2025 Update to 2022 Powers Engineering Letter Report, "Clean Alternative Emergency Power Supply for PVSC"

Bill Powers, P.E., May 13, 2025

I. Summary

This letter report supplements the July 1, 2022 report I prepared for Earthjustice titled, "*Clean Alternative Emergency Power Supply for PVSC*."[1] The supplement responds to the issuance by the New Jersey Department of Environmental Protection of the final air permit for the Passaic Valley Sewerage Commission (PVSC) Standby Power Generation Facility (SPGF) on April 2, 2025. The purpose is to (1) address new information available since July 2022 and to (2) further review deficiencies in the design and selection of the SPGF as the preferred standby power alternative for the PVSC Wastewater Treatment Plant (WWTP).

II. Background On Selection of SPGF as Standby Power Source

FEMA and the NJDEP, in the wake of Hurricane Sandy, identified PVSC as a critical component of New Jersey's infrastructure and recommended that the facility be protected from similar storm events. Guidance issued by FEMA called for the protection of wastewater treatment plants, as critical infrastructure, to the 500-year storm event.[2]

PVSC and FEMA worked jointly on an analysis of alternatives to assure power supply reliability at the facility. The August 2013 PVSC/FEMA proposal considered three power supply alternatives:[3]

1. Placement of an additional utility feed
2. Use of standby power generators at each building/site at the PVSC WWTP
3. Construction of an on-site standby power generation facility at the PVSC WWTP

An on-site standby power generation facility (SPGF) alternative using natural gas as fuel was selected by the project team as the preferred alternative. The stated reasons for this selection are: (1) the reliability of natural gas during storm events, (2) the ease of constructability, and (3) an economic analysis.[4]

FEMA prepared its *Passaic Valley Sewerage Commission Floodwall and On-Site Power*

[1] ICC/Earthjustice, *Comments on PVSC Standby Power Generation Facility AO-25 Compliance Statement*, July 1, 2022, Attachment 1, B. Powers, *Clean Alternative Emergency Power Supply for PVSC*, July 1, 2022 ("Powers Report 2022").
[2] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project, Program Interest ID No. 07329 BOP 190004*, AO 2021-25 Compliance Statement, March 30, 2022, p. 10 ("PVSC 2022").
[3] Ibid, p. 12.
[4] Ibid, p. 12.

System Environmental Assessment (EA) in May 2014. Public comments on the EA (1) expressed concern about the air quality impacts of the proposed SPGF, and (2) requested an evaluation of sustainable energy sources as the PVSC backup power supply.[5] FEMA issued a *Finding of No Significant Impact* in August 2014, authorizing the SPGF project to move forward.[6]

PVSC has stated the SPGF is an essential part of its FEMA Hazard Mitigation Program plan, implying that the SPGF must be built as designed to avoid failure of the overall plan:[7]

> *FEMA and NJDEP directed PVSC to formulate and implement a resiliency plan to prevent PVSC from in the future (a) losing electrical power, and/or (b) having an interruption in service due to natural or man-made causes. The SPGF is a result of that directive. Thus, the SPGF cannot be considered in a vacuum. Rather, it is an integral part of one overall FEMA Hazard Mitigation Program plan, without which the plan will fail.*

FEMA and PVSC looked at several viable alternatives, all of which would have met the design objective of preventing PVSC from losing electrical power in the future. The PVSC statement that the overall FEMA Hazard Mitigation Program plan will fail if the SPGF is not built as designed is incorrect. The project team in 2013 preferred a centralized onsite standby power system fired by natural gas. No overriding engineering consideration precluded selecting the other power supply options available to assure power to the PVSC WWTP in an emergency.

III. Need for PVSC to Revise the 2013 Economic Analysis that Resulted in Selection of the SPGF Alternative

PVSC identifies three factors for selecting the SPGF over an additional power feed or standby generators at each building in 2013: *(1) the reliability of natural gas during storm events, (2) the ease of constructability, and (3) an economic analysis*.[8] It is unknown whether PVSC considered at the time it prepared its economic analysis that PSE&G was pursuing a $415 million project to raise the height of its low-lying substations above the 500-year flood level, including those that feed power to the PVSC WWTP, specifically to address the deficiency that caused the loss of grid power to the WWTP during Hurricane Sandy.[9]

[5] Ibid, pp. 12-13.
[6] Ibid, p. 13.
[7] Ibid, p. 14.
[8] Ibid, p. 12.
[9] Powers Report 2022, p. 6.

A. De Facto "Additional Power Feed" Alternative Was Realized for PVSC by PSE&G

An obvious equivalent to adding a new power feed to the PVSC WWTP is to harden the PSE&G substations that flooded during Hurricane Sandy to assure that they continue to function reliably under a similar 500-year flood condition in the future. PSE&G did this. PSE&G rebuilt the substations so they are in effect "new" power feeds that can withstand a 500-year flood event. The PSE&G substation rebuild project was completed in 2018. Power outages prior to Hurricane Sandy had been several hours or less.[10] There have been no reported grid power outages at PVSC since Hurricane Sandy, including during Tropical Storm Ida in 2021.[11]

The PSE&G substations have been elevated and the issue that caused the power outage has been addressed. The PVSC assertion that PSE&G cannot guarantee continuity of service under every eventuality is in effect a non sequitur:[12]

> *As part of the record in this matter, PVSC submitted documentation of PSE&G representations, . . .that, despite making its own grid resilience improvements, PSE&G could not guarantee continuity of service in the event of extreme weather-related conditions, accidents, and equipment failure and damage*.

PSE&G can guarantee that its substations serving PVSC that flooded during Hurricane Sandy have been elevated to avoid flooding under 500-year flood conditions in the future. That addresses the specific cause of the interruption of power to PVSC during Hurricane Sandy. Outside of the Hurricane Sandy event, no electrical outage at PVSC has lasted more than a handful of hours.[13]

That outage duration, with a reasonable margin of safety of several additional hours, should be the design outage duration assumed for the design of the backup power system at PVSC.

It is important to underscore that PVSC cannot guarantee that the SPGF will provide continuity of service *in the event of extreme weather-related conditions, accidents, and equipment failure and damage*. The reliance of the SPGF on a single fuel, natural gas, for both the combustion turbines and the black start engines, delivered by an offsite provider via pipeline, is a major vulnerability.

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[10] Ibid, p. 4.
[11] Ibid, p. 5.
[12] New Jersey Department of Environmental Protection, Environmental Justice Decision and Imposition of Special Conditions pursuant to Administrative Order No. 2021-25, Passaic Valley Sewerage Commission, Project ID #07329, BOP 190004, Title V Air Operating Permit Modification and Renewal BOP 210002, Standby Power Generation Facility, July 18, 2024, p. 2.
[13] Powers Report 2022, p. 4.

Natural gas supply emergencies have occurred in the vicinity of PVSC in recent years. Consolidated Edison declared a natural gas emergency and called for immediate conservation measures in New York City in December 2022. A report on the impact of the storm concluded that the utility had narrowly avoided a catastrophic natural gas supply failure. The report noted "*had pipeline pressures not recovered, Con Edison could have faced an unprecedented loss of its entire system that, in this worst-case scenario, would have taken months to restore*."[14]

The CEO of New Jersey Gas has also underscored the potential for natural gas shortages to impact New Jersey customers unless additional pipeline capacity is constructed.[15] PVSC cannot guarantee that the SPGF, which is completely dependent on pipeline natural gas, will be able to generate standby power when it is needed.

The SPGF will also increase the potential for natural gas shortages adversely affecting grid reliability under high stress emergency conditions by consuming natural gas to generate up to 34 MW of onsite power in relatively inefficient combustion turbines.[16] The three combustion turbines will have the potential to generate 28 MW each, or a total of 84 MW.[17]

The most likely time for natural gas supplies to fail is during a major emergency. If natural gas supply is lost unexpectedly for whatever reason, there will be no way to start the SPGF until the natural gas supply is restored. PVSC has also designed the "black start" engines, needed to start the SPGF combustion turbines, to use only natural gas. PVSC would then need to rely on the proposed 5 MW/10 MWh battery storage units to do the same job the natural-gas fired black start engines are supposed to do to start the combustion turbines.[18]

B. The Two-Week PVSC WWTP Outage Duration Assumption Has No Basis in Fact and Unfairly Restricts Standby Power Alternatives

PVSC simply states that "*The proposed SPGF and its auxiliary components are being designed for an electrical utility outage lasting 14 continuous days*."[19] PVSC offers no credible rationale for setting as a standby power design criterion a two-week outage. The longest grid power outage at PVSC other than Hurricane Sandy outage was no more than

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[14] Congressional Research Service, *Natural Gas Reliability: Issues for Congress*, July 15, 2024, p. 12.
[15] Steve Westhoven, President/COO New Jersey Natural Gas, New Jersey 2019 Energy Master Plan (EMP) Stakeholder Meeting (led by New Jersey Board of Public Utilities), testimony on New Jersey's natural gas capacity, September 28, 2018, pp. 20: https://www.nj.gov/emp/docs/pdf/092818_CE_F.pdf. "*Without additional supply infrastructure, our utility and other New Jersey natural gas utilities estimate a shortage of natural gas to meet our coldest-day demand needs. And, without greater diversification of our supply infrastructure, the risks of a major disruptive outage affecting service to our customers continues to loom*."
[16] PVSC 2022, pp. 14.
[17] New Jersey Department of Environmental Protection, Air Pollution Control Operating Permit Significant Modification, Permit Activity Number: BOP210002, Passaic Valley Sewerage Commission, April 2, 2025, pdf p. 212 (PVSC Equipment Inventory).
[18] PVSC 2022, p. 31.
[19] Ibid, p. 33.

several hours. The PSE&G substation deficiencies that caused the Hurricane Sandy outage have been fully resolved. As a result, standby power sources that can provide up to several hours of standby power to the PVSC WWTP fully meet the standby power need of the facility.

PVSC cannot justify a standby power duration requirement of greater than 8 to 12 hours given (1) the history of power outages at the PVSC WWTP and (2) the fact that the PSE&G substations that flooded during Hurricane Sandy have been upgraded to withstand a 500-year flooding event.

The only conceivable point of the excessively long design outage requirement is to make the battery storage alternative infeasible. PVSC states this explicitly: "*The proposed SPGF and its auxiliary components are being designed for an electrical utility outage lasting 14 continuous days. Therefore, the SPGF must provide 34 MW times 336 hours, or 11,424 megawatt-hours (MWh) of electricity . . . Therefore, battery storage is considered a technically infeasible option for replacing the SPGF*."[20]

C. Battery Storage Is a Less Costly and More Reliable Alternative to Meet a Reasonable Standby Power Outage Duration

The cost and performance of battery storage is addressed in the 2022 Powers Report.[21] Battery storage pricing has declined since 2022, from $193,000/MWh of storage to $148,000/MWh.[22]

PVSC indicates a total of up to 8.5 acres can be dedicated to battery storage at the PVSC WWTP.[23] Battery storage projects with 560 MWh of capacity are currently operational on 7 acres of land.[24,25] 560 MWh is sufficient to enable the PVSC WWTP to operate for 50 hours at its minimum demonstrated demand of 11 MW. It is sufficient for PVSC WWTP to operate for 16 hours at its maximum potential demand of 34 MW.

The cost of 560 MW of battery storage would be: 560 MWh x $148,000/MWh = $83 million.

However, it is important to underscore that the PVSC WWTP can operate for extended periods at its minimum demonstrated operating demand of 11 MW.[26] 132 MWh of battery

[20] Ibid, p. 33.
[21] Powers Report 2022, pp. 11-12.
[22] Energy Storage News, *BESS prices in US market to fall a further 18% in 2024, says CEA*, February 7, 2024: https://www.energy-storage.news/bess-prices-in-us-market-to-fall-a-further-18-in-2024-says-cea/.
[23] PVSC 2022, p. 33.
[24] Terra-Gen, *Valley Center Battery Storage Project Fully Online*, February 15, 2022: https://terra-gen.com/valley-center-online/.
[25] Terra-Gen, *Valley Center Energy Storage Facility*, 2025: https://terra-gen.com/valley-center/.
[26] Powers Report 2022, p. 10.

storage would be necessary to meet 11 MW of demand for 12 hours. The cost of 132 MW of battery storage would be: 132 MWh x $148,000/MWh = $19.5 million.

An advantage of onsite battery storage as the standby power resource instead of the SPGF is that solar power generation connected to the PVSC WWTP distribution grid can recharge the batteries to a degree during an outage. This advantage is recognized by PVSC: ". . . *these solar panels could supplement facility operating electricity usage, especially in combination with the five MW of battery storage . . .*".[27]

The battery storage alternative would be grid-connected with the ability to island in an emergency. As a result of being grid-connected, the battery storage system could be a participant in the PJM market as a capacity resource. This means the battery storage system, unlike the current SPGF proposal, could receive capacity payments and generate power sales at times of high demand to offset some of the cost of the system.

D. SPGF Design Weakness: It Is Oversized for the SPGF's Most Resilient, Lowest Demand Operating Mode Under Grid Stress Conditions

The reducing or shutting-off of non-critical loads is a commonsense procedure, known as demand response (DR), implemented when the electric grid is under stress. This is done to avoid brownouts and blackouts, to assure that community residents are less likely to, among other problems . . . "*have sewage backing up into basements and streets during such [blackout or brownout] events*."[28]

PVSC currently participates in the PJM DR program. PJM is the regional electric grid operator. PVSC states that: "*Continued participation in the [DR] program will increase reliability of the grid and increase resiliency of PVSC's operation*."[29]

PVSC responds to the PJM request to implement DR measures by shedding load or temporarily shutting down some processes to reduce electrical demand.[30] PVSC has demonstrated it can reduce demand to approximately 11 MW when called by PJM to implement its DR measures.[31]

However, PVSC will not be able implement the full suite of its DR measures *to increase resiliency of PVSC's operation* under emergency conditions if the SPGF is built as designed. For the SPGF combustion turbines (CT) to operate in a stable and efficient manner, approximately 15 MW of electrical load needs to be present at the PVSC WWTP.[32] This means the SPGF is oversized for PVSC's most resilient operating mode under grid

[27] PVSC 2022, p. 34.
[28] Ibid, p. 17.
[29] Ibid, p. 17.
[30] Ibid, p. 17.
[31] Powers Report 2022, p. 10.
[32] PVSC 2022, p. 16.

stress conditions. It also means that the SPGF will have a higher natural gas demand than necessary under grid stress conditions, when natural gas may be in short supply to meet regional demand.

IV. It Is Not Too Late for PVSC to Recoup a Substantial Amount of Its Sunk Costs in the SPGF

A major complicating factor affecting PVSC's consideration of any alternatives to the SPGF is that a large investment in the project has already occurred. PVSC states:[33]

> *PVSC issued the request for proposals for the power generation system equipment in 2018 and executed a contract for the same in 2019, Contract B129, with Siemens Energy, Inc., to provide all goods and special services required. The value of Contract B129 is $51,466,049. Fabrication is complete and the turbines are ready to be shipped to PVSC upon notice. Contract B128 consisted of preparing the proposed site for the construction SPGF by removing existing underground structures. Construction of this contract began in June 2019 and was completed in November 2020 for a total cost of $3,904,412.90.*

PVSC, as of 2020, had already expended over $55 million, $51 million for equipment and $4 million for site preparation, of the original SPGF project budget of $118 million.[34] The remaining contract for construction of the SPGF is presumptively $63 million.

The cost to add sufficient battery storage to meet a conservative and reasonable outage duration of 12 hours at minimum WWTP demand is approximately $20 million. This is far less than the $63 million in pending construction costs necessary to complete the SPGF, and represents a major savings for customers served by the WWTP.

In addition, the money already expended by PVSC on SPGF equipment and site preparation is not necessarily lost if the SPGF project is cancelled and another alternative selected. A battery storage can be located on the prepared site.

There is also a very active resale market for gas turbines and related equipment.[35] There is strong demand for gas turbines currently and prices are high.[36] PVSC has the potential to recover $10s of millions in sunk SPGF equipment costs through the gas turbine power plant resale market if the SPGF project is cancelled.

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[33] Ibid, p. 15.
[34] J. Rotolo, P.E. – PVSC, *The PVSC Resiliency & Mitigation Efforts/ Lessons Learned*, PowerPoint, January 18, 2018, p. 38.
[35] PowerConsult, *Power Plant Equipment – Sales*, website accessed May 11, 2025: https://equipment.power-consult.com/.
[36] Gas Outlook, *Costs to build gas plants triple, says CEO of NextEra Energy*, March 25, 2025: https://gasoutlook.com/analysis/costs-to-build-gas-plants-triple-says-ceo-of-nextera-energy/.

V. Conclusion

The reliance of the SPGF and its supporting black start engines on pipeline natural gas as the only fuel is an inherent weakness. PVSC cannot assure that standby power will be available at the PVSC WWTP when it is needed due to this natural gas supply vulnerability.

The excessive two-week outage duration design requirement for standby power at the WWTP bears no relation to the actual history of the duration of power outages experienced at the site. The PSE&G substation deficiencies that resulted in a 50-hour outage at the WWTP during Hurricane Sandy have been resolved. The longest outage duration experienced at the WWTP outside of the Hurricane Sandy event has been several hours. A reasonable and conservative outage duration design requirement would be 12 hours, not 14 days.

Battery storage is a much less expensive and much more responsive standby power supply than the SPGF combustion turbines. Battery storage also has no direct air emissions and can earn additional income for PVSC by participating in PJM capacity and power markets.

The fact that PVSC has already spent $55 million of the $118 million total SPGF project budget does not preclude cancelling the project and selecting battery storage. The cost of battery storage to address minimum WWTP demand for 12 hours is approximately $20 million, far less than the $63 million allocated to construct the SPGF. PVSC can also recover a substantial amount of the investment in SPGF equipment by reselling that equipment in the gas turbine resale market.

Attachment 1

Clean Alternative Emergency Power Supply for PVSC

Bill Powers, P.E., July 1, 2022

I. Summary

The backup onsite power system proposed by Passaic Valley Sewerage Commission (PVSC) should be designed for a service duration much shorter than the proposed two weeks and a peak load substantially less than 34 megawatts (MW). The backup power supply should be designed to address the longest credible Public Service Electric and Gas (PSEG) grid outage duration and should supply only the critical PVSC loads during that outage. The longest credible PSEG grid outage, after PSEG has raised all low-lying substations above the 500-year flood level, is no more than 12 hours. The PVSC critical loads are less than 15 MW. This equals a maximum potential PVSC backup power demand of 180 megawatt-hours (MWh). Battery storage alone can meet this 180 MWh backup power demand more cost-effectively and more reliably than the gas turbines proposed for the SPGF.

PVSC proposes to construct a 34 MW onsite Standby Power Generation Facility (SPGF) at a cost of $118 million. The plant will consist of three Siemens natural gas-fired 17 MW combustion turbines (CTs). It will be designed to operate in "island" mode, disconnected from the PSEG grid. The genesis of the SPGF project was the loss of PSEG grid power to PVSC during Hurricane Sandy due to flooding of low-lying PSEG substation(s), and flooding of process units at PVSC. PSEG has upgraded the affected substations. PVSC is in the process of upgrading its facilities to assure future flooding will not affect reliable operation. The maximum duration of non-flood related PSEG power outages has been a few hours.

The proposed SPGF CTs must be operational in advance of PVSG isolating from the PSEG grid in an emergency, as the CTs require some time to go from a cold condition to full output. For this reason, PVSC projects that the CTs could collectively operate as many as 1,284 hours per year, anticipating up to ten storm events per year with CT startup two days in advance of the anticipated arrival of each storm event. PVSC has withdrawn its earlier proposal to operate the SPGF as a peak shaving facility, for up to 700 hours per year, to avoid the associated air emissions.

PVSC has applied for incentives to add up to 19 MW (direct current) of onsite and offsite solar power.[1] PVSC has also proposed to add 5 MW/10 MWh of battery storage for peak load management.[2]

The PVSC proposal to convert the CTs to green hydrogen fuel at some point in the future is conjectural and uncertain. All elements of the SPGF, including the fuel piping component materials, pipe sizes, sensors and safety systems, and gas turbine metals exposed to hydrogen combustion exhaust gases, may require modification or replacement to enable use of 100 percent

[1] Passaic Valley Sewerage Commission, *Request for Proposals for a Renewable Energy Power Generation System*, February 2022, p. 7.
[2] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, p. 49.

hydrogen fuel.[3] PVSC indicates that the SPGF will cost $118 million.[4] There is no indication that PVSC has considered the additional cost of converting the $118 million SPGF to burn 100 percent hydrogen, or considered the potentially high cost of producing the green hydrogen that will be required.

PVSC's average power demand is 22 MW. PVSC participates in the regional PJM demand response program, and can voluntarily reduce its demand by approximately half, to about 11 MW, when called to participate. PVSC has a contractual obligation to maintain this reduced demand for up to 12 hours if requested by PJM to do so.

PVSC assumes, as design conditions of the PVSC, that a 34 MW demand must be met continuously for 14 days. These design conditions are too conservative. PVSC can operate at about 11 MW in demand response mode for up to 12 hours (or more) with only critical facility loads operational. The new PVSC flood water pumps will add another 2 MW of demand if they are needed. These pumps will only operate if required. They are not critical loads that must be supported as the PVSC shifts from grid power to backup power.

The longest PSEG outage PVSC endured before Hurricane Sandy in 2012 was a few hours. The susceptibility of low-lying PSEG substations to flooding has been resolved. Therefore, the design condition for grid power outage duration should be a small number of hours. PVSC is already obligated to reduce load substantially for up to 12 hours as a participant in PJM's demand response program. A PSEG outage duration of no more than 12 hours should be the SPGF design "grid emergency duration" assumption.

The PVSC minimum critical load is 11 MW. The flood water pumps, if needed during the event, would add another 2 MW of power demand. The design PVSC power demand, to conservatively assure critical loads are met during the emergency event with the flood water pumps operating, should be 15 MW.

The SPGF would need to provide 180 MWh of backup power to meet a continuous demand of 15 MW over 12 hours. The current cost of utility-scale battery storage is approximately $200,000 per MWh. At this unit value, a 180 MWh battery storage-only SPGF at PVSC would cost $36 million. This is about 30 percent of the $118 million capital cost projected by PVSC for the proposed CT-based SPGF.

A battery-based SPGF would emit no air emissions. For this reason, the battery-based SPGF could also earn income for PVSC as a peak-shaving resource reducing PVSC power costs and by bidding into the PJM regional market.

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[3] Siemens, *Hydrogen power with Siemens gas turbines*, 2020, p. 16: file:///C:/Users/Bill/Downloads/Siemens%20Energy%20-%20Hydrogen%20Power%20with%20Siemens%20Gas%20Turbines.pdf.

[4] J. Rotolo, P.E. – PVSC, *The PVSC Resiliency & Mitigation Efforts/ Lessons Learned*, PowerPoint, January 18, 2018, p. 38: https://www.nj.gov/dep/dwq/pdf/20180118_NJWWRRAP_Workshop_07_JRotolo.pdf.

A battery-based SPGF could also seamlessly isolate from the PSEG grid in real-time. There would be no justification or need for up to two days of anticipatory operation before each storm event as is proposed by PVSC for the CT-based SPGF.

II. Background - Description of Problem the SPGF Is Intended to Address

Low-lying PSEG substations along the Passaic River were flooded during Hurricane Sandy, requiring PSEG to shut down power to those substations. PSEG provides grid power to PVSC. As a result of the flooding, PSEG discontinued power to PVSC for approximately 50 hours.[5] Subsequently, PSEG raised the elevation of these substations to one foot above the Hurricane Sandy flood level to assure these substations remain in operation during the 500-year flood event.[6]

Hurricane Sandy exposed three major resiliency weaknesses at PVSC's main facility: 1) the lack of protection from storm surges, 2) the susceptibility of the substantial underground portions of PVSC to flooding, regardless of the cause of the flooding, and (3) the lack of reliable backup electrical power in the event of a transmission grid (PSEG) failure.[7]

The PVSC also is in the process of hardening it operations to assure continued operation during the 500-year flooding event. This resiliency project has five primary elements: 1) installation of flood walls, 2) elevation of switchgear and MMCs, 3) reconfiguration of drainage systems, 4) addition of flood water pumps, and 5) the installation of an on-site SPGF. The SPGF has not yet been constructed. The design of the SPGF is the subject of this letter report.

A. Flooding of PSEG Substations and PVSC Processes During Hurricane Sandy

Adequate control of 500-year floodwaters, either through the elevation of critical equipment above the 500-year flood event water level or through the construction of flood walls of sufficient height to achieve the same objective, is necessary to prevent the future loss of external PSEG power and damage to PVSC wiring and process equipment.

PSEG shut down power to PVSC during Hurricane Sandy due to flooding of its low-lying substations, as detailed in the October 31, 2012 US DOE Situation Report on Hurricane Sandy:[8]

> The storm surge flooded a large number of (PSEG) substations along the Passaic, Raritan, and Hudson rivers, disrupting service to customers in Hudson, Essex, and Middlesex counties. The magnitude of the flooding in contiguous areas caused

[5] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, pp. 6-8. At p. 7: "500-year catastrophic natural disaster".
[6] PSEG, *Petition for Approval of Electric and Gas Base Rate Adjustments Pursuant to the Energy Strong Program* March 30, 2018, Attachment 1, p. 2 (pdf p. 15): https://publicaccess.bpu.state.nj.us/CaseSummary.aspx?case_id=2106258.
[7] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, p. 2.
[8] U.S. DOE - Office of Electricity Delivery & Energy Reliability, *Hurricane Sandy Situation Report #6*, October 31, 2012, p. 8: https://www.oe.netl.doe.gov//docs/2012_SitRep6_Sandy_10312012_1000AM_v_1.pdf.

PSEG to take these stations out of service, wait for the flood waters to recede to assess the damage, dry out the equipment, replace equipment when necessary, and re-energize the system to restore service.

The PSEG substation outages along the Passaic, Raritan, and Hudson rivers were caused by the flooding of the substations, not by failure of the bulk power system to continue supplying those substations with grid power. The PSEG substation flooding resulted in grid power to PVSC being curtailed for approximately 50 hours, from 9:00 pm on October 29, 2012 to 10:40 pm on October 31, 2012, as detailed in the timeline shown in Table 1.

Table 1. Timeline of PSEG curtailment and restoration of power to PVSC, October 29-31, 2012[9]

Date/time	Event
October 29, 2012, 9:00 pm	PVSC lost both the primary and backup direct electrical utility feeds from PSEG. Once power was lost and PVSC had no way to get sewage flow through the WWTP, strategic combined sewer overflows (CSOs) were automatically activated, which diverted the raw sewage coming from PVSC's Main and Southside Interceptors into the Passaic River.
October 31, 2012, 10:30 am	Sewage flows from Hudson County continued to be pumped into the PVSC plant via a force main, further adding to the flooding until 10:30 am on October 31st. PVSC was able to bypass the plant by diverting the raw sewage coming from Hudson County into Newark Bay in order to prevent further flooding in the plant.
October 31, 2012, 10:40 pm	PSEG restored power to PVSC's Substation 1, which feeds power to the rest of the WWTP.
Nov. 3, 2012, 8:45 am	From 9:00 pm on October 29 to 8:45 am on November 3, it is estimated that approximately 840 million gallons of raw sewage were bypassed into the Passaic River and Newark Bay.

The only major loss of the PSEG bulk power supply in New Jersey in the 21st Century occurred during the historic August 2003 Northeast blackout. Power was restored to most PSEG customers "within hours" after this 2003 event occurred.[10] The 2003 blackout did not result in PVSC proposing the construction of an onsite backup power plant to improve power supply reliability. PVSC can apparently withstand a number of hours of grid power interruption – in the absence of onsite flooding – without unduly compromising process operations.

PVSC identifies the Hurricane Sandy storm surge as "a 500-year catastrophic natural disaster."[11] The 500-year flood conditions experienced by PSEG and PVSC during Hurricane are the design basis for the offsite substation upgrades by PSEG and the PVSC onsite upgrades.

[9] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, pp. 6-8.
[10] nj.com, *A decade after historic blackout, N.J. utilities focus on strengthening the system*, August 11, 2013: https://www.nj.com/business/2013/08/a_decade_after_the_big_blackou.html. "In New Jersey, where most customers had power restored within hours, PSEG relay stations prevented further damage by disconnecting from the system to stop the domino effect of outages . . ."
[11] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, p. 7.

The SPGF was conceived by PVSC as a reliability response to the loss of PSEG power due to the flooding of PSEG substation(s) supplying PVSC caused by Hurricane Sandy. However, PSEG has resolved the flooding risk at its substation(s) serving PVSC by elevating the substation equipment above the 500-year flood water level.

PVSC is addressing the flooding risk to its process operations by: 1) building flood wall(s) around its east and west compounds, 2) elevating electrical switchgear and MMCs, 3) improving drainage, and 4) adding flood water pumps to address rainwater collecting inside the PVSC flood walls. In theory, no SPGF should be needed with critical PSEG infrastructure now protected, and with the PVSC infrastructure upgrades that are intended to prevent 500-year flood waters from impacting facility operations.

B. PSEG Has Effectively Addressed the Substation Flooding Problem That Led to Outages During Hurricane Sandy

The low-lying PSEG substations were tested to a degree in 2021 when Tropical Storm Ida hit PSEG service territory. Newark experienced record-breaking flooding.[12] PSEG invested heavily in hardening its electric and natural gas infrastructure in the wake of Hurricane Sandy. According to PSEG, major storms such as Ida have much less impact on PSEG infrastructure now than when Hurricane Sandy hit in 2012:[13]

> The $4.8 billion investment in infrastructure strengthening and modernization programs, portions of which are still in progress, spans PSE&G programs Energy Strong I and II and Gas System Modernization Program I and II and includes raising, rebuilding, eliminating and equipment upgrades at 26 stations, many of which were damaged by flooding during Sandy. PSE&G also installed smart grid technologies, replaced close to 2,000 miles of aging gas lines and added digital and other technologies to make the network more intelligent and agile.
>
> The benefit to customers was evident last year (2021) when Tropical Storm Ida brought historic flooding to most of the utility's service territory. Tropical Storm Ida and its remnants would cause more than $75 billion in damage nationwide – surpassing the damage caused by Superstorm Sandy in 2012. PSE&G's infrastructure stood strong. A total of 215,000 customers lost power compared to more than 2 million who suffered lengthy outages during Sandy.

It was the failure of PSEG substation(s) due to flooding damage that led to the loss of power at PVSC during Hurricane Sandy. That failure mode has been eliminated by PSEG. The design parameters for the SPGF need to reflect the upgraded reliability of the PSEG substation(s) serving PVSC.

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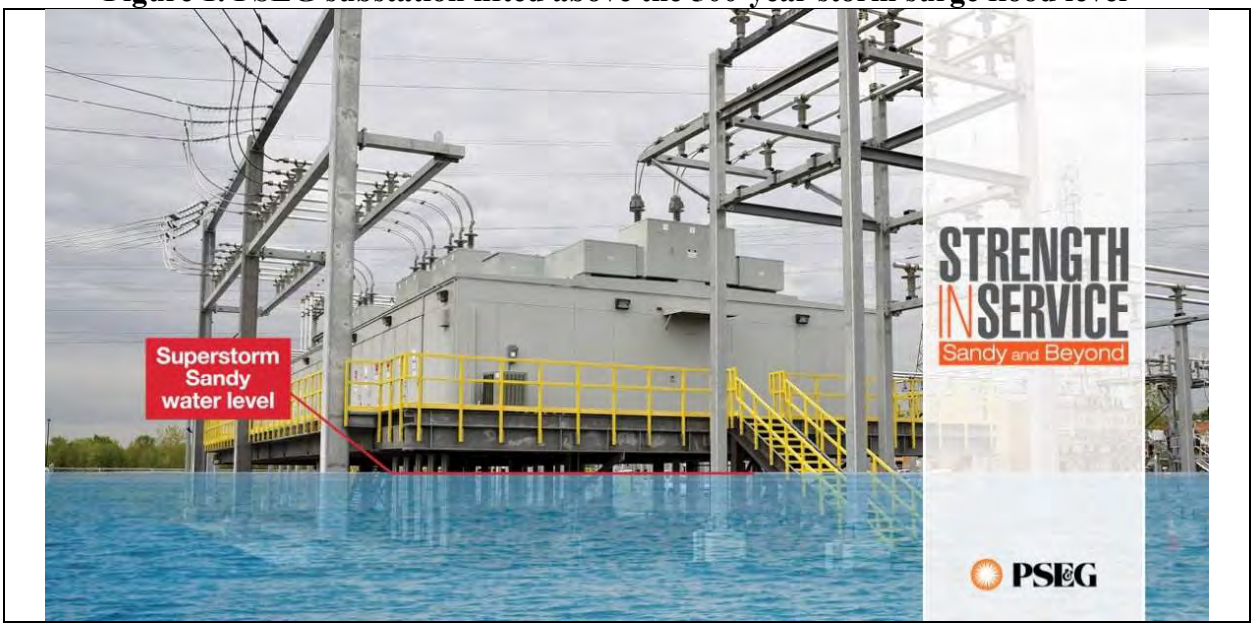
[12] TapintoNewark, *Tropical Storm Ida Pummels Newark With Record-Breaking Rainfall, Prompting Rescue Efforts for Hundreds of Residents*, September 2, 2021: https://www.tapinto.net/towns/newark/sections/police-and-fire/articles/tropical-storm-ida-pummels-newark-with-record-breaking-rainfall-prompting-rescue-efforts-for-hundreds-of-residents.

[13] PSEG press release, *A Decade after Superstorm Sandy, New Jersey's Infrastructure is Considerably More Prepared for Hurricane Season*, June 9, 2022: https://nj.pseg.com/newsroom/newsrelease303.

III. Post-Sandy Actions Taken by PSEG and Proposed by PVSC to Minimize Future Outage Duration During 500-Year Event

PSEG has raised the elevation of twenty-six substations in low-lying areas to one foot above the 500-year storm surge flood level.[14] See Figure 1. The only reason identified by PSEG for the loss of PSEG power during the Hurricane Sandy storm surge was flooding of the PSEG substation(s) providing grid power to the PVSC onsite substation.[15]

Figure 1. PSEG substation lifted above the 500-year storm surge flood level[16]



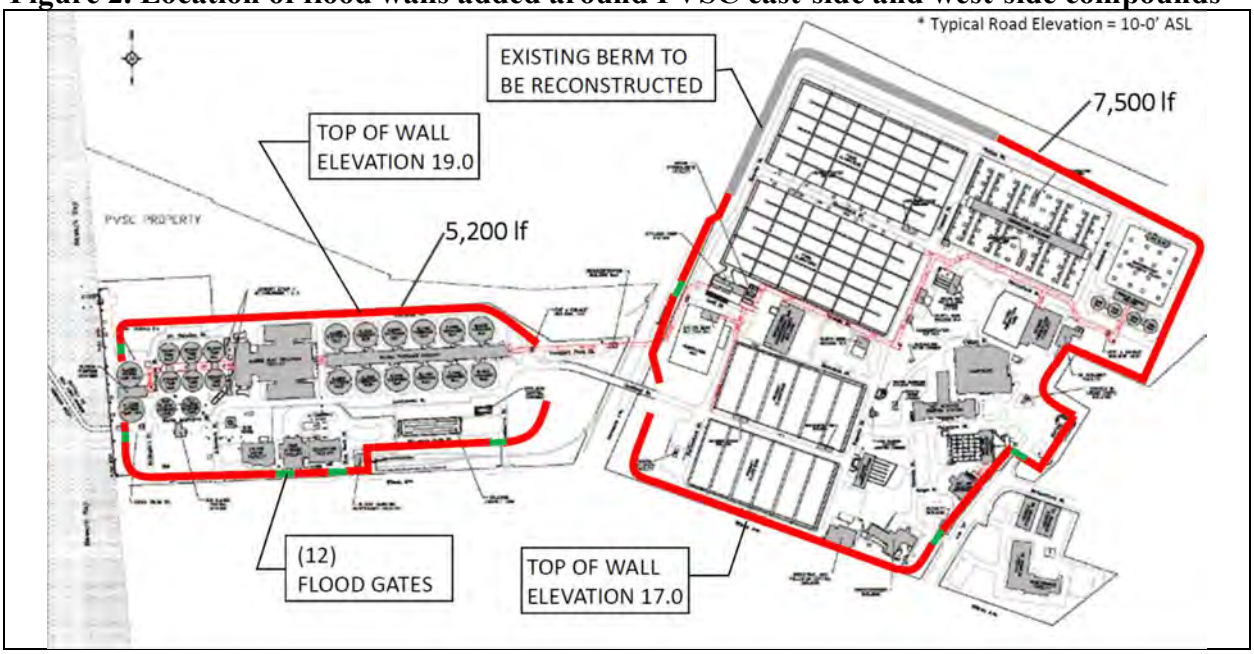
PGEG has spent $415 million elevating these twenty-six substations above the 500-year flood level.[17]

IV. Post-Sandy PVSC Mitigation Measures to Minimize Impact on Process Equipment During 500-Year Event

PVSC is in the process of adding flood walls, elevating switchgear and MMCs, improving drainage, and adding flood water pumps. The locations of the flood walls are shown in Figure 2.

[14] PSEG, *Petition for Approval of Electric and Gas Base Rate Adjustments Pursuant to the Energy Strong Program* March 30, 2018, Attachment 1, p. 2 (pdf p. 15): https://publicaccess.bpu.state.nj.us/CaseSummary.aspx?case_id=2106258.
[15] U.S. DOE - Office of Electricity Delivery & Energy Reliability, *Hurricane Sandy Situation Report #6*, October 31, 2012, p. 8: https://www.oe.netl.doe.gov//docs/2012_SitRep6_Sandy_10312012_1000AM_v_1.pdf.
[16] PSEG press release, *A Decade after Superstorm Sandy, New Jersey's Infrastructure is Considerably More Prepared for Hurricane Season*, June 9, 2022: https://nj.pseg.com/newsroom/newsrelease303.
[17] PSEG, *Petition for Approval of Electric and Gas Base Rate Adjustments Pursuant to the Energy Strong Program* March 30, 2018, Attachment 1, p. 1 (pdf p. 14).

Figure 2. Location of flood walls added around PVSC east-side and west-side compounds[18]



PVSC indicates it must have reliable onsite backup power to assure that water accumulating inside the flood walls can be removed.[19] There is no discussion in the PVSC analysis of the $415 million that PSEG has spent to elevate its low-lying substations to assure PSEG's ability to provide reliable power to customers, including PVSC, under 500-year flood conditions.

Reliable power will be available from PSEG to operate the PVSC flood water pumps. If PSEG does experience an outage unrelated to substation flooding during a storm event, it will be of short duration based on past PSEG outage history. The SPGF design should be based on a short-duration PSEG outage.

V. Proposed Design Basis and Cost of Emergency Power SPGF Supply

A. Proposed SPGF Design Should Be Based on Maximum PSEG Outage Duration of 12 Hours, Not the Maximum PVSC Flood Damage Duration

The proposed function of the SPGF is to provide onsite power when PSEG power is interrupted during storm events.[20] PSEG has flood-hardened the substation(s) supplying PVSC. These substations are no longer subject to outages due to 500-year flood elevation levels. PVSC will

[18] J. Rotolo, P.E. – PVSC, *The PVSC Resiliency & Mitigation Efforts/ Lessons Learned*, PowerPoint, January 18, 2018, p. 20.

[19] J. Rotolo, 2018, p. 11. "Construction of the floodwall would require that drainage systems be redone as well as the installation of pump stations to remove significant water from rainfall. However, the floodwall and associated work could result in a catastrophe should a power failure occur, as building the floodwall without the certainty of having reliable power to pump out the walled-in grounds would not alleviate the flooding hazard . . . Therefore, in addition to the floodwall, the team agreed that the solution required a reliable, centralized, onsite standby power system that is available in all weather conditions."

[20] As noted, PSEG restored power to customers within hours in the wake of the August 2003 blackout which was caused by regionwide tripping of transmission lines and generators. This blackout was not caused by severe weather.

have flood walls around its east-side and west-side compounds to protect the compounds from 500-year flood water levels.

The duration of the PSEG power outage caused by Sandy, and the duration of PVSC downtime resulting from the flood water levels caused by Sandy, are not the relevant design criteria for the SPGF. Post-Sandy PVSC conditions following the PSEG and PVSC upgrades are the correct design criteria for the SPGF.

PVSC considered PSEG grid power reliable, without onsite backup power, prior to Sandy and after the August 2003 blackout. A valid argument can be made that, by increasing height of the low-lying PSEG substations above the 500-year flood level, reliable grid power is assured under all weather conditions and the SPGF is not necessary to assure power reliability at PVSC.

The difference between the August 2003 blackout and Hurricane Sandy was the unprecedented flooding caused by Sandy, and the damage it did to PSEG and PVSC equipment. The PSEG and PVSC infrastructure upgrades (not including the SPGF), neutralize the impact of 500-year flooding and allow normal operations to proceed reliably under severe weather conditions.

B. SPGF Design Proposed by PVSC

The SPGF proposed by PVSC would consist of three 17- MW Siemens CTs, to meet a projected facility demand of 34 MW.[21] Two of the CTs would be operational under normal standby power operation conditions, with the third CT in standby mode. The facility would only isolate from the grid, and operate in "island" mode as a standalone microgrid, if PSEG power is not available. However, PVSC will not be able to immediately switch to the CTs if they are offline when grid power is lost (CT startup can take up to 30 minutes).[22]

PVSC will not be able to immediately switch to the SPGF to address a sudden PSEG power outage. For this reason, PVSC is projecting that the SPGF will be started as much as 48 hours in advance of a forecast storm event.[23] PVSC, for the purpose of calculating annual usage of the SPGF CTs, is projecting up to ten storm events per year. This translates into a potential for up to 480 hours per year of operating time each for the two primary 17 MW CTs. There would also be 100 hours per year of operation and maintenance (O&M) testing of each CT. These hour totals do not include actual operating hours during storm events. PVSC projects that the CTs could collectively operate as many as 1,284 hours per year.[24]

PVSC has withdrawn its earlier proposal to operate the SPGF as a peak shaving facility, for up to 700 hours per year, to avoid the associated air emissions.[25]

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[21] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, pp. 15-21.
[22] Ibid, p. 18. "Starting up the SPGF itself would take less than a half-hour."
[23] Ibid, p. 18. "Action items would include starting the facility at least 24 hours in advance of the expected event, and up to 48 hours in advance if deemed necessary."
[24] Ibid, p. 21.
[25] Ibid, p. 31.

Effectively all of the operating time projected for the CTs is due to: 1) the inability of the CTs to instantly provide replacement power from a cold start when grid power is lost, and 2) the complexity of the turbine machinery that necessitates regular O&M test runs to assure the CTs will be ready when needed. The complexity of the CT, and the resulting possibility that any one CT may not be available when needed, is the reason a third standby CT is specified for the SPGF.

C. PVSC Can Operate Under Emergency Conditions at Much Less Than 34 MW

The average annual demand of the PVSC is approximately 22 MW.[26] PVSC participates in the PJM demand response program, intended to reduce demand on the grid during periods of peak demand. PVSC is obligated to reduce demand for up to 12 hours.[27] PVSC describes the process units included in the demand response program in the following manner:[28]

> PVSC currently participates in the PJM Demand Response Program. PVSC responds to the PJM request by shedding load, or temporarily shutting down some processes to reduce electrical demand. The equipment operation curtailment can be for up to 12 consecutive hours. The list of equipment that is shut down or put on standby operation for the demand response request period includes the Zimpro sludge heat treatment system, the sludge filter press units, the decant and storage system, and half of the oxygenation units.

The equipment that PVSC curtails during a 12-hour demand response event represents about half of PVSC's average demand.[29] Curtailing this load would reduce PVSC demand to about 11 MW on average. PVSC provided the demand curve for the one demand response test event it carried-out on March 15, 2022. During this event, PVSC reduced its demand to 11.5 MW, and maintained demand at less than 15 MW for sixteen hours.[30] The load curve for this demand response test event is attached to this letter report.

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[26] Passaic Valley Sewerage Commission, *Request for Proposals for a Renewable Energy Power Generation System*, Appendix D – PVSC Annual Electricity Usage by Facility, pdf p. 89, February 2022. Annual PVSC usage = 194,827,564 kWh. Annual average demand = 194,827,564 kWh ÷8,760 hr/yr = 22,241 kW (22.2 MW).

[27] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, p. 17. "PVSC currently participates in the PJM Demand Response Program. PVSC responds to the PJM request by shedding load, or temporarily shutting down some processes to reduce electrical demand. The equipment operation curtailment can be for up to 12 consecutive hours."

[28] Ibid, p. 17.

[29] Passaic Valley Sewerage Commission, Request for Proposals for a Renewable Energy Power Generation System, Appendix D – PVSC Annual Electricity Usage by Facility, pdf p. 89, February 2022. Annual average demand: 1) sludge heat treatment = 5.8 MW; sludge filter press units = 0.3 MW; decant and storage system = 0.2 MW; O_2 compressor/production = 9.1 MW. Total average load reduction during demand response event = 5.8 MW + 0.3 MW + 0.2 MW + (9.1 MW/2) = 10.9 MW.

[30] E-mail communication from M. Witt, PVSC, to J. Smith, Earthjustice, June 30, 2022 (PVSC demand response event graphic, March 14-15, 2022). The event took place during the planned maintenance of other equipment.

PVSC indicates that only half of the oxygenation units are curtailed during a demand response event. The oxygenation process equipment, producing 500 tons per day of 95 percent pure oxygen,[31] consumes about 40 percent of PVSC's average power demand.[32]

Additional onsite oxygen storage would potentially allow PVSC to shut down the entire oxygenation system during the demand response event (or storm event), reducing the demand from 11 MW to about 7 MW.[33]

Adding oxygen storage to eliminate the power demand of oxygen production during the storm event would likely be substantially less expensive than designing the SPGF to meet that oxygen production power demand. One-half of PVSC's oxygen consumption over 12 hours would be 125 tons. The cost of adding 125 tons of additional cryogenic oxygen storage onsite at PVSC would be less than $500,000 [34]

The new flood water pumps, with a combined demand of just over 2 MW,[35] are not a part of the operational processes at PVSC. However, they may be needed and operational under emergency storm event conditions.

Therefore, during a 12-hour demand response event, under the current scenario described by PVSC the facility-wide power demand would be about 11 MW. With the flood water pumps fully operational, the demand would increase by 2 MW to 13 MW. If sufficient oxygen storage is added onsite to eliminate oxygen production power demand during the emergency event, PVSC critical load power demand would be about 7 MW. This power demand would rise to 9 MW if all flood water pumps were operational during the storm event.

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[31] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, p. 19.
[32] (34,731.910 kWh/yr + 44,972,047 kWh/yr) ÷194,827,564 kWh/yr = 0.409 (40.9 percent).
[33] 22.2 MW – (5.8 MW + 0.3 MW + 0.2 MW + 9.1 MW) = 6.8 MW.
[34] B. Powers telephonic communication with E. Blanco, sales manager, Universal Industrial Gases, Inc. (http://www.uigi.com/index.html), June 24, 2022. Estimated cost of 250 tons of liquid oxygen storage is approximately $500,000. B. Powers note: Only 125 tons of additional liquid oxygen would be needed to provide half of the PVSC oxygen demand over 12 hours.
[35] J. Rotolo, 2018, p. 38. "Storm Water Pumping Stations ($39.5 million): West: (5) 375hp pumps, 158MGD; Northeast: (4) 150hp pumps, 59.5MGD; Southeast: (3) 100hp pumps, 27.2MGD. Total pumping hp = 2,775 hp (2,069 kW).

D. Solar and Battery Storage Are Proposed for PVSC in Addition to the SPGF

PVSC has applied for incentives to add up to 19 MW (direct current) of onsite and offsite solar power.[36] PVSC has also proposed to add 5 MW/10 MWh of battery storage to support SPGF operations and as a peak shaving resource.[37,38]

Battery storage is already in operation at another wastewater treatment plant impacted by Hurricane Sandy, the Atlantic County Utilities Authority (ACUA) wastewater treatment plant in Atlantic City, NJ. The 1 MW battery at the ACUA wastewater treatment plant provides frequency regulation services in the PJM market and peak shaving to reduce the electric bill at the ACUA wastewater treatment plant.[39]

VI. Eventual Use of Hydrogen as Fuel in SPGF Gas Turbines Is Speculative and Uncertain

The PVSC proposal to convert the CTs to green hydrogen fuel is highly speculative. All elements of the SPGF may require modification or replacement to enable use of 100 percent hydrogen fuel.[40] These elements include: fuel piping component materials, pipe sizes, sensors and safety systems, and gas turbine components exposed to hydrogen combustion exhaust gases.[41] There is no indication that PVSC has considered the additional cost of converting the $118 million SPGF to burn 100 percent hydrogen, or the potentially high cost of producing the green hydrogen that will be required.

VII. Battery Storage Alternative to the Proposed SPGF

Battery storage is a better alternative for backup power at PVSC for the limited number of hours, 12 hours or less, that backup will potentially be necessary. Electric utilities now view battery storage as a superior alternative to CTs for cost reasons alone. NextEra Energy states that "batteries are now more economic than gas-fired peakers (CTs), even at today's natural gas prices."[42] NextEra Energy is the parent company of Florida Power & Light.[43] NextEra Energy

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[36] Passaic Valley Sewerage Commission, *Request for Proposals for a Renewable Energy Power Generation System*, February 2022, p. 7.
[37] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, p. 31. "PVSC now proposes to supplement the black start generators with five MW (10 MWh) of on-site battery storage. This would be enough to start the CTGs in the event of total loss of utility power, and make use of the BSGs necessary only if the batteries fail."
[38] Passaic Valley Sewerage Commission, *Standby Power Generation Facility Project - Program Interest ID No. 07329 BOP 190004, AO 2021-25 Compliance Statement*, March 30, 2022, p. 49.
[39] Atlantic County Utilities Authority, Battery Storage Project, webpage accessed June 30, 2022: https://www.acua.com/Projects/Renewable-Energy-Battery.aspx.
[40] Siemens, *Hydrogen power with Siemens gas turbines*, 2020, p. 16.
[41] Ibid.
[42] GreenTech Media, *NextEra looks to spend $1B on energy storage in 2021*, April 22, 2020.
[43] Companies owned by NextEra Energy: https://www.nexteraenergy.com/company/subsidiaries.html.

also forecasts the production cost of solar plus battery storage is less than the production cost of an existing CT.[44]

The total battery storage capacity needed for a battery-based SPGF would be: 12 hours x 15 MW = 180 MWh. A 15 MW demand is conservatively assumed for PVSC for design purposes to meet the maximum calculated PVSC critical load demand during storm events of 13 MW.

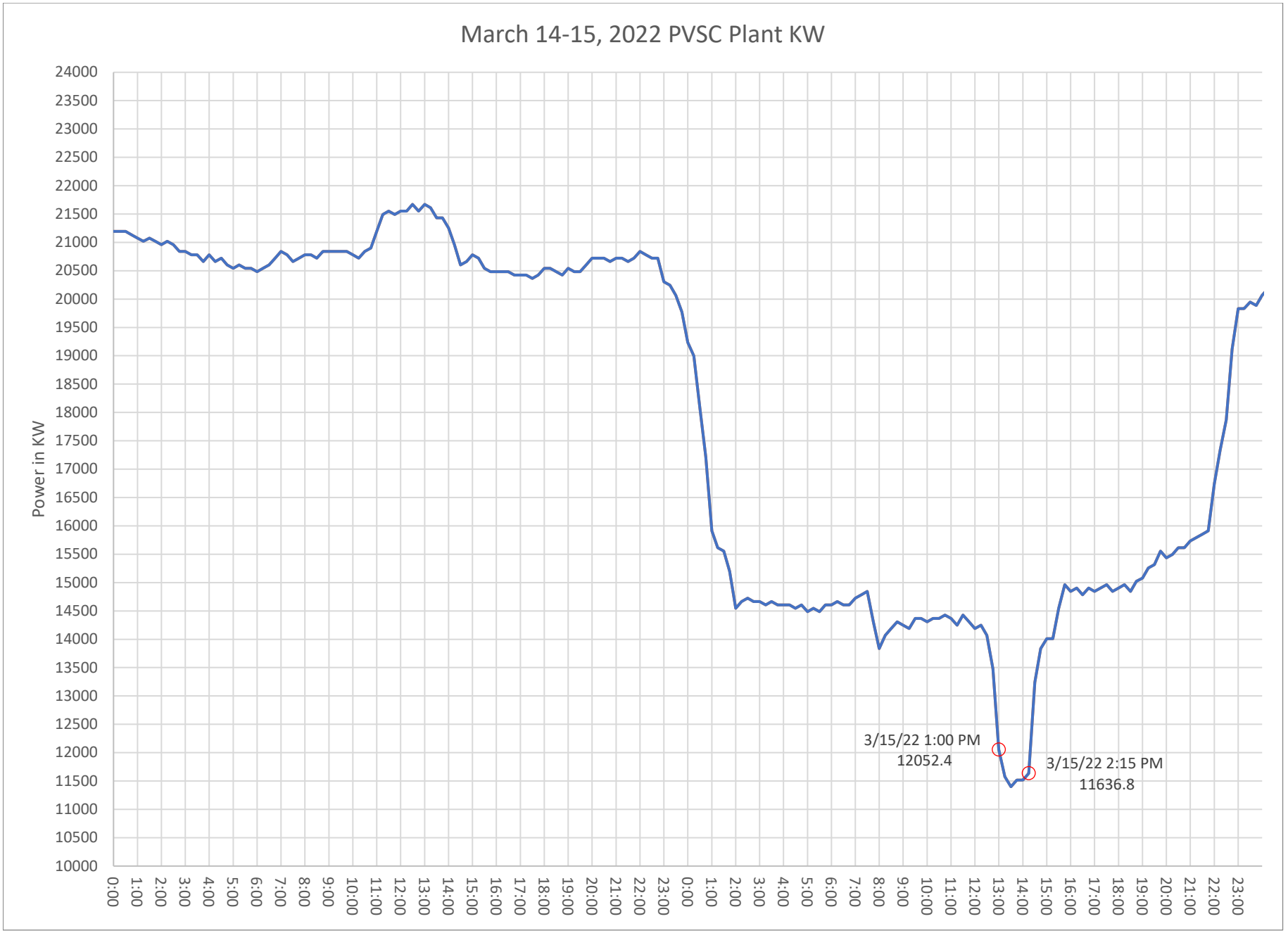
The estimated unit capital cost of 200 MWh of battery storage capacity is $193,000/MWh.[45] The estimated capital cost of 180 MWh of battery storage capacity for a battery-only SPGF is: ~$200,000/MWh x 180 MWh = $36 million. This compares to PVSC's cost estimate for the CT-based SPGF of $118 million.

A properly designed battery-based microgrid is capable of seamlessly switching from grid power to an islanded microgrid, and then back to grid power when grid power is restored.[46] A battery storage microgrid would typically be designed to meet only the critical loads during the brief switchover (in milliseconds) from grid power to islanded microgrid operation.[47] Other loads may be added as needed after the microgrid is functioning in islanded mode, up to the design capacity (in MW) of the battery storage system.

VIII. Conclusion

PVSC should design the SPGF for a maximum 12-hour storm event outage at a reduced power demand of 9 MW (if additional oxygen storage is added so that all oxygen demand met from storage tanks during event) to 13 MW. The SPGF should consist of battery storage only. The design of the battery-based microgrid should allow PVSC to seamlessly isolate from the grid in the case of a grid power outage. To generate income for PVSC, the battery capacity should be bid into the PJM market and also used as a peak shaving resource, similar to the operation of battery storage at the Atlantic County Utility's Authority wastewater treatment plant.

[44] NextEra Energy, Investor Conference 2022, PowerPoint, June 14, 2022, p. 26: https://www.investor.nexteraenergy.com/~/media/Files/N/NEE-IR/news-and-events/events-and-presentations/2022/06-14-2022/June%202022%20Investor%20Presentation_Website_vF.pdf.
[45] Lazard, *Lazard's Levelized Cost of Storage Analysis - Version 7.0*, October 28, 2021, pdf p. 23: https://www.lazard.com/media/451882/lazards-levelized-cost-of-storage-version-70-vf.pdf. Storage capital cost for 100 MW/200 MWh storage only system ($/kWh) = ($147 + $239)/2 = $193/kWh.
[46] Microgrid Knowledge, *Two pitfalls to avoid when selecting batteries for your industrial microgrid*, June 21, 2022: https://microgridknowledge.com/selecting-batteries-industrial-microgrid/.
[47] Ibid.


March 14-15, 2022 PVSC Plant KW
Power in KW
24000
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