is therefore not included in this condition assessment. Sargent & Lundy's color-code scoring system for this assessment is defined in Table 3-1.

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

	System like new (replaced or refurbished within the past 5 years)
	System 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 Palo Seco thermal production unit is mandated to take an environmental outage at intervals of 12–18 months. Sargent & Lundy assumed that all required maintenance activities are conducted during each mandatory environmental outage except where progress is noted. This key assumption was used in the evaluation of each of the six major condition assessment categories.

3.1.2. Condition

In general, when any unit was placed into short- or long-term layup, Plant personnel indicated that a unit would be drained, but no dehumidification systems were used. Limited nitrogen blanketing is used in the facility for corrosion prevention. Many examples of deterioration due to disuse were noted. A condition assessment table is provided at the end of each unit discussion that follows herein.

3.1.2.1. Unit 1

The mechanical equipment for Unit 1 scored below industry averages due to several major issues with rotating mechanical and electrical equipment; however, the condition of most of the remaining major electrical equipment for Unit 1 is consistent with its age. The overall condition assessment summary of Palo Seco Unit 1 can be found in Table 3-2.

Unit 1 was in operation during the December 2018 site trip, but its use is limited to an 8% capacity factor by the Mercury Air Toxics Standards (MATS) currently in place. As of October 20202, the unit had been offline since August of 2020. The Plant personnel indicated Unit 1 components were being replaced with components from the non-operational Unit 2, with tracking of repairs and replacements done manually. Additionally, the Plant personnel indicated there are unit output issues due to excessive air infiltration in the ductwork, and a plan has been developed to help resolve these issues, though no corrective action has been taken to date; furthermore, severe corrosion is present on the northeast structural platforms and around the deaerator tank. The Plant replaced many of these major structural sections and platforms in May 2018 based on input from GE Power. Encapsulation and restoration were also used to improve the columnar steel interfaces with major foundations.

Most of the major electrical equipment is original and nearing the end of its useful life, but some equipment has been replaced as needed. All generators, power transformers, switchgear, batteries, and relays undergo periodic maintenance and testing. The generator for Unit 1 was rewound in 2008 after it was damaged in a fire. The gas analysis for Transformer ESST1-2, taken in January 2018, showed evidence of moderate partial discharge and overheating of cellulose. This condition needs to be monitored and rechecked every three months if the transformer is to see continued use. The insulation is considered wet, which is another problem because it causes cellulosic insulation to age faster. A subsequent dissolved-gas analysis performed in August 2020 noted that the condition was of no immediate concern but recommends that resampling and analysis be performed again in six months or sooner.

Table 3-2 — Palo Seco Unit 1 Overall Condition Assessment

Plant Name: Palo Seco Unit 1

Item	System	Assessment Method			Scoring Category				Notes
		Visual	Interview	Data	End of Life	Reliability	Unit Output	Subtotal	
1	**Safety Hazards**	yes	yes	no		*n/a*	*n/a*		Severe corrosion at the facility due to NE winds from the sea.
2	**Corrosion Control**	yes	yes	no		*n/a*	*n/a*		Severe corrosion on platforms on NE and DA system but are currently being restored and repaired.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		Nothing to note.
4	**Mechanical Assessment**								
4.1	Steam Generator (boiler/HRSG)	yes	yes	no					Unit is not currently in operation with noted issue of air infiltration to the boiler (designated as limited-use boiler, annual capacity factor less than 8%) . Economizer and reheater may be near their end of life (plant input).
4.2	FD and ID Fans and Auxiliaries	no	yes	no					This scoring only relates to the ductwork leakages/infiltration. The unit currently sees a unit derate due to the high air in-leakage.
4.3	High Energy Piping (HEP)	no	yes	no					No issues noted but limited information provided.
4.4	Condensate System	no	yes	no					No issues noted but limited information provided but frequency of cleaning is more than units 3 and 4.
4.5	Feedwater System	no	yes	no					No issues noted with the feedwater system but components are being used from Unit 2.
4.6	Turbine and Auxiliaries	yes	yes	no					No issues noted but limited information provided.
4.7	Circulating Water and Aux Systems	yes	yes	no					No issues noted with the system but components are being used from Unit 2. Aquatic life an issue. 1 CW pump is removed for repair. Circulating water connections to condenser are leaking and have significant corrosion. Report from Sept 2007 indicated condenser was at the end of life.
4.8	Station Air System	yes	yes	no					No issues with station air and each units station air is shared between the other units.
4.9	Emission controls	no	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	No emissions controls installed.
4.10	Fuel Systems	yes	yes	no					Heavy fuel oil tank R-3 damaged and out of service.
4.11	Seawater Intake	yes	yes	no					Seaweed is currently an issue and no chlorination is used.
4.12	Water Treatment	yes	yes	no					Currently no redundancy is available, however due to limited dispatch this has not been an issue. Plans for a RO system within the next 2 years.
4.13	Underground Piping	no	yes	no					No issues noted but limited information provided.
4.14	Fire Protection Systems	no	yes	no					No issues noted but limited information provided.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					No issues noted during walkdown.
5.2	Transformers	yes	yes	yes					ESST1-2 is showing evidence of partial discharge and wet insulation.
5.3	Switchgear	yes	yes	no					No issues noted during walkdown.
5.4	Protective Relays	yes	yes	no			*n/a*		No issues noted during walkdown.
5.5	Black Start Engines	no	yes	no					No issues noted during walkdown.
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		No issues noted during walkdown.
6.2	Turbine Controls	yes	yes	no			*n/a*		No issues noted during walkdown.
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no			*n/a*		No issues noted with buildings.
7.2	Structural Steel	yes	yes	no			*n/a*		Severe corrosion on platforms on NE and DA system but are currently being restored and repaired.
7.3	Tanks / Containment	yes	yes	no					No issues noted with tanks/containment
7.4	Cranes	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	No issues noted.
8	**Overall Condition Assessment**								Deficiencies were noted.

3.1.2.2. Unit 2

Unit 2 is in extended layup. It was not in operation during the site visits, and it has been inoperable since 2016 due to steam turbine and generator issues and is not expected to return to service.

The mechanical equipment for Unit 2 scored well below industry average for several major reasons. Corrosion is present throughout the facility and is currently being maintained based on input from GE Power. As discussed earlier in this section, appropriate boiler and auxiliary equipment layup procedures were not applied when the unit went offline in 2016. Major inspections should be performed, and a layup procedure should be developed and implemented for the station.

Additionally, Boiler Feedwater Pump 2-1 is damaged; there are no current plans for replacement. As discussed above, parts are currently being removed from Unit 2 for other systems at the facility. Boiler feedwater pump parts are currently being scavenged from Unit 2 to use on Unit 1. The condition of the major electrical equipment for Unit 2 is consistent with its age. Most of the major electrical equipment is original and nearing the end of its useful life, but some equipment has been replaced as needed. The low voltage switchgear breakers for Unit 2 were replaced in 2005.

The generator for Unit 2 is out of service. This generator was completely rewound in 2002, but recent megger test readings in the stator were low. Low megger readings indicate compromised insulation, and it was determined that the generator would need to be rewound to return to operation. PREPA decided not to invest in the repair of the Unit 2 generator.

The 2019 gas analysis for Transformer MPT-U2, B Phase showed evidence of severe partial discharge, and the dryness of the insulation was considered wet, which is another problem because it causes cellulosic insulation to age faster. The Unit 2 main power transformer has since been refurbished for use as a tie-in point for new generation. This connection was used as a temporary tie-in for two FEMA-provided gas turbines following the 2017 hurricanes, which were subsequently removed in early 2019. The Unit 2 MPT connection is currently used as the tie-in point for the three new PWPS MOBILEPAC FT8 units. Additionally, Unit 2 batteries are currently out of service, but there is a tie to the batteries of Unit 1 that can power the Unit 2 loads.

All generators, power transformers, switchgear, batteries, and relays undergo periodic maintenance and testing.

Sargent & Lundy's overall condition assessment summary of Palo Seco Unit 2 can be found in Table 3-3.

Table 3-3 — Palo Seco Unit 2 Overall Condition Assessment

Plant Name: Palo Seco Unit 2									
Item	System	Assessment Method			Scoring Category				Notes
		Visual	Interview	Data	End of Life	Reliability	Unit Output	Subtotal	
1	**Safety Hazards**	yes	yes	no		*n/a*	*n/a*		Corrosion at the facility due to NE winds from the sea.
2	**Corrosion Control**	yes	yes	no		*n/a*	*n/a*		Corrosion noted on other plants and is a constant maintenance item.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		Nothing to note.
4	**Mechanical Assessment**								
4.1	Steam Generator (boiler/HRSG)	no	yes	no					Unit 2 is currently out of service. Plant has no plans to bring Unit 2 back online and parts from Unit 2 are being used for corrective maintenance to Unit 1 as needed.
4.2	FD and ID Fans and Auxiliaries	no	yes	no					No layup procedure applied to equipment. Concerns on overall condition of the system.
4.3	High Energy Piping (HEP)	no	yes	no					No issues noted but limited information provided.
4.4	Condensate System	yes	yes	no					No layup procedure applied to equipment. Concerns on overall condition of the system.
4.5	Feedwater System	no	yes	no					Pump 2-1 is currently damaged and no plans for replacement. Components from this system are being used on Unit 1.
4.6	Turbine and Auxiliaries	yes	yes	no					Plant indicated generator/stator issues. No plans for replacement.
4.7	Circulating Water and Aux Systems	yes	yes	no					No layup procedure applied to equipment. Concerns on overall condition of the system.
4.8	Station Air System	yes	yes	no					No issues with station air and each units station air is shared between the other units.
4.9	Emission controls	no	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	No emissions controls installed
4.10	Fuel Systems	yes	yes	no					Heavy fuel oil tank R-3 damaged and out of service.
4.11	Seawater Intake	yes	yes	no					Seaweed is currently an issue and no chlorination is used.
4.12	Water Treatment	yes	yes	no					Currently no redundancy is available, however due to limited dispatch this has not been an issue. Plans for a RO system within the next 2 years.
4.13	Underground Piping	no	yes	no					No issues noted but limited information provided.
4.14	Fire Protection Systems	no	yes	no					No issues noted but limited information provided.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					Megger tests of the stator yielded low readings.
5.2	Transformers	yes	yes	yes					Phase B transformer has severe partial discharge, elevated hydrogen, and wet insulation. Transformer currently in use for FT8 GT Units.
5.3	Switchgear	yes	yes	no					No issues noted during walkdown.
5.4	Protective Relays	yes	yes	no			*n/a*		No issues noted during walkdown.
5.5	Black Start Engines	no	yes	no					No issues noted during walkdown.
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		No issues noted during walkdown.
6.2	Turbine Controls	yes	yes	no			*n/a*		No issues noted during walkdown.
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no			*n/a*		No issues noted with buildings.
7.2	Structural Steel	yes	yes	no			*n/a*		Corrosion noted on other plants and is a constant maintenance item.
7.3	Tanks / Containment	yes	yes	no					No issues noted with tanks/containment.
7.4	Cranes	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	No issues noted.
8	**Overall Condition Assessment**								Not in operation due to end of life.

3.1.2.3. Unit 3

During the 2018 site visit, the circulating water gates for Unit 3 were being repaired, and the condenser was opened for cleaning and seal replacement. Following this outage, Unit 3 was successfully put back into service on December 6, 2018 but has been operating well short of its nominal output with a 101-MW limitation due to a high differential across the air heaters and air infiltration into the boiler. Unit 3 was taken out of service in September of 2020 for the environmental outage, during which the Plant intended to make

repairs to improve the air and gas duct integrity and replace the air preheater cold- and hot-end baskets and seals. The unit was forecast for resumed operation in May 2021. Additional deficiencies with Unit 3 are outlined in Table 3-4 and described herein.

The mechanical equipment for Unit 3 scored well below industry average. Boiler Feedwater Pump 3-2 was recently repaired with new water seals installed. Additionally, portions of the furnace wall and economizer are near their end of life according to Plant personnel. No recent inspection reports or remaining useful life assessments were available for review. These components should be evaluated in more detail during the next phase of this Project; furthermore, corrosion is present throughout the facility and as of the end of 2020 was being maintained or repaired based on input from GE Power.

The condition of the major electrical equipment at the plant is consistent with its age. Most of the major electrical equipment is original and nearing the end of their useful life, but some equipment has been replaced as needed. All generators, power transformers, switchgear, batteries, and relays undergo periodic maintenance and testing. The generator for Unit 3 underwent a complete overhaul in 2008.

The August 2020 gas analysis testing of the Unit 3 main power transformer (MPT-3) showed evidence of moderate partial discharge. Unit 3 is currently out of service, and Plant staff notes that there are plans in place to inspect and fix MPT-3. Ongoing and future repair of Unit 3 is expected to continue as needed to maintain base-load availability during PREPA's repowering efforts, but maintenance decisions should focus on minimizing capital expenditures since the unit is projected to retire by 2025 in accordance with the 2019 integrated resource plan (IRP).

Table 3-4 — Palo Seco Unit 3 Overall Condition Assessment

Plant Name: Palo Seco Unit 3									
Item	System	Assessment Method			Scoring Category				Notes
		Visual	Interview	Data	End of Life	Reliability	Unit Output	Subtotal	
1	**Safety Hazards**	yes	yes	no		*n/a*	*n/a*		Corrosion at the facility due to NE winds from the sea.
2	**Corrosion Control**	yes	yes	no		*n/a*	*n/a*		Corrosion noted on other plants and is a constant maintenance item.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		Nothing to note.
4	**Mechanical Assessment**								
4.1	Steam Generator (boiler/HRSG)	no	yes	no					Unit 3 was in undergoing annual maintenance as of 10/1/2020 Dispatch Report. The unit is derated due to BFP and air infiltration issues but has been recently able to attain 115 MW output according to the 9/7/2020 Dispatch Report. Portions of furnace walls and economizer may be near its end of life.
4.2	FD and ID Fans and Auxiliaries	no	yes	no					This scoring only relates to the ductwork leakages/infiltration. The unit currently sees a unit derate due to the high air in-leakage.
4.3	High Energy Piping (HEP)	no	yes	no					No issues noted but limited information provided.
4.4	Condensate System	yes	yes	no					Tubes were replaced with titanium recently but issues with original design of system. Plant intends to change design to help with reliability issues.
4.5	Feedwater System	no	yes	no					BFP 3-2 was recently repaired with a new water seal.
4.6	Turbine and Auxiliaries	yes	yes	no					No issues noted but limited information provided.
4.7	Circulating Water and Aux Systems	yes	yes	no					No issues noted but limited information provided. Condenser was open and seals and gaskets were being repaired during the Dec 2018 site visit.
4.8	Station Air System	yes	yes	no					No issues with station air and each units station air is shared between the other units
4.9	Emission controls	no	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	No emissions controls installed
4.10	Fuel Systems	yes	yes	no					Heavy fuel oil tank R-3 damaged and out of service.
4.11	Seawater Intake	yes	yes	no					Seaweed is currently an issue and no chlorination is used.
4.12	Water Treatment	yes	yes	no					Currently no redundancy is available, however due to limited dispatch this has not been an issue. Plans for a RO system within the next 2 years.
4.13	Underground Piping	no	yes	no					No issues noted but limited information provided.
4.14	Fire Protection Systems	no	yes	no					No issues noted but limited information provided.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					No issues noted during walkdown.
5.2	Transformers	yes	yes	yes					MPT has moderate partial discharge
5.3	Switchgear	yes	yes	no					No issues noted during walkdown.
5.4	Protective Relays	yes	yes	no			*n/a*		No issues noted during walkdown.
5.5	Black Start Engines	no	yes	no					No issues noted during walkdown.
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		No issues noted during walkdown.
6.2	Turbine Controls	yes	yes	no			*n/a*		No issues noted during walkdown.
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no			*n/a*		No issues noted with buildings
7.2	Structural Steel	yes	yes	no			*n/a*		Corrosion noted on other plants and is a constant maintenance item.
7.3	Tanks / Containment	yes	yes	no					No issues noted with tanks/containment
7.4	Cranes	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	No issues noted.
8	**Overall Condition Assessment**								Deficiencies were noted.

3.1.2.4. Unit 4

Unit 4 was out of operation from 2016 to 2019 for a major steam turbine repair on the HP section, generator cooling fan, and rotor completed in 2019. The turbine was removed for repairs, including restoration of corrosion damage present on the critical areas of the rotor shaft, bearing and sealing surfaces, and the machine casings. These turbine repairs, along with reseating and repairs to the steam turbine generator

control valves, throttle valves, reheater valves, and interceptor valves were completed in early 2019. The turbine turning and balancing procedure was performed in early 2019, and the unit was made available again in May 2019. At the time of this report, Unit 4 remains in service with a 66-MW limitation due to a high differential across the air heaters and air infiltration into the boiler yielding a reduced 145-MW output.

Ongoing and future repair of Unit 4 is expected to continue as needed to maintain base-load availability during PREPA's repowering efforts, but maintenance decisions should focus on minimizing capital expenditures since the unit is projected to retire by 2025 in accordance with the 2019 IRP.

Sargent & Lundy's overall condition assessment summary of Palo Seco Unit 4 can be found in Table 3-5.

Table 3-5 — Palo Seco Unit 4 Overall Condition Assessment

Plant Name: Palo Seco Unit 4									
Item	System	Assessment Method			Scoring Category				Notes
		Visual	Interview	Data	End of Life	Reliability	Unit Output	Subtotal	
1	**Safety Hazards**	yes	yes	no		*n/a*	*n/a*		Corrosion at the facility due to NE winds from the sea.
2	**Corrosion Control**	yes	yes	no		*n/a*	*n/a*		Corrosion noted on other plants and is a constant maintenance item.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		Nothing to note.
4	**Mechanical Assessment**								
4.1	Steam Generator (boiler/HRSG)	yes	yes	no					The Plant reports the unit is in service but derated to 150 MW (66 MW derate) due to air infiltration issues and issues with the air preheater basket seals.
4.2	FD and ID Fans and Auxiliaries	yes	yes	no					This scoring only relates to the ductwork leakages/infiltration. The unit currently sees a unit derate due to the high air in-leakage.
4.3	High Energy Piping (HEP)	no	yes	no					Plant reports work for the reseating and repairs of the U4 steam turbine generator control valves, throttle valves, reheater valves, and interceptor valves completed May of 2019.
4.4	Condensate System	yes	yes	no					Tubes were replaced with titanium recently but issues with original design of system. Plant intends to change design to help with reliability issues.
4.5	Feedwater System	no	yes	no					No issues noted but limited information provided.
4.6	Turbine and Auxiliaries	yes	yes	no					Plant reports correction of damage to HP turbine, generator cooling fan, and rotor issues completed in 2019. No further issues noted.
4.7	Circulating Water and Aux Systems	yes	yes	no					No issues noted but limited information provided. Condenser water side was opened for cleaning and inspection during 12/5 visit. Repairs to water gates were completed May of 2019.
4.8	Station Air System	yes	yes	no					No issues with station air and each units station air is shared between the other units.
4.9	Emission controls	no	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	No emissions controls installed.
4.10	Fuel Systems	yes	yes	no					Heavy fuel oil tank R-3 damaged and out of service.
4.11	Seawater Intake	yes	yes	no					Seaweed is currently an issue and no chlorination is used.
4.12	Water Treatment	yes	yes	no					Currently no redundancy is available, however due to limited dispatch this has not been an issue. Plans for a RO system within the next 2 years.
4.13	Underground Piping	no	yes	no					No issues noted but limited information provided.
4.14	Fire Protection Systems	no	yes	no					No issues noted but limited information provided.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					Rotor is being inspected.
5.2	Transformers	yes	yes	yes					2018 Transformer NSST-U4 gas analysis showed moderate overheating of cellulose. No further information provided.
5.3	Switchgear	yes	yes	no					No issues noted during walkdown.
5.4	Protective Relays	yes	yes	no			*n/a*		No issues noted during walkdown.
5.5	Black Start Engines	no	yes	no					No issues noted during walkdown.
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		No issues noted during walkdown.
6.2	Turbine Controls	yes	yes	no			*n/a*		No issues noted during walkdown.
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no			*n/a*		No issues noted with buildings.
7.2	Structural Steel	yes	yes	no			*n/a*		Corrosion noted on other plants and is a constant maintenance item.
7.3	Tanks / Containment	yes	yes	no					No issues noted with tanks/containment.
7.4	Cranes	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	No issues noted.
8	**Overall Condition Assessment**								Deficiencies were noted.

3.1.2.5. Generators

No issues were noted with the Units 1 and 3 generators, and Unit 4 returned to service in May 2019 after its generator rotor was rewound. The Unit 2 generator connection to the switchyard is disconnected, and the Unit 2 main power transformer is currently used as the tie-in for the three FT8 MOBILEPAC GT units.

The last Unit 2 generator test indicated low megger readings in the stator; low megger readings indicate compromised insulation. Discussions revealed that there is no plan to repair the Unit 2 generator.

3.1.2.6. Gas Turbines

3.1.2.6.1. GE Gas Turbines

The original GE GTs are near the end of their useful life. The gas turbines are used as peaker units and for emergency dispatch. The units are nearing 50 years old but have comparably low hours of actual use. The units are adjacent to the ocean, and exposure to the marine elements has shown up as significant exterior corrosion on the enclosures and equipment.

- Unit PSGT1-1 underwent major repairs in 2015 and 2016 and is the most serviceable of the group. Repairs included a new exhaust stack, air ducts, and accessory box. As of the end of 2020, the unit was due for a combustion inspection.
- Unit PSGT1-2 was unavailable, and its return to service date remains to be determined. The October 1, 2020 dispatch report notes that it is undergoing repairs to the stack. In the 2018 site visit, Sargent & Lundy noted that the unit also requires a generator rotor replacement and fan box and combustion repairs.
- Unit PSGT2-1 was unavailable, and its return to service date remains to be determined. The October 1, 2020 dispatch report notes the reason for outage to be a probable ground fault. In the 2018 site visit, Sargent & Lundy noted that the accessory box, air duct, and stack require repair as well.
- Unit PSGT2-2 is unavailable and in a long-term outage. In the 2018 site visit, Sargent & Lundy noted that the unit requires major repair.
- Unit PSGT3-1 is unavailable and in a long-term outage. In the 2018 site visit, Sargent & Lundy noted that the unit requires minor repairs.
- Unit PSGT3-2 is unavailable and in a long-term outage. In the 2018 site visit, Sargent & Lundy noted that the unit requires major repair.

Figure 3-1 — Palo Seco GE Gas Turbine Unit 3-1

Figure 3-2 — Palo Seco GE Gas Turbine Corrosion

Each GT weather enclosure was compromised. The enclosure doors and seals were corroded, loose, or missing. Many of the doors were open, allowing the interior of the GT enclosure to be exposed to the environment. On some units, the shell steel was corroded throughout. The operators indicated that, despite the appearance, the units in operation are reliable and were in use after the 2017 hurricanes to provide emergency power to the grid.

The infrastructure required to keep the GTs available is minimal, with essentially only a fuel and electrical connection required. Future operability requires repair and inspection of the units as suggested. The units could be evaluated for temporary repair while replacement units are being considered. Life extension repair of the units could be considered; however, the skid and enclosure supporting the GTs are in poor condition, and the feasibility of repairs is limited.

Table 3-6 — Palo Seco GE GT Overall Condition Assessment

Plant Name: Palo Seco, 6 GE GT Units: 1-1, 1-2, 2-1, 2-2, 3-1, 3-2.									
Item	**System**	**Assessment Method**			**Scoring Category**				**Notes**
		Visual	**Interview**	**Data**	**End of Life**	**Reliability**	**Unit Output**	**Subtotal**	
1	**Safety Hazards**	yes	no	no			*n/a*		Fire Protection deficiency. Integrity of enclosure compromised.
2	**Corrosion Control**	yes	no	no			*n/a*		Significant corrosion inside and outside of enclosure and on unit and equipment. Enclosure is not able to be secured due to lack of door integrity.
3	**Overall Cleanliness & Housekeeping**	yes	no	no	*n/a*		*n/a*		Nominal fuel in containment noted. Significant corrosion and debris.
4	**Mechanical Assessment**								
4.1	Combustion Turbine	no	yes	no					Units are at end of useful life. Unit 1-2 out of service, expected return TBD, Units 2-2, 3-1, and 3-2 are on long-term outages. Units 1-1 and 2-1 are available for peaker or emergency service.
4.2	Station Air System	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	None noted.
4.3	Emission controls	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	None noted.
4.4	Fuel Systems	no	no	no					Skid leakage in containment noted during the 2018 walkdown.
4.5	Water Treatment	yes	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	None noted.
4.6	Underground Piping	no	yes	no					No issues noted during the 2018 walkdown.
4.7	Fire Protection Systems	no	yes	no					Enclosure is not able to be secured due to lack of door integrity.
5	**Electrical Assessment**								
5.1	Generator	yes	yes	no					Unit is at end of useful life.
5.2	Transformers	yes	yes	no					Unit is at end of useful life.
5.3	Switchgear	yes	yes	no					Unit is at end of useful life.
5.4	Protective Relays	yes	yes	no			*n/a*		Unit is at end of useful life.
5.5	Black Start Engines	no	yes	no					2 units to be required for black start.
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	yes	yes	no			*n/a*		No issues noted during the walkdown.
6.2	Turbine Controls	yes	yes	no			*n/a*		No issues noted during the walkdown.
7	**Civil / Structural Assessment**								
7.1	Buildings	yes	yes	no					Significant corrosion. Gaskets and door seals are gone.
7.2	Structural Steel	yes	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	No issues noted during the walkdown.
7.3	Tanks / Containment	yes	yes	no					Minor leakage noted in containment.
7.4	Cranes	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	
8	**Overall Condition Assessment**								Major issues noted.

3.1.2.6.2. FT8 MOBILEPAC Gas Turbines

The FT8 MOBILEPAC GTs were newly installed in 2019 but have been restricted in operation until water injection for NO_X control can be installed. The MOBILEPAC units have been available as peaker units and for emergency dispatch; however, their operation will be limited until the installation of water injection

systems is completed, which was projected for the first quarter of 2021. The units are located adjacent to the GIS building and tie into the MPT previously dedicated to thermal Unit 2. The Units are in good condition but should be closely monitored, as exposure to the marine elements at Palo Seco has yielded significant corrosion on other enclosures and equipment at the site.

Sargent & Lundy's overall condition assessment shown in Table 3-7 is based on a desktop review of provided documents and responses by the Plant staff to written questions.

Table 3-7 — Palo Seco FT8 GT Overall Condition Assessment

Plant Name: Palo Seco, 3 FT8 MOBILEPAC GT Units: MP1, MP2, MP3.

Item	System	Assessment Method			Scoring Category				Notes
		Visual	Interview	Data	End of Life	Reliability	Unit Output	Subtotal	
1	**Safety Hazards**	no	no	no			*n/a*		Units and enclosures are new.
2	**Corrosion Control**	no	no	no			*n/a*		Units and enclosures are new.
3	**Overall Cleanliness & Housekeeping**	no	no	no	*n/a*		*n/a*		Units and enclosures are new.
4	**Mechanical Assessment**								
4.1	Combustion Turbine	no	yes	no					Units are new as of 2019, but output is limited because the GTs lack the water injection they require for NOx control.
4.2	Station Air System	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	None noted.
4.3	Emission controls	no	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	Water injection system scheduled for completion in Q1 of 2021.
4.4	Fuel Systems	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	Refer to GE GT Condition Assessment.
4.5	Water Treatment	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	None noted.
4.6	Underground Piping	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	None noted.
4.7	Fire Protection Systems	no	no	no					No issues noted.
5	**Electrical Assessment**								
5.1	Generator	no	yes	no					Generator is new as of 2019.
5.2	Transformers	yes	yes	yes					Phase B transformer has severe partial discharge, elevated hydrogen, and wet insulation.
5.3	Switchgear	yes	yes	no					No issues noted.
5.4	Protective Relays	yes	yes	no			*n/a*		No issues noted.
5.5	Black Start Engines	no	yes	no	*n/a*	*n/a*	*n/a*	*n/a*	Refer to GE GT Condition Assessment.
6	**Instrument and Controls Assessment**						*n/a*		
6.1	Plant Controls	no	yes	no			*n/a*		No issues noted.
6.2	Turbine Controls	no	yes	no			*n/a*		No issues noted.
7	**Civil / Structural Assessment**								
7.1	Buildings	no	no	no					Units and enclosures are new.
7.2	Structural Steel	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	No issues noted, Units installed at grade.
7.3	Tanks / Containment	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	Refer to GE GT Condition Assessment.
7.4	Cranes	no	no	no	*n/a*	*n/a*	*n/a*	*n/a*	
8	**Overall Condition Assessment**								No major issues.

3.1.3. Common Systems

Common systems are discussed above briefly as applicable to the individual units. Additional descriptions are provided below for the main systems.

3.1.3.1. Circulating Water Systems

Repairs to the Unit 4 condenser water gates were completed in May of 2019, and the Unit 3 condenser water gates were scheduled for repair to begin October of 2020. During the 2018 site visit, Pump Motor 1-1 was out of service, the entire assembly was removed for repair, and the piping was blanked off. One of the traveling screens for the Units 1 and 2 circulating water system was also removed for service at the time. Circulating Water Pump 1-1 remained out of service, and no return-to-service date is available. The system would require significant conversion for another once-through plant; however, a smaller capacity system requirement for a cooling tower may allow some limited reuse of the existing intake structure.

3.1.3.2. Fuel Systems

The fuel system is consistent with its age for a system 50 years or older. The last detailed inspection provided was from 2012, with corrosion-related repairs required as noted. During the 2018 site visit, it was noted that HFO Tank R-3 was damaged due to an overfilling incident and was out of service, as shown in Figure 3-3. As noted in Section 2.1.6.2, the full reserve capacity with tanks R-1 through R-4 provides 21 days of storage to the plant; however, there are currently approximately 16 days of storage for continuous running due to Tank R-3 being out of service.

Figure 3-3 — Damaged Palo Seco HFO Fuel Oil Reserve Storage Tank R-3

A temporary fuel pipeline and pump station for the two FEMA-supplied GT generator units were installed in the No. 2 fuel oil system and used through early 2019 but have since been removed.

3.1.3.3. Compressed-Air Systems

The compressed-air systems are adjacent to each respective unit in the auxiliary building and headered together for the block. The system is a mixture of different units and contains Atlas Copco compressor units, Pneumatic Products (SPX) dryers, and air receivers for the instrument and service air systems. Additional backups include compressor units in shelters outside the auxiliary building. The units were in service with no issues noted by site staff. They are, however, older technologies, and reuse should be evaluated against newer and more efficient units.

3.1.3.4. Fire Protection System

The fire protection system is consistent with its age, with some portions 50 years and older, with newer drives and Aurora (Pentair) electric and jockey pumps. The jockey pump was not running during the visit, indicating that the underground system was in serviceable condition.

3.2. RECOMMENDATIONS

The facility, while durable, has reached the end of its useful operating life (except for the new MOBILEPAC units). A dedicated site staff, service extensions, facility upgrades, and infrastructure repair have enabled the Plant design to exceed the typical life of exposed oceanside equipment. The care and maintenance of a plant adjacent to the sea is challenging, and phased replacement is recommended. The upgraded infrastructure as it is, including the newer gas insulated substation, was key to getting the older units online and the grid back up and functioning following the 2017 hurricanes.

Sargent & Lundy recommends that Palo Seco be phased out of service and replaced by a plant with capacity and flexibility as determined by a separate load demand and resource study. PREPA is studying the need for additional grid support and generation throughout the island. Palo Seco was built during an era predating most emissions controls. A newer plant will also take advantage of cleaner technologies developed over the past 60 years, providing cleaner power for the Island. The 2020 PREB decision confirms the IRP's projected retirement of the original HFO thermal and GE GT units by 2025 but grants a budget for preliminary economic, siting, permitting and planning analysis of a new fossil fuel-powered unit and/or energy storage at the site. To help offset this loss in generating capacity, Palo Seco is also being considered as a site for three of the eleven new peaker GT units that will be added to PREPA's fleet with recently approved funding from FEMA. Ongoing and future repair of the original GE GTs and HFO thermal units is expected to continue as needed to maintain base-load availability during PREPA's repowering efforts, but

maintenance decisions should focus on minimizing capital expenditures since these units are projected to retire by 2025 in accordance with the 2019 IRP.

While it is recommended the facility be replaced, Palo Seco has multiple benefits to be considered for reuse or repurposing. The site location is conveniently near San Juan, which is a significant and beneficial feature. The area is in a major load demand center, and it can serve the populace without extensive transmission exposure. Care must be taken to address future operation in the coastal environment.

Additional features to consider for future site use, other than location, include the newer GIS facility, existing intake and discharge structures, existing buildings, and ample site space.

The GIS facility was newly installed in 2012 and can be considered and evaluated for reuse in a new plant design. The equipment and building are in clean condition and sheltered from the elements, and it includes a backup emergency generator in an enclosure. The equipment is adjacent to open space near the warehouses to the west for expansion.

The intake and discharge structures may be repurposed for a future Plant design. The concrete structures, however, are old, and due to the current once-through design, marine life has been a problem. It is probable that a redesigned plant will have a significantly lower water demand if a cooling tower were used as part of the cooling water design; therefore, the capacity should not be an issue, and a closed-cooling water system, with appropriate discharge controls for blowdown, could be considered. For a cooling tower makeup arrangement, instead of the current once-through design, much of the once-though system would be removed and replaced with smaller, updated systems with appropriate materials. The redesign can take advantage of the intake location without using the older concrete structures and tunnels throughout the Plant. The discharge side to the former Bayamón River can be evaluated for environmental impact with the benefit of a lower (cooling tower blowdown vs. larger once-through cooling system) discharge rate.

The steel framework for the intake overhead service crane is a feature not typically offered on newer plants. It is integrated into the existing facility, and reuse could be assessed. For potentially smaller equipment, the reuse would be of limited benefit. Given the amount of infrastructure and maintenance associated with the overhead crane, changing to mobile and less exposed equipment would be recommended.

Figure 3-4 — Palo Seco Unit 3 and 4 Circulating Water Pump Station

The existing buildings include offices and warehouses that can be reused. The warehouses adjacent to the GT generator area on the west have potential for use as laydown and shelter for additional incoming equipment during a construction phase. The auxiliary building and other equipment buildings are in good shape considering the age; however, with new considerations and designs, the existing infrastructure footprint dedicated to an older design will need evaluation for reuse.

Other balance-of-plant systems are tied to the existing layout and sized to suit the equipment currently in place. Their reuse for the air, cooling water, fuel, or fire protection systems would be limited. Altering and attempting to reuse the underground piping will be problematic for most new design layouts. The underground may not lend itself well for different, new power block sizes and foundation requirements, and it may need significant changes and modification. The fire protection pump and tank sizing could be evaluated for reuse; however, for new comparable, fuel oil generation plants, pumps meeting current fire protection codes would be required, likely much larger than the existing 1500-gpm pumps and associated two-hour water storage system.

Figure 3-5 — Palo Seco Administrative Building

The Palo Seco facility has significant space for repurposing and reuse (see Figure 3-6, with the conceptual repurposed area shaded in green). This is in addition to the currently open areas at the southwest side of the Plant. The HFO system should be retired with any plant upgrade to newer technology or tank made available as additional No. 2 storage. If consideration for a diesel fuel oil system is anticipated for a backup fuel, the system can be evaluated as is or expanded as required. If fuel gas is considered either as a primary or as a dual-firing design, some or all the areas dedicated to fuel tanks and containment can be reclaimed for other equipment or use.

Figure 3-6 — Palo Seco Potential Reclamation Areas

A phased-in approach for equipment replacement may be considered. Temporary rentals may be used with the newly constructed GIS facility to keep the Plant online and generating power as demolition and a systematic restoration and replacement plan is carried out. The Plant has potential for more efficient, cleaner, combined-cycle plant design, possibly coupled with a hybrid configuration for instantaneous power.

4. INFRASTRUCTURE AND INTERCONNECTIONS

4.1. SHARED SERVICES

Primary shared services for the units are service and instrument air, service and treated water, fire protection, and fuel storage and transfer systems. To some extent, the circulating water is shared. The circulating water intake system and discharge system is common, and there are ties between the pumping stations for Units 1 and 2 and Units 3 and 4. The cross ties use common supply headers and spare pumps to provide redundancy.

4.2. EXISTING FUEL SUPPLY

HFO and No. 2 are delivered to the plant via transfer lines from a docking station at San Juan Harbor. Recent (April 2018) certificates of fuel analysis were provided, and no indications of fuel issues were found.

Detailed inspections of the systems were conducted in 2005. The results of the No. 2 fuel oil system indicated that there were no issues; however, a follow-up inspection suggested for 2007 was not conducted. The HFO system required repairs due to pitting and corrosion. No additional follow-up repair confirmation was provided.

Fuel oil for Palo Seco is provided under two separate agreements: one for HFO and one for No. 2 fuel oil. The HFO contract is with Freepoint Commodities, LLC. The No. 2 fuel oil contract is with Puma Energy Caribe, LLC.

4.2.1. HFO Contract

On July 31, 2015, PREPA entered a fuel oil purchase contract (Contract Number 902-02-15) with Freepoint Commodities, LLC for the supply of HFO to the Aguirre Steam, Costa Sur, Palo Seco Steam, and San Juan Steam plants. The contract has been extended for additional years through various amendments. PREPA and Freepoint Commodities, LLC finalized a fifth amendment to the contract extending the term until October 31, 2021.

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

4.2.2. No. 2 Fuel Oil Contract

On November 21, 2019, PREPA entered a contract (Contract 902-01-19) with Puma Energy Caribe, LLC for the supply of No. 2 fuel to all PREPA plants that operate with this fuel. The original term of the contract was for one year, but the contract includes a provision for an automatic extension upon mutual agreement.

PREPA and Puma Energy Caribe, LLC are finalized details for the 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.

4.3. WATER SUPPLY AND TREATMENT

Freshwater for the Plant is from the PRASA municipal supply. Seawater is used for circulating water cooling. It should be noted that no biocide is used to control bio-fouling in the circulating water system. Seaweed and hard marine buildup have been an issue that requires continuous attention to maintain suitable cooling system service. A ball cleaning system was once used to keep the condenser clean, but it was determined to not be useful for the service. The site does have the ability to reverse the circulating water flow, which does provide some advantage, and the operations staff does this occasionally to clean the system.

Boiler water treatment is provided by a shared demineralizer/reverse osmosis with polisher plant. The treated boiler water is provided as makeup to the condensate system, and the polishers are in line between the condensers and the boilers. The polishers provide a higher level of treatment for the boilers.

Wastewater is treated by an onsite plant. Waste streams from the sludge basin, cooling tower blowdown, polisher waste, demineralizer regeneration waste, equipment drains (including boiler blowdown), and floor drains are collected and treated and released to the outfall system.

Seven oily water separators are provided to accommodate the extensive system of water treatment requirements. These systems include separation for the fuel oil systems and stormwater retention as well as floor drains throughout the site.

All water, except for sanitary water, is treated and discharged back to the ocean. Sanitary water is discharged into the PRASA system.

5. OPERATIONS AND MAINTENANCE

5.1. STAFFING AND TRAINING

The management commitment for a long-term program to maintain and extend the life of Palo Seco is apparent in the evidence that most of the Plant is still operable despite considerable age, environmental exposure, and limited resources. 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, and system upgrades.

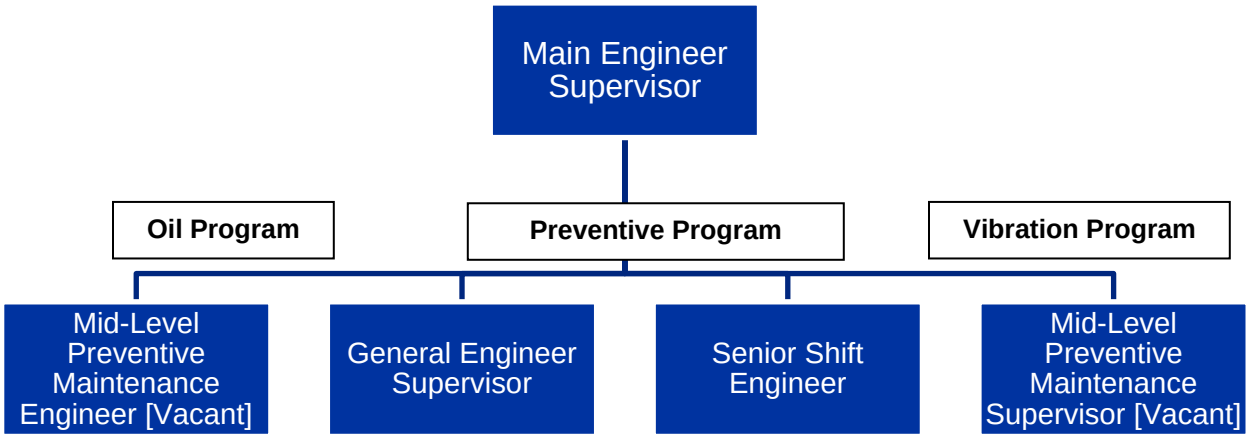
Training for operators focuses on safety. Operation-specific training also emphasizes running equipment and systems efficiently. A comprehensive maintenance plan includes preventative maintenance, corrective maintenance, and predictive maintenance programs. The focus of the plan is to maintain availability of the units. The preventative maintenance program capitalizes on the regularly scheduled outage intervals for completing many of the required maintenance items systematically in a controlled manner.

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.

Palo Seco has a dedicated staff. Many of the workers have been there for decades. Three department heads report to the Plant manager: the administration head, operations head, and maintenance head. The operations head has a head shift engineer and shift engineer with a shift divided into three separate operations: the operator for Units 1 and 2, the electric board operator, and the operator for Units 3 and 4.

As of February 2018, there were 16 workers—out of the Plant's approximate 168 staff—associated with the maintenance department. They are arranged as shown in Figure 5-1 with the 2018 supervisor vacancies as indicated. Sargent & Lundy has requested the current staff operations that have not been provided for review.

Figure 5-1 — Palo Seco Maintenance Organization Structure



The Plant staff uses the control room as the center of operations. It is manned continuously for 24-hour operation, 7 days a week. Daily meetings in the mornings are used to direct activity and coordinate efforts among the staff. During each shift, the shift engineer oversees the Plant operations and management. There are typically 10 workers per each operations shift.

5.2. MAINTENANCE PROGRAMS

The Palo Seco units have low dispatch, and they are required to have regular outages for maintenance and environmental reasons per the EPA agreement and PREPA management requirements. In general, the frequent scheduled outages at Palo Seco 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 are scheduled as needed. Upgrades and significant design modifications are planned during the major overhauls.

The main objective of PREPA's maintenance plan is to use preventative maintenance in conjunction with predictive techniques developed at the Plant level. Maintenance is performed using the original equipment manufacturers' specifications, Plant experience, Plant routine inspections, equipment monitoring, and O&M manuals as applicable. There is not a standing formal service agreement with specialist manufacturers except as needed at the Plant level. Each Plant has extensive workshop capability and, to a large part, is mostly self-reliant for repairs of equipment.

5.2.1. Mandatory Environmental Outage

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

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

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

Plant personnel indicated that all these maintenance activities are conducted during each environmental outage. If the timing permits, additional outage-required maintenance is performed during these environmental outages as needed by each unit.

5.2.2. Preventative Maintenance

Since the Palo Seco units have low dispatch and are required to have regular outages for maintenance and environmental reasons, many maintenance items are delayed as necessary to the next scheduled outage as parts and supplies become available.

Part requisitions are routed through the main office in San Juan. Because parts for the older and less used plants, such as Palo Seco, have lower priority compared to more dispatched and newer plants, part and supply requests have been delayed or deferred as deemed necessary. Site personnel have been conscious of this and, where recent unforeseen requirements have demanded electrical generation, parts from unavailable units have been repurposed to ensure the units are available to meet the required demand for generation.

5.2.3. 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.

5.2.4. Predictive Maintenance

A predictive maintenance program is used. The program reads and records the vibration recording for the main equipment. Vibration readings were provided for review, and site personnel did not identify abnormalities. In general, vibration readings were provided for the boiler feed pumps, combustion fans, circulating water pumps, and steam turbines. Vibration monitoring is also conducted for the GT units and is used to identify issues.

5.3. MAINTENANCE AND OUTAGE SCHEDULES

As noted in Section 5.2.1, unit maintenance is often performed during the mandatory environmental outages. The outage schedule is extended to accommodate a larger maintenance scope when necessary. A summary of recent or ongoing outage dates, as known in October 2020 and as provided by PREPA, and brief descriptions of any maintenance outside the standard environmental outage activities for fiscal years 2019–2020 and 2020–2021 are included in Table 5-1. The table includes units where maintenance activities were identified including environmental inspections, mechanical dynamics and analysis (MD&A), and other miscellaneous maintenance, repairs, and system upgrades. No specific activities were identified for PSGT1-1; PS2 is in a long-term outage and considered irreparable, and PSGT2-2, PSGT3-1, and PSGT3-2 are currently out of service per EPA permit restrictions.

Table 5-1 — Plant Maintenance Outage Activities

Plant Name	Start	Finish	Reason	Description
Palo Seco Steam Turbine #1 (PS1)	July 2019	Jan 2020	Env. Inspection	Standard environmental inspection
	Aug 2020	TBD	Maintenance Outage	Required maintenance, including repairs to boiler casing and inspection of field grounding issues
	Aug 2021	Sept 2021	Env. Inspection	Standard environmental inspection
Palo Seco Steam Turbine #3 (PS3)	Jan 2020	April 2020	Maintenance Outage	Rehabilitation, repairs, surface prep, and recoating of 4 condenser cast iron waterboxes and replacement of 8 transition pieces
	Sept 2020	Dec 2020	Env. Inspection	Environmental inspection, including work to improve gas duct integrity and replacement of air preheater cold- and hot-end baskets and seals; inspection will also assess the remaining useful life of Unit 3 boiler
Palo Seco Steam Turbine #4 (PS4)	Nov 2018	May 2019	Turbine Inspection	Steam Turbine #4 disassembled, inspected, and repaired where possible; additional recommendations for future inspections and repairs included in MD&A final report
	Jan 2015	June 2019	Env. Inspection	Extended environmental inspection, including many additional maintenance activities; work included replacement of many valves, seals, gaskets, bearings, strainers, and several smaller pumps and fans; refer to “Programmed Environmental Outage Report Unit 4” for details
	Dec 2020	Jan 2021	Env. Inspection	Standard environmental inspection
Palo Seco Gas Turbine (PSGT1-2)	April 2020	TBD	Maintenance Outage	Unit out of service for repairs to stack
Palo Seco Gas Turbine (PSGT2-1)	Sept 2020	TBD	Maintenance Outage	Unit out of service with ground fault issues reported
Palo Seco Gas Turbines (PSMP1, PSMP2, PSMP3)	Jan 2020	Nov 2020	Emissions Control	EPC to add pump skid and piping to deliver demineralized water from existing demineralization tank to new FT8 turbines for water-injection NO_X control

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

- PREPA currently has a tank inspection program, per API Code and SPCC compliance, planned in the next six years for all power plants. Rehabilitation and maintenance of the three diesel Tanks 1, 2, and 3 began November 2019 and were completed in June 2020.
- Fire protection system testing is conducted per NFPA requirements, but no recent or planned maintenance issues have been identified.

- A fuel line inspection program is planned for all PREPA power plants in the next six years for code compliance, maintenance, and life extension; however, the detailed timing of the program for Palo Seco was not provided.
- Condition assessment programs for the boilers and high-energy piping are also planned in the next six years. The detailed timing of the program for Palo Seco has not been provided.

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

5.4. SPARE PARTS

A spares list for Palo Seco was available for review during the 2018 visit. Spares on site are limited and on occasion appropriated from unavailable units. Despite this, the site staff has managed to provide much needed availability with these older units during the recent crisis from the 2017 hurricanes.

5.5. ENERGY MANAGEMENT SYSTEM

At the corporate level, PREPA 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 an energy management system (EMS) to regulate the supply-side generation of electricity to match real-time electric power demand side from the users.

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

6. PERFORMANCE REVIEW

To evaluate the performance of the Plant, Sargent & Lundy reviewed historical operating performance provided by PREPA of steam Units 1–4 and the GE GT units and benchmarked them against a group of industry peer units where data was available. Operational data for the MobilePac GTs was unavailable for review. Primary performance indicators reviewed include the following:

- 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 time period, including the impact of deratings (times when the unit is operating at a lower power output). EFOR is a measure of an electric generating unit's unreliability; it is the percentage of time that a unit is in a forced outage during a specified time period, including the impact of forced unit derates.

PREPA provided operation data for 2015–2020. Sargent & Lundy also reviewed data cataloged by NERC within its Generating Availability Database System (GADS)[9] and established separate peer groups of units comparable to Steam Units 1 and 2, Steam Units 3 and 4, and PSGT1-1, PSGT1-2, PSGT2-1, PSGT2-2, PSGT3-1, and PSGT3-2 to compare reliability data.

Sargent & Lundy applied the selection criteria identified in Table 6-1 to the NERC GADS database[10] to establish the reliability peer group for the two steam unit groupings. The resulting peer group that reflects these unit characteristics identified for Unit 1 and 2 included 18 units owned by 9 different operators, with the dataset including 92.67 operating years of reporting data. The peer group for Units 3 and 4 included 10 units owned by 7 different operators for 34.85 operating years. Note that heat rate is not reported to NERC;

[9] 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 the GADS, filters can be applied to review reliability data by plant characteristics, such as plant prime mover, nameplate capacity, fuel type, and age. Filters can also be applied for plant generating statistics, such as plant capacity factor. In this way, 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 Palo Seco units.

[10] Accessed via pc-GAR software on November 10, 2020. Version: PC-GAR v4.01.16.

therefore, peer group data is not presented in this report. Table 6-2 provides a summary of the key performance data for Costa Sur Units 1–4 and the two peer groups. PREPA reports the total steam units together.

Table 6-1 — Palo Seco Steam Unit Peer Groups

	Unit Characteristics			Peer Group Characteristics			
	COD	Unit Capacity (MW)	Operating Fuel	COD	Unit Capacity (MW)	Operating Fuel	Age of Unit
Steam Units 1 and 2	1960–1961	85	HFO	1955–1970	50–125	Distillate Oil or Oil	50–65
Steam Units 3 and 4	1967–1968	216	HFO	1960–1975	150–300	Distillate Oil or Oil	45–60

Table 6-2 — Palo Seco Steam Units Key Performance Data Summary

Key Performance Indicator	2015	2016	2017	2018	2019	2020	Peer Group 1/2	Peer Group 3/4
Generation (MWh)[2]	1,127,316	1,611,305	491,835	1,022,669	1,311,525	1,977,704	—	—
Equivalent Availability (%)[2]	26.15	38.81	11.12	26.87	39.85	46.29	86.54	88.78
Net Capacity Factor (%)[2]	21.38	30.47	9.33	19.39	28.96	43.55	15.85	4.07
Equivalent Forced Outage Rate[1]	52.96	57.76	83.04	70.25	52.44	42.46	8.84	16.28
Net Heat Rate (Btu/kWh)[2]	11,961	11,754	10,547	10,995	11,402	11,428	—	—

[1] Values for 2015–2018 include statistics for Units 3–6; 2019 and 2020 include statistics for Units 5 and 6 only.

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

Sargent & Lundy also applied the selection criteria identified in Table 6-3 to the NERC GADS database to establish the reliability peer group for the GT units. The resulting peer group that reflects these unit characteristics included 204 units owned by 43 different operators, with the dataset including 1,221.25 operating years of annual reporting data. Although the units are similar, the units in the peer group primarily run on natural gas rather than No. 2 fuel oil (as the GT units do). As previously noted, heat rate is not reported to NERC; therefore, peer group data is not presented in this report. Table 6-4 provides a summary of the key performance data for the Palo Seco GTs and their peer group.

Table 6-3 — Palo Seco GT Units Peer Group

Palo Seco GT Units			Peer Group Characteristics				Black Start Capability
Years in Service	COD	Unit Gross Capacity (MW)	Years in Service	COD	Unit Gross Capacity (MW)	Capacity Factor	
47–48	1972–1973	21	40–60	1965–1980	15–25	0–20%	Yes

Table 6-4 — Palo Seco GT Units Key Performance Data Summary

Key Performance Indicator	2015	2016	2017	2018	2019	2020	Peer Group
Generation (MWh)	89,100	75,187	177,952	121,258	126,830	244,731	—
Equivalent Availability (%)	61.05	47.78	40.26	37.08	56.24	32.42	89.07
Net Capacity Factor (%)	8.07	6.79	16.00	11.00	11.49	22.11	0.48
Equivalent Forced Outage Rate	27.90	52.86	59.77	62.46	43.95	67.59	88.60
Net Heat Rate (Btu/kWh)[1]	14,050	14,282	14,568	14,449	14,700	15,096	—

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

6.1. GENERATION

Generation for steam Units 1–4 is provided in Figure 6-1 while the generation of the GT units is shown in Figure 6-2. The generation figures provide totalized information for the annual plant generation of power. Power output has decreased over the last few years for all units, coinciding with the availability of the units.

Figure 6-1 indicates that Unit 3 is the most used unit with Unit 4 recently operating more frequently. The Plant was not dispatched significantly in 2017; however, after the 2017 hurricanes, the units were again dispatched where required by demand. Unit 2 has not been used since the boiler feedwater pump failure in 2016 (see Section 3.1.2).

Figure 6-1 — Palo Seco Steam Units Generation

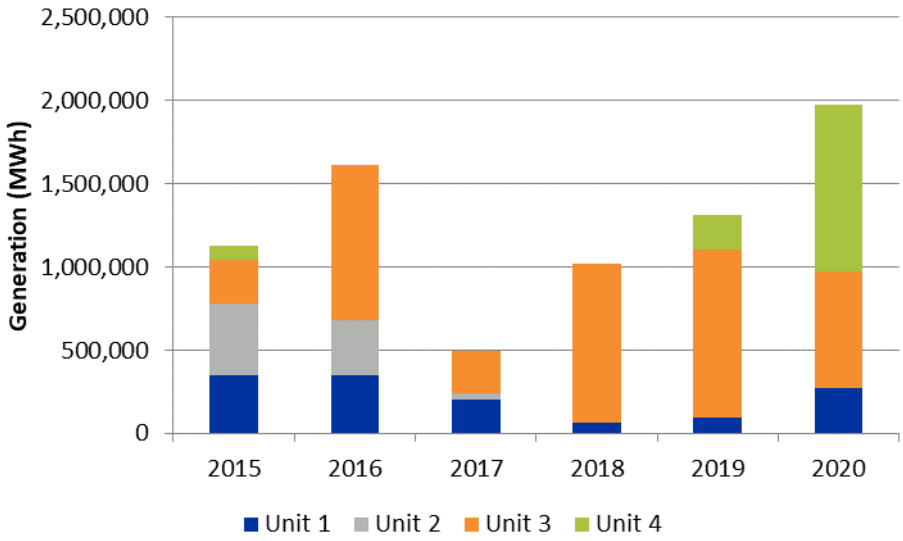
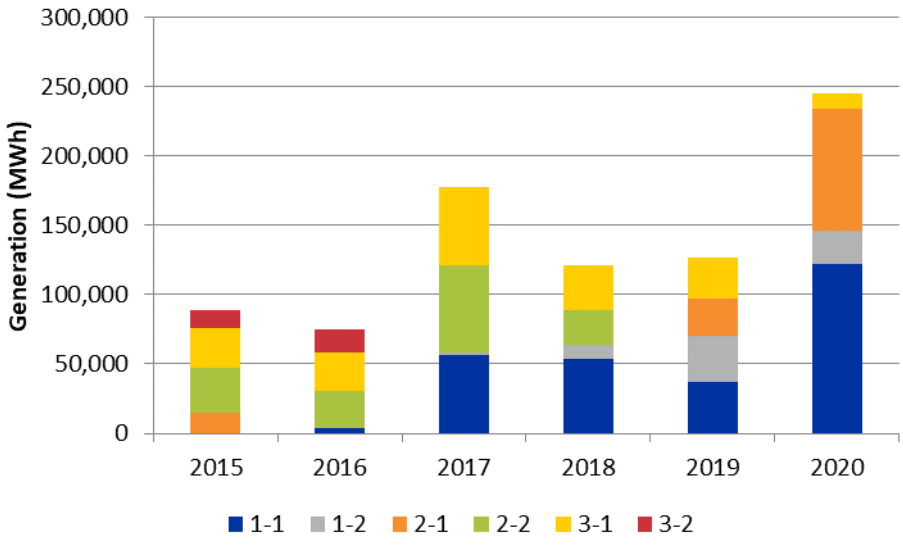


Figure 6-2 indicates that the use of the GT units increased significantly after the 2017 hurricanes. They agree with the corresponding maintenance issues noted in Section 3.1.2. The most run and reliable unit is Unit 1-1, which has had a recent major overhaul. The units are used as peakers and as emergency response pending load demand.

Figure 6-2 — Palo Seco Gas Turbine Generation



6.2. AVAILABILITY FACTOR

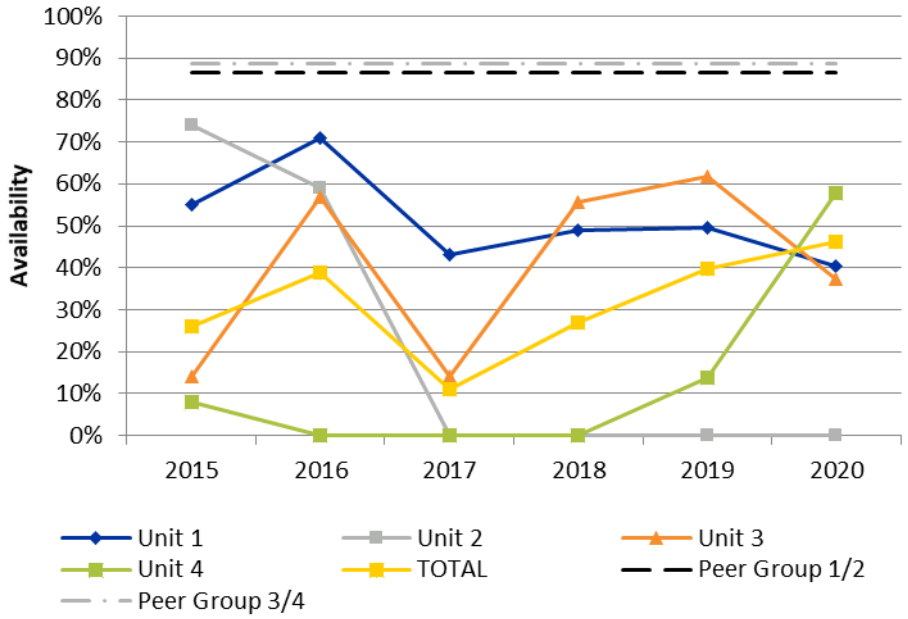
The EAF is the fraction a facility is available to generate electricity at net dependable capacity less derated conditions. EAF is calculated as follows:

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

Some of the hours in the formula are considered “equivalent” because they equate a unit’s derate into outage hours. A unit is derated when it can operate but not at its rated capacity. Following NERC procedures, this derated condition is translated into equivalent outage hours for use in the availability formula. When a unit is in an outage, it is not available to add power to the grid, and this is reflected in the “available hours” component of the formula. If a unit is offline for an entire year, its availability is zero for that year. This is seen in the Figure 6-4, with Unit 2 offline for extended periods.

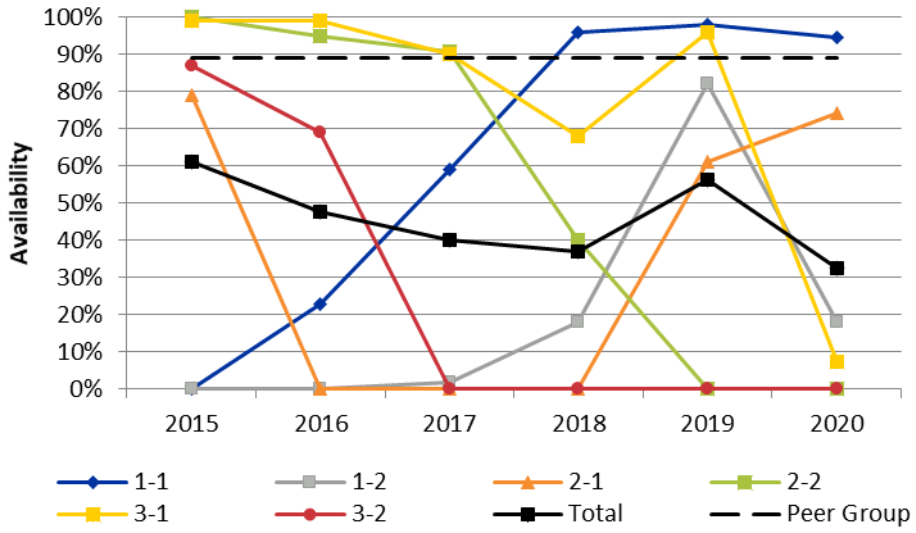
Availability is one of the best single metrics for the condition of the Plant. It indicates that it is available to generate power. Whether the Plant is dispatched to operate has to be correlated with the net capacity factor for relevance. The availability of the steam units is reflective of older units that have known issues with maintenance and reliability. Units 1, 3, and 4 are the currently operating units, and those are indicated to be available approximately half the time in recent years. The steam units’ availability has steadily increased over the last few years, showing increased reliability; however, is still below the peer groups averages near 90%.

Figure 6-3 — Palo Seco Steam Units Equivalent Availability Factor



The GT availability shown in Figure 6-4 is indicative of older gas turbines with known maintenance and reliability issues, as noted in Section 3.1.2. Unit 1-1 was overhauled and returned to service in 2015 and is the only unit currently operating; it is currently the most used unit with an availability factor higher than the peer group. Each of the other GT units have significant repairs required before they are available operable.

Figure 6-4 — Palo Seco Gas Turbine Equivalent Availability Factor



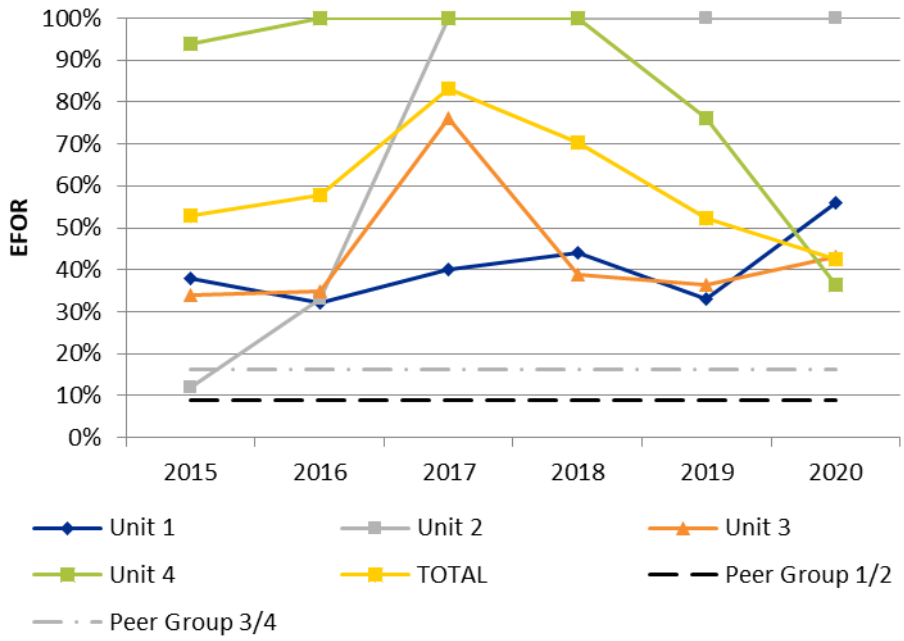
6.3. EQUIVALENT FORCED OUTAGE RATE

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

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

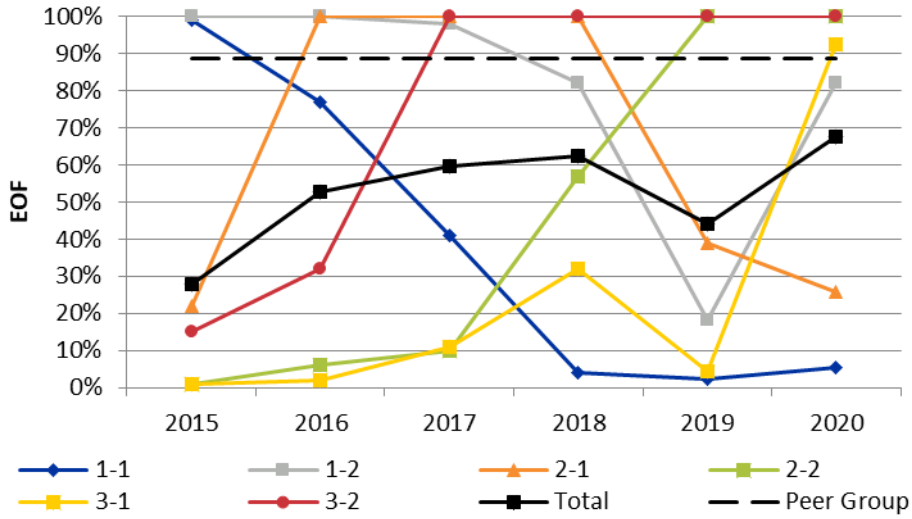
The EFOR of the steam units has remained above the peer group average, with the EFOR of Units 2 and 4 significantly impacting the indicator. This is indicative of older units with known maintenance and reliability issues, such as the HP turbine blade damage problems on Unit 4, the condenser corrosion issue, and the Unit 3 boiler feed pump seal problems.

Figure 6-5 — Palo Seco Steam Units Equivalent Forced Outage Rate



The GT units at Palo Seco show high EFOR, with the exception of Unit 1-1 in recent years. The rates are consistent with older units with known maintenance and reliability issues. The EFOR upward trend reflects the previous EAF downward trend. Unit 1-1 was overhauled and returned to service in 2015 and was in operation during the December 2018 visit; currently, it is the most used unit. Unit 1-1 is the only unit with a low EFOR in the last three years. Each of the other GT units has significant repairs required before they are available for full capacity or operable. The significant repairs impact the EFOR by increasing it. Although high, the GTs in the peer group have also experienced high EFOR, nearing 90% on average.

Figure 6-6 — Palo Seco Gas Turbine Equivalent Forced Outage Rate



6.4. CAPACITY FACTOR

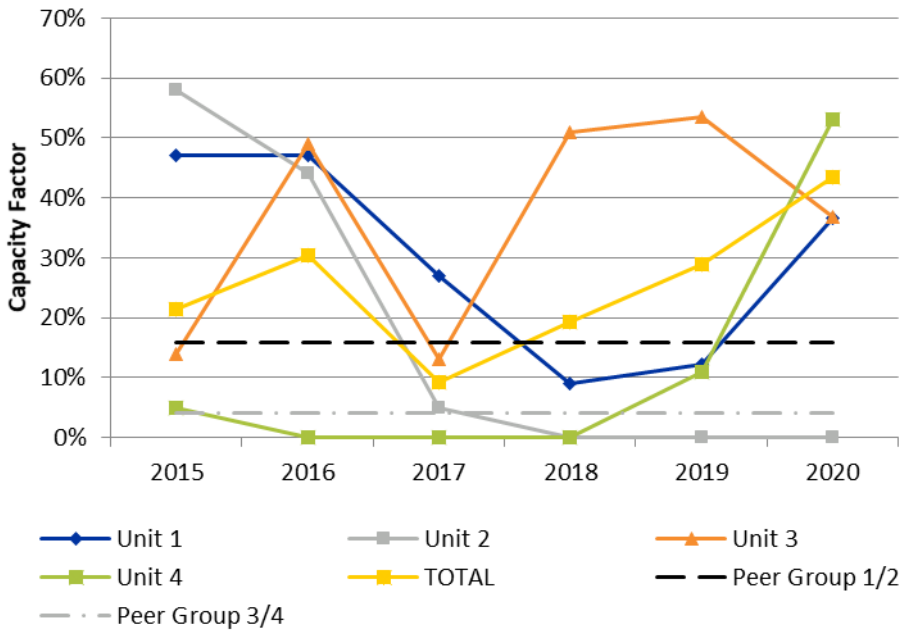
When reviewing availability and forced outage value changes, it is important to identify if the unit was being dispatched differently. In a gross fashion, the NCF provides insight into this. NCF is a percentage representing the average output of the facility during the time it was active (declared operational).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

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

The capacity factors exhibited by the Plant are plotted below and follow the same trends as annual generation. An important driver for the capacity factors and the annual generation is the dispatch demand for power. Other governing factors, such as those caused by the 2017 hurricanes, are disruptions to fuel and water supplies and damage to transmission and distribution systems.

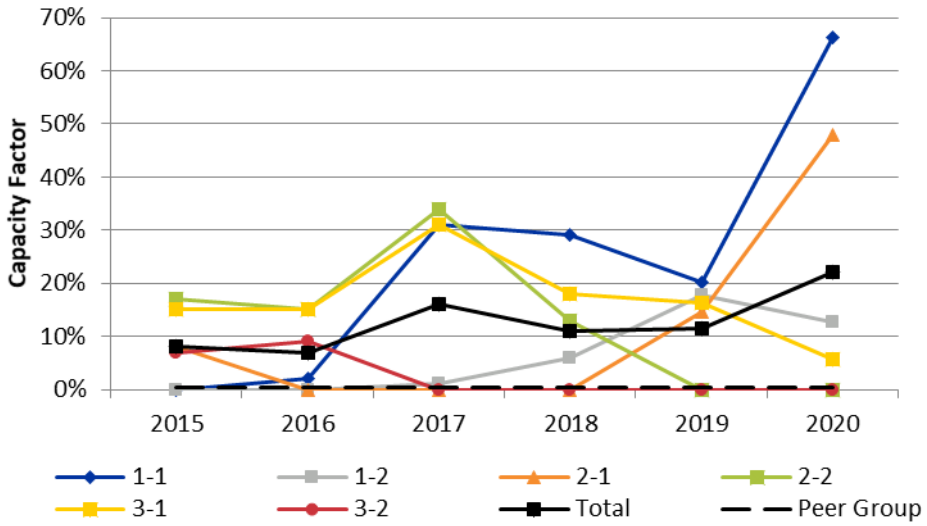
Capacity factor for the steam units is shown in Figure 6-7. The lower capacity factor in 2017 corresponds with the lower use of the plant that year. The chart indicates that, when the units are available, they are generally used as base-load units, and use has been trending up over the last few years. In contrast, similar units in the peer group are typically used as peaking units.

Figure 6-7 — Palo Seco Steam Units Capacity Factor



The GT capacity factor is shown in Figure 6-8. As the units are used for peaking and emergency, it has a lower value than a base-loaded unit and is not dispatched as much. These values correspond with the generation figures for the GT units; however, recently, GT 1-1 has been used a significant amount of time to provide additional support to the PREPA system, as other plants on the island have remained out of service due to the January 7, 2020 earthquake. While these units are not typically dispatched on a regular basis, the units have a higher capacity factor than their peer group.

Figure 6-8 — Palo Seco Gas Turbine Capacity Factor



6.5. NET HEAT RATE

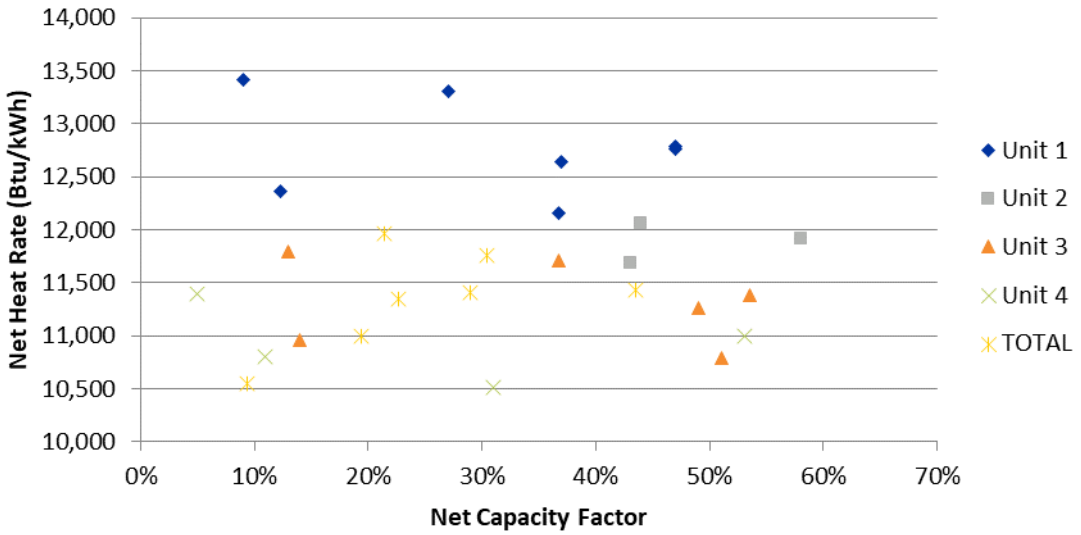
The heat rate is the amount of energy used by an electrical generator or power plant to generate one kilowatt hour of electricity. Heat rate shows, in general, the efficiency of the unit and to an extent represents the units to be considered in a dispatch hierarchy. The heat rate is slightly degraded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

Figure 6-9 shows the heat rate of the units decreasing as their capacity factors increase. Units are typically more efficient (lower heat rates) when operating at higher loads.

Net heat rate (higher heating value) for the steam units are in the range with other oil-fired thermal units in the PREPA fleet; however, the values provided are inconsistent with the data provided in the PREPA monthly reports. Sargent & Lundy recommends PREPA review the data. Data from the 2017 December monthly report indicates that the annual heat rate is 11,460 Btu/kWh; the data provided to Sargent & Lundy indicates that the 2017 annual heat rate is 10,547 Btu/kWh.

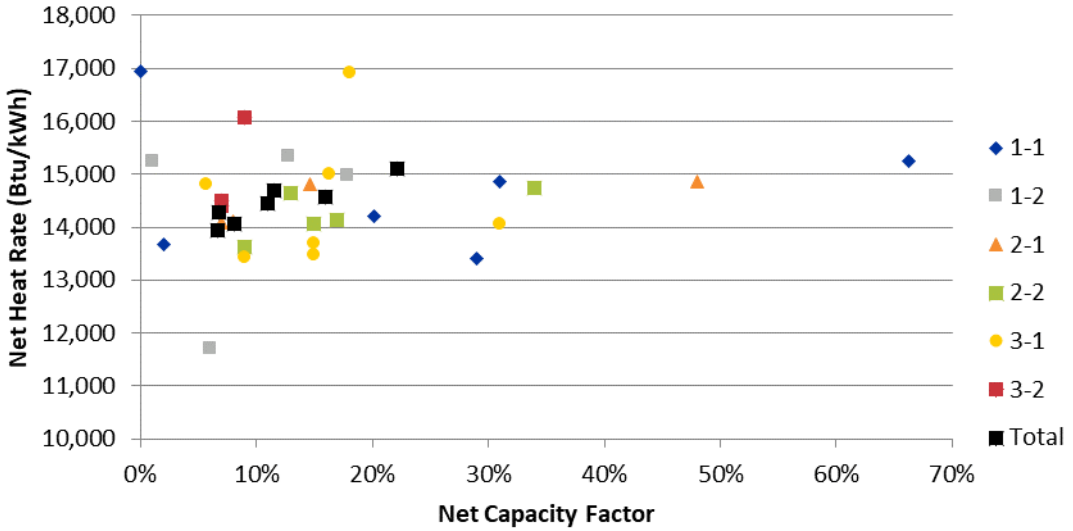
Unit 1 has one of the highest heat rates (worst performing) for the oil-fired units compared to several other PREPA plants and shows and average of 13,412 Btu/kWh for 2018. Unit 1 is grouped with the bottom quartile of all PREPA oil-fired units. Unit 4 is among the better performing units, with a heat rate of 10,806 Btu/kWh in 2019.

Figure 6-9 — Palo Seco Steam Units Heat Rate v. Capacity Factor



The net heat rate for the Palo Seco GT units' average is consistent with the model and age of the units. For a comparable value, the nominal (new) heat rate for current GT designs are on the order of 12,370 Btu/kWh. The net heat rates of the GTs have been fairly consistent when they've been operated over the past six years. They have high heat rates, but that is not as important as their availability and reliability for their role as emergency generators. Heat rate for the GT units are provided in Figure 6-10.

Figure 6-10 — Palo Seco Gas Turbine Heat Rate v. Capacity Factor



7. FINANCIAL REVIEW

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

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

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

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

7.1. FIXED AND VARIABLE O&M

Fixed O&M costs are independent of the amount of the plant generating output, such as fixed labor, materials, and administrative and general costs. Variable O&M costs are directly proportional to plant generating output, such as chemicals and consumables. The reported fixed and variable O&M costs for Palo Seco are aggregated as are the costs for Unit 3 (216 MW) and Unit 4 (216 MW).[11]

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

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

Palo Seco (216 MW) - Historical O&M Costs	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Operating Labor						
360 - Jefe Div. Central Gen. Palo Seco	$ 14,478,675	$ 13,704,210	$ 13,618,028	$ 13,271,800	$ 13,166,074	$ 12,649,747
361 - Administracion Proyectos - Palo Seco	$ -	$ -	$ -	$ -	$ -	$ -
Operating Non-Labor						
360 - Jefe Div. Central Gen. Palo Seco	$ 2,817,416.87	$ 4,721,444.51	$ 3,103,353.16	$ 4,100,506.93	$ 4,207,779.37	$ 4,542,560.76
361 - Administracion Proyectos - Palo Seco	$ -	$ -	$ -	$ -	$ -	$ -
Total O&M Costs ($)	$ 17,296,092	$ 18,425,655	$ 16,721,381	$ 17,372,307	$ 17,373,853	$ 17,192,308

FY = Fiscal Year, July 1 to June 30

[11] 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.

The aggregated O&M costs shown above correspond to the fixed and variable components estimated by PREPA in the Puerto Rico Integrated Resource Plan of 2018-19[12]. Table 7-2 summarizes PREPA's estimate of the fixed O&M (in $/kW-year) and variable O&M (in $/MWh) for both the steam and GT units at Palo Seco; these values assume an installed capacity of 216,000 kW and an annual generation of 1,037,000 MWh in 2015 for each of the steam units, and an installed capacity of 21,000 kW for each of the GT units. Sargent & Lundy compared these values with O&M costs for existing units in operation in North America of similar configurations and operating profiles. We determined that the Palo Seco O&M costs are within the typical range of costs for similar units, considering that higher O&M expenditures are required for plants firing HFO as compared with natural gas.

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

	Palo Seco Steam Unit 3 (216 MW) and Unit 4 (216 MW)	Palo Seco GE GTs (21 MW each)
Fixed O&M (2018 $)	$46.47/kW-year	$26.54/kW-year
Variable O&M (2018 $)	$4.95/MWh	$20.19/MWh

7.2. CAPITAL EXPENDITURES

Historical CAPEX, as reported by PREPA for Palo Seco 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.[13] We determined that the annual CAPEX expenditures for Palo Seco are within the typical range of costs for similar units.

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

Palo Seco (216 MW) - Historical CAPEX ($)	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
Construction/Maintenance Labor						
360 - Jefe Div. Central Gen. Palo Seco	$ 505,755	$ 2,507,229		$ 1,036,352	$ 1,323,148	$ -
361 - Administracion Proyectos - Palo Seco	$ -	$ -	$ -	$ -	$ -	$ -
Construction/Maintenance Non-Labor						
360 - Jefe Div. Central Gen. Palo Seco	$ 3,375,334.55	$ 2,127,254.78	$ 3,930,523.03	$ 3,669,981.76	$ 6,658,891.64	$ 3,175,120.21
361 - Administracion Proyectos - Palo Seco	$ -	$ -	$ -	$ -	$ -	$ -
Total CAPEX ($)	$ 3,881,089	$ 4,634,484	$ 3,930,523	$ 4,706,333	$ 7,982,039	$ 3,175,120

[12] "Puerto Rico Integrated Resource Plan 2018-2019 – Draft for the Review of the Puerto Rico Energy Bureau", IRP2019 - Main Report REV2 06072019 (002).pdf, June 2019

[13] 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 Palo Seco and includes a limited review of the station's current environmental compliance status. This section does not include a review of new and proposed regulatory initiatives that may have an impact on future operations at Palo Seco.

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

Table 8-1 — Palo Seco Power Plant Key Permits and Approvals

Permit/Approval Description	ID Number	Permit Expiration Date
Title V Operating Permit	PFE-TV-4911-70-1196-0015	March 16, 2020 (renewal application submitted on March 18, 2019)
National Pollution Discharge Elimination System (NPDES)	PR0001031	March 31, 2021
Resource Conservation and Recovery Act – Hazardous Waste	PRD980644488	N/A
Franchise for the use of Waters of Puerto Rico	R-FA-FAID6-SJ-00173-24102013	N/A

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

8.1. AIR EMISSIONS

The Palo Seco Title V Operating Permit includes emission limits and monitoring, recordkeeping, and reporting requirements for Palo Seco. The facility's current permit was issued on March 16, 2015 and expires on March 16, 2020. The facility is required to submit a renewal application to the EQB at least 12 months prior to the expiration date. A renewal application was submitted to the EQB on March 18, 2019. The emission units regulated under the Title V operating permit include the following:

- Two HFO-fired boilers with steam turbogenerators with a capacity of 857.7 MMBtu/h each
- Two HFO-fired boilers with steam turbogenerators with a capacity of 1,971 MMBtu/h each
- Six oil-fired simple-cycle combustion turbines, each turbine having a capacity of 301.5 MMBtu/h

- Two diesel-fired emergency generators with an output of 500 kW each
- One diesel-fired emergency generator with an output of 250 kW
- One diesel-fired fire pump rated at 208 horse power

The facility is required to retain all required monitoring and supporting information for a five-year period. 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
- MATS compliance

8.1.1. Air Permit Compliance

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

PREPA's annual emissions reports for 2013 to 2019 show that Palo Seco's facility-wide emissions have been well below allowable annual levels (see Table 8-2 and Table 8-3).

Table 8-2 — Palo Seco Power Plant Annual Emissions 2013–2014

Pollutant	Allowable Emissions (ton/year)	Actual Emissions (ton/year)	
		2013	2014
PM	3,292	576	321
SO_X	42,905	5,880	3,221
NO_X	12,469	2,459	1,788
VOC	260	58	32
CO	1,206	378	209
Pb	1.15	0.11	0.07

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

Table 8-3 — Palo Seco Power Plant Annual Emissions 2015–2019

Pollutant	Allowable Emissions (ton/year)	Actual Emissions (ton/year)				
		2015	2016	2017	2018	2019
PM_{10}	1,387.38	311.25	439.73	101.38	275.50	300.11
SO_2	17,464.39	3,083.96	4,403.89	1,279.76	2,732.34	2,975.44
NO_X	12,276.89	1,863.14	2,325.25	1,316.68	1,912,46	1,997.68
VOC	130.04	30.89	43.88	13.31	26.72	29.38
CO	856.94	203.59	289.05	88.07	176.34	193.82
Pb	0.37	0.07	0.09	0.04	0.07	0.07
CO_{2e}	5,418,568.60	—	1,523,219.99	1,523,219.99	1,523,220	1,523,220
Nickel	14.04	—	4.86	4.86	4.86	4.86
Manganese	6.94	—	0.58	0.58	0.58	0.58
Formaldehyde	7.74	—	2.04	2.04	2.04	2.04
Toluene	1.03	—	0.36	0.36	0.36	0.36
Polycyclic Organic Matter	0.81	—	0.02	0.02	0.02	0.02
Total Hazardous Air Pollutants	36.78	—	15.30	15.30	15.30	15.30

PM_{10} = particulate matter, 10 micrometers or less | SO_2 = sulfur dioxide | CO_{2e} = carbon dioxide equivalent

The ECHO database does not identify any violations or enforcement actions with regard to air emissions; however, the compliance monitoring history (five years) reported on EPA's ECHO database indicates that there were Title V permit deviations as part of the annual certification for 2016 and 2017. The reported deviations are described herein.

Sargent & Lundy reviewed annual Title V compliance certifications for the years 2015–2019. For all years reviewed, PREPA reported deviations related to opacity levels, MATS compliance, and late submittal of quarterly monitoring reports. PREPA noted in the 2018 and 2019 annual compliance certifications that several emissions reporting requirements were "under the Title V reconsideration process between PREPA and PREQB since April 2015," and that Palo Seco Unit 4 had been out of service since prior to the MATS initial compliance date. Additional review of MATS compliance is included in Section 8.1.2. The excess opacity emissions are explained in the reports as being due to startup/shutdown, control equipment problems, process problems, and other known causes. Equipment was adjusted as needed or taken out of service. Note that during portions of 2017 and 2018, PREPA was operating under a "No Action Assurance"

granted by the EPA in the aftermath of Hurricanes Irma and Maria for relief from certain Title V permit requirements, including emission limitations.

Sargent & Lundy also reviewed semiannual monitoring reports for 2017, 2018, and the second half of 2019. Sargent & Lundy was not provided semiannual reports for any other periods. Semiannual monitoring reports for all the periods reviewed identify deviations related to opacity levels. The excess opacity emissions are explained in the reports as being due to startup/shutdown, control equipment problems, process problems, and other known causes. Equipment was adjusted as needed or taken out of service. Note that the "No Action Assurance" granted by the EPA was effective starting October 2017 and was extended through April 2018, covering portions of the second half of 2017 and first half of 2018 periods.

The semiannual report for the first half of 2017 also identifies deviations related to environmental outage and water washing for Boiler PS-1. PREPA explained in a letter to the EQB that due to unforeseeable malfunctions out of PREPA's control, PREPA was not able to comply with water washing and outage requirements for PS-1. Both Palo Seco's Title V permit and PREPA's 1999 consent decree with the United States require water washing and environmental outages. PREPA submitted an emergency variance request to EQB and a force majeure request to the EPA pursuant to the consent decree to delay environmental outage and water washing. On July 12, 2017, EPA granted the force majeure request, delaying compliance with the requirements until mid-October 2017. In early October 2017, PREPA submitted additional force majeure requests to the EPA related to Hurricanes Irma and Maria. According to PREPA, Palo Seco was out of service in October 2017 due to structural issues, and the environmental outage and water washing was completed in January 2018.

Semiannual monitoring reports for the second half of 2017, first half of 2018, and second half of 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; therefore, under the "No Action Assurance," the EPA extended reporting deadlines for all reports covered under the "No Action Assurance" to May 30, 2018. According to PREPA, the EPA gave PREPA until July 30, 2018 to submit the reports, and the EQB informally extended the deadline consistent with the 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.

8.1.2. Mercury and Air Toxics Standards

The four HFO-fired boilers at Palo Seco are subject to the EPA's MATS. The MATS compliance date was April 16, 2015 with the option for a one-year extension to April 16, 2016. PREPA submitted an extension

request for Palo Seco, but the extension request was denied on the basis of being incomplete. In communications with the EQB, PREPA explained that they were continuing to analyze options for compliance.

Units 1 and 2 are designated as limited-use units (i.e., they are subject to a heat input limit of 8% averaged over a 24-month block period). Limited-use units are subject to significantly less stringent requirements under MATS. While these units must comply with the tune-up work practice standard, they are not subject to emissions limits for PM, HCl, and HF or the startup/shutdown work practice standards. According to PREPA, Palo Seco Units 1 and 2 failed to meet the 8% heat input limit during the first 24-month block period (2015–2017). Palo Seco Unit 1 also failed to meet the 8% heat input limit during the second 24-month block period (2017–2019); however, Unit 2 was in compliance with the heat-input limit during the second 24-month block period. It is Sargent & Lundy's understanding that Palo Seco Units 1 and 2 are not currently in operation and are not considered future generating resources in the IRP.

Units 3 and 4 include the PM continuous emissions monitoring system for demonstrating compliance with the MATS PM limit. Compliance with the hydrochloric acid and hydrogen fluoride limits is demonstrated based on fuel moisture content being less than 1.0%.

Sargent & Lundy reviewed MATS compliance reports for the fourth quarter of 2016 and the first half of 2017. Sargent & Lundy was not provided MATS compliance reports for any other periods. During the fourth quarter of 2016 and the first half 2017 (both quarters), PM emissions from Unit 3 exceeded the MATS standards. According to PREPA, Unit 4 has been out of service since March 2015, prior to the MATS compliance date.

The Palo Seco Title V compliance certification for 2019 indicates that the facility is not in compliance with MATS. Sargent & Lundy has not been provided with MATS compliance reports from 2017 (Q3) through the present; thus, the nature of noncompliance has not been determined.

8.1.3. One-Hour SO_2 NAAQS

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

The one-hour SO_2 NAAQS were published on June 2, 2010. Palo Seco is located in the Municipality of Toa Baja, which is currently designated a "non-attainment area" for the one-hour SO_2 NAAQS. A plan will need

to be developed by the EPA/EQB for bringing the area into attainment with the one-hour SO_2 NAAQS. At this time, Sargent & Lundy cannot predict what the plan will require regarding SO_2 reductions from Palo Seco Units 1–4; however, since the boilers primarily combust No. 6 fuel oil, it is expected that some reductions may be required. Potential options for reducing SO_2 emissions, if deemed necessary by EPA/EQB, include firing lower-sulfur-content fuels and the installation of post-combustion SO_2 controls.

8.2. WATER AND WASTEWATER DISCHARGE

Sources of wastewater from Palo Seco include cooling water, cooling tower blowdown, boiler blowdown, reverse-osmosis plant reject water, equipment drains, screens wash water, hydrostatic test waters, groundwater, fire protection system test water, wastewater treatment plant effluent, and stormwater. Wastewater is discharged to the San Juan Bay via the Old Bayamón River Bed through two separate outfalls (001A and 001C), and stormwater is discharged to the Boca Vieja Bay via its own outfall (002).

The facility's discharges are authorized under NPDES Permit Number PR0001031. The permit's expiration date is March 31, 2021, and the facility was required to submit a renewal application by September 30, 2020. Sargent & Lundy has not been provided with the NPDES permit renewal application for review.

8.2.1. NPDES Permit Compliance

Sargent & Lundy performed a review of the EPA's ECHO database to determine the facility's NPDES permit compliance status. The ECHO database identifies unresolved Clean Water Act (CWA) violations for the Palo Seco facility dating back to the fourth quarter of 2015. In the ECHO report, the listed violations are identified as effluent limit violations and failure to report the discharge monitoring reports (DMRs).

PREPA explained that the fourth quarter of 2015's exceedances were related to parameters that are no longer subject to compliance under the current water quality standards of Puerto Rico and Palo Seco's current NPDES permit. Sargent & Lundy was not provided any DMRs from 2015, 2019, or 2020 for review. Sargent & Lundy reviewed DMRs and addendum reports that PREPA submitted to the EPA for 2016, 2017, and 2018.

PREPA did not report any violations during the first quarter of 2016; therefore, it appears that this ECHO violation is in error. In the second quarter of 2016, a new NPDES permit went into effect with more restrictive limits for metals and temperature, and the exceedances were related to those parameters. From the second quarter of 2016 through the third quarter of 2020, PREPA reported exceedances for various parameters, including nickel, copper, sulfates, and temperature. In the DMRs, PREPA stated that the exceedances were largely related to a major overhaul performed at the wastewater treatment plant. PREPA stated that they

were performing adjustments to comply with the new limits. ECHO indicates that the facility continues to exceed copper effluent limits through the third quarter of 2020.

In the second and third quarters of 2016, PREPA reported exceedances for turbidity and total suspended solids (TSS). PREPA attributed these exceedances to rain events. In the fourth quarter of 2016 and the first quarter of 2017, PREPA reported exceedances for total residual chlorine. These exceedances were attributed to elevated chlorine levels in the source water. In the first quarter of 2017, PREPA reported an exceedance for hydrogen sulfide. This appears to be an isolated event, and PREPA did not provide an explanation.

From the fourth quarter of 2016 through the fourth quarter of 2018, the ECHO database lists TSS exceedances; however, based on TSS values reported in the DMRs, PREPA was in compliance with the TSS limit throughout this timeframe. PREPA noted in the addendum reports that the net DMR recognized TSS results as exceedances even though the reported values complied.

For the third quarter of 2017 through the third quarter of 2020, ECHO lists violations for failure to report DMRs. Sargent & Lundy was provided all DMRs for this timeframe except for July 2017 and the second quarter of 2018 through the third quarter of 2020. Third-quarter 2017 DMRs were submitted late due to hurricanes Irma and Maria; however, fourth-quarter 2017 and first-quarter 2018 DMRs were submitted on time. Sargent & Lundy notes that PREPA was operating under the “No Action Assurance” granted by the EPA from October 2017 through April 2018. According to PREPA, the ECHO database in not accurate with regards to listed violations, and the only valid violations are those reported by PREPA in the DMRs.

8.2.2. 316(b) Cooling-Water Intake Structure Requirements

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

Palo Seco withdraws cooling water from the Boca Vieja Bay through two intake channels that pass through the condensers for non-contact cooling water. The cooling water is discharged directly to the Old Bayamón River Bed using a once-through cooling system.

PREPA has negotiated a 316(b) compliance strategy with the EPA. The compliance strategy for PREPA as a whole is to focus on the Aguirre Power Complex and Costa Sur plant in the south of the island in the short-term with a long-term implementation for the Palo Seco and San Juan plants. Per the NPDES permit for Palo Seco, information on source water, cooling-water intake, source-water biology, the cooling-water system, and impingement and entrainment is to be collected and analyzed and a status report indicating

PREPA's preferred impingement mortality compliance method was due September 30, 2020. Sargent & Lundy has not been provided with the NPDES permit renewal application for review.

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) 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 (TRI) to federal and state agencies.

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

PREPA provided Sargent & Lundy with TRI reports for calendar years 2016 and 2017. The reports provided by PREPA and EPA's ECHO database confirms that PREPA has prepared and submitted TRI report; however, PREPA originally failed to file TRI Form R reports for hydrochloric acid for Palo Seco in 2010; the reporting violation led to enforcement action, which was settled in 2015 via a consent agreement and final order with the EPA (see Section 8.5.2).

8.4. OIL STORAGE SPILL PREVENTION

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

Sargent & Lundy also reviewed correspondence related to SPCC inspections provided by PREPA. On December 19, 2013, the EPA conducted an SPCC field inspection at Palo Seco. Sargent & Lundy was not provided a copy of the inspection report; however, the EPA requested additional information on February 6, 2014 following the inspection, and Sargent & Lundy reviewed a response letter that PREPA provided to the EPA. The additional information requested noted some deficiencies in the plan to which PREPA responded that various parts of the plan had been amended. PREPA also responded to other comments from the EPA, including questions regarding testing and inspections.

On December 4, 2014, the EPA conducted another SPCC inspection at Palo Seco and subsequently issued an inspection report. The EPA noted in the report that PREPA was to submit a schedule for when API 653 compliant internal and external integrity tests were to be conducted for each bulk storage tank. On December 19, 2014, PREPA responded to the EPA with the requested schedule. The EPA wrote to PREPA on August 4, 2015 and noted that testing was past due for various tanks and that the testing would be overdue based on the schedule that PREPA provided. The EPA requested an updated schedule within 30 days of the letter. PREPA responded to the EPA on September 4, 2015 clarifying which standards PREPA follows for testing and the required frequency; PREPA's response also stated that, based on those standards, testing was not overdue. PREPA also submitted the requested schedule. No further correspondence was provided to Sargent & Lundy for review.

8.5. ENFORCEMENT ACTIONS

8.5.1. PREPA Consent Decree

On March 19, 1999, the U.S. District Court for the District of Puerto Rico entered a consent decree between the United States and PREPA (Civil Action No. 93-2527). The Consent Decree includes detailed requirements to promote compliance with the following acts:

- Clean Air Act
- Clean Water Act
- Resource Conservation Recovery Act
- CERCLA
- EPCRA

Requirements for Palo Seco included implementing a Clean Air Act compliance program, Clean Water Act compliance program, and preparing a SPCC plan, among other requirements. A consent decree modification, lodged on June 21, 2004, included additional objectives for monitoring and reducing air emissions such as conducting opacity readings, reducing fuel sulfur content, and reducing nitrogen-oxide emissions.

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

8.5.2. TRI Violation

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

8.5.3. CERCLA Violations

The ECHO database identifies one CERCLA enforcement action that occurred between 2014 and 2017 for the recovery of past response costs by the EPA. The case status is listed as closed. According to PREPA, this enforcement action likely refers to the Palo Seco general depot superfund site. The 2012 EPA ROD indicates that this case was related to a 1983 spill of sulfuric acid, a 1989 release of corrosion inhibitor (completely recovered), a 1990 spill of mercury (completely recovered), and a 1995 release of acidic wastewater. The ROD evaluated both the Palo Seco site and the depot area (i.e., the "Investigated Area"); however, Sargent & Lundy notes that the general depot has a separate address and is located 1500 feet southwest of the site. The EPA conducted both human health and ecological risk assessments and determined that levels of residual contaminants at the "Investigated Area" fall within EPA's acceptable risk range. The EPA ultimately granted the area a status of "No Further Action."

8.6. SUMMARY

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

- **Air Emissions**
  - Sargent & Lundy was not provided MATS compliance reports for the second half of 2017 through 2020.
  - PM emissions from Unit 3 exceeded the MATS standard for all compliance periods reviewed by Sargent & Lundy.
  - Toa Baja is currently designated nonattainment for the one-hour SO_2 NAAQS. The EPA/EQB's forthcoming plan for bringing the area into attainment with the one-hour SO_2 NAAQS may require SO_2 reductions from Palo Seco.

- **Water and Wastewater**
  - From the second quarter of 2016 through the third quarter of 2020, PREPA reported exceedances for various parameters.

9. RECOMMENDATIONS AND CONCLUSIONS

The Palo Seco nameplate capacity is 809 MW; however, as of October 2020 the operating capacity was approximately 237 MW. A decline in plant performance and reliability should be expected during the operating life of a thermal power generation plant and is evident in the case of Palo Seco. The Plant has provided power generation service since the 1960s and is at the end of its design life. Sargent & Lundy recommended that Palo Seco be phased out of service and replaced by a plant with capacity and flexibility as determined by a separate load demand and resource study, which is ongoing.

Since its initial siting, Palo Seco—due to its proximity to the large San Juan population, the availability of seawater supply for cooling, and the nearby port services—has always been an ideal location for power generation on the island, and PREPA is studying the need for additional grid support and generation throughout the Puerto Rico. The 2020 PREB decision confirms the IRP's projected retirement of the original HFO thermal and GE GT units by 2025 but grants a budget for preliminary economic, siting, permitting and planning analysis of a new fossil fuel-powered unit and/or energy storage at the site. To help offset this loss in generating capacity, Palo Seco is also being considered as a site for 3 of the 11 new peaker GT units that will be added to PREPA's fleet with recently approved funding from FEMA. Ongoing and future repair of the original GE GTs and HFO thermal units is expected to continue as needed to maintain base-load availability during PREPA's repowering efforts, but maintenance decisions should focus on minimizing capital expenditures since these units are projected to retire by 2025 in accordance with the 2019 IRP.

For new generation equipment, a modern design should be considered—one that uses best available technologies for improved efficiency, environmental conditions, and emissions controls. The new generation units can have additional operational flexibility designed for rapid response to support shifting load demands and a greater penetration of renewable sources of power like wind and solar. The redesign must include much better protection and material selection than currently in place for this coastal installation as well as hardening of the facilities to enable command and control of power production during emergency conditions, such as harsh weather events.

Care must be taken to ensure that replacements or upgrades to the Plant are suitable for an aggressive, salt-laden marine environment exposed to coastal winds. Typically, competitively priced original equipment manufacturer standards for power generation and balance-of-plant equipment are not well-suited for this type of operating environment. New equipment must be configured for the challenging conditions at Palo Seco. Failure to make allowances for suitable materials, equipment selection, buildings/enclosures, and other aspects of the facility design to protect the plant from 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 at Palo Seco should consider the guidelines provided herein. With the release of the 2019 IRP, 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.

Additional features other than location to consider for reusing the site include the GIS facility, intake and discharge structures, existing buildings, and ample site space.

The GIS facility is relatively new, built in 2012, and connection to it can be considered and evaluated in a new plant design. The equipment and building are in clean condition, sheltered from the elements, and include a backup emergency generator in an enclosure. The equipment is adjacent to open space to the west near the warehouses for expansion.

The intake and discharge structures can be considered for reuse. A cooling tower with seawater makeup, instead of the current once-through design, would not require a significant portion of the existing equipment. The redesign can take advantage of the intake location without using the older concrete structures, cranes, and tunnels throughout the Plant. The discharge side to the former Bayamón River can be evaluated for environmental impact with a lower discharge rate.

The existing buildings, including offices and warehouses, can be reused. The warehouses and available open areas have potential for use as laydown and shelter for additional incoming equipment during a construction phase. If fuel gas is considered, either as a primary or as a dual-firing design, some or all of the areas dedicated to fuel tanks and containment can be reclaimed for other equipment or use. The auxiliary building and other equipment buildings are dedicated to an older design and will need evaluation for reuse.

The balance-of-plant systems are tied to the existing layout, and equipment sizes and their reuse for the air, cooling water, fuel, or fire protection is limited. Altering and attempting to reuse the underground piping will be problematic for most new design layouts. The underground piping placement may not lend itself well for different, new power block sizes and foundation requirements and may need significant changes and modification. Due to age, Sargent & Lundy does not recommend reusing these systems.

10. REFERENCES

1. Sargent & Lundy report, “Palo Seco Phase I Environmental Site Assessment,” SL-014468.PS.ESA, dated May 20, 2019.
2. Sargent & Lundy report, “Demarcation of PREPA Generation Assets from the Transmission and Distribution System,” TD-0003, dated October 4, 2019.