Review and Refutation of NJ TRANSITGRID TRACTION POWER SYSTEM Combined Final Environmental Impact Statement/Record of Decision, APPENDIX D: Scoping Alternatives Analysis

The purpose of this Don't Gas the Meadowlands (DGTM) Coalition document is to refute numerous assertions in APPENDIX D: Scoping Alternatives Analysis of the NJ TRANSITGRID TRACTION POWER SYSTEM Combined Final Environmental Impact Statement/Record of Decision[1] regarding the technical and economical viability of renewable energy and energy storage technologies as solutions for NJ Transit's proposed NJ TRANSITGRID TRACTION POWER SYSTEM microgrid project. This document is structured as follows (the section identifications in these topics refers to the subject titles in APPENDIX D):

Overview

The Don't Gas the Meadowlands (DGTM) Coalition made several requests during 2019 and 2020 for any NJ Transit analysis of renewable energy solutions for its NJ TRANSITGRID TRACTION POWER SYSTEM microgrid project. The statement in NJ Transit's May 2019 Draft Environmental Impact Statement (DEIS) regarding renewable energy solutions was limited to the following paragraph with no other detail, data, or analysis:

> The use of solar panels, wind energy, and other "green" technologies to fully "island" the NJ TRANSIT and Amtrak electrical systems from the larger commercial power grid are not practical or reasonable alternatives to a natural gas-fired generation plant due to the required load generation capacity, siting requirements for these technologies, the need to meet rapidly fluctuating loads associated with traction power systems under island conditions (especially due to the need for energy storage to guarantee a reliable power source), and cost.

No further information per the DGTM Coalition's request for additional analysis from NJ Transit was ever provided.

[1] https://njtransitresilienceprogram.com/wp-content/uploads/2020/04/Appendix-D-Scoping-Alternatives-Analysis.pdf

Having clearly recognized that its claims to have studied renewable energy alternatives were not credible, NJ Transit added a new appendix (APPENDIX D: Scoping Alternatives Analysis (page 436)) to its updated April 2020 Final Environmental Impact Statement (FEIS),[2] which provides some additional analysis. Section 2.2 of APPENDIX D states: "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." However, none of the details or data provided in APPENDIX D were ever demonstrated to have existed before the publication of the FEIS and were certainly not in the February 2014 NJ TRANSITGRID Feasibility Study prepared by Sandia National Laboratories.

Nevertheless, as will be shown below, this new analysis is deeply flawed and is focused on demonstrating that renewable energy technologies cannot be used in this project rather than proactively looking for opportunities to use them as encouraged by the 2019 New Jersey Energy Master Plan (EMP) and in accordance with New Jersey's Clean Energy Act of 2018.

Below are claims and statements from APPENDIX D with analyses and refutations from the DGTM Coalition.

NJ Transit analyzed several renewable energy technology options, described in APPENDIX D.

- Solar Photovoltaic (PV) and Energy Storage
- Wind Turbines and Energy Storage
- Energy Storage Resources
- Biomass
- Alternative Fuels
- Wind Turbines (Offshore)

Our DGTM Coalition has never suggested that wind or biomass are currently viable alternatives for this project and, therefore, will not comment on NJ Transit's analysis of those options.

The first major flaw in NJ Transit's analysis is that it does not utilize an engineered total solution that combines the synergies of multiple types of energy/storage to develop an optimal solution. Instead, it looks at each renewable energy technology in a "stove-pipe" fashion in order to find ways to demonstrate it is not feasible. Stove-pipe approaches produce much higher costs than necessary as they rely on single technology solutions to provide peak power.

The second major flaw in NJ Transit's analysis is that it does not evaluate any hybrid mix of multiple energy technologies for traction power (either a combination of multiple renewable energy and energy storage technologies, or a combination of renewable energy, energy storage and conventional energy technologies). It only looks at solar PV energy as

[2] https://njtransitresilienceprogram.com/documents/combined-final-environmental-impact-statement-record-of-decision/

a complete stand-alone solution. The flaw in this approach is that most renewable energy solutions are based on fluctuating sources of natural energy, each of which alone would require costly overbuilding of generating and storage capacity to meet energy needs during periods of low volumes of natural energy but when combined, can complement each other to provide very efficient, resilient, and reasonable cost solutions.

One example of an effective mix of energy sources is a hybrid combination of renewables with fossil fuel, i.e., augmenting a mainly renewable energy and energy storage based solution with a small amount of emergency backup fossil fuel power. There are small, quick-starting turbines available today that are specifically designed to be integrated with a solar PV energy generation and battery storage system into a hybrid microgrid in order to provide resilient and cost effective solutions, especially in isolated grids.[3]

Another example of mixed energy sources is a combination of solar PV energy with tidal power. As with an emergency backup fossil fuel system, the tidal power system, which can include pumped hydro storage, can provide steady base-load power, to ensure batteries remain charged during periods with insufficient solar power.

A February 2016 Caterpillar Inc. white paper, *Hybrid Microgrids: The Time Is Now*,[4] asserts that microgrids powered by renewable energy generation and conventional gas-fueled generation along with energy storage are generally more effective economic solutions for environments dealing with unreliable commercial power grids than pure conventional power generation (aka the current NJ Transit solution). Below are some excerpts from that paper:

- A better model is emerging that combines newly cost-effective renewable energy from wind or solar sources with conventional gas-fueled generation. These installations, called hybrid microgrids, also employ energy storage to add power system stability and enable further energy cost reduction.
- Wind or solar energy reduces reliance on power produced from generator sets, saving fuel and, to a lesser extent, maintenance costs. The generator sets firm the renewable sources and follow the load. Sophisticated digital controls tie the system together. Energy storage enhances system economics and helps the generator sets respond smoothly to significant fluctuations in output from the renewable resources, while maintaining consistent voltage and frequency.
- Improvements in the costs and capabilities of photovoltaic (PV) systems, energy storage and telematics, along with advances in technology and communications, now economically justify hybrid applications that previously would have required special support or incentives. The integration of renewable technologies reduces operating expenses when compared to purely conventional generation, while also optimizing system reliability, efficiency and flexibility.

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[3] For example, Wartsila's "Flex Gas engines" for transitioning to solar renewables. Wartsila, a Finnish-based company, has designed newer modular gas engines or gas plants to provide reliability for renewables but with the capability of running smaller modules such as producing only 10% of the total power needed. Because they are modules, as solar renewables improved one could pull out a module for some other use. https://www.wartsila.com/twentyfour7/in-detail/powering-isolated-grids
[4] http://s7d2.scene7.com/is/content/Caterpillar/C10868274

- In a hybrid microgrid, renewable energy capacity can account for any percentage of the total peak load. In general, **the greater the contribution from renewables, the greater the potential fuel and operating cost savings.**
- The hybrid microgrid combines the benefits of renewable and conventional power generation while offsetting their weaknesses. The basic cost equation demonstrates that, in return for higher capital cost, a hybrid microgrid delivers lower long-term operating cost and a lower total cost of ownership **than pure conventional power generation.**
- The hybrid microgrid concept is quickly becoming the preferred approach to delivering low-cost, reliable power in settings beyond the reach of larger electric utility infrastructure.

In other words, the inclusion of small backup gas turbines enables the use of renewable energy sources (and energy storage systems) which, by themselves cannot economically provide the resilience required due to the need to build for peak demand and deal with renewable energy variances. It is a synergistic relationship. Tidal power is a somewhat unique form of renewable energy as it does not have the random variances in power generation of solar PV energy and should be considered as an alternative to a backup gas-fired turbine.

Given the improvements in cost-effectiveness of renewable energy and energy storage technologies since 2106, this argument is now even stronger. By ignoring this solution, NJ Transit may very well be suboptimizing its microgrid project.

Our Coalition has stated that we would accept a solution that includes backup gas-fired turbines to "firm" the energy supply during emergency situations when the commercial grid is down for more than a few hours and the availability of solar PV energy is limited due to output fluctuations (cloudy weather and night-time conditions). (See the Proposed Model section below for an estimate of the size of such a backup system). The Coalition is not opposed to this type of solution if a robust engineering and economic analysis determined this to be a feasible and highly-effective solution to the fluctuations in renewable energy and the engineering and economic basis for such a design is transparently available for review.

Our Coalition has also provided NJ Transit with a complete proposal from GMax Tidal Energy that demonstrates the feasibility of using tidal currents in the nearby Hackensack River to produce 140 MW of tidal power with complete 24x7 resilience (power production would not be affected by any changes in natural resources). However, NJ Transit chose to ignore this proposed alternative energy source for any role, backup or otherwise, in generating power for its microgrid project.

The third important flaw in APPENDIX D is the lack of NJ Transit efforts to adopt load reduction and conservation measures, even those recommended by its own engineering consultant, Jacobs Engineering Group. Reducing peak demand is a very powerful tool to reduce costs because building generating and storage capacity for infrequent use is extremely costly and inefficient. These suggestions are described in the Energy Storage Associated with Solar Photovoltaics section below.

These three flaws (stove-pipe use of technology, no consideration of a hybrid approach and a lack of peak power reduction techniques), produced **a worst case scenario that no engineer would ever design**. Apparently, this is the only way NJ TRANSIT can disprove the viability of renewable energy and storage technologies. This is not a professional, best practice approach and must be rejected by NJ TRANSIT management.

The Coalition and its technical advisors believe that the development of a hybrid microgrid using renewable energy, energy storage, and backup emergency fossil fuel or tidal power is simply an engineering and economic challenge to determine the optimum mix of these capabilities. NJ Transit's approach clearly has not been to look for an engineered solution to optimize the combined use of renewable energy/storage technologies along with firm power supply technologies. Instead, it has been to look at renewable energy (and energy storage) technologies in "stove-pipe" fashion in order to find ways to demonstrate that each technology is not feasible. This is not a professional, best practice approach and is not in step with the current state of the art in microgrids. Clearly, NJ Transit has yet to properly evaluate the use of renewable energy (and energy storage) technologies for this project.

This approach to microgrid design, along with the effort by NJ Transit to find reasons to not investigate the availability of property for hosting solar panels, is another demonstration of its lack of intention to even encourage bidders to submit alternative technology designs for this project, despite its statements to the contrary. Consider that in a normal procurement effort, a customer interested in evaluating a solar PV energy solution would formulate some plan to provide space for siting solar panels. They either would own property or have some locations identified for purchase or lease. They would cooperate fully with a bidder in terms of helping the bidder evaluate potential properties. They would not ask a bidder to design a solar PV solution while providing no information or help on panel siting or, worse yet, declaring there is no property available for this. Yet this is what NJ Transit has done so far in this project. This behavior is what we should label as being that of a "hostile customer," one who says they are interested but makes it very hard for providers to comply.

Our Coalition's subject matter experts have told us that it is far from a foregone conclusion, as NJ Transit would have us accept, that use of renewable energy and energy storage technologies is an unreasonably costly or technically infeasible approach, as is demonstrated by the model provided by Mr. Lyle Rawlings[5] in the Proposed Model for Renewable Energy/Storage section below. We strongly recommend that NJ Transit conduct a professional, objective analysis of the feasibility of using a mix of renewable energy, energy storage, and emergency backup firm power generation to meet the objectives of this project.

Lastly, we have compiled information on the use of renewable energy sources providing traction power to trains in other countries as described in APPENDIX II, as further proof of this approach.

[5] President and CEO of Advanced Solar Products

Compatibility with Executive Order (EO) No. 28, Executive Order (EO) No. 100 and the 2019 New Jersey Energy Master Plan (NJ Energy Master Plan) released on January 27, 2020.

APPENDIX D contains the following statement to demonstrate its compatibility with the above EOs and the NJ Energy Master Plan:

> *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.*

The term "Renewable Natural Gas" (RNG, aka biogas) is a fossil fuel industry ploy to confuse the public into thinking that the technology is somehow in the same category as true clean renewable energy technologies such as solar, wind, and tidal energy. Given RNG's dirty nature, as well as its inability to reduce greenhouse gases, it is unacceptable as a solution to fighting climate change and improving air quality, especially in Environmental Justice (EJ) communities. Moreover, this document will demonstrate that solar PV and tidal energy are feasible solutions and, therefore, there is no need for NJ Transit to claim that it will at some time in the future be able to use RNG as proof that NJ Transit is designing the project for renewable fuels. This will be addressed further in the section under Alternative Fuels.

It must also be noted that the NJ Energy Master Plan[6] does not endorse the use of RNG in particular or of biofuels in general. Its only reference to biofuels (page 129) states: "Bio-fuel and bio-gas can provide a mechanism that will allow for the decarbonization of energy end uses that are difficult to electrify with today's technologies." As demonstrated below, the NJ Transit microgrid project can be electrified with today's renewable energy alternatives. Given the problems of RNG described in the section below under Alternative Fuels, it is certainly disputable that it has any positive value at all. Regardless, its applicability to the NJ TRANSITGRID microgrid project would seem to be a stretch. NJ Transit is only citing RNG as a weak argument to support its plans to develop a dirty technology solution that would be in operation for the next 30 years.

The refutation of NJ Transit's claims in the second paragraph above regarding true renewable energy technologies will be evident in the sections below.

It is also important to demonstrate that NJ Transit's Draft Environmental Impact Statement uses an incorrect value for the Global Warming Power (GWP) of methane and also uses a

[6] https://nj.gov/emp/docs/pdf/2020_NJBPU_EMP.pdf

questionable value for estimating methane emissions. On page 7-1, it cites the GWP value of 25 for methane, which is based on a 100-year lifetime average. However, recent New Jersey legislation now requires the use of a 20-year lifetime average, which increases the global warming power factor to 86. Even more significant is that the NJ Transit estimate of annual methane leakage is only 44.6 tons. Its total annual gas consumption is expected to be 212,517 tons. Therefore, its estimate of leakage is only 0.02%. Studies of life cycle methane emissions indicate that 3% is a reasonable and conservative estimate. Using this value, total leakage emissions would be 6,376 tons of methane or 548,294 tons of CO2e (CO2 equivalent), using a GWP of 86. Given that NJ Transit estimated the CO2-only greenhouse gas (GHG) emissions of its proposed gas-fired power plant at 579,993 tons/year, adding another 548,294 tons from methane **would double its total estimate and make it about 1,119,230 tons of CO2/year. This would increase total New Jersey GHG emissions by over 1% annually.**

Solar Photovoltaics (PV) (section 2.2.1)

The NJ Transit analysis describes the issues associated with providing solar PV energy as follows:

> *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). (Total power required is 127.5 MW). To produce this much energy using only solar power would require the construction of a PV power plant with a capacity of nearly 390 MWAC requiring approximately 2,600 acres of land (4.1 square miles) and at an estimated cost of $600 - 800 Million to construct.*

A footnote states:

> *MWAC 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*

Another footnote in APPENDIX D relates to the size and cost estimate states:

> *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.[7] 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."*

[7] https://www.nrel.gov/docs/fy13osti/56290.pdf

The estimate of 390 MWac (from use of the PVWatts Calculator) is the required solar PV energy capacity for an all-solar power source[8] for the microgrid project in the New York metro area. In this model, there is no hybrid gas-fired power plant or tidal power for periods with low solar PV output. In other words, it is not an optimal design that any renewable energy technology provider would bid and should not be used as a gauge for any decisions. As can be seen in the model proposed by Mr. Lyle Rawlings in the Proposed Model section below, the amount of power needed from solar PV generation is much less when complemented with emergency backup firm power generation. However, it is worth examining NJ Transit's model to expose its assumptions.

First of all, such a solution only has to be sized to generate the required output during power outages. NJ Transit's Draft Environmental Impact Statement admits, on page 2-3, that "*The actual traction power loads are less than 104 MW; however, the Main Facility's generation capacity must be great enough to account for intra-hour peaks and down time for equipment maintenance, as well as provide stable voltage and frequency as load changes occur*." A renewable energy/storage system could accommodate intra-hour peaks with storage, not additional generating equipment and should not require equipment maintenance be performed during infrequent outages.

Using the PVWatts Calculator and assuming the need for 104 MW instead of 127.5 MW, the total capacity of an all-solar power plant would be 318 MW,[9] not 390 MW. Even 318 MW is excessive as shown in the Proposed Model section below.

More importantly, the NJ Transit calculation of acreage required for generating such power is based on older data that should not be applied in this situation. It is based on a 2013 National Renewable Energy Laboratory (NREL) study, *Land-Use Requirements for Solar Power Plants in the US*,[10] which caused NJ Transit to estimate that the solar PV output would be 0.15 MW/acre (390 MW/2,600 acres), or 6.7 acres/MW.

The NJ Transit assumption of 0.15 MW/acre can be easily refuted as follows. The 2013 NREL study is based on data from 166 projects completed or under construction as of August 2012 and 51 proposed projects as of August 2012. The purpose of the study was to determine land area needed for siting solar panels. As stated in the APPENDIX D footnote cited above, "*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."* Clearly, the study reviewed many different types of solar PV energy technologies, which is fine as a general yardstick for developers but it produced aggregated results which do not apply to any single technology and should not be used for specific systems.

The solar PV installations in the study had an overall weighted average of 6.9 acres/MW. They ranged from 2.2 acres/MW to 12.2 acres/MW. The systems ranged widely in size as

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[8] Other sections of this document describe the problems with assuming only one type of renewable energy with no use of hybrid fossil fuel engines to improve cost-effectiveness.

[9] The 18% reduction from 390 to 318 is derived from the ratio of 140/127.5 = 82%.

[10] https://www.nrel.gov/docs/fy13osti/56290.pdf

well. The above factors used in the 2013 NREL study do not even reflect the most efficient solar technology of 2012 and include technology used in prior years. NJ Transit used this overall average for its calculations. It did not use an engineered estimate based on 2020 solar panel efficiency applied to the types of spaces that it owns or can otherwise access.

Mr. Rawlings, co-founder of the Mid-Atlantic Solar Energy Industries Association and President and CEO of Advanced Solar Products, has informed us that 2.5 acres/MW is a good approximation of energy output using best panel technology in 2020. He stated, "*With the new crop of high-efficiency modules, current solar acreage is about 2.5 acres per megawatt, not including property boundary setbacks, wetlands, and the like*."

Using the ratio of 1 MW/2.5 acres produces an estimate of only 975 acres required to provide a capacity of 390 MW. Based on the issues described above with the calculation of 390 MW and assuming that only 318 MW is needed, the total acreage required would be 795 acres. NJ Transit's calculation of 2,600 acres is very flawed.

Members of the DGTM Coalition have looked at potential sites for hosting solar panels on NJ Transit property and estimate the following:

<u>NEC (Northeast Corridor) and Morris & Essex Line locations: total 160 MW</u>

- Koppers Coke site itself (currently owned by NJ Transit), 130 acres: 50 MW
- Standard Chlorine Chemical Company site: 10 MW
- Newark Solar tunnels similar to the Belgium Antwerp Solar tunnel: 15 MW
- Morris & Essex Line, Montclair Rail plus I-280 overpasses/tunnel, 50 acres for tunnel roof solar panels: 20 MW
- Railyard sheds, Train station non-historical roofs, platform roofs: 10 MW
- Parking Lot canopies: 20 MW
- Railyards of 115 acres: 35 MW

<u>Hudson-Bergen Light Rail parking lots: total 18.8 MW</u>

- Liberty State Park (LSP) station park and ride, 8 acres: 3 MW
- West Side Ave (Jersey City) park and ride, 7 acres: 2.8 MW
- Tonnelle Ave (North Bergen) park and ride, 5 acres: 2 MW
- 34th street (Bayonne) park and ride, 3 acres: 1 MW
- Maintenance sheds near LSP, 25 acres all together: 10 MW

<u>Other NJ Transit sites under investigation include</u>

- Meadowlands Maintenance Complex shed roofs
- Pennsylvania Railroad (PRR) Railyard
- Hoboken Ferry roofs
- Secaucus Transfer station
- Penn Station Newark roof
- Lot next to rail tracks near Meadows Maintenance Complex of 76 acres

This does not include the potential for siting solar panels directly above or adjacent to the tracks or even on the sleepers between the tracks (an approach being used in Europe). One mile of track can support enough solar panels to produce 1 to 3 MW of solar PV energy. Assuming 1.5 MW/mile, 100 miles of track could produce 150 MW.

The known acreage total (without the other NJ Transit sites under investigation listed above) would support about 320 MW. We must also acknowledge this would require solar installations on many roofs or open areas.

In addition to, or as an alternative to, the space described above, there are a number of large open areas just north of the Koppers Coke site that have minimal vegetation and may have previously been industrial sites that are now cleared. There are also many lagoons in this area, which are excellent sites for floating solar panels. A map of this area along with Mr. Lyle Rawlings notes is in APPENDIX I. This area includes the following tracts:

- Amtrak 41 Substation-Newark-Jersey City Turnpike: 20 acres. This is open land adjacent to existing tracks and may already be owned by a railroad. Its availability for siting solar panels would have to be explored further.
- Essex Expressway (Essex Freeway)/Newark Jersey City Turnpike: 47 acres. This open tract is southeast of the intersection of these two roads in Kearny. This property is owned by NJ Transit.
- Keegan Landfill: 45 acres. This landfill is being capped. There is no information on its intended use but it is owned by Kearny, which might be interested in leasing it to NJ Transit for siting solar panels.
- New Jersey Meadowlands Commission (NJMC) 1-E Landfill: 409 acres. This landfill, owned by the NJMC, is along the western border of the New Jersey Meadowlands in Kearny and North Arlington. It contains a leaf-composting facility and transfer station and passive open space, which could support the siting of solar panels.
- Harmon Cove: 333 acres. This consists of two open areas directly across the Hackensack River from the Harmon Cove development, along Berry's creek, separated by the New Jersey Turnpike and would need to be investigated in terms of its potential to host solar panels.
- Croxton Peninsula: 302 acres. This is an open area at the east end of the Portal Bridge, along the east bank of the Hackensack River. It includes NJ Transit tracks leading to Secaucus Junction. It appears to have numerous lagoons that could support floating solar panels. This area would have to be investigated in terms of its potential to host solar panels.
- Richard Dekorte Park: 46 acres. This is a protected wetlands park and also the home to the New Jersey Meadowlands Commission. It is unknown if any part of it could be used to host solar panels.
- Kingsland Landfill: The developer that purchased it plans to build industrial space. However, there are New Jersey Department of Environmental Protection (NJ DEP) restrictions as to what can be built and a 10/23/2019 NorthJersey.com article[11]

[11] https://www.northjersey.com/story/news/bergen/2019/10/23/work-begins-encap-kingsland-site-meadowlands-nj/4002188002/

> stated, "*Much of the land could be used as a solar energy farm, large enough to create a 20-megawatt output*."

This area needs more investigation but the preliminary indication is that it could provide 300 acres or more of space to site solar panels, which would support 120 MW of generation. Moreover, this would provide large tracts that would be more cost-effective than using many smaller areas such as rooftops. We encourage NJ Transit to explore the possibilities that this area has to offer.

NJ Transit's estimate of $600 to $800 million in solar PV construction cost is also flawed. Mr. Rawlings has stated that current costs are about $1.5 million per MW, which would make the cost to construct 318 MW of capacity about $477 million. (The size and, therefore, the cost of solar based on a hybrid microgrid in the Proposed Model below, is much less).

Evidence for even lower costs can be seen in the May 2020 Southeastern Pennsylvania Transportation Authority (SEPTA**)** power purchase agreement (PPA) contract with Lightsource BP to build two solar farms that would produce 43.8 MWdc to generate about 20% of SEPTA's annual electricity demand. Lightsource BP will invest $47 million to build the farms ($1.07M/MW). [12]

Also, it is necessary to make the point that solar PV energy systems are not only economical – which NJ Transit's gas-fired power plant, per the 2014 Sandia feasibility study, is not – but solar PV energy would actually produce a substantial profit for NJ Transit. The proof for this statement is the dozens of public-sector solar projects being built every year. (An estimate of the potential NJ Transit revenue from solar and storage in the Proposed Model is currently being developed).

Energy Storage Associated with Solar Photovoltaics (section 2.2.1)

The NJ Transit analysis describes the issues associated with energy storage used to support a solar PV energy solution:

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.

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

With energy storage, a PV system could potentially provide the necessary frequency regulation.

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

[12] https://www.rtands.com/passenger/septa-and-lightsource-bp-sign-contract-for-43-8-megawatts-of-solar-power/

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 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]

NJ Transit's arguments in this section, which are mainly related to cost issues, state that it is technically feasible to use solar PV energy combined with different types of energy storage technologies to meet the requirements of the microgrid project.

Before addressing NJ Transit's estimates on total power and battery sizing, it is important to describe the means by which the total energy requirement, peak requirement, and fluctuation rates can be reduced by following Jacobs Engineering Group's recommendations and additional measures. Jacobs stated the importance of identifying the optimal rail operation mitigation strategies to reduce stress and power load on the power system during microgrid operation, which included identifying specific strategies for reducing demand where appropriate. This included:

- Investigation of optimal trade-offs between trip time (which translates to system efficiency and peak fleet requirements) and energy savings.
- Speed restriction caps, and evaluation of tractive effort ("notching")[13] restrictions as well, noting that imposing both types of restrictions simultaneously has synergistic benefits.
- Potential modifications to planned service such as staggering train start/acceleration periods, coordinating the times of accelerating trains with the times of decelerating trains, using slower acceleration rates and other timing optimization schemes.
- Investigating phased rolling stock replacements to occur concurrently with microgrid deployment. One fertile area is recent improvements in on-board energy savings through regenerative braking.
- Retrofit or replacement of NJ Transit locomotives over the medium term offers the prospect of 5 percent energy savings, which will likely translate into a higher "peak of the peak" demand reduction. With proper training and engineer coaching, there are opportunities for additional savings.

There is no indication in NJ Transit's power requirements that any of these strategies have been included.

NJ Transit's statement that rapid cycling of charging and discharging batteries would damage them is misleading for two reasons:

- In a design focused on using renewable energy and batteries to power trains only during commercial grid outages, batteries would be used infrequently (only during outages) to support traction power and flywheels could do the heavy lifting for train acceleration. (Batteries can be used every day for ancillary services not associated with traction power).
- Frequent discharge is exactly what grid-scale batteries are made to do. This is now common in utility-based revenue-generating applications. Grid-scale batteries that perform frequency regulation are required to cycle many times every day and they can commonly be purchased with 10-year warranties.

[13] Manual settings allowing train engineers to direct a specific response from the locomotive. Engine RPM speed must be increased gradually during normal operation. As the engineer demands more power from the locomotive by moving a notch at a time, the power throttle sends a signal to the computer to increase engine RPMs by only that defined amount.

NJ Transit's original plan already included flywheels to provide the power to accelerate trains and avoid the need to build a larger power plant just for those peak demands. Our coalition agrees that flywheel technology is an excellent solution for this purpose. The estimated cost of $5 million to $30 million was presumably included in NJ Transit's original plan although not stated explicitly in the 2014 Sandia National Laboratories feasibility study. It is not clear why NJ Transit added this information to its APPENDIX D as it is not used to produce a conclusion or statement regarding the effectiveness of renewable energy.

However, it is worth noting that Mr. Paul DiMaggio, founder and CEO of GMax Tidal Energy, has stated that the costs of pumped hydro storage for its system are approximately $775/kWh, which is less than the flywheel costs cited by NJ Transit above (from the 2017 IRENA study)[14] while performing basically the same function of providing peak power on demand. Mr. DiMaggio stated that this cost is based on a centralized recirculating pump water system in each building's holding tank, under 10 pounds per square inch (psi) which eliminates the need for large mountains.

NJ Transit described the need for flywheels due to step loads or instantaneous changes in demand for power on the system 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. As mentioned above, this appears to be the power requirement today without any of the suggested peak power reduction strategies described above. As shown in the Proposed Model section, Mr. Rawlings believes this peak could be reduced on the order of 30% with these strategies.

NJ Transit stated that a 100% solar-powered system would require 230 MW of battery capacity. We challenge this design based on:

- Lack of use of peak reduction strategies
- Sizing that is not based on providing power only during outages
- Lack of use of hybrid energy capability (the 230 MW capacity is based on the assumption that there is no other source of power and that battery energy storage must handle all shortfalls in energy from solar PV energy)

It is also worth investigating NJ Transit's source for cost estimates. The source of these estimates is the 2018 NREL report, *2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark*.[15] The report shows that the estimates are based on total purchase and installation costs for only a solar PV solution and include the costs of land (which NJ Transit already owns in some cases), individual permits for the solar PV-only system, and other components such as inverters and developer net profit. While all of these are real costs, it is also reasonable to assume that they would be very different as part of a multi-hundred million dollar project including power generation rather than just a single 60 MW storage installation used in the report.

[14] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017.pdf
[15] https://www.nrel.gov/docs/fy19osti/71714.pdf

In fact, the same 2018 NREL report states, "*co-location enables sharing of several hardware components between the PV and energy storage systems, which can reduce costs. Co-location can also reduce soft costs related to site preparation, land acquisition, installation labor, permitting, interconnection, and EPC/developer overhead and profit.*" NJ Transit chose to not follow this approach in its pricing estimates, thus deliberately quoting higher than necessary prices.

Moreover, the high overhead associated with Li-ion battery installations has been noted in several studies. The Rutgers' May 23, 2019 report, *New Jersey Energy Storage Analysis (ESA)*[16] stated that the battery portion of these installations comprised only 35% of total costs, with the rest deriving from power conversion, monitoring and controls, thermal management, project management, permitting, site preparation, integration, engineering, procurement, construction and other overheads. This has been a significant obstacle to adoption of large behind-the-meter Li-ion applications but is now being addressed by the industry.

- Tesla announced its containerized Megapack, a utility-scale Li-ion battery energy storage product on July 29, 2019. "*Every Megapack arrives pre-assembled and pre-tested in one enclosure from our Gigafactory—including battery modules, bi-directional inverters, a thermal management system, an AC main breaker and controls. No assembly is required, all you need to do is connect Megapack's AC output to your site wiring*."[17] Thus the Tesla Megapack is designed to cut many of the balance of system (BOS) costs identified above.[18]
- More recently, in June 2020, Fluence launched its sixth generation of its integrated utility-scale battery energy storage product stating: "*The design shifts labor from the field to the factory, where more systems and quality checks will take place than with previous generations. Fluence used to install batteries into enclosures onsite; the cube will ship with batteries already assembled, eliminating the variables that arise from installation in the field. Prepacking the batteries could cut installation times in half*."[19]

A May 8, 2019 S&P Global Intelligence article, "*US solar-plus-storage prices plunge in utility contracting surge*"[20] shows that the costs of utility-scale solar plus storage power purchase agreements (PPA) is dropping quickly. "*Prices for large-scale solar farms coupled with big lithium-ion batteries, typically offering four hours of energy storage, have fallen to between $30/MWh and $40/MWh in several recent deals and contracts under negotiation*." If NJ Transit were able to obtain a similar PPA at $35/MWh, the cost of its annual power demand would be $24.4 million (698,062 MWh/year x $40), which also would cover the total cost of the plant's construction. As Mr. Rawlings stated, "*Solar projects have stand-alone economic*

[16] https://www.bpu.state.nj.us/bpu/pdf/commercial/New%20Jersey%20ESA%20Final%20Report%2005-23-2019.pdf
[17] https://www.tesla.com/megapack
[18] https://www.tesla.com/blog/introducing-megapack-utility-scale-energy-storage
[19] https://www.greentechmedia.com/articles/read/fluence-launches-next-generation-battery-storage-product-with-800mw-orders
[20] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/us-solar-plus-storage-prices-plunge-in-utility-contracting-surge-51328301

viability. Third parties will compete to finance and build them, with the projects providing savings (for PPA projects) and/or revenue (for lease projects) to NJ Transit. Basically free money." We encourage NJ Transit to consider such solutions.

Another example of falling PPA pricing from solar plus storage solutions is the Nevada Public Utility commission approval in December 2108 of three solar/storage PPAs proposed by NV Energy for 2021 delivery:[21]

- 101 MW solar + 25 MW battery facility for $26.50/MWh
- 200 MW solar + 50 MW battery facility for $26.51/MWh
- 100 MW solar + 25 MW battery facility for $29.96/MWh

NJ Transit's statement regarding the scarcity of utility-scale solar PV plus storage applications needs to be tempered with the fact that this technology may just be on the verge of a growth spurt.

An April 23, 2020 Utility Dive article, *"84 GW US renewables+storage pipeline has developers anxious for market integration rules"*[22] stated:

> "Utility Dive in 2018 and 2019 found few utility-scale hybrid projects operating in the U.S. market. "*It's like the storm is brewing but hasn't coalesced yet*," InterTran Energy Consulting Founding Principal Rhonda Peters told Utility Dive in 2019. It appears the storm has broken. There are 61 renewables projects, at least 1 MW or higher, "co-located with batteries" online in the U.S., representing 4.6 GW of capacity, the paper reports. There are also 88 projects, representing 14.7 GW, "in the immediate development pipeline" and "69 GW in the seven main U.S. market interconnection queues.

In fact, the 690 MW Gemini solar project on Bureau of Land Management land outside of Las Vegas, Nevada, now under construction, would be the largest solar project in the United States when completed. It would include a "mammoth 380 MW/1,400 MWh lithium-ion battery, one of the larger batteries being deployed today. This would be 65% more power than the 230 MW requirement from NJ Transit. [23]

In June 2018, Pacific Gas & Electric (PG&E) entered into long-term contracts for over 567 MW of battery storage resources made up of separate installations of 4-hour duration batteries with the following capacities, 300 MW, 182.5 MW, 75 MW, and 10 MW.[24]

NJ Transit's assertion that its 230 MW project would be the largest in the United States is not true.

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[21] http://pucweb1.state.nv.us/PDF/AxImages/DOCKETS_2015_THRU_PRESENT/2018-6/30441.pdf

[22] https://www.utilitydive.com/news/84-gw-us-renewablesstorage-pipeline-has-developers-anxious-for-market-inte/575875/

[23] https://pv-magazine-usa.com/2020/05/15/the-largest-us-solar-plus-storage-plant-will-deploy-690-mw-of-bifacial-modules-on-trackers/

[24] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M229/K550/229550723.PDF

The report produced by NJ Transit consultant Jacobs Engineering Group also reveals that the ability of the gas-fired power plant's spinning reserves[25] is very limited and inadequate. Batteries are much more capable of fulfilling this role. Furthermore, New Jersey will be releasing a battery incentive program to comply with the Clean Energy Act's requirement for 2,000 MW of energy storage by 2030. The NJ TRANSITGRID microgrid can be part of the 2,000 MW compliance buildout and its associated benefits and incentives.

Energy Storage Resources (section 2.2.3)
This scenario assumes no generation of power for up to 14 days and that all power is sourced from stored energy. "*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.*"

This statement appears to be another effort by NJ Transit to find arguments for not considering renewable energy and energy storage technologies. It presumes that this would be viewed as an enormous amount of energy that makes it impractical and not cost-effective.

While we have never advocated for such a solution, it deserves a few comments. For one thing, the stated energy storage does not comport with the stated total annual energy required. The total annual energy required per APPENDIX D is 698.062 GWh. Therefore the requirement for two weeks should be 1/26 of this or 26.8 GWh, not 33.6 GWh. (Even this is high, based on the discussion of ways to reduce this demand in a previous section of this document).

Second, Tesla Megapacks can be used to deploy an emissions-free 250 MW, 1 GWh power plant in less than three months on a three-acre footprint. Megapacks can also be DC-connected directly to solar farms, creating seamless renewable energy plants. [26]

Therefore, 26.8 GWh would require 27 Megapacks and 81 acres of space. As described elsewhere in this document, there is more than adequate space owned by NJ Transit for a deployment of this volume of Megapacks, including the Koppers Coke site itself.

This battery farm could be charged from the commercial grid during off-peak hours and could be used to provide ancillary revenue generating services year-round. It would not require any new power sources, whether fossil fuel or renewable-based. As stated above, it would also become part of New Jersey's battery incentive program to comply with the Clean Energy Act's requirement for 2,000 MW of energy storage by 2030.

The price of Tesla Megapacks is not publicly available and a Google search failed to find any information. It is likely this is due to the highly-customized and negotiated prices associated with each installation. Nevertheless, NJ Transit should investigate this option

[25] The **spinning reserve** is the extra (unused) generating capacity that is available by increasing the power output of generators that are already connected to the power system. For most generators, this increase in power output is achieved by increasing the torque applied to the turbine's rotor.
[26] https://www.tesla.com/blog/introducing-megapack-utility-scale-energy-storage

as it could provide a very effective and elegant solution to address its needs and, at the same time, eliminate the need to design and construct a new gas-fired power plant.

<u>Alternative Fuels (section 2.2.5)</u>
NJ Transit described potential use of fuels such as Renewable Natural Gas but states that it is not currently available. Below are major points from APPENDIX D:

> *Renewable Natural Gas (RNG) is a type of class of "carbon-neutral" biofuels that ultimately decrease the net CO2 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. CO2 in the atmosphere is absorbed by photosynthesizing organisms where the carbon is fixed to build the organism's biomass.*
>
> *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. 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.*
>
> *Currently, there is no commercially available technology to blend hydrogen with the utility provided natural gas supply for these turbines*

So-called Renewable Natural Gas (RNG) is biogas, which is very dirty and often made from animal waste, sewage sludge, landfills, and food waste. As NJ Transit noted above, there is still no process to clean these impurities. Moreover, the process to make RNG is polluting and often emits methane as well as noxious and toxic pollutants. RNG often uses its own methane emissions as a fuel source, thus creating more air pollutants than natural gas. It is usually produced in Environmental Justice communities, as would be the case with the NJ Transit project. It burns much dirtier than fracked natural gas and emits a lot of particulate and carbon-based pollutants including CO2, ammonia, hydrogen sulfide, and ozone precursors. RNG will only exacerbate the air pollution problem, not correct it.

In addition, even if the lifecycle greenhouse gas emissions of RNG were neutral, it does not address the climate change problem, which is the need to dramatically **<u>decrease</u>** our GHG emissions, not find ways to keep them constant. We need to stop burning carbon-based fuels and we need to increase plant sequestration of carbon, not harvest the plants so that their carbon can be re-emitted. Even if RNG were to become technically feasible, it is a bad choice of fuel and cannot be considered renewable in the same sense as solar, wind or tidal energy. The fossil fuel industry is only promoting RNG as renewable in order to greenwash their climate-destroying activities.

Proposed Model for Renewable Energy/Storage

Mr. Lyle Rawlings, President and CEO of Advanced Solar Products, has provided a high-level hybrid model based on using solar PV energy for the microgrid project during outages. The model is based on his best estimates from years of experience with solar energy and energy storage. It uses a combination of solar energy, battery storage and backup conventional generation to firm the total energy supply, which could be backup gas generators or tidal power. However, the gas-fueled generation would only be needed to power trains during emergency conditions when the commercial grid is down for more than a few hours, and solar PV generating capacity is limited due to suboptimal weather conditions. Under normal operating conditions, the solar/storage infrastructure would be used to sell power and provide revenue-generating ancillary services to the commercial grid.

Actual power need (MW)*	95
Estimated 24-hour average (MW)**	31.7
24-hour avg. after conservation/caps (MW)***	21.9
Daily energy need (daily avg. x 24) (MWh)	526
Firm load (MW)****	32
Battery size	76 MW/228 MWh
Solar size @ 67% of peak need (MW)^	97.1
Solar acres (2.5 acres/MW)	243
Solar cost ($M) ($1.5M/MW)	$146
Battery cost ($M)	$69.7

*The actual power need includes total power capacity for Amtrak's NorthEast Corridor (NEC) line, NJ Transit's Morris &Essex (M&E) line, and NJ Transit's Hudson-Bergen Light Rail (HBLR) system.
**The average power need over a 24-hour period is estimated to be 1/3 of the peak. This is used to calculate total daily power needed.
***The amount of power saved by the conservation and other measures described above in this document is estimated to be about 30%.
****The firm generation, which could be hybrid gas-fueled engines, or tidal energy, would provide power during periods of insufficient solar PV energy output during outages. It would respond to battery charge levels. When batteries have discharged to a certain level (e.g., 10%) it would turn on and run until batteries had reached an upper threshold (e.g., 90%). The total use of such power would be minimal. For example, if a 14-day outage occurred every 5 years and the generator was needed 40% of the time during the 14-day period, it would only run for 135 hours every 43,800 hours or .00003% of the time.
^ The amount of solar PV energy needed was computed as follows:

- 1 MW of solar capacity in New Jersey provides 1,325 MWh/year (3.63 MWh/day)
- Total MWh/day required is 526.
- Only 67% of this power is required to come from solar.
- Solar capacity required in MW = (526/3.63) X .67 = 97.1 MW

In this model, only 243 acres of solar panels would be needed. The area required for battery storage would be about an acre (Tesla Megapacks provide 250 MW/1 GWh on three acres).

This model was built without access to NJ Transit's confidential information on minute-by-minute traction power needs. If NJ Transit does not agree with the assumptions in this model, we would appreciate any additional information that it is willing to supply.

It is worth noting that nowhere in its APPENDIX D, did NJ Transit provide any hybrid models such as this, using a combination of existing synergistic technologies to truly assess the technical and economic viability of renewable energy and energy storage technologies.

Conclusion

The Don't Gas the Meadowlands Coalition has analyzed NJ TRANSIT's Combined Final Environmental Impact Statement/Record of Decision Appendix D – Scoping Alternatives Analysis. In this appendix, NJ TRANSIT attempts to demonstrate that renewable energy and storage technologies are not capable of providing the power, resilience and other attributes required for the NJTRANSITGRID TRACTION POWER microgrid. Our detailed analysis effectively disputes NJ TRANSIT's claims. NJ TRANSIT's analysis suffers from many flaws. A summary of our major conclusions is presented below:

- Overall, it does not utilize an engineered total solution that combines the synergies of multiple types of energy/storage to develop an optimal solution. Instead, it looks at each renewable energy technology in a "stove-pipe" fashion in order to find ways to demonstrate it is not feasible. Stove-pipe approaches produce much higher costs than necessary as they rely on single technology solutions to provide peak power.
- It does not consider any hybrid mix of renewable energy sources or a hybrid solution comprised of renewable energy with emergency backup fossil fuel generation. Such hybrid microgrids are state-of-the-art in the industry and have been demonstrated to be highly cost effective solutions that provide reliable and resilient solutions when commercial power is not available. As stated in our paper, hybrid design "*makes it more feasible and profitable to use renewable energy and storage while offering better economics than traditional gas-only power generation.* "
- It ignores recommended techniques for reducing step loads and power peaks. As recommended by NJ TRANSIT's own consultant, Jacobson, reducing peak power demands is an extremely effective means of reducing costs by avoiding the need to build excess capacity.
- These three flaws (stove-pipe use of technology, no consideration of a hybrid approach and a lack of peak power reduction techniques), produced a worst case scenario that no engineer would ever design. Apparently, this is the only way NJ TRANSIT can disprove the viability of renewable energy and storage technologies. This is not a professional, best practice approach and must be rejected by NJ TRANSIT management and Governor Murphy.

In addition to this fatally flawed approach, other problems with the analysis include:

- Its costs for solar power generation are based on data from 2012 and prior years for estimating the efficiency and cost of solar power when it is widely acknowledged that these factors are improving every year. As a result it grossly over estimates both the space required and cost of solar panels. In addition these costs are based on averages across diverse projects whose conditions may or may not apply to a solution specific to this project.
- It utilizes cost studies for storage that include only stand alone systems instead of using lower costs from the synergies of co-located integrated storage and power systems which are stated in NJ TRANSIT's source reference to be more effective. It also ignores recent improvements in storage costs due to containerization efficiencies.
- It ignores real estate it currently owns as viable locations for solar panels as well as large open areas and lagoons just north of the Koppers Coke peninsula as potential sites for solar panels. The hybrid model solution proposed in our paper shows much less need for space as well as much less need for battery capacity than NJ TRANSIT's estimates.
- It makes false statements indicating the size of the potential PV-plus-energy-storage system required would be larger than any others in existence, while one is being constructed now that would be 65% larger than the size required by NJ TRANSIT.
- NJ TRANSIT tries to demonstrate it will use renewable energy by citing the potential to burn bio gas, which is much dirtier than natural gas, will not reduce greenhouse gas emissions and would be even worse for the health and welfare of local residents.
- It ignores the potential to use tidal power from the adjacent Hackensack River.

In short, we believe that design of the optimal solution, (a hybrid microgrid using renewable energy, storage technologies and backup emergency fossil fuel or tidal power) is simply an engineering and economic challenge to determine the best mix of these capabilities. NJT's approach clearly has not been to look for an engineered solution to maximize the use of renewable energy. Instead, it has used "worst engineering practices" to find ways to demonstrate that it is not feasible. This is clearly not a professional, best practice approach.

Instead of undertaking futile efforts to prove what cannot be done, NJ TRANSIT must undertake a feasibility study (similar to the Sandia study of 2014) of a hybrid microgrid using renewable energy and storage, current best-cost estimates and best energy system design practices. Using that new study it should be able to develop an objective cost/benefit comparison of multiple alternatives. Without such a comparative analysis, and even setting aside all environmental concerns, NJ TRANSIT is not acting as a good steward of its Federal and NJ grant monies.

APPENDIX I: Potential Areas for Solar Panels

The image below shows some areas of interest, some water, some land. Only a small fraction of the area pictured would be necessary.

The small outline at the top is a landfill. Not outlined is PSE&G's Kearny landfill PV system, which you can see is adjacent to the tracks, just above the yellow pin labeled "Silverman". That building could accommodate a large array, too. The Kearny Point site itself is also outlined.

2.5 acres per MW is adequate area for PV arrays. That refers to usable area.

APPENDIX II: Nations' Use of Solar to Power Train Traction (Based on Online Information Sources)

Five nations – Austria, Belgium, Germany, India, and the United Kingdom -- are constructing, piloting or operating at least one rail line with traction power directly fed from solar (or wind) energy. This finding is based entirely on reviewing news posts online. Efforts to obtain direct information from railways' staff or any other reliable source with equivalent knowledge have not been successful to date,

1. Austria – solar-powered traction project

In December 2014, Austrian Federal Railways (commonly known as ÖBB) began a pilot project to determine if providing traction power directly into the rail system from a solar energy farm was feasible. News reports describe the solar power plant as the world's first one designed to provide 16.7 Hz traction power.

The rail line is the Eastern Railway, a two-track electrified line that runs from Vienna towards Hungary.

The solar power plant was built in Wilfleinsdorf in lower Austria along the train's route. It consists of 7,000 cubic meters of solar panels, with a total surface of 2 hectares, having an annual generating capacity of 1,100 MWh.

A new power inverter was developed to transform the solar energy output into single-phase 16.7 Hz traction power fed directly into the catenary (overhead line), reducing conversion and transmission losses to a minimum.

One post states, "The results of the first solar power plant are used for a roll out of solar power plants along the train's route in Austria." Another post states "Plans are to build further power plants in the future, which will provide green traction power from wind and solar energy."

Links:

- https://cleantechnica.com/2018/05/31/austrian-federal-railways-pilot-adds-pv-solar-generation-to-train-lines/
- https://uic.org/com/uic-e-news/538/article/results-from-3rd-edition-of-the-uic-global-rail-research-innovation-awards?page=modal_enews
- https://oevz.com/en/greenpeace-oebb-cooperation-100-per-cent-green-electricity-for-the-railway/

2. Belgium – solar and wind-powered traction projects

a. Solar energy

Although the language is less clear and does not include such phrases as "providing traction power directly into the rail system", some news posts appear to state that the 16,000 solar panels atop a 2-mile long rail tunnel built over a high-speed train line between Paris and Amsterdam that produce 3,300 MWh annually do just that.

"The first "green train"… its engines plugged into the solar energy source fitted along the line. The electricity produced feeds into the line's infrastructure, for lighting, signals and in-train power points,…"

"Trains gliding along the E19 highway in Belgium at about 180 miles per hour are drawing power from 2.1 miles of solar panels…. The tunnel's 3.3-megawatt solar roof now generates electricity for the railway's trains, signals and lights and helps heat stations, such as the nearby Antwerp Central Station."

Links:

- https://phys.org/news/2011-06-solar-tunnel-powers-paris-amsterdam-line.html
- https://www.zdnet.com/article/sun-powered-high-speed-rail-rises-in-europe/

b. Wind energy

In fall 2015, Belgium launched a project to partially power 170 passenger trains a day (named "sail trains") on 3 rail lines with wind energy from the Greensky wind turbines in Gingelom, Limburg province built along the main rail line between Leuven and Liege. The wind farm is connected to the railway installations through a high-voltage substation in Avernas. The remaining third of the wind energy is fed into the main electric grid. Once all 25 turbines are built, the wind farm is expected to produce 35,000 MWh.

Link:

- https://uic.org/com/uic-e-news/505/article/belgium-greensky-wind-farm-and-sail-trains-win-belgian-energy-and-environment?page=iframe_enews

3. Germany – solar-powered traction project

In January 2020, Deutsche Bahn, the German national railway's passenger service division, announced a power purchase agreement under which a developer would build and own a 42 MW solar power plant in Wasbek, in Schleswig-Holstein, eastern Germany, to supply power to be fed directly into DB's 16.7 Hz traction network via a converter substation in Neumünster. The plant is to produce about 38 GWh annually. Construction is set to start after the necessary land-use approvals are obtained.

Link:

- https://railway-usa.com/news/24265-db-to-feed-solar-power-directly-into-its-traction-network

4. India – solar and wind-powered traction projects

As part of a top-down intiative to make its railway system 100% green, India is working to fully electrify its railway system by 2023, powering train car interiors and stations with solar energy; and building renewables on 51,000 hectare of land alongside railway lines to directly provide 1 GW of solar energy and 200 MW of wind energy by 2021-2022 and 5 GW by 2030 for both traction and non-traction purposes.

The solar energy generated will be fed directly to a 25 kV AC traction system or to the grid.

"A proof of concept of feeding solar power directly to 25 kV AC traction system of 5 kVA capacity is already demonstrated."

Two pilot projects of 2 MW at Diwana (Haryana) and 1.7 MW at Bina (MP), which are already under different stages of execution and are likely to be completed by June 2020. "50 MW solar power at Bhilai (Chhattisgarh) is likely to be completed by March 2021. Another project of 400 MW solar power through Rewa Ultra Mega Solar (RUMS) is under bidding process."

Links:

- https://www.socialnews.xyz/2020/02/01/railways-to-generate-1000-mw-solar-power-by-next-year/
- https://sunshot.in/blogs/solar-for-indian-railways/
- https://www.business-standard.com/article/pti-stories/fm-proposes-solar-power-plants-along-rail-tracks-rlys-says-51-000-hectares-of-unused-land-available-120020101761_1.html
- https://www.eqmagpro.com/solar-power-for-traction-requirement/
- https://www.eletimes.com/renewable-resources-in-indian-railways-for-clean-and-green-environment

5. United Kingdom – solar-powered traction project

In early 2017, 10:10, Turbo Power Systems, Community Energy South, and Imperial College London's Energy Futures Lab started collaborating on a project to investigate using solar panels track-side for train traction power. They initially decided to focus on the third rail "to establish how to match the DC power of solar panels to DC railway lines without having to convert to AC in the middle."

In December 2017, the collaborators issued a report, Riding Sunbeams: Powering our railways with solar PV.

Its executive summary made these points:

- Solar PV can be directly connected to electrified railways to power trains (without having to connect to the main electrical grid), using specially-designed power electronics
- Small solar farms installed alongside Britain's electrified tracks could provide about 1/10th of the electricity needed to power trains on those routes annually
- Connection costs are competitive
- For railways, solar traction power would be cheaper than power supplied through the grid
- There are major opportunities to deploy direct traction power in the UK and other nations

The report dealt with a range of engineering challenges (including intermittency, traction DC voltage, the protection system, train operation, metering, track connection, converter design, energy storage technologies and sizing, and connection locations) – and the remaining barriers in the UK (product acceptance, contractual complexity, emerging technologies, stacking unknown value, insurance, and trackside constraints).

The report can be found at:
https://static1.squarespace.com/static/5c7014458dfc8ca9655f10c5/t/5c73e0bb7817f79f73b5c0ea/1551098050918/RidingSunbeams_Report_final.pdf

In August 2019, British charity Riding Sunbeams launched a solar energy pilot project, connecting 135 solar panels to an ancillary transformer on the traction system to power lights and signal equipment. The 10:10 and Riding Sunbeams will use the test data in order to design and test systems that directly can supply solar energy to the DC traction network. 10:10 already has started to implement another pilot project in Wales.

Links:

- http://www.imperial.ac.uk/news/176786/imperial-researchers-collaborate-project-supply-solar/
- https://www.theguardian.com/sustainable-business/2017/feb/15/solar-powered-trains-uk-india-renewables-tracks-electric
- http://files.1010global.org/documents/Riding_Sunbeams_1010.pdf
- https://www.solarpowerportal.co.uk/news/solar_could_directly_power_10_of_uks_electrified_train_routes_study_finds
- https://www.pv-magazine.com/2019/08/06/dont-have-a-node-for-your-solar-plant-connect-it-to-the-railway/
- https://www.railengineer.co.uk/2019/10/02/first-light-the-riding-sunbeams-trial-of-solar-powered-electric-traction/