Offshore Wind Transmission Systems

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Learning from the Experts

This webinar series is hosted by NYSERDA’s offshore wind team and features experts in offshore wind technologies, development practices, and related research.

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The views and opinions expressed in this presentation are those of the presenter and do not represent the views or opinions of NYSERDA or New York State.
Content

- **Background**
  - U.S. Offshore Wind Generation Contracted and Committed
  - New York OSW Context

- **Offshore wind transmission**
  - Transmission configurations
  - Advantages of gen-ties vs. planned transmission
  - Case studies: NJ, UK, New England, NY
  - Risk mitigation

- **Takeaways**
Major technological advances are reducing the cost of OSW generation

Issues & Opportunities: Technology & the Growth of the Wind Turbine
Substantial off-shore wind generation planned and needed in eastern U.S.

Thousands of MW of new clean resources will need to be built to achieve state decarbonization goals—including substantial offshore wind beyond the 30,000 MW of current commitments.

A key challenge: **ensuring a pathway low-cost, low-impact solutions** for delivering offshore wind energy to onshore grid and population centers.

<table>
<thead>
<tr>
<th>Region</th>
<th>Already Contracted</th>
<th>Total Committed</th>
<th>Potentially Needed</th>
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<tbody>
<tr>
<td>New England</td>
<td>3,120 MW</td>
<td>5,900 MW</td>
<td>25-40,000 MW by 2050</td>
</tr>
<tr>
<td>New York</td>
<td>4,316 MW</td>
<td>9,000 MW</td>
<td>10-25,000 MW by 2040</td>
</tr>
<tr>
<td>Mid-Atlantic</td>
<td>4,129 MW</td>
<td>13,900 MW</td>
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PSC and NYSERDA completed the Initial Report on **New York Power Grid Study (PGS)**, which consists of three components:

- **Utility Study**: local transmission and distribution (LT&D) needs; advanced grid technologies
- **Offshore Wind (OSW) Study**: bulk transmission to integrate 9,000 MW of offshore wind
- **Zero Emissions Study**: bulk transmission, generation, and storage needed to achieve 70% renewable generation by 2030 and a zero emissions grid by 2040

Map from NYISO 2019 CARIS Report

See: Full [PGS Report](#) and Summary [Presentation](#)
New York PGS: Substantial Renewable Generation and Storage Needs

Analyzed transmission, generation, and storage needed to meet NY’s goals of zero-emission electricity by 2040 and 70% renewable generation by 2030 (drawing on New York Decarbonization Pathways Study)

**2040 Results:**

- Installed capacity more than double today’s
- **10-15 GW each: onshore wind, offshore wind, solar, and storage**
- Ideally developed in certain areas:
  - Onshore wind primarily in western and northern NY (NYISO Zones A-F)
  - Offshore wind downstate (I, J, K)
  - Solar in central NY
  - Storage in central and downstate NY
- **17 GW of “thermal” backup generation fueled by renewable natural gas (as placeholder for future technologies)**
- **By 2040, congestion and curtailments point to the potential need for cost-effective bulk transmission upgrades into downstate, NYC, and Long Island**
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What will a cost-effective OSW transmission solution look like for the Eastern U.S.?

Transmission Elements for Integrating Offshore Wind Generation

- Upgrades to existing grid
- Onshore link to existing grid
- Offshore substation (and links, if any)

Source: Why 2020 Has Been a Surprisingly Good Year for US Offshore Wind | Greentech Media
Transmission Planning Challenges for Offshore Wind Generation

The ISOs “generation interconnection” processes are workable for connecting offshore wind with individual gen ties

- Though ISOs existing generation interconnection study processes are challenging
  - Generators face long study timelines and highly uncertain network upgrade costs
  - Queue-based processes can reduce competition among OSW developers
- Does not work well for large-scale OSW developments and offshore grids

ISO “regional transmission planning” processes often not ready to develop cost-effective plans for offshore grids in a timely fashion

- ISO regional planning processes are time consuming and often ineffective
  - Frequently undefined for addressing public policy needs
  - Exception: NYISO’s public-policy transmission planning process (PPTPP)
- Limited ISO and stakeholder expertise with “wet” transmission facilities and offshore transmission technology options
- Developing a cost-effective offshore grid would require:
  - Phased-in plan that aligns timing of transmission investments with generation development
  - Coordinated planning and permitting to mitigate environmental impacts and project risks
  - Capturing synergies: offshore transmission to reinforce the on-shore grid
### Offshore Transmission Concepts

**Radial Tie Lines**
Transmission links bundled with individual OSW plants

**Meshed Generation Ties**
Individual tie lines to shore linked through offshore transmission

**Shared Collector Station**
Planned transmission tie lines for multiple OSW plants

**Backbone Offshore Grid**
Planned transmission tie lines for multiple OSW plants

**Gen ties vs. “planned” OSW transmission alternatives:**

- **Radial generator tie lines** built by OSW generation have been the prevailing approach for early rounds of OSW procurements
  - Initially reduces project-on-project risk through joint G+T planning and development

- **Planned OSW transmission** allows for the long-term optimization of offshore and onshore transmission
  - Mitigates environmental impacts and reduces overall costs for generation, OSW transmission, and onshore upgrades
Example: PJM’s current solicitation of OSW transmission for New Jersey

- Solicitation for transmission solutions for NJ’s public policy need to integrate up to 7,500 MW of OSW generation (net of previous and ongoing procurements)
- Responses can address individual elements (Options 1a-3) or offer complete solutions
- Scale of solicitation hoped to yield more attractive solutions compared to interconnecting individual generators through PJM’s GI process

Illustration of “Options”

Option 1a - Onshore Upgrades on Existing Facilities

Option 1b - Onshore New Transmission Connection Facilities

Option 2 - Offshore New Transmission Connection Facilities

Option 3 - Offshore Network

Source:
https://www.pjm.com/planning/competitive-planning-process.aspx
Choosing between gen-ties and planned OSW transmission solutions

<table>
<thead>
<tr>
<th>Factors favoring <strong>gen ties</strong> to individual offshore wind plants</th>
<th>Factors favoring <strong>offshore grids</strong> to serve multiple wind plants</th>
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</thead>
<tbody>
<tr>
<td>▪ Modest total development and small incremental steps</td>
<td>▪ Large size of total wind generation commitment with sizable procurement steps</td>
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<tr>
<td>▪ 400 MW per HVAC circuit only?</td>
<td>▪ 1600 MW per HVDC circuit within a few years?</td>
</tr>
<tr>
<td>▪ Modest distance from shore</td>
<td>▪ Several plants close to each other but long distances from shore or from sufficiently-robust onshore transmission nodes</td>
</tr>
<tr>
<td>▪ Less than 40 miles?</td>
<td>▪ Greater than 40 miles?</td>
</tr>
<tr>
<td>▪ Many landing points with robust on-shore transmission</td>
<td>▪ More efficient use of scarce right-of-way</td>
</tr>
<tr>
<td>▪ Requires 4 HVAC circuits for every 1,600 MW of total OSW development?</td>
<td>▪ Few landing points with robust on-shore transmission</td>
</tr>
<tr>
<td>▪ Long distances between offshore locations to be interconnected</td>
<td>▪ Difficult permitting of landing points and onshore interconnection study process</td>
</tr>
<tr>
<td>▪ Uncertain OSW lease areas</td>
<td>▪ Network benefit (offshore redundancy and reinforcement of on-shore grid)</td>
</tr>
<tr>
<td>▪ Easy permitting of landing points and interconnection studies</td>
<td>▪ Create more competition for wind developers through open access to offshore hubs</td>
</tr>
<tr>
<td>▪ Wind developer has significant offshore transmission experience</td>
<td>▪ Create competition between experienced offshore transmission developers</td>
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Potential benefits of **planned** offshore transmission

Our studies of OSW transmission alternatives and found that well-planned transmission (and procurement) can offer substantial advantages

<table>
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<tr>
<th>Elements examined</th>
<th>A planned approach can...</th>
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| **Total onshore + offshore transmission**  
  • Onshore transmission upgrades | Lower overall long-term costs  
  • **Substantially lower onshore costs** and project development risks  
  • Slightly higher offshore costs |
| **Offshore transmission** | |
| **Losses over offshore transmission** | Reduced losses |
| **Impact to fisheries and environment** | **Possibly substantially lower impacts** |
| **Effect on generation & transmission competition** | Increased competition |
| **Utilization of constrained landing points** | Improved landing point utilization |
| **Enabling third-party customers** | Improved third-party participation |

Examples: Brattle-Anbaric OSW transmission studies for [New York State](#) and [New England](#)

Initial **NY Power Grid Study**: routing 5-7 GW of OSW into NYC with high-capacity HVDC lines (that can be meshed to increase reliability) offers the best solution
Example: UK study of current and “integrated” OSW transmission approach

Results: if planning for 18,000 MW of new OSW generation during 2025-30 (and 41,000 MW during 2030-50) starts now, the “integrated” solution reduces estimated transmission costs by 19% and the number of landing points by 50-70%. Delaying planning by only 5 years reduces 2050 benefits by half.

Source: download (nationalgrideso.com)
Reducing the number of offshore platforms, cabling, seabed disturbance, and cables landing at the coast reduces impacts on existing ocean uses and marine/coastal environments to the greatest practical extent.

Avoiding high costs of onshore upgrades reduces total costs and risks ... with estimated savings of $0.5 billion (approx. 10%).
Planning ahead avoids expensive and time-consuming onshore transmission upgrades

Already-selected New England projects connecting to Cape Cod face up to $787 million in onshore transmission upgrades, and continuing this approach for even the next 3600 MW of procurements could lead to an additional $1.7 billion in onshore upgrades.

Planned off-shore transmission can significantly reduce the necessary onshore upgrades.

Given the difficulty of permitting and building new onshore transmission, a planned approach also reduces the risk of cost overruns and delays.

Source of figure: GE analysis for Anbaric.

* ISO-NE’s Feasibility Study for interconnecting three projects totaling 2,400 MW to Cape Cod (QP 828)
NYSERDA’s Offshore Wind Integration Study

NYSERDA’s OSW Study assessed bulk transmission needs for 9,000 MW of offshore-wind generation by 2035

- “Onshore” assessment” to identify points of interconnection (POIs) and on-shore bulk-power transmission upgrades
- Development of offshore buildout scenarios from wind energy areas to selected POIs
  - Analyze offshore transmission to connect OSW plants
- Preliminary permitting and feasibility study of offshore cable routes and onshore landing points

Findings:

- Integrating 9000 MW of OSW is feasible without major near-term bulk transmission upgrades if: 5000-7000 MW of OSW can be routed into NYC (so only 2000-4000 MW connect to the grid on L.I.)
  - New transmission from Long Island likely needed by 2030-35 (if not sooner)
  - Significant uncertainty about POIs and lease areas (OSW Study vs. contracts vs. other studies)
- Requires careful planning of OSW procurement, battery deployment, coordinated routing and permitting, and well-planned integration into local NYC grid (possibly through local “OSW hubs” as proposed by ConEd)
- Pursue options that allow for a more flexible and reliable “meshed” offshore grid
Constrained NYC access routes require well-coordinated routing, permitting, and planning

There are a limited number of robust POIs for connecting offshore wind to the onshore grid and limited access routes to these POIs.

If each OSW project builds its own gen tie to the onshore transmission system (without coordination), viable landing sites and cabling routes will become constrained. A well-coordinated planned transmission approach can make better use of the limited landing sites.

The clearest example of this is the cable approach route through the Narrows to reach POIs in New York’s inner harbor.

Landing Limitations along NY Coast

Limited space through narrows and inner harbor

Challenging environmental, physical and social resource constraints
Brattle-Anbaric Study for New York: alternative transmission approaches for 9,000 MW of OSW

Higher-Impact: HVAC Gen Ties

Lower Impact: Planned HVDC Grid

Note: Phase 1 is already contracted using HVAC cables. NYSERDA since has provisionally awarded two additional projects for 2490 MW, interconnecting into the Astoria (using HVDC) and Barrett substations.
The meshed OSW transmission option evaluated in NYSERDA’s OSW Study

Note: the provisionally-awarded Beacon Wind project will support the responsible retirement of aging fossil fuel plants in Astoria as part of the transition to clean energy; and the Empire Wind project may evolve to potentially support the retirement/repowering of the E.F. Barrett Generation Station in Nassau County.

Additional meshed links would be possible to OSW projects connecting to Long Island, New England, and NJ.
Mitigating risk with through coordinated generation and transmission development

Bundled development of OSW generation and radial transmission by single companies, mitigates offshore risks but faces increasing on-shore risks:

- Reduces offshore project-on-project risks through coordination in joint planning and construction of OSW generation and transmission tie line.
- After “low-hanging” onshore interconnection points are utilized, this approach faces increased permitting risks and risks related to the costs and on-time completion of expensive onshore upgrades.

Planned offshore grids (e.g. NJ, Europe) can address project-on-project risks:

- Staggered transmission and generation project completion timelines (e.g., developing the offshore grid in segments that can completed in time for interconnection of individual generating plants).
- Strong performance and completion incentives (rewards or penalties) for both transmission and generation developers to meet project deadlines.
- Allowing generation developer to participate in transmission procurement (with the condition that the transmission will be open access).

If only gen ties are used initially, scale procurement to 1200+ MW and add options so the lines can later be connected into a meshed OSW grid.
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Implications for U.S. OSW transmission

U.S. offshore wind development will require substantial offshore (and supporting onshore) transmission infrastructure

- The ~30,000 MW of committed off-shore wind development in the Eastern U.S. will require **1,500 to 3,000 miles of offshore transmission** plus significant onshore reinforcements

- For example: to integrate 30,000 MW with radial 220kV HVAC gen-ties for every 400 MW of wind generation (up to 30-60 miles offshore) would require about **3000 miles of offshore cables to 75 landing points** with associated onshore grid reinforcements

- **Planned off-shore grids** for larger wind plants and to optimize onshore grid capabilities—such as used in Germany, the Netherlands, Belgium, and proposed by Atlantic Wind and Anbaric in NJ and Anbaric, Bluewater, and Ørsted in MA—would yield scale economies, more resilient meshed grids, and only about **1500 miles of cables to 25 landing points**
A planned approach to offshore transmission has distinct advantages

Radial generation ties (bundled with OSW generation) can have distinct disadvantages over planned transmission solutions:

- Less efficient use of limited onshore POIs
- Increased environmental impact on seabed and shoreline
- Reduced competition for transmission and off-shore wind generation
- Higher onshore transmission costs and higher overall costs in the long run

A planned approach is better suited to support the large scale of states’ OSW goals:

- Reduce number of cables and landing points
- Reduce the need for onshore transmission upgrades
  - Select more optimal interconnection points consistent with coordinated long-term plan (even if not lowest-cost in short run)
- Consider solicitations for OSW transmission (e.g., 7500 MW by NJ BPU)

Hybrid: create options that allow evolving from gen-ties to a meshed offshore grid
Long-term: OSW generation integrated into a more geographically-diverse national grid?

As state and regional shares of renewable generation increase, a robust inter-regional grid will become critical to ensure reliability and cost effectiveness:

- The geographic scale of the grid needs to (1) reach well beyond the size of large weather systems; and (2) integrate a diverse mix of resources (wind, solar, hydro, ...)
- Local storage and distributed resources will help, but not eliminate the need for broad geographic diversification of uncertain intermittent generation

 Transmission Planning for 100% Clean Electricity - ESIG

Additional Reading


Chang and Pfeifenberger, “*Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future*,” WIRES and The Brattle Group, June 2016.


Johannes Pfeifenberger, a Principal at The Brattle Group, is an economist with a background in electrical engineering and over twenty-five years of experience in wholesale power market design, renewable energy, electricity storage, and transmission. He also is a Senior Fellow at Boston University’s Institute of Sustainable Energy (BU-ISE), a Visiting Scholar at MIT’s Center for Energy and Environmental Policy Research (CEEPR), and serves as an advisor to research initiatives by the Lawrence Berkeley National Laboratory’s (LBNL’s) Energy Analysis and Environmental Impacts Division and the US Department of Energy’s (DOE’s) Grid Modernization Lab Consortium.

Hannes specializes in transmission and wholesale power markets. He has recent studied New York power grid needs, evaluated offshore wind transmission options in New York State and New England, analyzed the role of renewable generation and transmission in economy-wide decarbonization, and presented renewable integration challenges at a number of industry meetings, including the Atlantic Council and the Harvard Electricity Policy Group.

He received an M.A. in Economics and Finance from Brandeis University’s International Business School and an M.S. and B.S. (“Diplom Ingenieur”) in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.
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