APPENDIX D: Scoping Alternatives Analysis

TABLE OF CONTENTS

LIST OF TABLES

ATTACHMENT

1.0 SCOPING ALTERNATIVE ANALYSIS

During the public comment period (May 20 – July 19, 2019), several commenters identified alternatives to the proposed Project that were either previously screened as not technically feasible alternatives prior to the Public Scoping Period (2016) or were otherwise not considered in the Draft Environmental Impact Statement (DEIS) due to incompatibility with the Project's Purpose and Need. The NJ TRANSITGRID Final Scoping Document (May 2016) and DEIS are available on the project website (https://njtransitresilienceprogram.com/documents/).

Several commenters also raised concerns about the proposed Project's compatibility with changes to the State of New Jersey's energy policy. On January 27, 2020, Governor Murphy unveiled New Jersey's Energy Master Plan (EMP) which outlines key strategies to reach a goal of 100% clean energy in the State of New Jersey by 2050. On January 27, 2020, Executive Order (EO) 100 was signed, instructing reform to existing state regulations in order to reduce emissions and adapt to climate change.

As a state agency, NJ TRANSIT is committed to the clean energy initiatives outlined in EO28 (signed May 23, 2018), EO 100 and the newly released EMP. As discussed in the Final Environmental Impact Statement (FEIS), to support the Governor's clean energy initiatives, the NJ TRANSITGRID TRACTION POWER SYSTEM will be designed and constructed to accommodate carbon neutral power generation options, such as Renewable Natural Gas (RNG) (made from food waste or other organic materials) and fuel cells (using the chemical energy of hydrogen or another fuel to cleanly and efficiently produce electricity) as they become more commercially feasible.

Currently, Technologies for solar power, land-based or offshore wind power are not be able to provide adequate load balance for NJ TRANSIT's traction power for running the trains during emergencies. Solar or wind would also not meet the resilience needs of the proposed project and NJ TRANSIT does not have access to the acreage in Northern New Jersey to build solar or wind farms. There are significant current limitations in electrical storage technology. Other current limitations to alternative technologies suggested during the public comment period are discussed further in the sections below.

2.0 ANALYSIS OF ALTERNATIVE POWER GENERATION TECHNOLOGIES

2.1 Purpose and Need of the Proposed Project

The purpose of the proposed Project is to enhance the resiliency of the electricity supply to the NJ TRANSIT and Amtrak infrastructure (i.e., the segment of Northeast Corridor) that serves key commuter markets in the New York and New Jersey metropolitan area to minimize public transportation service disruptions. The region's public transportation infrastructure is vulnerable to power outages due to the increasing intensity and frequency of severe weather events, which can damage existing power generation and transmission systems. Also, the nature of the current centralized power distribution system creates dependencies on a single distribution system.

Reliable electric power (traction power) is essential to NJ TRANSIT commuter rail and Amtrak intercity passenger rail because diesel trains are not permitted to operate in the Hudson River rail tunnels due to diesel exhaust, so electric locomotives are required. Electric traction power also reduces diesel emissions and air quality impacts in northern New Jersey. Additionally, the Hudson Bergen Light Rail (HBLR) operates exclusively on electrical power. The need for the proposed Project is based on the vulnerability of the commercial electrical power grid that serves these critical transportation networks. Over 143,000 commuters use the NJ TRANSIT rail system daily, including those who transfer to other regional public transportation systems. In 2016 an average of just under 52,000 daily riders also utilized the NJ TRANSIT operated Hudson-Bergen Light Rail (HBLR). Electric power is also necessary to operate the signal system and switch motors to safely route train movements and to power ventilation equipment and pumps in the tunnels. Major disruptions to the existing power grid can result in suspension of these critical systems.

When major disruptions occur due to weather related (flooding, damaging winds etc.) and other disasters, critical emergency preparation and recovery activities create additional demand for power when it is most at risk. The region's rail transportation system was largely shut down due to flooding and power outages after Superstorm Sandy in 2012, with enormous economic and societal consequences. The loss of rail service in its entirety for nearly a week was compounded by lack of power for rapid emergency response and recovery. Critical emergency facilities including emergency operation centers, maintenance facilities, and pump stations need to be energized to provide planning and coordination during emergencies, to inspect the equipment, and to pump water from the tunnels, before returning trains to normal operating service. The use of emergency diesel generators offers some degree of resilience but the scale of power demand, uncertain fuel supplies and air quality impacts make extended use of this alternative insufficient. The region's rail transportation system was largely shut down due to flooding and power outages after Superstorm Sandy in 2012, with enormous economic and societal consequences. The loss of rail service in its entirety for nearly a week challenged all prior expectations of the system's resilience.

The overarching premise for the proposed Project is for the microgrid to generate enough independent power in a resilient manner to energize the identified transportation assets during emergencies. The power generated by the microgrid would also replace power that NJ TRANSIT would otherwise purchase through the commercial grid during normal operations. The proposed microgrid infrastructure would be resilient to extreme weather events and other power interruptions, making the transportation system substantially safer and more reliable to commuters. During weather emergencies, transit service could remain available longer, preventing commuters from being stranded and providing alternative means of evacuation.

The NJ TRANSITGRID Project uses energy-efficient technology that results in low rates of emission of GhGs per megawatt-hour (MWh) of energy production. The approximately 22.5 MW simple cycle turbines (SCTs) of the NJ TRANSITGRID central power plant would emit 0.645 tons/MWh of carbon dioxide (CO_2). The 60 MW combined cycle turbines (CCTs) (two natural gas turbines and one steam-driven turbine) would emit 0.484 tons/MWh of CO_2. In total, the approximately 127.5 MW power plant would emit 0.569 tons/MWh of CO_2. These low emission factors result in overall estimated annual reductions of CO_2 emissions of the Regional Fossil Generation Fleet ranging from 185,452 to 296,172 tons. For a more detailed analysis of the emission reduction potential of NJ TRANSITGRID, see *Resiliency and Environmental Sustainability – An Evaluation and Quantification of NJ TRANSIGRID Benefits, December 2019.* This analysis of benefits can be found on the project website at: https://njtransitresilienceprogram.com/wp-content/uploads/2019/12/NJ-TRANSITGRID-Benefits-Evaluation.pdf.

2.2 Alternative Energy Generation

During the initial project design phases, alternative energy generation sources were analyzed. The sections that follow discuss the alternatives to the proposed natural gas-fired electric power generating plant part of the proposed Project.

2.2.1 Solar Photovoltaics (PV)and Energy Storage

The potential annual energy output from the proposed power plant is estimated to be 698,062 MWh per year assuming 100% capacity factor operation of the two CCT units (525,600 MWh/year) and 7 hours per day (average) for the three SCT (172,462 MWh/year). To produce this much energy using only solar power would require the construction of a PV power plant with a capacity of nearly 390 MW_{AC}[1] requiring approximately 2,600 acres of land (4.1 square miles)[2] and at an estimated cost of $600 - 800 Million to construct.[3]

This economic analysis of net-zero replacement of the NJ TRANSITGRID natural gas power generation, however, only considers grid-connected scenarios. To achieve the stated resiliency goals of the project, the solar and energy storage components would have to be able to operate disconnected from the grid during emergency conditions. This scenario would add additional costs as large installations of energy storage components (e.g., flywheels or batteries) would have to be used to replace the energy, ancillary services, and flexibility benefits that would otherwise be provided by the gas turbines.

The traction power systems for the NJ TRANSIT and Amtrak service lines, along with all of their auxiliary and supporting services, require a complex power delivery system that relies on specialized equipment and critical voltage and frequency regulation. The electrified railway systems have no onboard power plant or fuel supply. Power is supplied to these trains with an overhead wire conductor (the “overhead electric catenary system”) while the running rails act as the return wire. Traction power substations located along the rail track right-of-way convert electric power to the required voltages, current types and frequencies. Although the solar panels of a large PV system could, in theory, provide the total energy required, the additional ancillary services needed in grid-connected and islanded modes to balance the

---

[1] MW_{AC} are megawatts converted from direct current (DC) to alternating current (AC). The estimated capacity of the PV power plant was calculated with use of the “PVWatts Calculator” provided by NREL at the web site: https://pvwatts.nrel.gov/pvwatts.php.

[2] The estimate for required land area was derived from generation-based area estimates given in Ong, S.; Campbell, C.; Denholm, P.; Margolis, R. & Heath, G. (2013). “Land-Use Requirements for Solar Power Plants in the United States.” National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-6A20-56290. https://www.nrel.gov/docs/fy13osti/56290.pdf. See Table ES-1. “Summary of Land-Use Requirements for PV and CSP Projects in the United States.” Estimates used are for “generation-weighted average land use (acres/GWh/yr).” As indicated in the report, the use of generation-based results (i.e. acres/GWh/yr) “…provides a more consistent comparison between technologies that differ in capacity factor and enables evaluation of land-use impacts that vary by solar resource differences, tracking configurations, and technology and storage options.”

[3] Costs of construction were derived from estimates in Fu, R.; Feldman, D.; & Margolis, R.; (2018) “U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018.” National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-6A20-72399. https://www.nrel.gov/docs/fy19osti/72399.pdf. See Figure 27: “Q1 2018 benchmark by location: 100-MW utility-scale PV systems, EPC only.” The estimated cost for construction of a utility-scale 1-axis tracking system power plant using union labor in New Jersey is estimated at $1.22/$W_{DC}$ ($1.5875/$W_{AC}$) or $1.587 Million per MW_{AC}. (Conversion between W_{AC} and W_{DC} uses a DC to AC ratio (inverter loading ratio) of 1.3.)

system and provide frequency regulation must be provided by energy storage systems, such as flywheels and batteries, coupled with the PV power plant.

These ancillary services balance the supply and demand for power in the rail transmission and distribution systems and maintain system frequency within acceptable levels. For example, the electrified rail system encounters frequent high rates of change in power demand due to transient loads. It is estimated that additional "step loads" or instantaneous changes in demand for power on the system (resulting from a failure of power sources or electrical components, or a large consumer load start-up) are expected to be as high as 10.8 MW per second, while "load rejection" or the sudden loss of load (due to braking, for example) could be as high as 18.8 MW per second. The gas turbine power plant as designed, using some auxiliary energy storage components, has been finely tuned to address such contingencies. It is because of their ability to provide low-running spinning reserves and quick response flexibility to demand changes that gas turbines play such a crucial role in modern electricity supply systems.

Large-scale PV power plants cannot provide this type of flexibility and rapid cycling – in fact, as discussed, the high variability of large-scale renewable energy output would only increase the requirements for flexibility in the system. Absent the use of dispatchable resources, the energy storage components must, therefore, provide such balancing, quick ramping and frequency regulation for NJ TRANSITGRID in islanded operation. Battery storage, however, is not amenable to this type of service. Although the cost of battery technology has decreased rapidly over the past few years, particularly for the lithium-ion ("Li-ion") battery, making grid-scale energy storage economical in a growing range of uses, such a rapid cycling of charging and discharging of the batteries due to the frequent load/unload requirement of the system would damage the batteries making their repeated and costly replacement inevitable.

Flywheel energy storage systems, on the other hand, can provide the rapid cycling for frequency regulation without deleterious effects and provide the instantaneous supply of the large bursts of power on the order of 10-20 MW per second to match the anticipated step loads. The technical feasibility for this level of operation has already been demonstrated in grid-connected pilot projects. For example, Beacon Power opened a 5 MWh (20 MW over 15 mins) flywheel energy storage plant in Stephentown, New York in 2011 using 200 flywheels and a similar 20 MW system at Hazle Township, Pennsylvania in 2014.[4] The installed costs of flywheel energy systems are estimated between $1,500 - $6,000 per kWh; therefore a flywheel energy storage system for NJ TRANSITGRID capable of providing the required short-term frequency support could cost between $5-30 Million.[5]

As flywheel energy storage systems are currently generally unsuitable for uses other than short-term

---

[4] See Beacon Power Operating Plants: https://beaconpower.com/stephentown-new-york/
& https://beaconpower.com/hazle-township-pennsylvania/.

[5] Energy pricing for flywheel energy storage systems estimated from: IRENA (2017). Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf
According to the analysis the energy installation costs for flywheel systems are expected to decline to between $1,000 - $3,900/kWh as cycle and calendar lifetimes substantially improve.

storage (due in part to self-discharge rates of 15% or higher)[6] energy storage for NJ TRANSITGRID in islanded operation to support the PV power plant would most likely be provided by Li-ion batteries. For the 390 MW_{AC} PV power plant required to replace the fossil fuel-fired power components of NJ TRANSITGRID, the utility-scale energy storage system is estimated to require a battery size of 230 MW_{DC}.[7] Given the wide variety of uses required of the Li-ion batteries in island mode, storage duration amongst the battery arrays may vary between 0.5 – 4 hours. For short durations (0.5 – 1 hour), energy storage would be used primarily to balance generation and load and smooth some short-term variations in voltage and current for frequency response not handled directly by the flywheel energy storage systems. For longer storage durations (2- 4 hours), the storage could shift energy supply to periods of low power production and mitigate variable energy output during peak operations.

This 230 MW_{DC} battery storage system would require between 28 - 224 forty-foot containers (depending on the mix of storage duration per battery array) and cost between $125 - $425 Million dollars to install (using an estimate of $380/kWh to $895/kWh for 4-hour duration and 0.5-hour duration, respectively).[8] This energy storage system, should it be built, would far exceed any existing utility-scale PV-plus-storage application. The only U.S.-based utility-scale system recorded in the U.S. DOE Energy Storage Database is a 13-MW PV plus 52-MWh energy storage system in Kauai, Hawaii.[9]

A combined solar and battery storage system as described above would clearly be too costly and too cumbersome to be feasible to meet the desired project goals. However, NJ TRANSIT will monitor advances and technological developments in solar and storage technologies and adopt such improved technologies once they can be shown to have achieved feasible costs and physical implementation scenarios.

2.2.2 Wind Turbines and Energy Storage

To produce the energy output (698,062 MWh per year) that would be generated by the natural gas turbine technology using only land-based wind power would entail construction of a wind farm consisting of approximately 110 3-MW wind turbines[10] requiring approximately 27,182 acres[11] of land (42.5 square miles) and at an estimated cost of $543 Million[12] to construct.

Similar to the solar PV analysis, the net-zero replacement of the NJ TRANSITGRID natural gas power generation only considers grid-connected scenarios. To achieve the stated resiliency goals of the project, the wind, and energy storage components would have to be able to operate disconnected from the grid during emergency conditions. Wind, like solar PV, will increase the requirements for flexibility in the

---

[6] Ibid. See page 20.
[7] Using a DC to AC ratio (also known as the inverter loading ratio or "ILR") of 1.3 and an inverter/storage size ratio of 1.67. See: Fu, R.; Remo, T.; & Margolis, R.; (2018) "2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark" National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-6A20-71714. https://www.nrel.gov/docs/fy19osti/71714.pdf.
[8] Ibid. See page 11.
[9] Ibid. See Introduction.
[10] Using a capacity factor of 24.1% based on techno-resource group (TRG) 8 from NREL Annual Technology Baseline. See https://atb.nrel.gov/
[11] Assuming a power density of 3 MW/km^2 based on the NREL Annual Technology Baseline. See https://atb.nrel.gov/electricity/2018/index.html?t=lw
[12] Ibid. See footnote 2.

system introducing a range of storage technologies necessary to balance the short-term rapid load fluctuations, while providing longer-term durations for those times when wind production is low. As previously discussed, the utility-scale energy storage system is estimated to require a battery size of 230 MW_{DC}. This utility-scale storage system would require between 28 - 224 forty-foot containers (depending on the mix of storage duration per battery array) and cost between $125 - $425 million dollars to install (using an estimate of $380/kWh to $895/kWh for 4-hour duration and 0.5-hour duration, respectively). Consequently, a wind power plus storage solution for the projects specific resilience purpose is not feasible from a cost space and timing perspective.

NJ TRANSIT will monitor advances and technological developments in wind and storage technologies and adopt such improved technologies once they can be shown to have achieved feasible costs and physical implementation scenarios.

2.2.3 Energy Storage Resources

In addition to renewables plus storage alternatives studied, NJ TRANSIT analyzed energy storage resources normally connected to the grid without any coupled generation. This type of configuration will not allow NJ TRANSIT to provide power for significant periods, limited by the state of charge[13] and reliance on external sources of generation. Consequently, this will inhibit NJ TRANIST's ability to provide power under normal grid conditions. However, since the main premise of the project is grid resiliency, NJ TRANSIT did analyze this type of configuration under a 14-day[14] utility outage. As previously discussed, the highly variable loads require a storage system that can provide short, rapidly cycling regulation, such as flywheels. However, without a generation asset, the storage system must also provide the energy for the duration of the outage, in this case, 14 days. Long duration types of storage systems include Pumped Hydro technology sized for storage times between 8-10 hours and Compressed Air Energy Systems (CAES) sized for storage times between 8 to 26 hours. Pumped Hydro and CAES are the only commercial bulk energy storage plants available today.[15] Land use requirements for these types of systems are significant and geographically limited. For example, pumped storage requires geographical height and water availability limiting systems to be in proximity to hilly or mountainous regions.

Even if storage duration could be increased to 14 days, the energy storage system would be required to store approximately 33.6 GWh of electricity.[16] To put this in perspective, the U.S. has approximately 23.9 GW of energy storage capacity representing 200 GWh of energy capability.[17] Indeed, if an energy storage system could be built to meet the proposed Project demands, it would increase the U.S. energy storage capability by approximately 16.8%. Based on the commercially available energy storage system technology today and considering the application demanded by the proposed Project, storage only

[13] Defined as the available capacity expressed as a percentage of some reference, sometimes its rated capacity but more likely its current capacity.
[14] The system must have the capability to support train transportation in the context of a power outage scenario described for an extended period of time. Extended period of time is defined as 14 days or longer.
[15] See Chapter 2 https://www.sandia.gov/ess-ssl/publications/SAND2015-1002.pdf.
[16] Capacity is estimated based on average load of 100 MW over the 14-day period operating 24 hours/day.
[17] DOE Global Energy Storage Database. Accessed May 2019. https://energystorageexchange.org/

alternative is not considered feasible or practical.

An energy storage system as described above would clearly be too costly and too cumbersome to be feasible to meet the desired project goals. However, NJ TRANSIT will monitor advances and technological developments in energy storage technologies and adopt such improved technologies once they can be shown to have achieved feasible costs and physical implementation scenarios.

2.2.4 Biomass

Using a solid biomass facility (such as one that would burn wood chips or agricultural waste products) to meet the required power load is not considered to be feasible due to the general market unavailability of sufficient quantities of biomass material, the associated costs, and environmental impacts resulting from the generation of the material. Most of the active biomass generation facilities in New Jersey are co-located at wastewater treatment facilities, capturing biogas from anaerobic digestion, or at landfills where electricity is generated with the methane produced from the decay of organic materials. The proposed Project is not located in proximity to these types of facilities that would naturally generate biogas for use in the generators.

2.2.5 Alternative Fuels

Renewable Natural Gas (RNG) is a type of class of "carbon-neutral" biofuels that ultimately decrease the net CO_2 emissions of electric power production. Biofuels are carbon-neutral because they use biomass as feedstock that sequesters carbon through the carbon fixation process, such as those that occur in plants or microalgae through photosynthesis. CO_2 in the atmosphere is absorbed by photosynthesizing organisms where the carbon is fixed to build the organism's biomass. The amount of the emissions decrease resulting from the use of RNG varies due to several factors, the primary one being the nature of the feedstock (i.e., food waste, sewage treatment, landfill gas, etc.).

Upon harvesting of this biomass (as agricultural products or organic wastes), this material can subsequently be used in the production of biofuels. Up until the time the biofuel is combusted, the carbon remains sequestered. However, when the biofuel is combusted, GhGs are released in much the same proportion as the fossil-derived fuel. The difference is that by using biofuels such as RNG, a power plant that combusts these products is participating in a natural renewable cycle that ultimately neutralizes the GhGs released by new biomass growing and fixing atmospheric carbon that essentially takes the place of the biomass in the fuel. The annual planting and harvest of corn used as feedstock for biofuels is one example of this regenerative, carbon-neutral process. So is the use of methane gas derived from landfills.

Current estimates are that supplies of RNG produced from a range of existing sources have the potential to meet ten percent of current natural gas demand and that the existing natural gas distribution network can be used to deliver the renewable fuel.[18] However, recent initiatives by utilities, such as SoCalGas, the

---

[18] M.J. Bradley & Associates, LLC (April 2017). "Renewable Natural Gas: The RNG Opportunity for Natural Gas Utilities." https://www.mjbradley.com/news-events/renewable-natural-gas-rng-opportunity-natural-gas-utilities "Estimates of the amount of RNG that could be produced in the U.S. vary, but show that meaningful amounts of customer demand for natural gas could be met with RNG. The high end of a range of potential RNG volumes from an American Gas Foundation study is equal to ten percent of the natural gas delivered to U.S. customers in 2015." (p. iii).

nation's largest natural gas distribution utility to subsidize and promote the use of RNG, and large-scale research programs such as those being conducted at the University of California at Davis (UC Davis), are providing promise of increased stocks and availability of RNG at prices similar to those of the current supply of fossil-derived natural gas.[19] Many states have electric renewable portfolio standard (RPS) programs that also allow RNG to generate renewable energy credits (RECs) when it is used to produce electricity. A study conducted by UC Davis estimates that more than 20 percent of California's current natural gas use could be provided by RNG and that the sources of the biogas used in making refined RNG exist all over the country. Currently, however, there is no available supply of RNG for customers of natural gas utilities in much of the U.S., including the northeast. Federal and state policy has steered the use of RNG to the transportation fuel market, which is the most prominent use of this fuel. Currently, RNG is only available via pipeline to natural gas users in areas located close to landfills that have a ready supply of methane. Because of technical challenges involving impurities in raw biogas, there are currently very few pipeline operators (none in New Jersey) that have published specifications that would allow RNG to be inserted into their pipelines.

As mentioned above, RNG is a strongly carbon-neutral technology. RNG is considered a carbon-neutral fuel because it comes from organic sources that once absorbed carbon dioxide from the atmosphere during photosynthesis. RNG has even greater benefits when it's produced from organic waste that would otherwise decay and create methane emissions. By capturing more GhGs than it emits, RNG may be considered carbon-negative in some scenarios. NJ TRANSIT will continue to monitor market advances and technological developments in this drop-in substitute for fossil natural gas and will implement an RNG purchasing program once it can be shown to have achieved feasible costs and physical implementation scenarios.

High-Volume Hydrogen Gas Turbines are another promising future technology that can support zero-carbon emitting electric energy production. Several of the major natural gas-fired turbine manufacturers, including Mitsubishi Hitachi Power Systems, GE Power, and Siemens Energy have developed hydrogen-ready turbines.[20] When hydrogen burns and combines with oxygen, it can produce electricity that delivers zero CO_2 emissions - only water and heat are exhausted. If hydrogen is blended with the natural gas supply to these turbines, the result is reduced carbon and GhG emissions.

Although most of the world's hydrogen today is being produced through a CO_2-intensive process called Steam Methane Reforming (SMR), hydrogen can also be produced through a process that makes use of renewable electricity, leading to the production of "green" or CO_2 neutral hydrogen. To date, only small amounts of hydrogen have been generated from renewable energies, although that amount is expected to increase in the future as new technologies continue to develop. Hydrogen's production from renewables through electrolysis—which uses renewable power to split a water molecule—allows for the "renewable hydrogen" to be produced. When fired at 30% hydrogen, high-volume hydrogen gas turbines

---

[19] Jaffe, A.M. et al. (June 2016). "The Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute." University of California at Davis. https://steps.ucdavis.edu/the-feasibility-of-renewable-natural-gas-as-a-large-scale-low-carbon-substitute/

[20] Patel, S. (May 1, 2019). "High-Volume Hydrogen Gas Turbines Take Shape." Power Magazine. https://www.powermag.com/high-volume-hydrogen-gas-turbines-take-shape/

can decrease carbon emissions by about 10% compared to a conventional combined cycle power production. Current research expects to bring hydrogen gas mixtures up to 90%, resulting in up to a 50% decrease in CO_2 emissions.[21] A 10% and 50% reduction in CO_2 emissions could result in overall reductions of 51,934 tons and 234,4440 tons, respectively by NJ TRANSITGRID when using new high-volume hydrogen gas turbines. Currently, there is no commercially available technology to blend hydrogen with the utility-provided natural gas supply for these turbines. However, NJ TRANSIT will monitor advances and technological developments in hydrogen technologies and adopt such improved technologies once they can be shown to have achieved feasible costs and physical implementation scenarios.

2.2.6 Wind Turbines (Offshore)

Offshore wind power is still in the early stages of development in the United States. The 5-turbine 30-MW Block Island Wind Farm pilot project located off the coast of Rhode Island is currently the only operating commercial offshore wind farm in U.S. waters and serving a U.S. customer base. Development projects for additional offshore wind farms are now underway including the proposed 1,100-MW *Ocean Wind* project to be located approximately 15 miles off the coast of Atlantic City, New Jersey. Construction is planned to begin in 2021 with power being delivered into the onshore grid by 2024. Once operating, *Ocean Wind* will become the largest producer of wind power in New Jersey and the largest offshore wind farm in the United States.

Due to the scale and complexity of planning, constructing and operating offshore wind power the development of offshore wind farms is restricted to a small group of companies that are experienced with offshore wind and well-capitalized to cover the substantial investment involved. For example, to produce the anticipated energy output (698,062 MWh per year) of the NJ TRANSITGRID that would be produced using natural gas turbine technology, using only offshore-based wind power would require the construction of a wind farm consisting of twenty-two 8-MW wind turbines[22] at an estimated cost of $1.15 Billion to construct. [23]

---

[21] Noon, C. (January 2019). “The Hydrogen Generation: These Gas Turbines Can Run On The Most Abundant Element In the Universe.” GE Reports. https://www.ge.com/reports/hydrogen-generation-gas-turbines-can-run-abundant-element-universe/

[22] Using an estimated capacity factor of 48% based on reported capacity factors in the United Kingdom for offshore wind power of recently constructed wind farms. It should be noted that capacity factors are also highly dependent on geographical placement due to the prevalence of high-speed wind and loss factors due to ocean wake and other locality-based influences. See: “UK offshore wind capacity factors.” (January 19, 2020). https://energynumbers.info/uk-offshore-wind-capacity-factors.

Public reports regarding the award of the Ocean Wind project indicate similar capacity factors are expected for the New Jersey based development. See: “New Jersey Board of Public Utilities Awards Historic 1,100 MW Offshore Wind Solicitation to Ørsted’s Ocean Wind Project.” (June 21, 2019). NJ Board of Public utilities. https://www.bpu.state.nj.us/bpu/newsroom/2019/approved/20190621.html

[23] The average expected “overnight” construction cost for new offshore wind farms in the U.S. are estimated by the U.S. Energy Information Agency (EIA) at $6,542 per kilowatt. See: “Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2019.” (January 2019). U.S. EIA. https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf

Recent efforts to attract new development of offshore wind to New Jersey and New York involved multi-year procurement processes to which only a small handful of developers with the capability to compete were invited to apply. Further, consideration of the development of a wind farm necessitates the possession of large offshore "wind lease areas" from the federal government in the Continental Shelf via the Bureau of Ocean Energy Management, a process that takes a great deal of expertise, time and money to complete. Thus, this technology is not feasible in the near term and NJ TRANSIT would not be able to participate directly in any way in the construction and operation of large-scale offshore wind power that would enable it to use this power for NJ TRANSITGRID.

2.3 Remarks

NJ TRANSIT analyzed alternatives to the proposed natural gas generation technology to fully power the NJ TRANSIT and Amtrak electrical systems necessary to satisfy the purpose of the proposed project and determined they are not practical or feasible due to siting, ability to meet rapidly fluctuating loads associated with traction power systems, and significant costs associated with storage. A summary comparison of the alternatives is included in Table 1.

Although the use of solar PV plus storage alone is not feasible to meet the proposed Project's full energy needs, four (4) acres of solar energy will be utilized to generate up to 0.6 MW of power and approximately 8 to 10 MW of flywheel energy storage will be utilized to provide frequency regulation during grid outages.

Table 1. Alternative Power Generation Technologies Comparison

Technology	Project Cost[24]	Size	Flexibility of Operation	Resilient	Market Availability
Proposed Combustion Turbines with Flywheels	$546M	20 acres	The project has been designed with the necessary equipment to provide frequency regulation.	Yes	Readily available.
Solar Photovoltaics (PV)	$600M - $800M	2,600 acres	A large-scale PV power plant cannot provide necessary frequency regulation.	No	Solar panels are readily available. Required land is not.

[24] Project costs presented in this table do not include property acquisition costs. Property acquisition costs for industrial properties vary based on location, availability, size, among other factors.

Technology	Project Cost[24]	Size	Flexibility of Operation	Resilient	Market Availability
Solar PV + Storage	\$600-\$800M + \$125-\$425M (battery storage)[25]	2,600 acres + 0.21 – 1.65 acres (battery storage)	With energy storage, a PV system could potentially provide the necessary frequency regulation.	Yes	Equipment is readily available. Required land is not.
Wind Turbines	Approximately \$543M	27,182 acres	Wind turbines alone would not provide necessary frequency regulation.	No	Wind turbines are readily available. Required land is not.
Wind Turbines + Storage	Approximately \$543M + \$125-\$425M (battery storage)	27,182 acres + 0.21 – 1.65 acres (battery storage)	With energy storage, a wind turbine system could potentially provide the necessary frequency regulation.	Yes	Equipment is readily available. Required land is not.
Energy Storage Resources	Unknown	Unknown	Energy storage system could potentially provide the necessary frequency regulation.	Unknown	Two available systems: Pumped Hydro (8-10 hours); and CAES (8-26 hours). Project requires a minimum duration of 168 hours representing 16.8 GWh. There is no storage technology available to meet this need.
Biomass	Not applicable due to lack of material availability.	Generally co-located at wastewater facility or landfill.	Not applicable due to lack of material availability.	Not applicable due to lack of material availability.	No. Sufficient quantities of material are unavailable.
Renewable Natural Gas (RNG)	Not applicable due to lack of material availability.	Anticipated to use existing turbines.	Will allow use of hybrid fuel systems.	Pipeline delivery moderate resiliency	No. Sufficient quantities of material are unavailable.
Hydrogen Gas Turbines	Not applicable due to lack of material availability.	Anticipated to use existing turbines.	Will allow use of hybrid fuel systems.	Pipeline delivery moderate resiliency	No. Sufficient quantities of material are unavailable.

[25] As noted in Section 2.2.1 Solar Photovoltaics (PV), flywheel energy storage systems are best suited for short-term storage. Therefore, to meet the project goals with a Solar PV plus storage configuration, the more costly lithium-ion batteries would be the preferred storage option that would meet the project objective.

3.0 TRANSMISSION ONLY IMPROVEMENTS

As noted above, during the public comment period of the DEIS (May 20 – July 19, 2019) suggested alternatives to the Proposed Project were provided. This section discusses the alternatives to power generation, as follows:

- Buy power from private providers on the national grid and build only the redundant cable transmission connections to provide resilient power;
- Contract with an existing local electric power supplier to add the needed 60 MW of power at another facility and build only the redundant cable transmission connections to provide resilient power; and
- Contract with an existing electric power provider to provide a stand-alone facility as described in the Build Alternative, but with power industry funds.

The alternatives proposed would not meet the primary Purpose & Need for the project, which is to maintain a resilient power supply to key commuter markets in New York and New Jersey during commercial grid power outages. Continuing to purchase electricity from existing power supply providers, even with new and redundant cables, would not allow for continued train service during power outages. The proposed microgrid would operate independently from the commercial power grid during power outages to supply safe, reliable power and will keep mass transit moving during emergencies. Although the PJM's regional grid is reliable and resilient, it does not and cannot meet the unprecedented reliability and resiliency requirements of NJ TRANSIT, even when considering net improvements that could be expected in the foreseeable future.

The Build Alternatives presented above disregard the key fact that NJ TRANSIT does not own, control or operate any portion of the high-voltage "national grid" or the medium-voltage power distribution infrastructure - including the portion of these systems that provide power to the three targeted NJ TRANSIT and NJ TRANSIT/Amtrak rail systems. NJ TRANSIT, therefore, has no ability to plan, fund or commission any upgrades to reliability on the national grid or local distribution system. These decisions regarding system reliability are the province of the approved Electric Distribution Company (EDC) and the Regional Transmission Organization (RTO). Planning, approval, funding and construction of reliability enhancements to transmission and distribution infrastructure has to consider the full range of the total system requirements and are subject to tariff processes at the state and federal levels. As detailed below, the EDC and RTO *cannot* and *will not* provide the reliability enhancement required to achieve the resiliency goals of NJ TRANSITGRID.

Although the local EDC (PSE&G) and RTO (PJM) have been primarily responsible for New Jersey scoring amongst the most reliable power distribution systems in the country, no EDC or high-voltage transmission provider provides for 100% reliability in their systems. Further, no EDC or high-voltage transmission provider design their systems to withstand all low-probability, high-impact events, such as Superstorm Sandy, that can trigger wide-spread and sustained power outages. It is these rare but catastrophic (low probability and high impact including regional emergencies) events that NJ TRANSITGRID is specifically designed to address. The EDC and RTO cannot and will not improve their systems to this level of reliability. Industry-standard reliability planning, such as the Reliability Standards of the North American Electric

Reliability Corporation (NERC) calls for levels of reliability below 100% and does not consider all low-probability, high-impact events. The Alternatives Analysis for the Grid (regional PJM Grid) (refer to Attachment I to this Appendix) performed by NJ TRANSIT indicates that there is a vanishingly small probability that NJ TRANSITGRID would not be able to cover peak loads at any of the three connections individually in blue-sky conditions and that for a loss of supply at all three connection points due to a severe systemic breakdown (i.e., emergency conditions or island mode), NJ TRANSITGRID would have a 96.3% probability of supplying the lost load, significantly improving reliability and resiliency for its internal connections in both blue-sky and island mode.

Moving responsibility for the creation of highly reliable systems from the centralized EDC and RTO planning operations to the public corporate governance of those institutions that require this level of enhanced reliability is the reason and purpose of NJ TRANSITGRID. They cannot rely solely on any other public agency to provide the level of reliability and resiliency required.

The redundant power distribution infrastructure that is planned for NJ TRANSITGRID is designed to minimize construction costs by use of a centralized location for on-site power generation with direct connections to each of the three rail systems from the chosen location on the Kearny Peninsula. Receiving power from any other location other than the chosen location for the central power plant of NJ TRANSITGRID only serves to greatly increase costs unnecessarily.

Furthermore, as a stipulation of the Federal Transit Administration's (FTA) grant award to NJ TRANSIT for this Project, all improvements (including electrical transmission line work) must be within transit right-of-way. In order to implement several of the above-mentioned alternatives, NJ TRANSIT would be required to rebuild all of the required infrastructures from the commercial powerplant to the substations included in the Project. Having a source of power closer to the substations that would use it further reduces the likelihood of power interruptions. The cost to build a stand-alone facility to power NJ TRANSIT assets would be the same amount as the proposed Project since it would have to meet the same needs as the Project. Having an electric provider staff and maintain the new facility would also be as costly as the proposed Project, if not more expensive, due to the added management costs associated with contracting through a commercial agency.

4.0 CONCLUSIONS

After reviewing the requirements to implement alternative sources of power or the transmission-only alternative, none of the proposed concepts would meet the Purpose and Need of the Project. All would either be too costly, require real-estate investments that are beyond the scope of the Project, or would not meet the resiliency and reliability needs of the Project.

Attachment I - Alternative Analysis for the Grid

Purpose Statement (from DEIS): "*The purpose of the proposed Project is to enhance the resiliency of the electricity supply to the NJ TRANSIT and Amtrak infrastructure that serves key commuter markets in New York and New Jersey to minimize public transportation service disruptions. The region's public transportation infrastructure is vulnerable to power outages due to the nature of the existing centralized power distribution system and the intensity and frequency of severe weather events*."

This alternative analysis is similar to the "no-action" alternative, as it explores continued use of the Grid (regional PJM Grid) as the exclusive source of power to the targeted NJ TRANSIT and Amtrak infrastructure, except that it adds reasonable scenarios that will see both likely improvements and decreases in Grid resiliency in the foreseeable future and whether the net change in resiliency can provide the stated level of resiliency and reliability that is the purpose of the NJ TRANSITGRID Project. As will be shown, it is not a question of the Grid being *able* to reach its resiliency goals, but what those goals are - and if those goals will meet the criteria of this Project. They do not.

There are three principal concepts in the Purpose Statement that must be addressed in this analysis, namely: 1) What does it mean to NJ TRANSIT to "enhance the resiliency of the electricity supply;" 2) What is "the nature of the existing centralized power distribution system" that keeps it from meeting the Project's resiliency goals; and 3) What is the significance of "the intensity and frequency of severe weather events."

1. *"...enhance the resiliency of the electricity supply…"*

The resiliency goal of NJ TRANSITGRID relates directly to "grid resilience," which may be thought of as an intrinsic characteristic of the electric transmission and distribution Grid to withstand and recover rapidly from service disruptions. However, as no standardized measures of grid resiliency currently exist, this analysis provides a measure of grid resiliency through a framework of desired levels of *reliability* for the targeted components of the NJ TRANSIT system. Reliability is a term of art in Power Systems Engineering that describes well-defined capabilities of the Grid, and may be thought of as that which comes into play once the resilient characteristic of the Grid has been breached.[26] Therefore, reliability, which has widely used measures in the power industry, particularly by electric distribution utilities, offers a good proxy measure of system resiliency.[27]

Given the intended use of NJ TRANSITGRID to provide power to portions of the NJ TRANSIT and Amtrak system, it is important to note differences between how reliability is experienced by traction power systems and the general utility customer. Reliability of traction power systems relates directly to operating within a normal scheme configuration and schedule without causing safety hazards, train delays or public nuisance. While utility reliability may be expressed in interruption duration and frequency for its customers, for a traction power system minutes of train delays caused by power interruption or delay-

---

[26] Taft, J.D. (March 2018). Electric Grid Resilience and Reliability for Grid Architecture. Pacific Northwest National Laboratory/ U.S. Department of Energy (DE-AC05-76RL01830).

[27] See Page 49 of: NJ TRANSIT's "Resiliency and Environmental Sustainability – An Evaluation and Quantification of NJ TRANSITGRID Benefits." NJ TRANSIT developed this analysis to evaluate and quantify the full value of the NJ TRANSITGRID TRACTION POWER SYSTEM project. References are to page numbers in this report. The full report is available on the Project website: https://njtransitresilienceprogram.com/documents/

minutes per passenger-mile is a more relevant metric. Mass transit service interruptions may also have damaging economic effects in excess of other uses and in some cases power failure to the traction system may cause catastrophic or life-threatening situations. In this light, reliability for traction power systems must be considered differently and in general tends to have higher economic value to society.[28]

In the U.S., transmission and distribution system reliability is enforced by the Federal Energy Regulatory Commission (FERC) through implementation of the Reliability Standards developed by the North American Electric Reliability Corporation (NERC). The NERC Reliability Standards are measured using standardized frequency and duration performance indices including SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Duration Index).[29]

An *Internal Reliability Model* was developed for NJ TRANSITGRID to quantify the reliability enhancements offered by NJ TRANSITGRID to confirm that it met the projects requirements.[30] The *Internal Reliability Model* tests the ability of NJ TRANSITGRID to respond to contingencies at the three internal connections located at Substation 41 (for the Amtrak portion of the Northeast Corridor line), the Mason Substation (for the Morris & Essex line and the NJ TRANSIT Meadows Maintenance Complex) and the proposed new NJ TRANSITGRID East Hoboken Substation (for the HBLR line). For this model, the reliability levels experienced by the impacted loads are found to be a function of (1) the reliability of the distribution network, (2) the probability of NJ TRANSITGRID to successfully transition, and (3) the available internal energy capacity. The methodology for quantifying the added reliability provided by NJ TRANSITGRID to internal loads proceeds as follows:

1. Assign a baseline reliability measure to the traction power substation connections to NJ TRANSITGRID.
2. Quantify the probability that NJ TRANSITGRID will be available to energize the connections at a time when the Grid may fail.
3. Use the baseline reliability measure (Step 1) and the Capacity Outage Table (Step 2) to quantify the amount of energy that NJ TRANSITGRID will be able to provide in the event of Grid outages.

The results of the analysis of the *Internal Reliability Model* Loss of Energy Expectation (LOEE) baseline for the NJ TRANSITGRID connections to PSE&G is approximately 144 MWh/yr of unserved energy. The combined SAIDI at the three NJ TRANSITGRID connections to PSE&G is approximately 3.9 hrs/yr. This is an annual average considering the industry reliability standard for the probability of the loss of supply at a substation from the bulk electricity system of 0.1 days/year (2.4 hrs/yr), which is equivalent to a customer experiencing one day of disconnection from the power source every 10 years. These events lead to a loss of power of varying duration to the traction power systems resulting in passenger delays, potently damaged equipment, and sometimes more dangerous circumstances such as stranded trains. Simulations indicate that there is a vanishingly small probability that NJ TRANSITGRID would not be able to cover peak loads at any of the three connections individually in blue-sky conditions and that for a loss of supply at all

[28] Ibid. Page 52.
[29] Ibid. Page 50.
[30] Ibid. Pages 56-61.

three connection points due to a severe systemic breakdown (i.e., emergency conditions or island mode), NJ TRANSITGRID would have a 96.3% probability of supplying the lost load, significantly improving SAIDI for its internal connections in blue-sky and island mode. [31]

Therefore, based on the *Internal Reliability Model*, the project provides virtually 100% reliability to all of the targeted NJ TRANSIT & Amtrak infrastructure under blue-sky conditions and a 96.3% reliability under the direst of circumstances due to a complete system failure. This is the meaning and signification of "enhanced resiliency."

2. "…the nature of the existing centralized power distribution system…"

It should first be noted that PSE&G has been primarily responsible for New Jersey scoring amongst the most reliable distribution systems of the fifty states and the District of Colombia since these indices began being tracked by the U.S. Energy Information Agency (EIA) after 2012. However, even with these relatively high system-wide average reliability scores, the system still leaves NJ TRANSIT without the level of resiliency provided by NJ TRANSITGRID, as demonstrated by the *Internal Reliability Model*. This is because utilities, as instruments of the public welfare, must make the same cost-benefit decisions society demands of all public goods. PSE&G, like all utilities, must make proposals for reliability enhancements to its regulator and go through the rate-making process that allows the utility to recover its investment costs through increases to electricity rates paid by consumers.

Utilities take on reliability enhancements to address increasing vulnerabilities from aging infrastructure and to repair damage from major outage events. The most recent major examples of this process for PSE&G in the NJ TRANSIT service area is the "Energy Strong" & "Energy Strong II" filings. In May 2014, the New Jersey Board of Public Utilities (BPU) authorized PSE&G to implement the Energy Strong Program by investing up to $600 Million in electric infrastructure improvements to be recovered through future base rate adjustments.[32] The work included raising or relocating switching and substations that were damaged by water in recent storms, creating redundancy in the system to reduce outages, deployment of smart-grid technologies to better monitor system operations, and the hardening of substations that were heavily damaged by water during Hurricane Irene or Superstorm Sandy.[33] In June 2018, PSE&G filed a petition for approval to implement the next phase of the Energy Strong Program ("Energy Strong II"). PSE&G proposed a five-year program with a total investment level of approximately $2.5 billion.[34]

According to the Cost-Benefit Analysis provided to BPU by PSE&G as part of its June 2018 *Energy Strong II* filing, it estimated improvements in reliability of 24.3% in return for the proposed investment.[35] Although impressive, it still does not meet the reliability goals of this project, which as shown, are

---

[31] Ibid.
[32] N.J. BPU. (May 21, 2014), "In re the Board's Review of the Petition of Public Service Electric and Gas Company for Approval of the Energy Strong Program." BPU Docket Nos. E013020155 and G013020156" ("Energy Strong Order'').
[33] PSE&G Energy Strong Website: https://www.psegtransmission.com/reliability-projects/energy-strong
[34] PSE&G. (June 8, 2018). "In the Matter of the Petition of Public Service Electric and Gas Company for Approval of The Second Energy Strong Program (Energy Strong II)." ("Energy Strong II Filing") https://nj.pseg.com/aboutpseg/regulatorypage/regulatoryfilings
[35] Ibid. See Figure 5 in Attachment 5, Page 26 of 119.

unprecedented levels of reliability to support critical infrastructure through dedicated power delivery systems. The point is that utilities do not seek the levels of reliability required by NJ TRANSIT; they seek to achieve the goals set by industry standards and what the regulated cost recovery process will bear. (It should be noted that in September 2019, BPU approved a scaled-back Energy Strong II proposal to allow PSE&G to upgrade its gas and power infrastructure, accepting a $842 Million, four-year program, rather than the $2.5 Billion proposed programming. This would reasonably be expected to result in a comparable percentage decrease in the planned 24.3% reliability improvements[36]).

3. "…the intensity and frequency of severe weather events."

The cost-benefit analysis provided by PSE&G also highlighted another important factor in reliability planning used by utilities, that if they are including major events at all in their calculations, they are assuming that the impacts of storm intensities in the future will most likely be as they have been in the past.[37] This is an understandable technique for a public filing, but the evidence is strong that storms and other major weather events are increasing in intensity, particularly in coastal areas of New Jersey. As discussed in the Executive Summary of the DEIS (Appendix G), "the high vulnerability of regional commercial power is also documented by the *Overview of New Jersey Power Outages: Risks to the New Jersey Grid,* which indicates a trend of increasing number of outages reported and number of days of power disruption due to hurricane/tropical storms over the past 20 years. This is likely a result of both increased severity of the storms as well as increasing vulnerability of an aging power grid." The design of NJ TRANSITGRID has specifically taken this evidence of the increasing severity of storms into account in its planning and design. The alternative, the national Grid, does not.

It should also be noted that increasing intensity of major weather events is not the only long-term threat to maintaining acceptable levels of electric power reliability on the Grid. Increased levels of penetration of variable renewable generation into the distribution system is now causing new reliability issues for utilities associated with rapid and difficult to forecast voltage fluctuations that increased flexibility can mitigate. Customers located on feeders receiving power from intermittent sources such as solar arrays or onshore/offshore wind are exposed to significant power quality issues as a result. Uncontrolled fluctuations due to a lack of flexibility on the local circuits can lead to damage and failure of utility and customer equipment. In September 2018, PSE&G proposed its $4 Billion *Clean Energy Future* program to the BPU for new fixed investments including flexibility enhancements. Analysis of the filing shows that expected improvements in reliability with these targeted flexibility investments are estimated at 6.3%.[38] Microgrids like NJ TRANSITGRID that have the needed operational requirements (e.g., the ability to ramp quickly, operate across a wider output range, and start up and shut down more quickly) can address flexibility requirements *without* any significant loss of reliability.[39]

---

[36] NJ Spotlight. (September 12, 2019). "PSE&G's Scaled-Back Proposal for Upgrading Gas and Power Grids OK'd." https://www.njspotlight.com/2019/09/19-09-11-pse-gs-scaled-back-proposal-for-gas-and-power-Grid-upgrades-is-approved/

[37] Energy Strong II Filing. Attachment 5, Page 26 of 119

[38] NJT (December 2019). See Pages 6, 49-50, 62-64.

[39] Electric Power Research Institute. (2015). The Integrated Grid: A Benefit-Cost Framework. Report No. 3002004878. See discussion on flexibility resources on pp 8-8, 8-9.

4. Conclusion

This Alternatives Analysis evaluates the use of the Grid, including likely net improvements of reliability and resiliency to the Grid in the foreseeable future and finds that the Grid is not a feasible alternative for the following reasons:

1. NJ TRANSIT requires unprecedented levels of reliability and resiliency to maintain its critical infrastructure. The proposed NJ TRANSITGRID Project has been demonstrated to meet that requirement.
2. The Grid is unable to provide this required level of reliability and resiliency due to the constraints of the public reliability planning and rate-making processes that electric utilities are subject to.
3. The Grid reliability planning process does not consider the growing intensity of storms and other major weather events, thereby making its reliability planning deficient in terms of the requirements of NJ TRANSIT.
4. The Grid is not adequately addressing the flexibility requirements made necessary by increasing penetration of variable renewable power injections. NJ TRANSITGRID will reduce these threats to reliability through high levels of flexibility made possible by the selected equipment.