Tufts University
Power Systems and Markets Research Group
School of Engineering
The Fletcher School

United States of America
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Date: October 26, 2020
Attn: Kimberly Bose, Secretary, Office of the Secretary
Subject: Technical Conference regarding Offshore Wind Integration in RTOs/ISOs (Docket No. AD20-18-000)

Ms. Bose:

The comments included herein were developed by a team of students and faculty mentors at Tufts University[1] in response to the Federal Energy Regulatory Commission (FERC) Docket No. AD20-18-000, which provides notice of the October 27, 2020 Technical Conference regarding Offshore Wind Integration in RTOs/ISOs.

Best regards,

Tufts Power Systems and Markets Research Group

Submission Contents

1 Any and all views expressed herein represent the opinions of Power Systems and Markets seminar participants and do not represent official positions of Tufts University or its Schools.

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1. INTRODUCTION

On October 14, 2020, the governors from Connecticut, Maine, Massachusetts, Rhode Island and Vermont issued a collective statement on electricity system reform. Governors Lamont, Mills, Baker, Raimondo, and Scott acknowledge that "a clean, affordable, and reliable regional electric grid – together with transparent decision-making processes and competitive market outcomes that fully support clean energy laws – is foundational to achieving our shared clean energy future."[2]

New England governors recognize the pressing need to work with federally-regulated grid operators to achieve clean energy goals and plan the regional transmission grid to support decarbonization. States are demonstrating critical leadership in driving climate objectives forward, but there are limits to what these officials can accomplish on their own, using the tools made available through the Regional Transmission Organization (RTO) tariffs.

As the governors rightly acknowledge, RTOs and Independent System Operators (ISOs) must mobilize into a proactive role, looking beyond established planning horizons and modus operandi for interconnection queues and transmission system planning. Furthermore, the role of the Federal Energy Regulatory Commission (FERC) is critical for setting new frameworks that act in concert with state climate objectives and facilitate the energy transition.

Our submission outlines the progress being made with respect to state offshore wind (OSW) commitments and project procurements. We focus on a review of RTO interconnection queues and the regional transmission topology. In light of the scale and speed of projected OSW development in the U.S., we advocate for proactive federal leadership around energy market reform, inter-RTO coordination and transmission planning, and the development of HVDC technology standards to stimulate the U.S. supply chain.

2. STATUS OF STATE COMMITMENTS AND WIND ENERGY AREAS

The U.S. Atlantic continental shelf is well recognized as having strong OSW energy resources that offer significant economic potential for the region. States that encourage this new U.S. industry are positioning to secure investments from developers as well as first-mover advantages related to establishing ports and manufacturing facilities.

State commitments to OSW have grown faster than expected, prompting a need to consider the full build-out capacity of existing Wind Energy Areas (WEAs) with respect to proposed procurement schedules, and bringing new focus to the transmission needed to enable this buildout. The Tufts Power Systems and Markets Research Group submitted an analysis of these topics to the New Jersey Board of Public Utilities (NJ BPU) in August 2020 in response to their information gathering docket on OSW transmission.[3]

Table 1 and Figure 1, originally from that submittal, show that approximately 9,000 megawatts (MW)[4] have already been procured from the 29,210 MW in state commitments. We estimate that the current lease areas have between

2 Baker, Charlie, Lamont, Ned, Mills, Janet, Raimondo, Gina, Scott, Phil. "New England's Regional Wholesale Electricity Markets and Organizational Structures Must Evolve for 21st Century Clean Energy Future." New England States Committee on Electricity (NESCOE). 14 Oct. 2020. Web. http://nescoe.com/wp-content/uploads/2020/10/Electricity_System_Reform_GovStatement_14Oct2020.pdf

3 Tufts Power Systems and Markets Research Group. "Subject: New Jersey Offshore Wind Transmission Information Gathering (NJBPU Docket No. QO20060463)." 28 Aug. 2020. https://createsolutions.tufts.edu/wp-content/uploads/2020/09/2020-08-28_NJ-BPU-Response-Tufts-Power-Systems-and-Markets.pdf

4 Offtake strategies are in place for 9,106 MW of offshore wind capacity, as shown in Table 1. Figure 1 takes a different approach to estimating that value, arriving at 8,400 – 8,900 MW of procured capacity. To develop the red areas shown in Figure 1, we conducted a spatial analysis of the WEAs, assuming uniform 1-nautical-mile grid spacing of turbines. Turbine capacities were set based on information from developers if publicly available. Otherwise, 12-MW turbines provide the lower-bound capacity estimate, and 15-MW turbines provide the upper-bound capacity estimate. Refer to our NJ BPU submittal (Footnote 3) for a full explanation and accounting.

17,500 – 21,900 MW of remaining available capacity (as shown by the yellow areas in Figure 1). States will struggle to hit their 2035 targets unless additional lease areas in the New York Bight are made available from the Bureau of Ocean Energy Management (BOEM). By 2022, it is likely that Massachusetts,[5] New York,[6] New Jersey,[7] and Maryland [8] will have collectively procured another 7,700 MW of new OSW capacity.

In order to make the build-out of OSW cost-efficient and timely, decision makers at all levels of government must look ahead in anticipation of what will come. States have led the way in driving the OSW industry forward. However, OSW projects will be built in federal waters, and transmission reinforcements will cross jurisdictions of all types. Federal agencies have a critical role to play in leading regional coordination, setting equipment standards for new technology, streamlining permitting processes, and facilitating appropriate market adaptations.

Table 1: State Commitments to Offshore Wind, Megawatts (MW)

State	Offshore Wind Capacity (MW)			Completed Procurements	Procurements Slated by 2022
	Committed [9]	Procured	Remaining		
Maine	12	12	0	*Aqua Ventus (12 MW)*	
Massachusetts	3,200	1,604	1,596	*Vineyard Wind (800 MW)* *Mayflower Wind (804 MW)*	1,600 MW [5]
Rhode Island	430	430	0	*Block Island (30 MW)* *Revolution Wind (400 MW)*	
Connecticut	2,300	1,104	1,196	*Revolution Wind (300 MW)* *Park City Wind (804 MW)*	
New York	9,000	1,826	7,174	*South Fork Wind (130 MW)* *Sunrise Wind (880 MW)* *Empire Wind (816 MW)*	2,500 MW [6]
New Jersey	7,500	1,100	6,400	*Ocean Wind (1,100 MW)*	2,400 MW [7]
Maryland	1,568	368	1,200	*MarWin (248 MW)* *Skipjack (120 MW)*	1,200 MW [8]
Virginia	5,200	2,662	2,538	*CVOW Pilot (12 MW)* *CVOW (2,650 MW)*	
Total	**29,210 MW**	**9,106 MW**	**20,104 MW**	**9,106 MW**	**7,700 MW**

Considering state goals to achieve a carbon neutral energy sector by 2050, it is not unreasonable to consider total OSW power procurements on the order of hundreds of gigawatts. It is with this perspective in mind that we encourage FERC to consider how near-term decisions will affect our pathway to 2050. In our opinion, now is the time to establish a common techno-economic-policy language that can allow decision makers and stakeholders to identify key issues, forge compromises, and move forward in a timely manner.

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5 Woodcock, Patrick C. “RE: Offshore Wind Energy Transmission under Section 21 of Chapter 227 of the Acts of 2018 (An Act to Advance Clean Energy).” Massachusetts Department of Energy Resources. 28 Jul. 2020. Web. https://www.mass.gov/doc/offshore-wind-transmission-letter-07-28-20/download

6 NYSERDA. “2020 Offshore Wind Solicitation (Open).” 21 Jul. 2020. Web. https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/Focus-Areas/Offshore-Wind-Solicitations/2020-Solicitation

7 New Jersey’s Clean Energy Program. “NJ Governor Phil Murphy Releases Offshore Wind Solicitation Schedule to Meet New 2035 Goals.” New Jersey Board of Public Utilities. 28 Feb. 2020. Web. https://njcleanenergy.com/nj-offshore-wind

8 Best, Amanda. “Re: Maryland OSW State Commitment and Procurement Schedule.” Message to Harry Warren. 26 Aug. 2020. E-mail.

9 American Wind Energy Association (AWEA). “U.S. Offshore Wind Industry: Status Update June 2020.” Jun. 2020. Web. https://www.awea.org/Awea/media/Resources/Fact%20Sheets/Offshore-Fact-Sheet.pdf

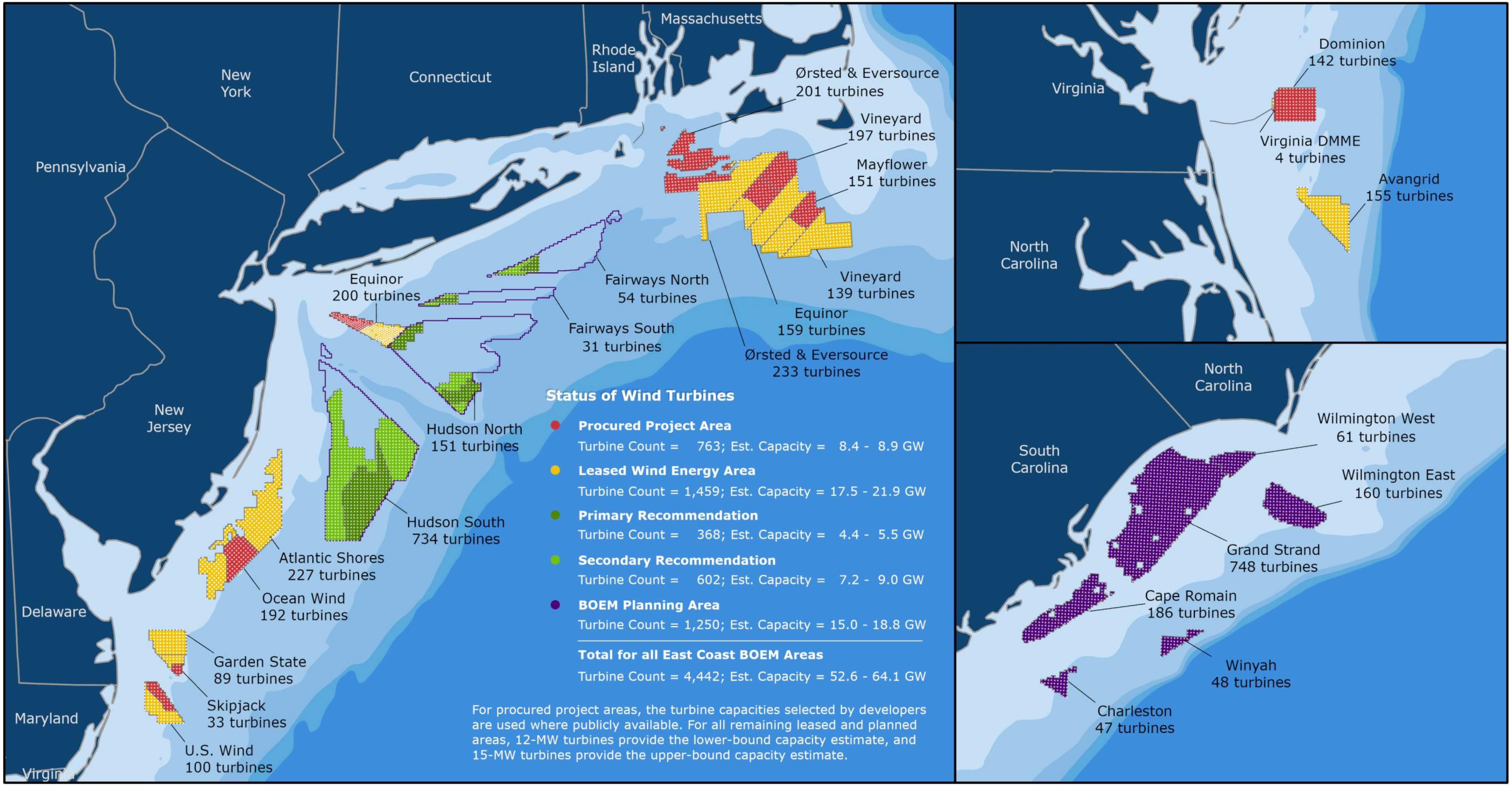

Figure 1: Turbine and Capacity Estimates for BOEM Wind Energy Areas and Reduced Call Areas

Total Estimated Capacity = 52.6 - 64.1 GW

August 27, 2020

3. NORTHEAST INTERCONNECTION POTENTIAL FOR OFFSHORE WIND

The future northeast electricity grid will require systems-level upgrades both onshore and offshore in order to reach ambitious state-level goals for carbon reduction and OSW procurement. Interconnections between the onshore and offshore grids must be built at unprecedented scale and speed along the U.S. Atlantic Coast. The slated OSW installations could easily overwhelm and congest the existing land-based grid, damaging the industry's reputation and short-changing its growth potential.

Studying the topology of the existing land-based grid is critical for envisioning build-out scenarios for OSW transmission. Each state and ISO has a unique history with its own assets and challenges.

3.1. Northeast Onshore Grid

The northeast transmission grid has a few dominant features that become apparent with the maps shown in Figure 2 and Figure 3. In ISO New England (ISO-NE), the highest voltage transmission lines crossing most of the region have a 345-kilovolt (kV) nominal line rating. These lines extend to the coasts of Connecticut, Rhode Island, and Massachusetts, but the number of 345-kV substations along the southern New England coast is relatively few.

A 2014 study commissioned by the Massachusetts Clean Energy Center (MassCEC) considered OSW interconnection to 345-kV substations only,[10] but developers have expressed interest in points of interconnection (POIs) with 115-kV maximum line ratings as well.[11] Nevertheless, 115-kV substations and below will likely require onshore upgrades earlier in the process than higher voltage lines and substations.

The three-phase surge-impedance loading (MW) for a high-voltage transmission line is related to the square of its nominal line voltage.[12] Surge impedance loading is used to predict the maximum loading capacity of transmission lines. Each step up in transmission line nominal voltage can move significantly more power. To transfer the power from large-capacity OSW projects (800 MW+), a POI would need a 345-kV line or multiple 115-kV lines in parallel.[12]

New York is the state with the most constrained coastal transmission infrastructure coupled with the most ambitious OSW commitment (9,000 MW by 2035).[9] Long Island is primarily served by 69-kV and 138-kV lines, and it has historically been at the receiving end of the power distribution network. The subsea transmission cables connecting Long Island to New Jersey and Connecticut highlight that it has historically been more feasible to serve Long Island's load from other states rather than build new onshore transmission across the congested, densely populated boroughs of New York City (see Figure 3). These challenges will undoubtedly come to bear as New York works towards its OSW procurement target.

Our assessment of regional transmission challenges includes parts of PJM, with a primary focus on New Jersey, which has announced an ambitious 7,500-MW state commitment,[9] as well as a clear procurement timeline.[7] Along the New Jersey coast and in the populous counties to the northeast of the state, most high voltage transmission infrastructure is 230 kV.

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10 ESS Group. "Offshore Wind Transmission Study Final Report." Massachusetts Clean Energy Center. Sep. 2014. Web.https://files.masscec.com/research/MassCECOSWTransmissionStudy.pdf

11 Massachusetts Clean Energy Center. Massachusetts Offshore Wind Transmission Technical Conference. 3 Mar. 2020, https://www.mass.gov/doc/technical-conference-slide-presentations-morning-session-hosted-by-masscec-pdf/download. PowerPoint Presentation, p. 15-18.

12 Mohan, Ned. "Electric Power Systems: A First Course." John Wiley & Sons, Inc. 2012. p. 69.

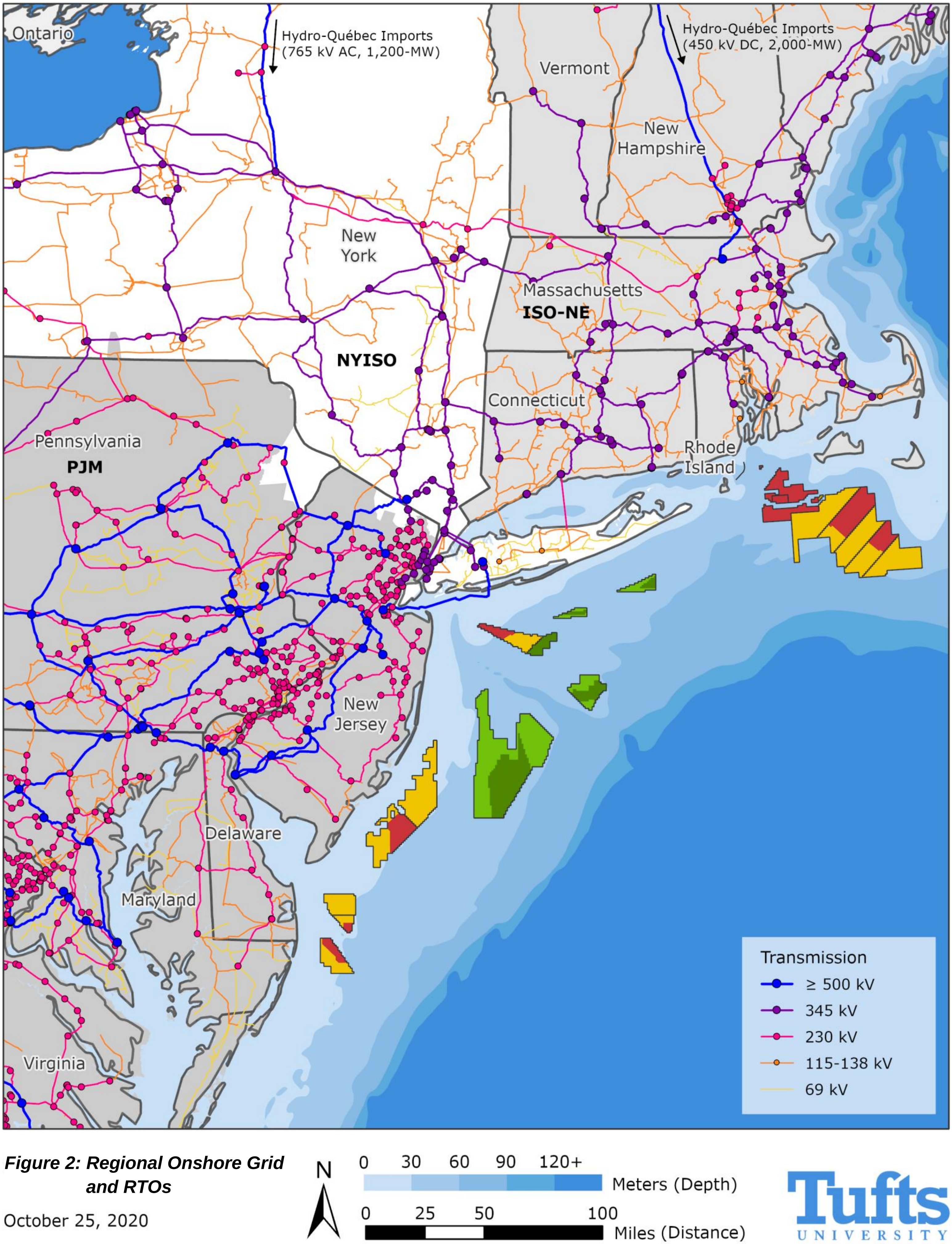

Figure 2: Regional Onshore Grid and RTOs

October 25, 2020

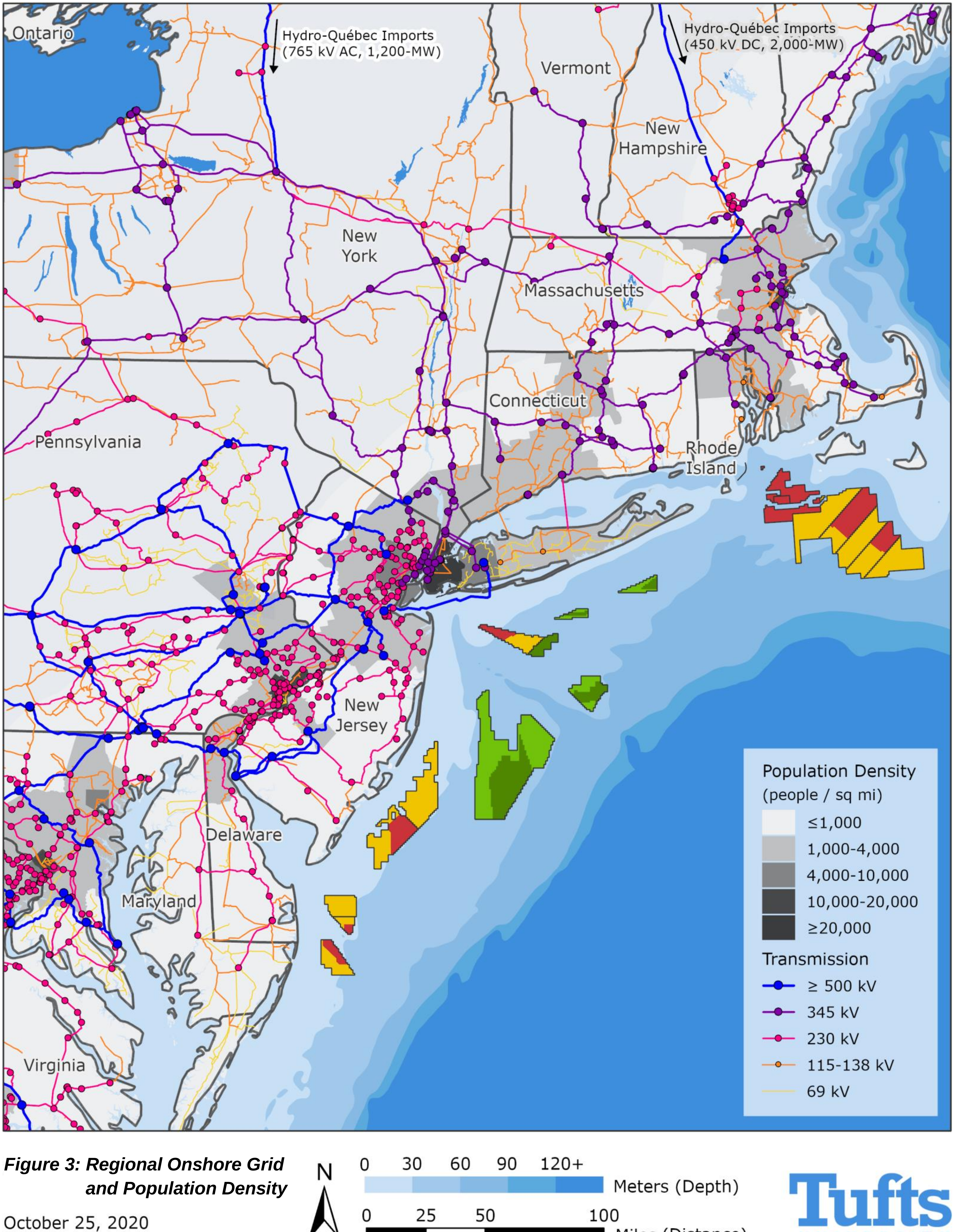

Figure 3: Regional Onshore Grid and Population Density

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Further inland, the system is more robust. The ring of 500-kV transmission that runs through Pennsylvania, New Jersey, Delaware, and into Maryland has its origins in the expansion of coal in western Pennsylvania, dating back to the late 1960s.[13] The initial 500-kV line ran from Keystone Generating Station in Shelocta, Pennsylvania east to Branchburg substation in central New Jersey.[13] The 500-kV ring also ties into the Salem-Hope Creek Complex, which operates along the Delaware Bay in southwest New Jersey. These lines transmit power throughout PJM and into the New York Metropolitan Area.

Also apparent in Figure 3 are two major lines entering NYISO and ISO-NE from Québec, Canada. The 765-kV line from Châteauguay, Québec to Marcy, New York was completed in 1978 and has the ability to import 1,200 MW of capacity.[14] The other line is a multi-terminal, 450-kV HVDC backbone importing up to 2,000 MW of capacity from James Bay in northern Québec to its southern-most terminus at the Sandy Hook Converter Station in Massachusetts.[15] The system build-out was split into two phases and took from 1983 to 1991 to complete.[16]

These major onshore transmission projects required approximately a decade to complete. Current OSW commitments are more than ten-fold the capacity of the Québec to Massachusetts HVDC system. If 29,210 MW of OSW is to be built within the next 15 years (see Table 1), the work to plan the system must start immediately, and the end result should be at least as technologically advanced, reliable, and well networked as the transmission infrastructure we depend on from prior decades.

Further analysis will extend down the Atlantic Coast to include Maryland, Virginia, and the Carolinas. The area that we have chosen to focus on for this submission is the nexus of ISO-NE, NYISO, and PJM. This nexus is an especially active and complex region for OSW.

3.2. ISO-NE, NYISO, and PJM Interconnection Queues

The public interconnection queues for ISO-NE, NYISO, and PJM provide useful lenses into new generation trends and preferences among OSW developers for the limited number of accessible and cost-effective POIs. Analysis of queue data is complicated by various developers' strategies: developers often study multiple interconnection options for one project or occupy multiple queue positions to secure competitive advantage for future procurement opportunities.[17] While more than half of all queue positions withdraw before an interconnection agreement is executed, the types and quantities of proposed generation in each RTO's interconnection queue reveal general industry trajectories.

The grey icons at the top of Figure 4 are scaled to show the relative size of each RTO's interconnection queue. These queue sizes correlate with each RTO's service population: ISO-NE serves 14.8 million people, NYISO serves 19.8 million, and PJM serves 65 million.[18, 19, 20] Despite the variation in population, each RTO has similar capacities of proposed OSW; the total OSW interconnection requests in each region are all between

13 PJM. "The Benefits of the PJM Transmission System." PJM Interconnection. 16 Apr. 2019. p. 15-16. Web. https://www.pjm.com/-/media/library/reports-notices/special-reports/2019/the-benefits-of-the-pjm-transmission-system.pdf

14 Hydro-Québec. "Exports to New York." Accessed 18 Oct. 2020. Web. https://www.hydroquebec.com/clean-energy-provider/markets/new-york.html

15 T&D World. "National Grid and ABB Celebrate 25th Anniversary of HVDC in New England." 20 Nov. 2015. Web. https://www.tdworld.com/overhead-transmission/article/20965931/national-grid-and-abb-celebrate-25th-anniversary-of-hvdc-in-new-england

16 Hydro-Québec. "Exports to New England." Accessed 18 Oct. 2020. Web. https://www.hydroquebec.com/clean-energy-provider/markets/new-england.html

17 FERC. "Standardization of Generator Interconnection Agreements and Procedures." Docket No. RM02-1-000; Order No. 2003. Page 31. 24 Jul. 2003. Web. https://www.ferc.gov/sites/default/files/2020-04/E-1_71.pdf.

18 ISO-NE. "Electricity Use." Key Grid and Market Statistics. Accessed 16 Oct. 2020. Web. https://www.iso-ne.com/about/key-stats/.

19 NYISO. "Who We Are." Accessed 16 Oct. 2020. Web. https://www.nyiso.com/who-we-are.

20 PJM. "2019 PJM Annual Report." p. 16. Accessed 16 Oct. 2020. Web. https://www.pjm.com/-/media/about-pjm/newsroom/annual-reports/2019-annual-report.ashx?la=en#:~:text=As%20the%20operator%20of%20the,people%20in%20the%20PJM%20region.

13,000 – 15,000 MW. This tight range shows that OSW developers are consistently applying for interconnection across all transmission zones up and down the U.S. Atlantic Coast. The pie charts in Figure 4 show the most recent five years of proposed generation by type in each of the three RTO interconnection queues.[21]

In 2020, ISO-NE's proposed generation capacity consists of almost two-thirds OSW. Since 2016, proposed OSW capacity has overtaken and effectively replaced proposed onshore wind capacity. OSW has also substantially outpaced the growing proposed solar capacity in ISO-NE. Despite the pause in OSW procurements since Connecticut awarded an 804-MW contract for Park City Wind in December 2019,[22] another 4,000 MW of OSW generation was proposed for study in the last year alone. Considering the previous growth in OSW from 2016 to 2020, ISO-NE will likely see further OSW interconnection applications when the next New England state procurement is announced.

In the NYISO queue, proposed OSW capacity has also overtaken onshore wind applications. The last two years have seen rapid proposed OSW capacity growth after New York's 9,000-MW OSW commitment in 2019.[9] Proposed onshore wind capacity has remained relatively constant over the last four years. Solar capacity has also seen substantial growth after New York stated commitments to 6,000 MW of solar and 3,000 MW of energy storage.[23] With the end of the wheel agreement between NYISO and PJM,[24] New York seems to be developing new approaches to inject power into New York City, such as aggressive build-out of OSW.

PJM serves a much larger population than NYISO or ISO-NE, and many of its load centers are inland rather than coastal. PJM also contains most of the Marcellus and Utica shale formations, which have driven the consistent dominance of the "Other" generation category across the last five years of PJM's interconnection queue. The progression of pie charts shows solar as the ever-growing, dominant renewable in PJM. However, growth in OSW is also apparent. In 2018, more proposed OSW generation was in the PJM queue (8,400 MW) than either NYISO (4,500 MW) or ISO-NE (4,100 MW). Since then, the capacity of OSW proposals has grown similarly across the three RTOs.

3.3. Inventory of Coastal POIs

RTO interconnection queues are a useful indicator of which POIs OSW developers find most attractive. Developers show preference for POIs that are close to shore and close to their project areas, since the length of subsea and onshore cable routes account for a significant share of generator lead line costs.

Current RTO practices attribute the cost of upgrading existing grid facilities to generators seeking interconnection, even though the resulting transmission upgrades may provide benefits to the system beyond an individual project. Transmission costs are bundled with other OSW project costs, which are recovered under state offtake agreements funded by ratepayers. The market dynamic of state procurements means that developers show preference for POIs that already service high-voltage lines and are well connected to the rest of the grid. Sites with retired or at-risk power plants are even more desirable because the onshore transmission infrastructure is already built to handle the nameplate capacity of a given plant.

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21 To synthesize Figure 4, the queue for each RTO was analyzed to capture annual snapshots from 2016 through 2020. All active queue applications as of July 31st of each year were considered to produce five representative snapshots from each RTO. Each row of pie charts has been scaled with respect to that row's peak total proposed generation, with the largest queue representing the full pie (year 2020 for ISO-NE and PJM; year 2019 for NYISO).

22 Vineyard Wind. "Vineyard Wind Selected to Deliver 804 MW of Clean Offshore Wind Power to Connecticut Electricity Customers." 5 Dec. 2019. Web. https://www.vineyardwind.com/press-releases/2019/12/5/vineyard-wind-selected-to-deliver-804-mw-of-clean-offshore-wind-power-to-connecticut-electricity-customersnbspnbsp

23 New York State. "Climate Act." Web. Accessed 17 Oct. 2020. https://climate.ny.gov/.

24 Giambusso, David. "NY and NJ Still Fighting over Wheel." Politico. 16 May. 2017. Web. https://www.politico.com/states/new-york/tipsheets/politico-new-york-energy/2017/05/ny-and-nj-still-fighting-over-wheel-007460

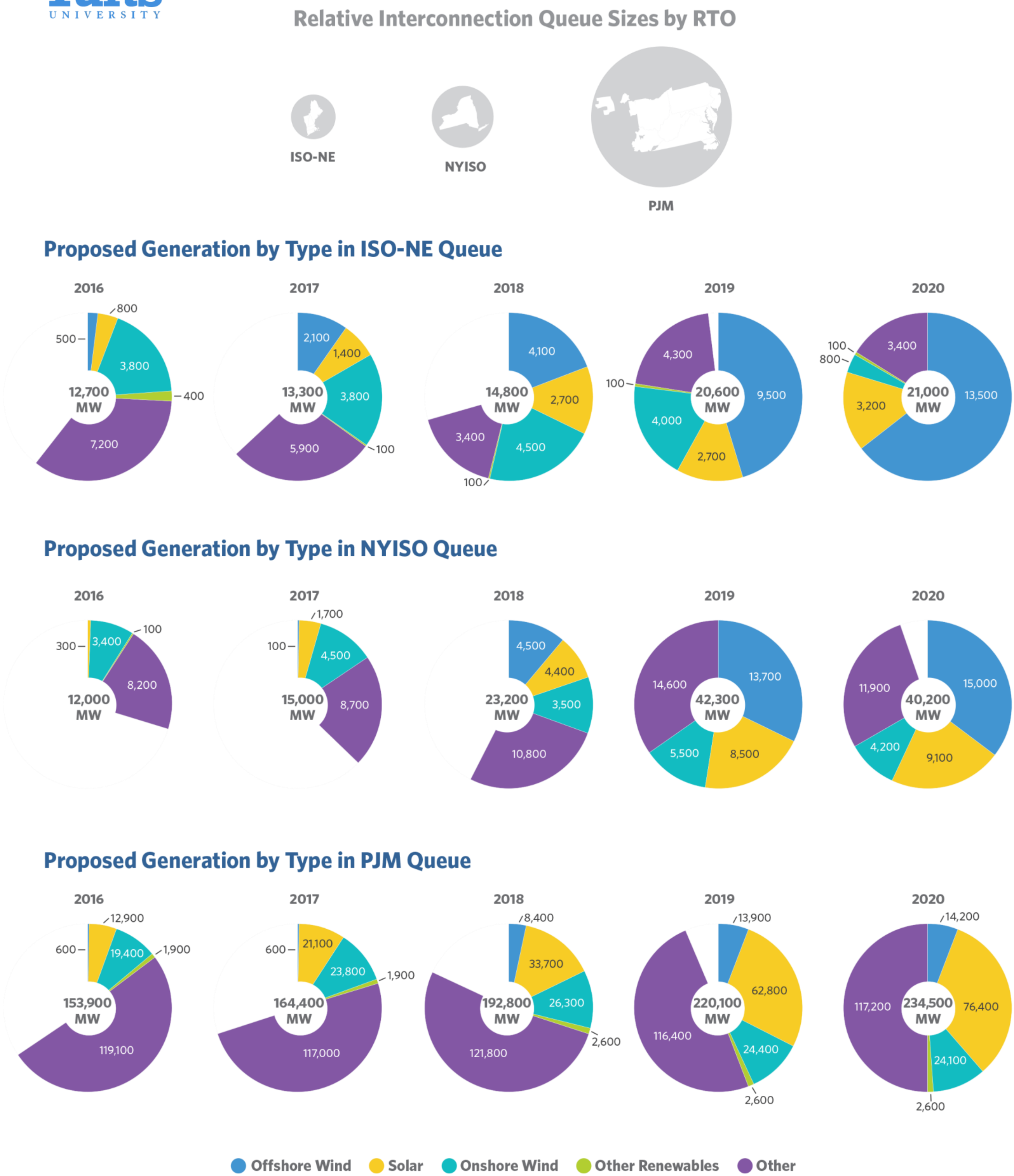

Figure 4: Interconnection Queues by Generation Type (ISO-NE, NYISO, and PJM)

The current practice of states selecting low-cost proposals using generator lead lines incentivizes developers to petition for the most desirable POIs during the first few rounds of state procurements. Considering these POIs as precious, limited, public resources, it is not hard to imagine how addressing the development of this new industry on a project-by-project basis can result in sub-optimal utilization of onshore resources. The size of each OSW project has more to do with state procurement decisions than with the limitations of existing onshore transmission infrastructure. As a result, a substation that can economically interconnect 2,000 MW of OSW may be selected for a single 800-1,200 MW project. In some instances, siting constraints may preclude more than one interconnection cable, eliminating a substation as a viable POI before its full potential can be utilized.[25]

The 2,400 MW of OSW procured by Massachusetts and Connecticut are poised to use all the available transmission capacity in the Cape Cod/Pilgrim area.[26] On October 21—just a few days ago—ISO-NE announced its intent to conduct a "Cape Cod Resource Integration Study" to assess at least five queue positions as a cluster.[27] The announcement acknowledges there are limits to how much power Cape Cod can export, and it further states that grid weaknesses and thermal issues between Cape Cod and Boston may only be resolvable through a new transmission line in its own right-of-way.[27]

Future developers (OSW or transmission) will be faced with an expensive choice: upgrade coastal substations already serving existing projects or interconnect further inland. It is our view that a planned, networked grid would improve the stewardship of existing POIs and facilitate systems planning that reduces conflict and confusion surrounding interconnection.

In an effort to develop a comprehensive list of coastal POIs from Massachusetts south to New Jersey, we reviewed recent queue data from ISO-NE,[28] NYISO,[29] and PJM [30] along with transmission and power plant spatial data from the Homeland Infrastructure Foundation-Level Data (HFLD).[31,32] All POIs on our list are substations within 10 miles of coastal waters, and each has a maximum voltage rating of at least 115 kV or is identified in an active queue position. Table 2 summarizes high-level information from this analysis, while detailed supporting tables listing all POIs are provided in the Section 5 attachment. Each of the three regions (ISO-NE, NYISO, and New Jersey/PJM) has roughly 20 OSW POIs.

Table 2 includes two different columns of capacity estimates derived using different methodologies. The column associated with operating (OP) or retired (RE) power plants *[Col. C]* aggregates the estimated capacity that each substation could accept if nearby power plants were to retire.[33] The reported 28,500-MW total *[Col. C]* is a low estimate because 22 of the 55 POIs do not have nearby power plants and therefore do not contribute to the total.

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25 Brattle, GE. "Offshore Transmission in New England: The Benefits of a Better-Planned Grid." 13 May. 2020. https://brattlefiles.blob.core.windows.net/files/18939_offshore_transmission_in_new_england_-the_benefits_of_a_better-planned_grid_brattle.pdf

26 ISO New England. "2019 Economic Study: Offshore Wind Integration." 30 Jun. 2020. Web. https://www.iso-ne.com/static-assets/documents/2020/06/2019_nescoe_economic_study_final.docx

27 ISO New England. "Notice of Initiation of the Cape Cod Resource Integration Study." 21 Oct. 2020. Web. https://www.iso-ne.com/static-assets/documents/2020/10/a6_initiation_of_the_cape_cod_resource_integration_study.pdf

28 ISO New England IRTT system. Generator Interconnection Queue. Accessed 8 Oct. 2020. Web. https://irtt.iso-ne.com/reports/external

29 New York ISO. NYISO Interconnection Queue 9/30/20. 15 Oct. 2020. Web. https://www.nyiso.com/documents/20142/1407078/NYISO-Interconnection-Queue.xlsx/b5d2d932-225a-10e6-5b45-075acb4fb4a9

30 PJM. New Services Queue. Accessed 10 Oct. 2020. Web. https://www.pjm.com/planning/services-requests/interconnection-queues.aspx

31 Homeland Infrastructure Foundation-Level Data (HIFLD). "Electric Substations." Accessed 9 Mar. 2020. Web. https://hifld-geoplatform.opendata.arcgis.com/datasets/755e8c8ae15a4c9abfceca7b2e95fb9a_0

32 Homeland Infrastructure Foundation-Level Data (HIFLD). "Power Plants." Accessed 9 Mar. 2020. Web. https://hifld-geoplatform.opendata.arcgis.com/datasets/power-plants?layer=0

33 This analysis includes operating (OP), at-risk, and retired (RE) power plants due to the difficulty associated with predicting when a power plant may retire or how a peaking plant could interact with the profile of an offshore wind project. In many cases, a "nearby" power plant may use the substation of interest as its own POI. In other cases, that information may be inferred from limited information. Best judgement was used in evaluating the topology and setting this criterion.

Figure 5 (ISO-NE), Figure 6 (NYISO), and Figure 7 (New Jersey/PJM) provide maps of the POIs. The numbers given in parentheses after some POI figure labels correspond to the total capacity of nearby power plants, if applicable *[Col. C]*. The names of the power plants can be found in the Section 5 tables.

The right-most column of Table 2 *[Col. E]* aggregated the capacity associated with all active OSW queue positions in each RTO. In Figure 5, Figure 6, and Figure 7, POIs that are shown with an underlying black star have one or more active queue positions proposing to interconnect OSW *[Col. E].* The Section 5 tables list the queue position numbers associated with the POIs.

Table 2: Summary of POI Analysis for ISO-NE, NYISO, and New Jersey (PJM)

Analysis Region/RTO *[Col. A]*	**Points of Interconnection** *[Col. B]*	**OP or RE Power Plant Capacity Near POIs** *[Col. C]*	**Active Queue Positions** *[Col. D]*	**Total Active OSW Queue Capacity** *[Col. E]*
ISO-NE	18	13,010 MW	20	16,372 MW
NYISO	20	8,040 MW	30	30,363 MW
New Jersey (PJM)	17	7,450 MW	12	7,711 MW
	55	**28,500 MW**	**62**	**54,446 MW**

Based on Table 2, New England appears to have promising POIs and an active queue. However, it is worth noting that approximately half of the total estimated POI capacity (13,010 MW) must be reached by cabling to western Connecticut or around Cape Cod to the Boston area. ISO-NE did not include New Haven or Bridgeport in its 2019 economic assessment of OSW interconnection potential.[26]

NYISO has the most active queue (30 positions totaling 30,363 MW) alongside the lowest estimated POI capacity (8,040 MW). New York POIs are concentrated on Long Island, where most lines have a maximum capacity of 138 kV. The queue activity in New York likely relates to the state's solicitation for up to 2,500 MW of OSW capacity, which closed to proposals on October 20, 2020.[34]

The proposed OSW capacity in the queue and the estimated POI capacity in New Jersey are roughly equivalent, and both are theoretically sufficient to meet the state's 7,000-MW procurement target. However, more than 70% of the 7,540 MW in estimated POI capacity comes from sites north of Oceanview or from the Salem-Hope Creek Nuclear Complex. No developers are pursuing interconnection to those regions, which indicates that active queue positions are slated to overload POIs along the southeast coast of New Jersey.

Our assessment of RTO queues and existing transmission infrastructure provides high-level insights into interconnection considerations facing the U.S. OSW industry, but it falls short of quantifying the actual interconnection capacity available in the onshore grid. Energy systems are complex and dynamic, and they are influenced by physical constraints as much as economic ones. Developing deeper insight into the system and planning for the future onshore-offshore grid calls for a comprehensive modeling effort.

34 NYSERDA. "2020 Offshore Wind Solicitation (Open)." 21 Jul. 2020. Web. https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/Focus-Areas/Offshore-Wind-Solicitations/2020-Solicitation

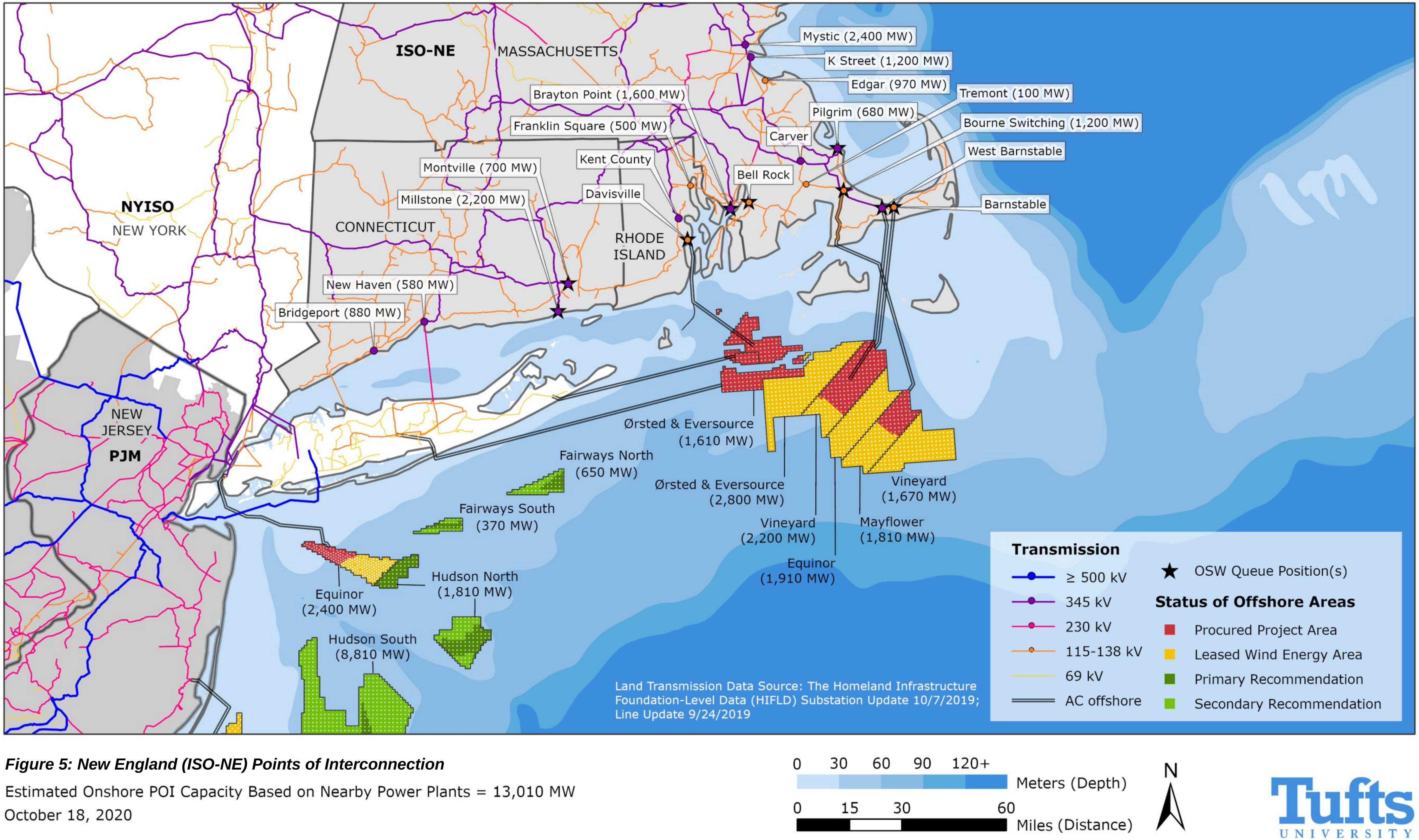

Figure 5: New England (ISO-NE) Points of Interconnection

Estimated Onshore POI Capacity Based on Nearby Power Plants = 13,010 MW

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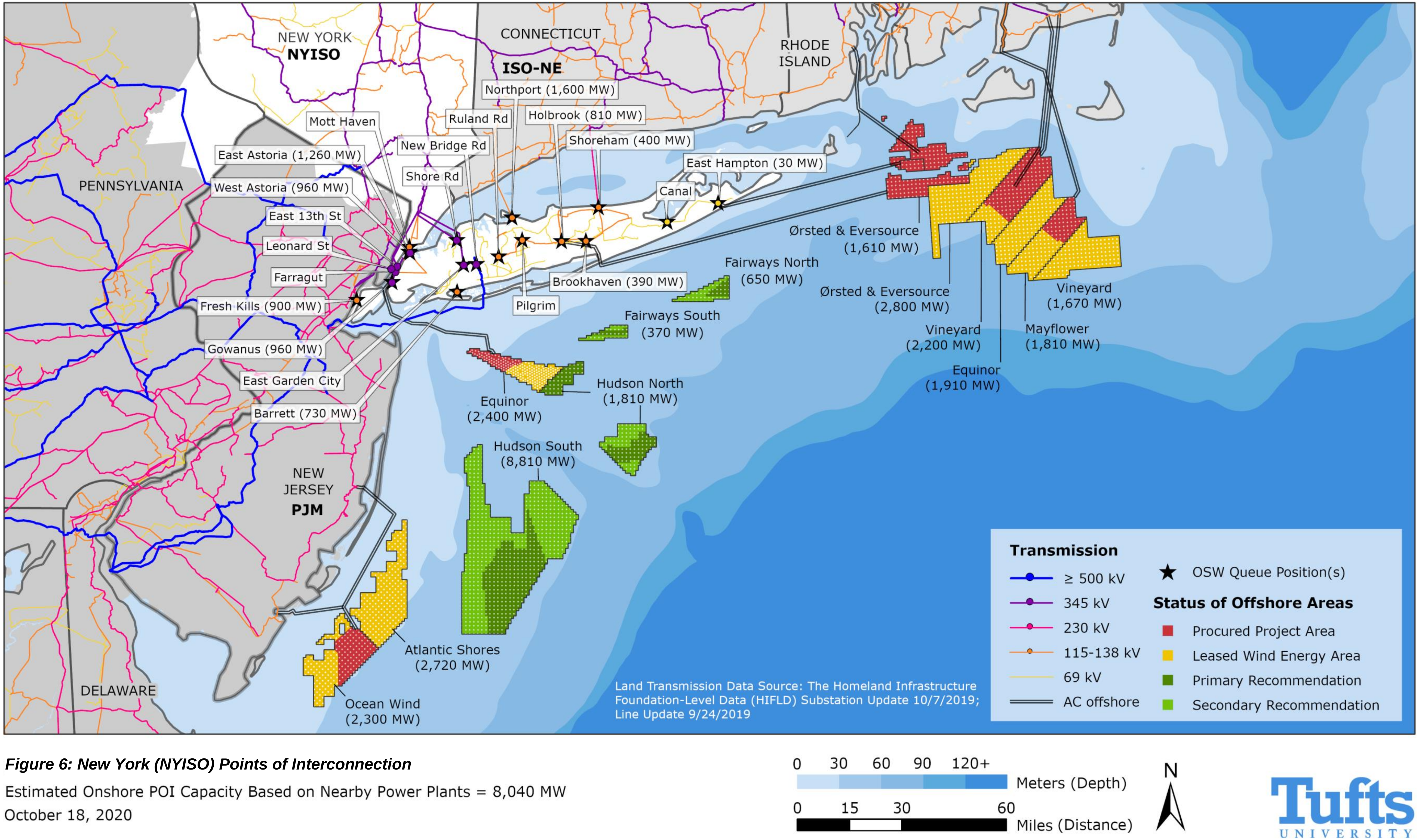

Figure 6: New York (NYISO) Points of Interconnection

Estimated Onshore POI Capacity Based on Nearby Power Plants = 8,040 MW

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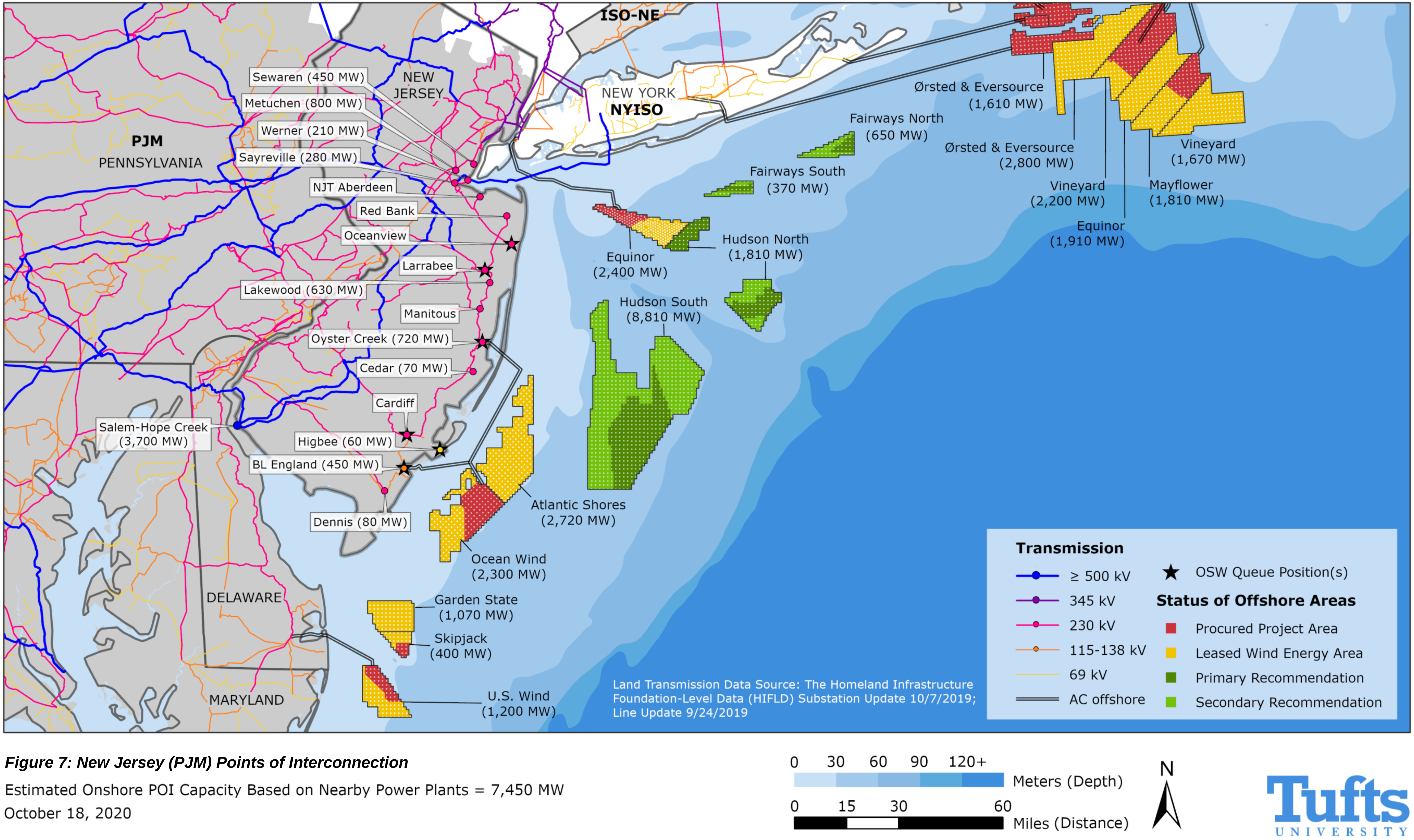

Figure 7: New Jersey (PJM) Points of Interconnection

Estimated Onshore POI Capacity Based on Nearby Power Plants = 7,450 MW

October 18, 2020

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3.4. Interregional Transmission Planning

Accepting the imperative to reach U.S. carbon neutrality by 2050, it is reasonable to imagine an OSW build-out that is an order of magnitude larger than current state commitments. Considering further the critical role that an offshore transmission network can play in the development of a U.S. macro-grid, efforts to modernize our grid could benefit substantially from a large-scale OSW power grid that provides high-capacity offshore connections between Atlantic Coast RTOs.

As Figure 2 shows, the U.S. OSW industry is launching at the nexus of three RTOs: ISO-NE, NYISO and PJM. The current rate of state OSW power procurements combined with the delay in finalizing and leasing the New York call areas (shown in green) means that New York procurements as early as this year will draw at least some power from offshore WEAs offshore MA/RI or NJ. The speed at which these interregional developments are occurring has outstripped even the most ambitious plans formulated two years ago.

To date, OSW grid integration studies have focused on specific regions with bundled radial transmission,[25,26,35,36,37] and there has not been a comprehensive study of a 30+ GW OSW build-out considering the effects of an offshore network on land-based transmission system upgrades. Regional studies have used accepted methods for simulating power flow, contingencies, and production cost, but each study has had its own focus area with its own research question. Without analyzing the same or comparable scenarios, these separate evaluations do not give a clear picture of what upgrades would best benefit the U.S. Atlantic Coast transmission system as a whole. Different analyses each tell a different portion of a larger story; in order to effectively make use of different models, a common language is needed to envision the future of the grid.

Transmission expansion planning (TEP) should form the basis for such a language. TEP requires several forms of analysis, such as power flow calculations, contingency and reliability testing, production cost under economic dispatch, and other specialized tools for modeling system performance. In the case of OSW, it also requires seabed analysis, routing obstacles, understanding competing use areas, wildlife impacts, and the assessment of feasibility on shore. What looks good on a load flow may not work in the real world. For example, the number of transmission cables that can be run into New York City is significantly constrained by geography. That counsels for the most to be made of each circuit put into the area, an unlikely result from radial interconnections trying to minimize per-project costs. If properly coordinated, these analyses could model the future of a deeply decarbonized grid and compare scenarios for full build-out of OSW resources along the U.S. Atlantic Coast. On the other hand, if these studies are not coordinated to assess the full build-out of OSW resources alongside accompanying transmission scenarios, they may miss critical externalities, guiding decision makers astray and costing ratepayers and coastal communities dearly.

A TEP model is a techno-economic model which would create a common language for envisioning both regional and interregional transmission upgrades under injection of OSW. With federal support, a TEP model could be applied to design the future of OSW transmission. By combining grid modeling, system performance, reliability analysis, economic modeling, and feasibility constraints, a TEP model would develop comprehensive insight into potential OSW transmission scenarios on an interregional scale. This information would clarify and promote

35 NREL. "The Potential Impact of Offshore Wind Energy on a Future Power System in the U.S." Jan. 2020. Web. https://www.energy.gov/sites/prod/files/2020/01/f70/74191.pdf

36 ABB Group. "National Offshore Wind Energy Grid Interconnection Study (NOWEGIS)" 31 Jul. 2014. Web. https://www.energy.gov/sites/prod/files/2014/08/f18/NOWEGIS%20Full%20Report.pdf

37 Pterra Consulting. "Study of Transmission Alternatives to Interconnect 9000 MW of Offshore Wind Generation in New York." 5 Aug. 2020. http://ny.anbaric.com/wp-content/uploads/2020/08/Pterra-Report-R161-20-New-York-Interconnection-of-9000-MW-Offshore-Wind-Rev-2.pdf

communication between stakeholders, regulators, and legislators, expand the criteria used in assessing large-scale transmission scenarios, and promote the best possible outcome for transmission development.

In their October 14, 2020 joint statement, the New England governors observed that "today's wholesale electricity market and organizational structures…lack a proactive transmission planning approach and tools that facilitate the development of a future system with more clean, dynamic, and distributed resources."[2] The tool necessary to facilitate this development would envision and simulate scenarios for transmission expansion planning to address the needs of OSW interconnection.

4. FEDERAL ROLE

Through conversations with established professionals across public, private, and non-profit sectors, we have come to recognize structural gaps in leadership and discourse around the energy transition. Elected officials are driving legislative change, but they lack the training and bandwidth to develop a deep technical understanding of the grid. Therefore, these officials rely on the skills and expertise of their government agencies, regulators, industry experts, and other engaged stakeholders. Meanwhile, the Public Utility Commissions (PUCs) and RTOs tend to see their authority in terms of regulating the current market. Regulator roles are defined by legislation, and decisions tend to be established on a project-by-project basis or, at best, by applying a regional view. States are establishing strong climate targets and mobilizing a new U.S. OSW industry. Energy markets, transmission planning, and transmission finance mechanisms all require reform in order to achieve deep decarbonization. In large states like California and Texas, much of this work can and has been accomplished at the state level. Atlantic Coast states are smaller and more congested, so collaboration between states and regions is essential to progress. Strong federal leadership fostering regional cooperation can make a difference.

4.1. Transmission Technology

Reliability, resilience, and redundancy are essential to a functioning grid and must be weighted similarly to short-term ratepayer benefits in any decision-making framework. Considering these objectives, it is our strong assessment that networked transmission systems offer several benefits over the generator lead line approach to OSW interconnection, creating an argument for system-wide planning. Networked transmission creates system redundancy which reduces the risk of stranded generation assets by offering power another route to shore when faults occur. In addition, a full build-out of the OSW resource with a networked system would channel the generated power into fewer transmission corridors, reducing impacts to the benthic environment. On the land side, a reduction in the number of export cables would likely translate to fewer landfall locations and less disruption to coastal communities.

By planning for interregional transmission, it is possible that OSW could become the impetus for a multi-terminal HVDC system. HVDC cables can move more power to shore on fewer cables and over greater distances than their HVAC counterparts.[38] Further, HVDC transmission provides less power loss per unit length than HVAC and does not require midpoint compensation for charging.[39] U.S. OSW generation developers have yet to publicly select HVDC for their export cable systems, but there are compelling reasons to choose it over HVAC. Networking OSW farms with DC technology would not require the same complex frequency regulation systems associated with AC technology. Under a proper regulatory framework, an offshore multi-terminal HVDC system could provide stability to the voltage and frequency of onshore grids. For example, contemporary voltage source converters

38 Brattle. "Offshore Wind Transmission: An Analysis of Options for New York." 6 Aug. 2020. Web. https://brattlefiles.blob.core.windows.net/files/19744_offshore_wind_transmission_-_an_analysis_of_options_for_new_york.pdf

39 HVAC lines can be extended via the use of midpoint compensation platforms, however the benefits of HVDC may still be realized in the case of networked systems.

provide approximately 400 MVAr for a 1,200-MW system. This critical voltage support allows more inverter-based generation to be integrated into the power system reliably.

HVDC manufacturers have developed products capable of meeting the demands of an interregional multi-terminal HVDC system. Table 3a shows the maximum rated power capacity and voltage for systems made by the two major HVDC manufacturers, which are well above the maximum contingency limits for the different RTO regions (shown in Table 3b). A single HVDC cable can deliver more capacity than three HVAC cables, and even more if single contingency limits do not apply. Recent developments in HVDC circuit breaker technology have achieved fast fault handling which will enable multi-terminal HVDC grids.[40] HVDC hardware has seen significant advancement in the last 30 years, and Voltage Source Converter (VSC) technology would equip OSW farms with black-start capability—a feature which, like voltage support, allows for the greater integration of renewables.

Table 3: Offshore Transmission Technology and Installation Assumptions

a. Regional Power Ratings HVDC and HVAC

Description	Value	Notes and Sources
Maximum HVDC line capacity (PJM)	1,350 MW	PJM single-sourced contingency limits[41]
Maximum HVDC line capacity (NYISO)	1,310 MW	NYISO single-sourced contingency limits[42]
Maximum HVDC line capacity (ISO-NE)	1,200 MW	ISO-NE single-sourced contingency limits[43]
Maximum HVAC (345 kV) line capacity	400 MW	PJM Training Presentation[44]

b. HVDC Manufacturer Specifications (2014)

Manufacturer	P Max	V Max
ABB [45]	2,600 MW	525 kV
Siemens [46]	2,200 MW	600 kV

Near-term standardization of the HVDC transmission industry in the U.S. would not only stimulate U.S. supply chain growth to support our domestic goals, but would also position the U.S. to compete in the future global market

40 ABB Grid Systems. "The HVDC Breaker: An Innovation Breakthrough Enabling Reliable HVDC Grids." Nov 2012. Web. https://library.e.abb.com/public/c9d5ba256e7e9671c1257ab6004b1feb/hybrid-hvdc-breaker---an-innovation-breakthrough-for-reliable-hvdc-gridsnov2012.pdf

41 Stefanowicz, Vince. "Real-Time Reserves." PJM Operating Committee. 1 May 2018. Web. Slide 10. https://pjm.com/-/media/committees-groups/committees/oc/20180501/20180501-item-33-real-time-reserves.ashx

42 Jain, Pallavi. "Ancillary Services Shortage Pricing." NYISO ICAPWG/MIWG. 27 April, 2020. Slide 16. https://www.nyiso.com/documents/20142/12170361/Ancillary%20Services%20Shortage%20Pricing%20MIWG%2004272020.pdf/9e1730e1-c8d2-33eb-b3c4-8e2e7574534a

43 ISO New England. "Single-Sourced Contingency." Operations Reports. Web. https://www.iso-ne.com/isoexpress/web/reports/operations/-/tree/single-src-cont.

44 PJM. "Transmission System Operations T01." 2014. Web PPT. https://www.pjm.com/~/media/training/nerc-certifications/TO1-transmissionops.ashx

45 ABB Grid Systems. "The New 525 kV Extruded HVDC Cable System." Aug 2014. Web. https://resources.news.e.abb.com/attachments/published/12792/en-US/D6D3A232A090/The-new-525-kV-extruded-HVDC-cable-system-White-PaperFINAL.pdf

46 Siemens. "Fact Sheet: High Voltage Direct Current Transmission." May 2014. Web. https://assets.new.siemens.com/siemens/assets/api/uuid:d5c5f4ae-d9f6-49e9-b68b-85bb7ceb4f41/factsheet-hvdc-e.pdf

that promises to grow throughout the energy transition. Appropriate voltages and power ratings should be standardized for components to allow developers to competitively source from any HVDC vendor and make the transmission system expandable. Additionally, standards and regulations ought to be established for system controls, communications, and protections.

4.2. Risks and Recommendations

Recent FERC rulings related to independent OSW transmission[47] and the interplay between state renewable incentives and existing capacity markets,[48] have profound impacts for the future of the northeast onshore-offshore grid and renewable energy more broadly. The June 18 transmission order missed an opportunity to adapt PJM merchant transmission requirements to recognize an OSW lease area as a control area.[47] A networked offshore grid will not develop organically under current frameworks, and this decision expresses a preference for a project-by-project approach with radial connections.

We ask FERC to recognize the scale of the future OSW build-out extending to 2050 and the need to plan the onshore-offshore grid. If this work is done proactively, the result can be a reliable offshore grid that provides added benefits by connecting onshore load centers, smoothing congestion, and lowering energy prices. New onshore transmission is difficult and time consuming to permit and build. POIs are valuable resources, and we can maximize their potential by being strategic about how they are used by industry.

While the first round of procurements and projects are critical to establishing the U.S. OSW industry, the long-term sustainability of this industry and the energy transition in general hinges on a long-term, interregional approach to transmission. We encourage FERC to look at full build-out of current and future WEAs with an eye toward how the system should function regardless of the limitations inherent to the current frameworks.

47 FERC. Docket No. EL20-10-000. Anbaric Development Partners, LLC v. PJM Interconnection, LLC. Order Denying Complaint. 18 Jun. 2020. https://www.ferc.gov/sites/default/files/2020-06/E-19-061820.pdf

48 FERC. Docket Nos. EL16-49-000, EL18-178-000. Calpine Corporation et al. v. PJM Interconnection, LLC. Order Establishing Just and Reasonable Rate. 19 Dec. 2019. https://cms.ferc.gov/sites/default/files/whats-new/comm-meet/2019/121919/E-1.pdf

5. ATTACHMENT – POI CAPACITY ANALYSIS TABLES

Table 4: ISO-NE Points of Interconnection

State	ISO-NE Point of Interconnection [31]	Town/City	Max kV Line	OP or RE Power Plant Capacity Near POI (MW) [32]	Active Queue Positions [28]	Active Queue Capacity (MW)
MA	Mystic	Boston	345 kV	2,400		
				Mystic Generating Station – At Risk – 2,400		
MA	K Street	Boston	345 kV	1,200		
				Edison Power Plant – Retired – 760		
MA	Edgar	Weymouth	115 kV	970		
				Potter Station 2 – At Risk – 220 *Fore River Generating Station – Operating – 750*		
MA	Pilgrim	Plymouth	345 kV	680	1	1,200
				Pilgrim Nuclear Power Station – Retired – 680	*QP 1059*	*1,200*
MA	Carver	Carver	345 kV			
MA	Bourne Switching	Bourne	115 kV	1,200	2	1,200
				Canal Power Plant – Operating – 1,200	*QP 829* *QP 922*	*1,000* *200*
MA	West Barnstable	Barnstable	345 kV		3	2,576
					QP 700 *QP 806* *QP 830*	*820* *880* *876*
MA	Barnstable	Barnstable	115 kV		2	800
					QP 624 *QP 955*	*800* *(CNR) 0*
MA	Tremont	West Wareham	115 kV	100		
				SEMASS MSW – Operating – 100		
MA	Bell Rock	Fall River	115 kV		1	880
					QP 909	*880*
MA	Brayton Point	Somerset	345 kV	1,600	4	3,240
				Brayton Point Power Station – Retired – 1,600	*QP 618* *QP 837* *QP 846* *QP 944*	*800* *1,200* *40* *1,200*
RI	Franklin Square	Providence	115 kV	500		
				Manchester Street Power Station – Operating – 500		
RI	Kent County	Warwick	345 kV			
RI	Davisville	North Kingston	115 kV		2	871
					QP 781 *QP 926*	*704* *167*
CT	Montville	Uncasville	345 kV	700	2	2,005
				Montville Power Station – At Risk – 700	*QP 792* *QP 927*	*805* *1,200*
CT	Millstone	Waterford	345 kV	2,200	3	3,600
				Millstone Nuclear Power Station – Operating – 2,200	*QP 893* *QP 1058* *QP 1060*	*1,200* *1,200* *1,200*
CT	New Haven Harbor	New Haven	345 kV	580		
				New Haven Harbor Power Station – Operating – 580		
CT	Bridgeport Harbor	Bridgeport	345 kV	880		
				Bridgeport Harbor Power Station – Operating – 880		
	ISO-NE Totals			**13,010 MW**	**20**	**16,372 MW**

Table 5: NYISO Points of Interconnection

State	NYISO Point of Interconnection [31]	Town/City	Max kV Line	OP or RE Power Plant Capacity Near POI (MW) [32]	Active Queue Positions [29]	Active Queue Capacity (MW)
NY	East Hampton	East Hampton	69 kV	30	2	136
				East Hampton Power Station – Operating – 30	*QP 612* *QP 695*	*96* *40*
NY	Canal	Hampton Bays	69 kV		1	440
					QP 764	*440*
NY	Shoreham	Brookhaven	150 kV	400	1	1,300
				Shoreham Energy – Operating – 100 *Wading River – Operating – 300*	*QP 1021*	*1,300*
NY	Brookhaven	Yaphank	138 kV	390	1	880
				Caithness Long Island Energy Center – Operating – 390	*QP 765*	*880*
NY	Holbrook	Ronkonkoma	138 kV	810	3	2,854
				Richard M. Flynn Power Plant – Operating – 160 *Holstville – Operating – 650*	*QP 766* *QP 987* *QP 1045*	*880* *924* *1050*
NY	Pilgrim	Smithtown	138 kV		2	2,728
					QP 1011 *QP 1058*	*1,403* *1,325*
NY	Northport	Huntington	115 kV	1,600	1	1,300
				Northport Power Station – Operating – 1,600	*QP 1020*	*1,300*
NY	Ruland Road	Huntington	138 kV		3	1,816
					QP 680 *QP 738* *QP 792*	*700* *816* *300*
NY	New Bridge Road	Hempstead	345 kV		1	1,325
					QP 1057	*1,325*
NY	East Garden City	Hempstead	345 kV		3	3,608
					QP 788 *QP 1010* *QP 1056*	*880* *1,403* *1,325*
NY	Shore Road	Glen Head	345 kV		1	1,300
					QP 1022	*1,300*
NY	Barrett	Hempstead	UNK	730	3	3,700
				E.F. Barrett Power Station – Operating – 730	*QP 958* *QP 959* *QP 1087*	*1,000* *1,500* *1,200*
NY	Mott Haven	Bronx	UNK		1	1,400
					QP 1066	*1,400*
NY	Astoria East	New York	345 kV	1,260	1	1,300
				Astoria Energy I and II – Operating – 1,260	*QP 1017*	*1,300*
NY	Astoria West	New York	138 kV	960	1	1,300
				Astoria Generating Station – Operating – 960	*QP 1016*	*1,300*
NY	East 13th	New York	345 kV			
NY	Leonard Street	New York	345 kV			
NY	Farragut	Brooklyn	345 kV			
NY	Gowanus	Brooklyn	345 kV	960	4	4,096
				Gowanus Generating Station – Operating – 640 *Narrows Generating Station – Operating – 320*	*QP 679* *QP 737* *QP 767* *QP 789*	*1,200* *816* *1,200* *880*
NY	Fresh Kills	Staten Island	138 kV	900	1	880
				Arthur Kill Generating Station – Operating – 900	*QP 790*	*880*
	NYISO Totals			**8,040 MW**	**30**	**30,363 MW**

Table 6: New Jersey (PJM) Points of Interconnection

State	PJM Point of Interconnection [31]	Town/City	Max kV Line	OP or RE Power Plant Capacity Near POI (MW) [32]	Active Queue Positions [30]	Active Queue Capacity (MW)
NJ	Sewaren	Elmer	230 kV	450		
		Sewaren Generating Station – Operating – 450				
NJ	Metchuen	Edison	230 kV	800		
		Woodbridge Energy Station – Operating – 800				
NJ	Sayreville	Sayreville	230 kV	280		
		Sayreville Generating Station – Operating – 280				
NJ	Werner	South Amboy	230 kV	210		
		Werner Generating Station – Retired – 210				
NJ	NJT Aberdeen	Matawan	230 kV			
NJ	Red Bank	Red Bank	230 kV			
NJ	Oceanview	Neptune City	230 kV		2	1,326
					AE1-238 *AF1-222*	*816* *510*
NJ	Larrabee	Howell	230 kV		2	1,327
					AE2-024 *AE2-025*	*882* *445*
NJ	Lakewood	Lakewood	230 kV	630		
		NAEA Lakewood – Standby – 250 *NAEA Ocean Peaking – Operating – 380*				
NJ	Manitous	Toms River	230 kV			
NJ	Oyster Creek	Forked River	230 kV	720	2	1,616
		Oyster Creek Nuclear – Retired – 630 *Forked River – Operating – 90*			*AE1-020* *AF1-101*	*816* *800*
NJ	Cedar	Cedar Run	230 kV	70		
		Cedar Station – Retired – 70				
NJ	Cardif	Egg Harbor	230 kV		4	2,710
					AE2-020 *AE2-021* *AE2-022* *AE2-251*	*605* *605* *300* *1,200*
NJ	Higbee	Atlantic City	69 kV	60	1	300
		Missouri Avenue Station – Retired – 60			*AE2-222*	*300*
NJ	BL England	Marmora	138 kV	450	1	432
		BL England Generating Station – Retired – 450			*AE1-104*	*432*
NJ	Dennis	Ocean View	230 kV	80		
		Middle Energy Center – Retired – 80				
NJ	Salem-Hope Creek	Hancocks Bridge	500 kV	3,700		
		Salem Nuclear Generating Station – Operating – 1,300 *Hope Creek Nuclear Generating Station – Operating – 2,400*				
	New Jersey (PJM) Totals			**7,450 MW**	**12**	**7,711 MW**

6. CONTRIBUTORS

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Aleksandar Stanković, Ph.D., F.IEEE, is the Alvin H. Howell Professor of Electrical Engineering at Tufts University. Dr. Stanković has over 30 years of experience in power systems engineering and control. He has chaired the Power Systems subcommittee of the Institute for Electrical and Electronics Engineers (IEEE) Power Engineering Society and served as a distinguished lecturer for the IEEE Circuits and Systems Society. He has edited the IEEE transactions of Smart Grids and co-edited a book series on Power Systems and Power Electronics for Springer. His work on power system stability and grid blackouts has over 2000 citations, making him one of the most sought-after voices on grid reliability in the Northeastern United States. Dr. Stanković completed his undergraduate and masters work at the University of Belgrade and holds a Ph.D. from MIT.