Learning from the Experts Webinar Series

Offshore Wind Transmission Systems

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Principal
The Brattle Group

May 12, 2021

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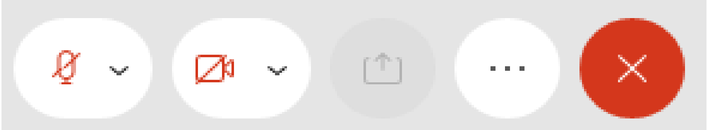

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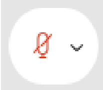
You'll see  **when your microphone is muted**

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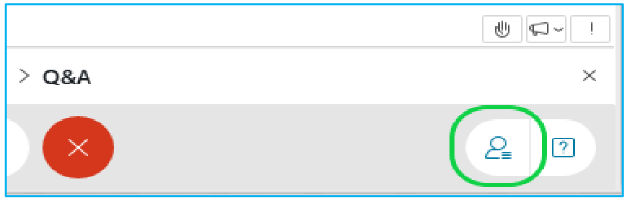

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Learning from the Experts

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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Transmission Options for Offshore Wind Generation

PRESENTED BY
Johannes Pfeifenberger

PRESENTED AT
NYSERDA Offshore Wind Webinar

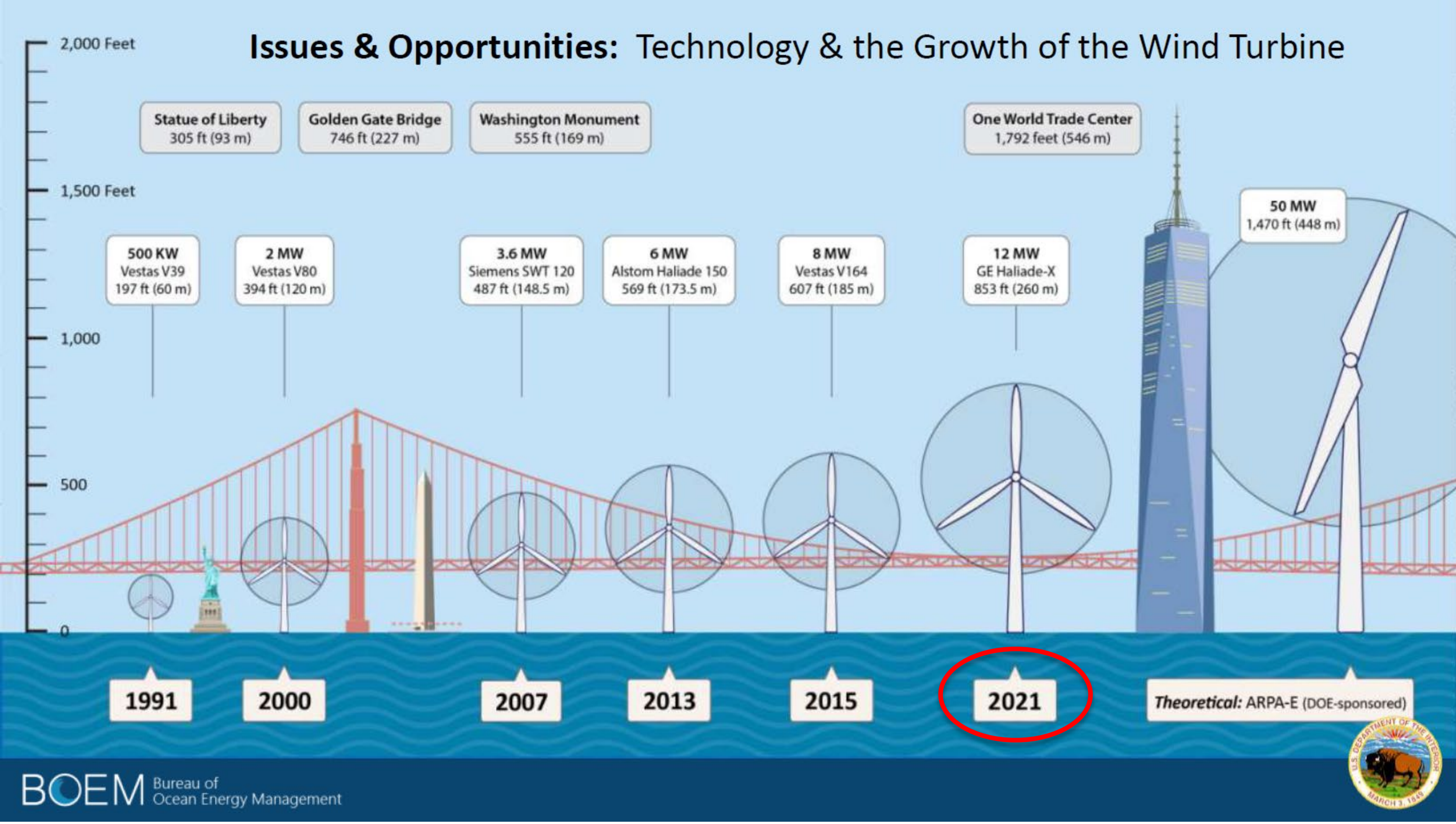
MAY 12, 2021

Brattle

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



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.

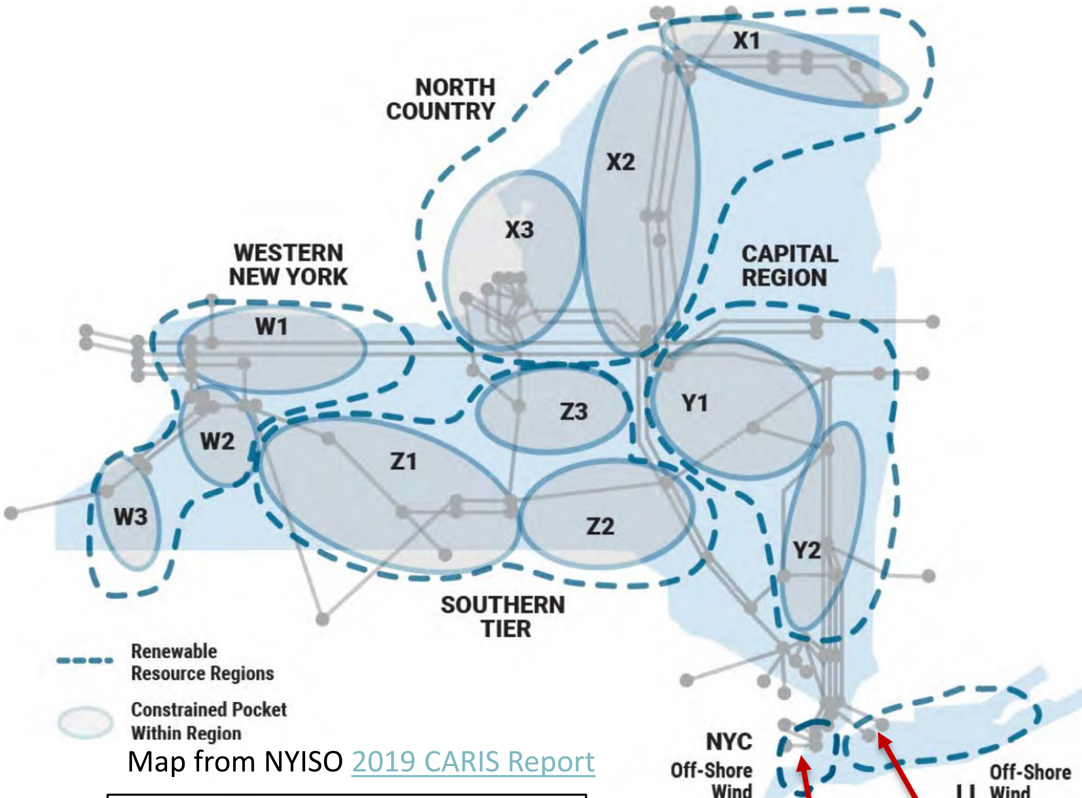
A key challenge: **ensuring a pathway low-cost, low-impact solutions** for delivering offshore wind energy to onshore grid and population centers

Region	Already Contracted	Total Committed	Potentially Needed
New England	3,120 MW	5,900 MW	25-40,000 MW by 2050
New York	4,316 MW	9,000 MW	10-25,000 MW by 2040
Mid-Atlantic	4,129 MW	13,900 MW	

Sources: **Contracted and committed**: ACP_FactSheet-Offshore_Final (cleanpower.org), 2021. **Potentially needed**: Brattle Study of NE by Jurgen Weiss and Michael Hagerty, "Achieving 80% GHG Reduction in New England by 2050," September 2019. Brattle Study for NYISO by Roger Lueken et al., "New York's Evolution to a Zero Emission Power System: Modeling Operations and Investment Through 2040." May 18, 2020. E3, "Electric Reliability under Deep Decarbonization in New England," August 4, 2020. E3, "Pathways to Deep Decarbonization in New York State," June 24, 2020. https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/Focus-Areas/NY-Offshore-Wind-Projects. Initial Report on New York Power Grid Study, January 19, 2021.

New York Power Grid Study

PSC and NYSERDA completed the Initial Report on New York Power Grid Study (PGS), which consists of three components:



Map from NYISO 2019 CARIS Report

9000+ MW OSW

See: Full PGS Report and Summary Presentation

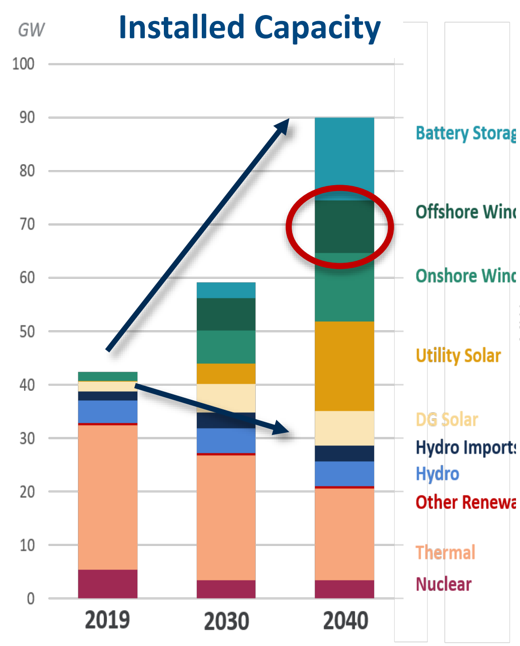
- **Utility Study**: local transmission and distribution (LT&D) needs; advanced grid technologies
- **Offshore Wind (OSW) Study**: bulk transmission to integrate 9,000 MW of offshore wind
- **Zero Emissions Study**: bulk transmission, generation, and storage needed to achieve 70% renewable generation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

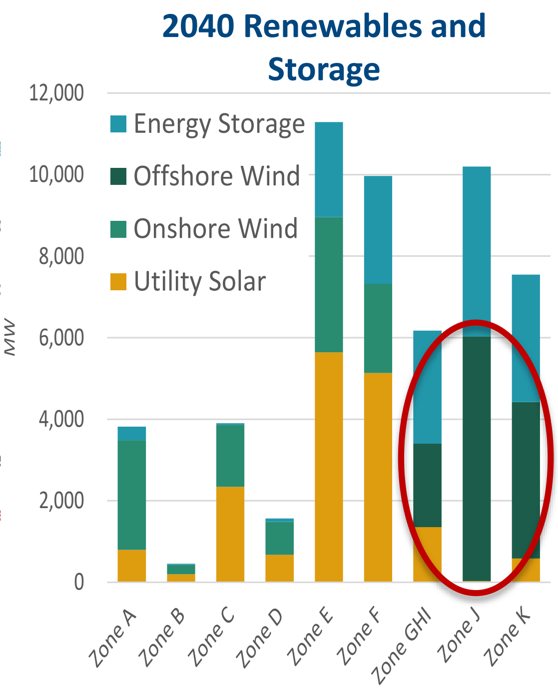
New York PGS: Substantial Renewable Generation and Storage Needs

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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  - Case studies: NJ, UK, New England, NY
  - Risk mitigation
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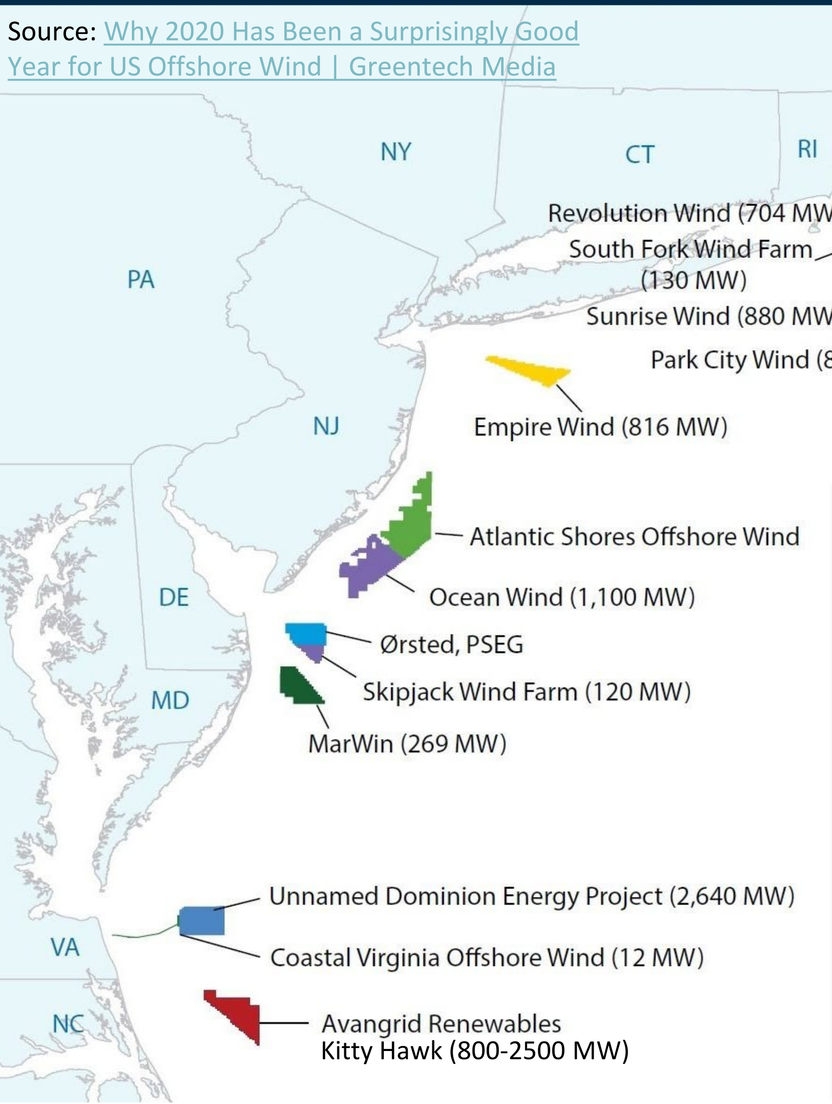
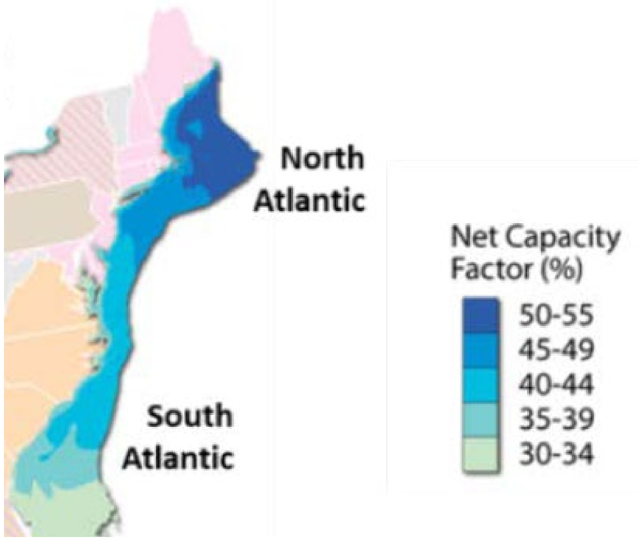
What will a cost-effective OSW transmission solution look like for the Eastern U.S.?

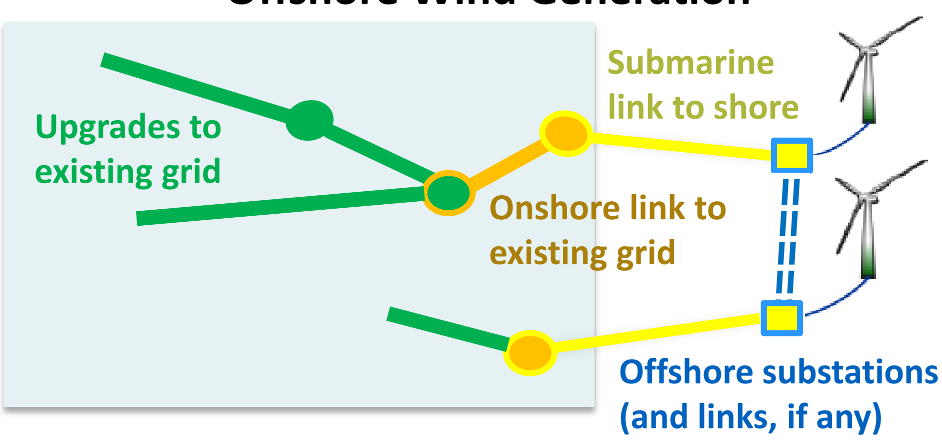
East Coast Offshore Wind Projects and Lease Areas

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





Transmission Elements for Integrating Offshore Wind Generation



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

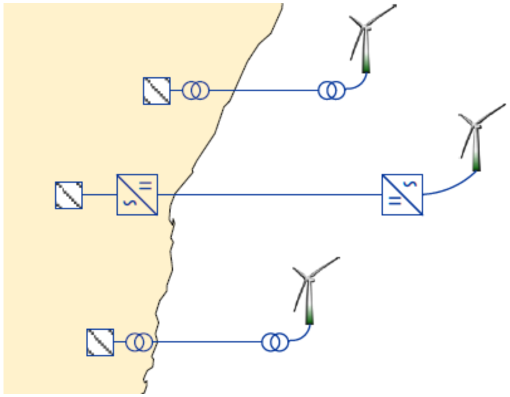
ISO "regional transmission planning" processes often not ready to develop cost-effective plans for offshore grids in a timely fashion

- 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

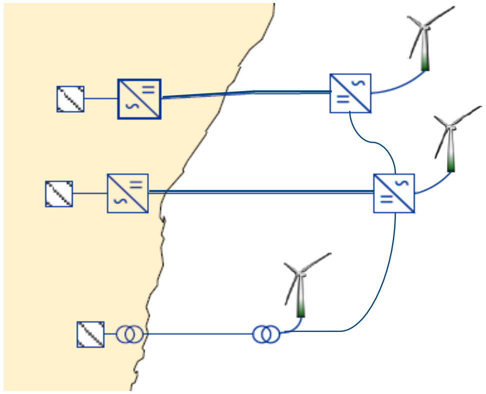
Radial Tie Lines

Transmission links bundled with individual OSW plants



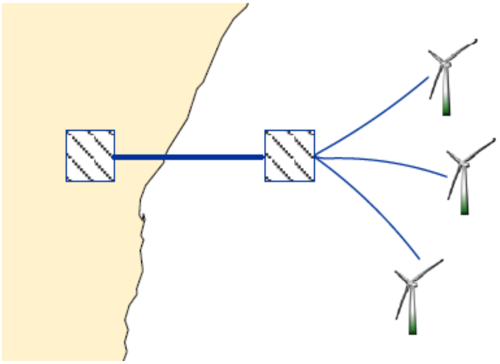
Meshed Generation Ties

Individual tie lines to shore linked through offshore transmission



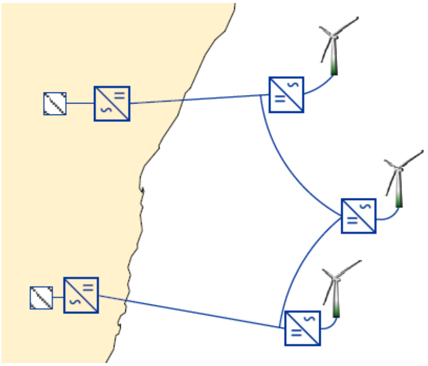
Shared Collector Station

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

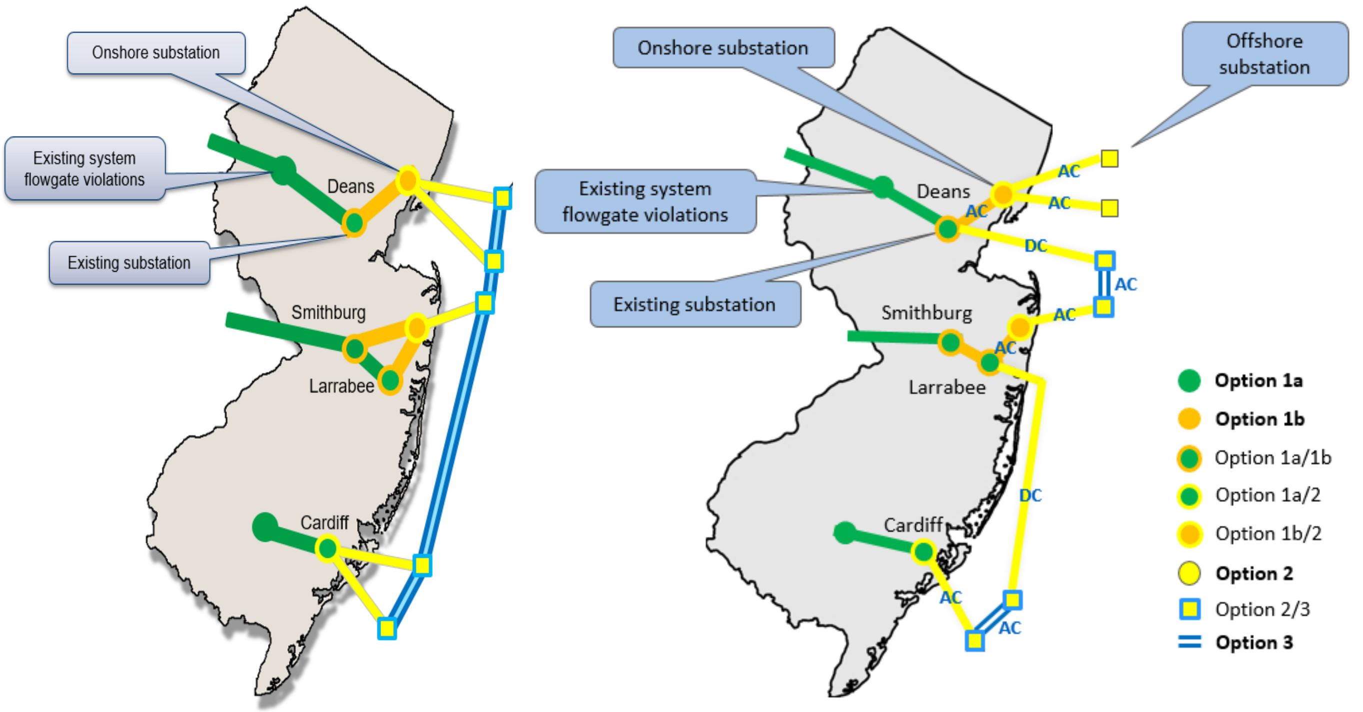


Illustration of "Options"

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

PJM's first-ever transmission solicitation under its State Agreement Approach (SAA):

- 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

Choosing between gen-ties and planned OSW transmission solutions

Factors favoring gen ties to individual offshore wind plants

- Modest total development and small incremental steps
  - 400 MW per HVAC circuit only?
- Modest distance from shore
  - Less than 40 miles?
- Many landing points with robust on-shore transmission
  - Requires 4 HVAC circuits for every 1,600 MW of total OSW development?
- Long distances between offshore locations to be interconnected
- Uncertain OSW lease areas
- Easy permitting of landing points and interconnection studies
- Wind developer has significant offshore transmission experience

Factors favoring offshore grids to serve multiple wind plants

- Large size of total wind generation commitment with sizable procurement steps
  - 1600 MW per HVDC circuit within a few years?
- Several plants close to each other but long distances from shore or from sufficiently-robust onshore transmission nodes
  - Greater than 40 miles?
- More efficient use of scarce right-of-way
  - Few landing points with robust on-shore transmission
  - Difficult permitting of landing points and onshore interconnection study process
- Network benefit (offshore redundancy and reinforcement of on-shore grid)
- Create more competition for wind developers through open access to offshore hubs
- Create competition between experienced offshore transmission developers

Potential benefits of planned offshore transmission

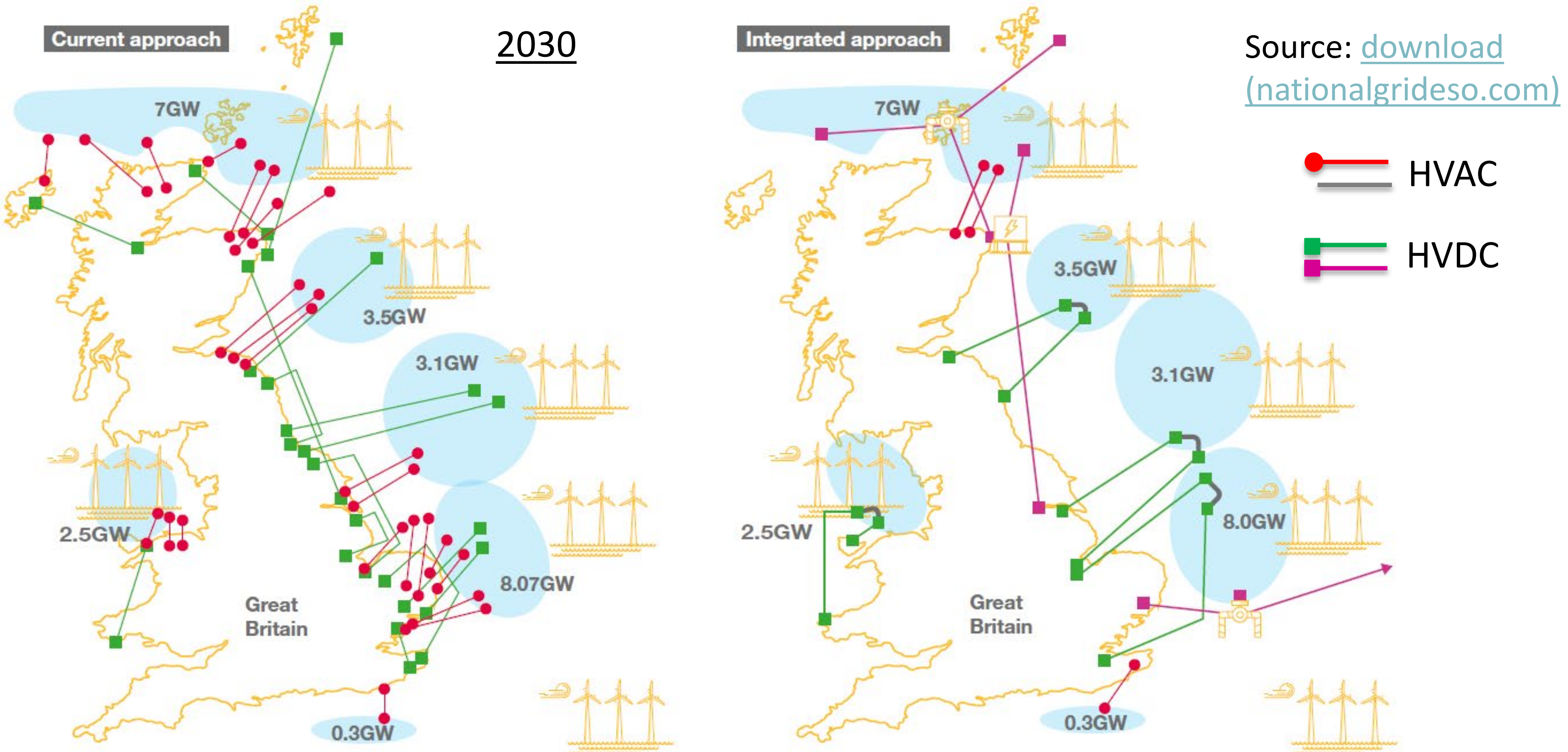
Our studies of OSW transmission alternatives and found that well-planned transmission (and procurement) can offer substantial advantages

Elements examined	A planned approach can…
Total onshore + offshore transmission • **Onshore transmission upgrades** • **Offshore transmission**	Lower overall long-term costs • **Substantially lower onshore costs** and project development risks • Slightly higher offshore costs
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

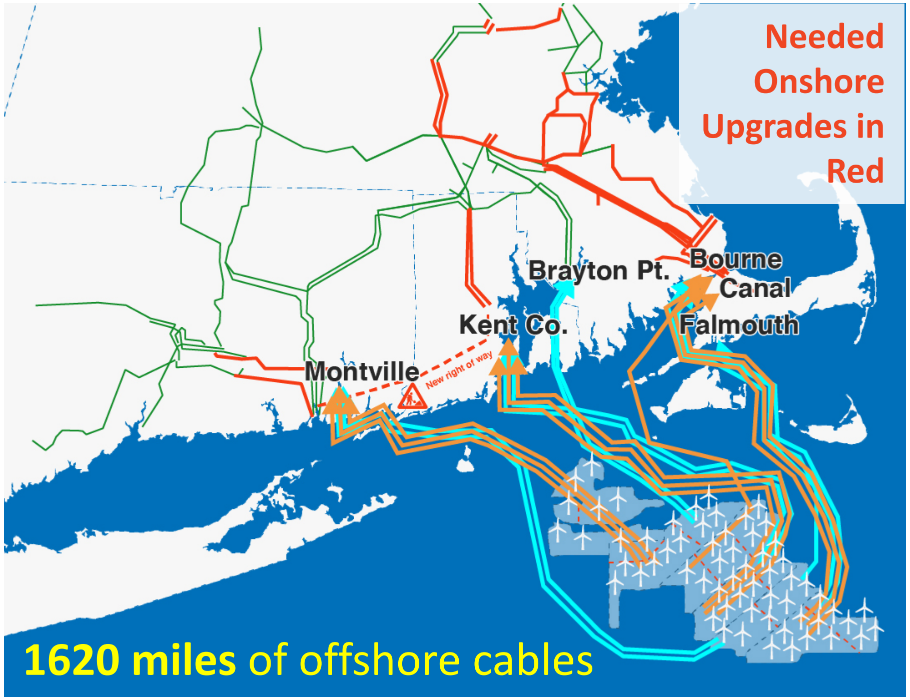


Source: [download (nationalgrideso.com)]

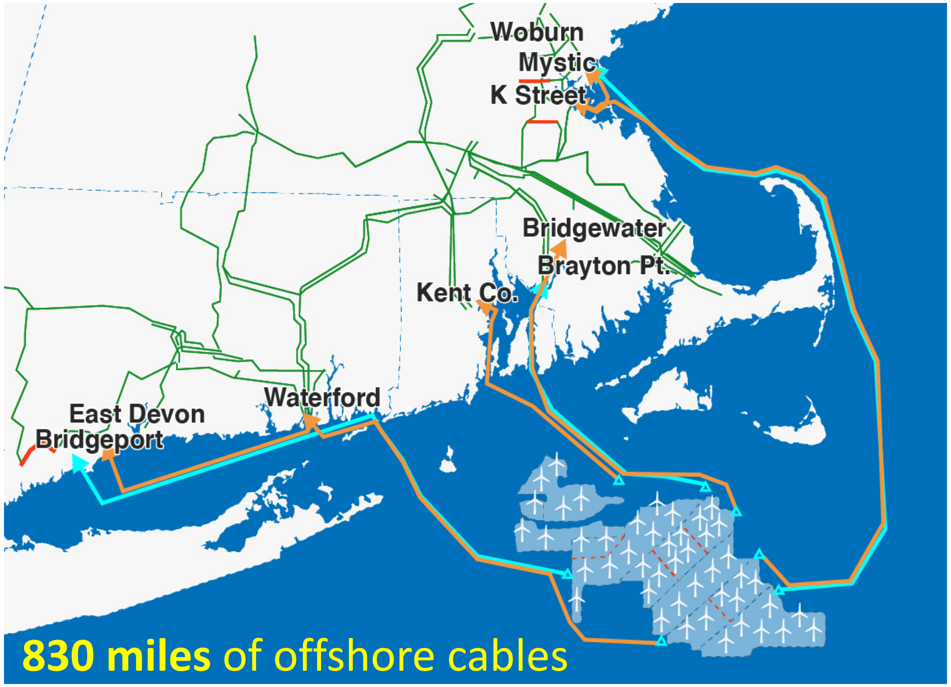
Results: if planning for 18,000 MW of new OSW generation during 2025-30 (and 41,000 MW during 2030-50) starts now, the "integrated" solution reduces estimated transmission costs by 19% and the number of landing points by 50-70%. Delaying planning by only 5 years reduces 2050 benefits by half.

Brattle-Anbaric Study: 2 transmission approaches studied for New England (~8,400 MW total OSW)

Plausible Gen Tie Approach



Planned Grid Approach

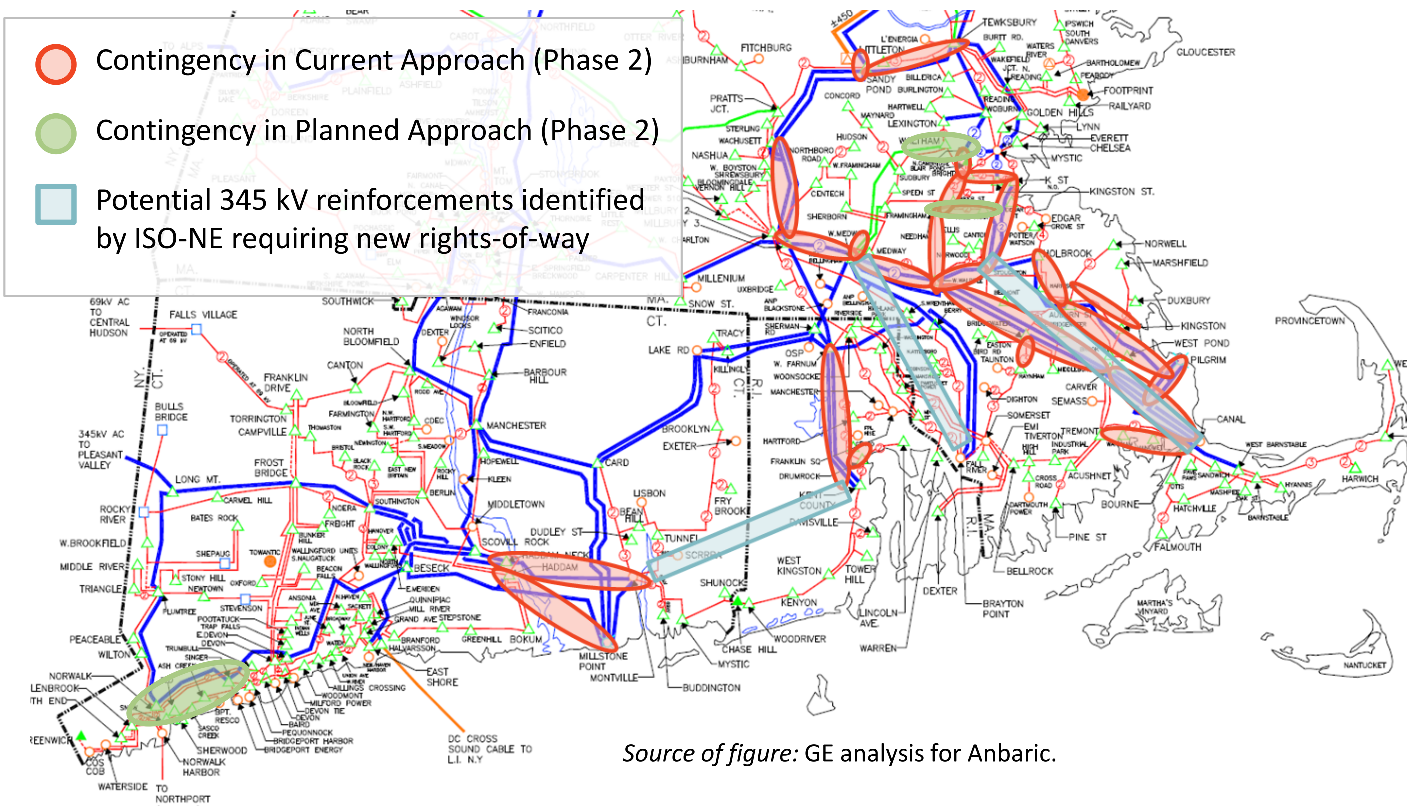


Reducing the number of offshore platforms, cabling, seabed disturbance, and cables landing at the coast **reduces impacts on existing ocean uses and marine/coastal environments** to the greatest practical extent

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 <u>$787 million</u> in onshore transmission upgrades,* and continuing this approach for even the next 3600 MW of procurements could lead to an <u>additional $1.7 billion</u> in onshore upgrades.



Source of figure: GE analysis for Anbaric.

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

Given the difficulty of permitting and building new onshore trans-mission, a planned approach also reduces the risk of cost overruns and delays

* 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**

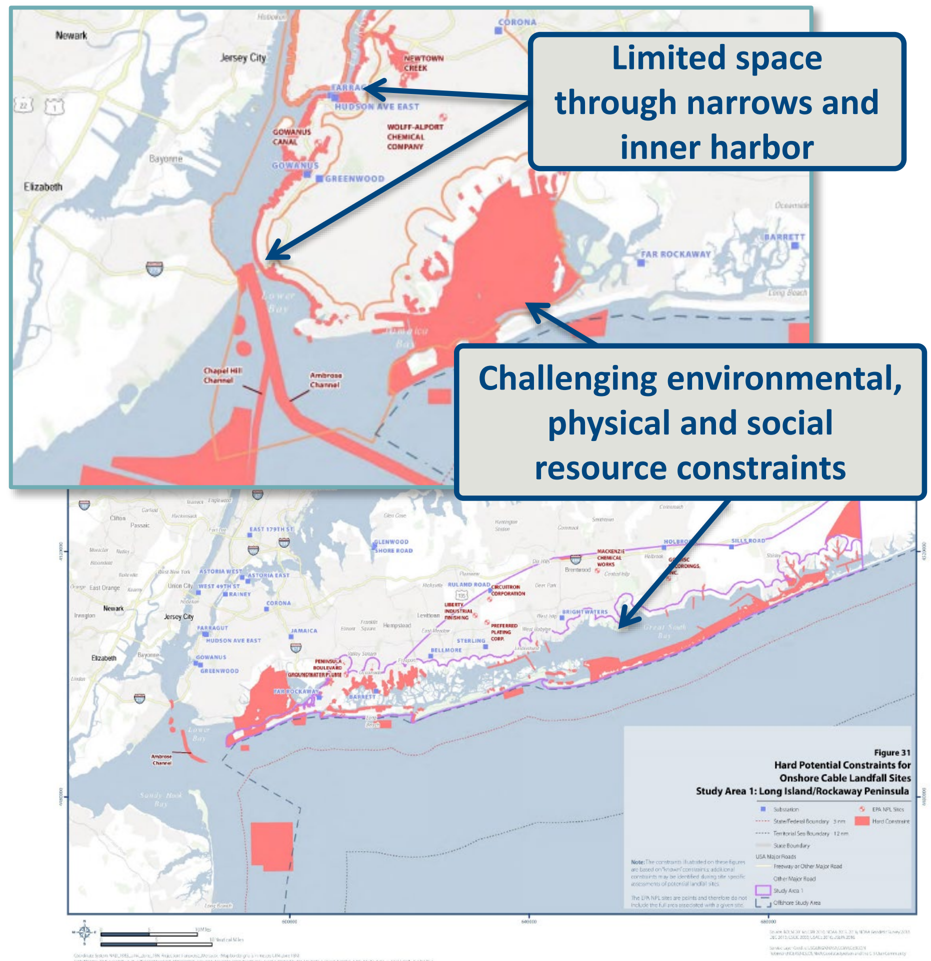
Constrained NYC access routes require well-coordinated routing, permitting, and planning

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**

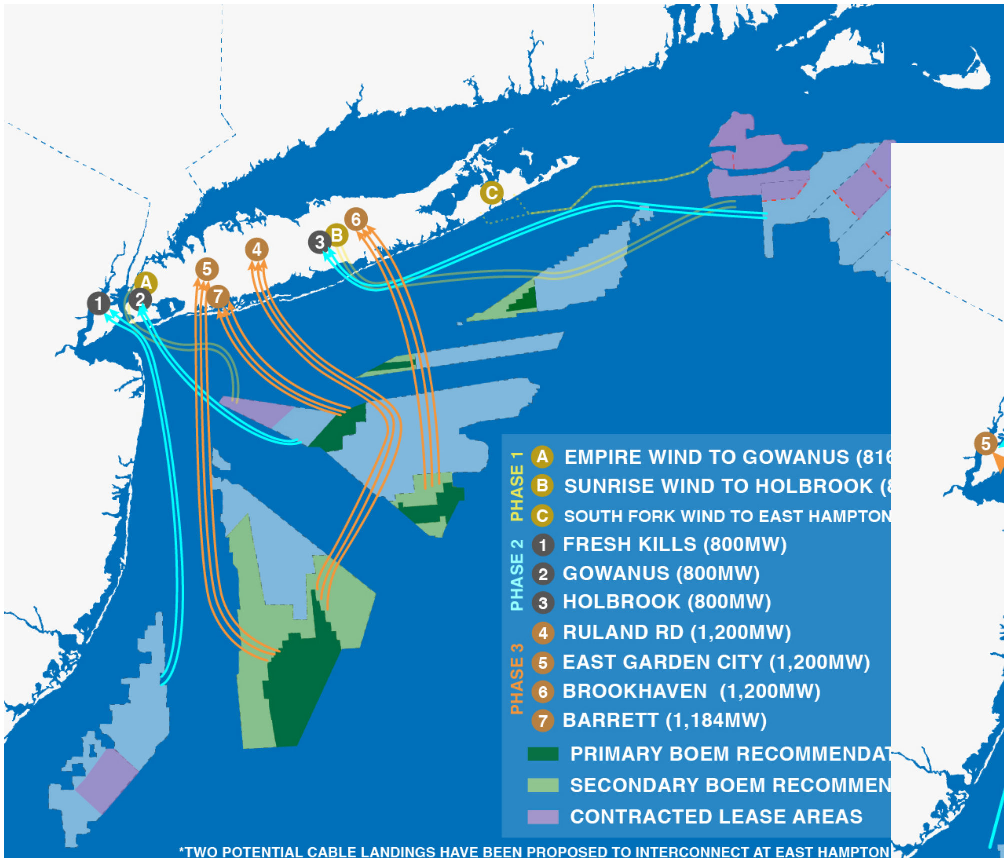
The clearest example of this is the cable approach route through the Narrows to reach POIs in New York's inner harbor

Landing Limitations along NY Coast

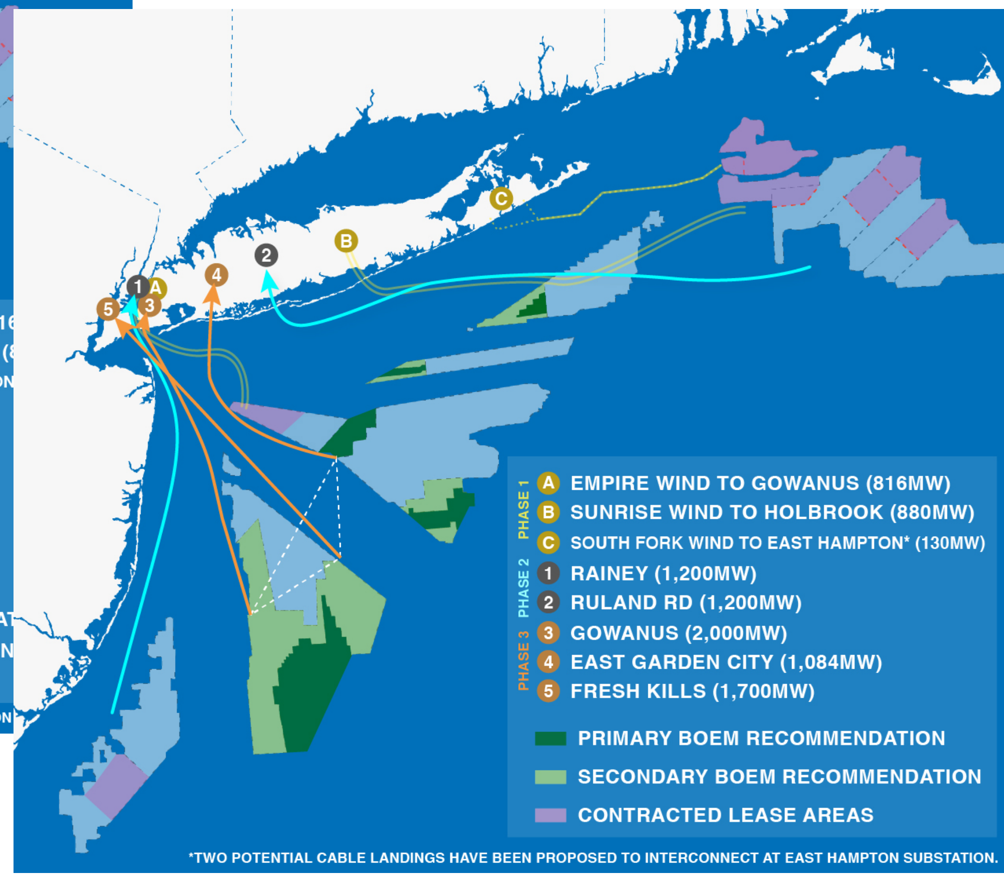


Brattle-Anbaric Study for New York: alternative transmission approaches for 9,000 MW of OSW

Higher-Impact: HVAC Gen Ties

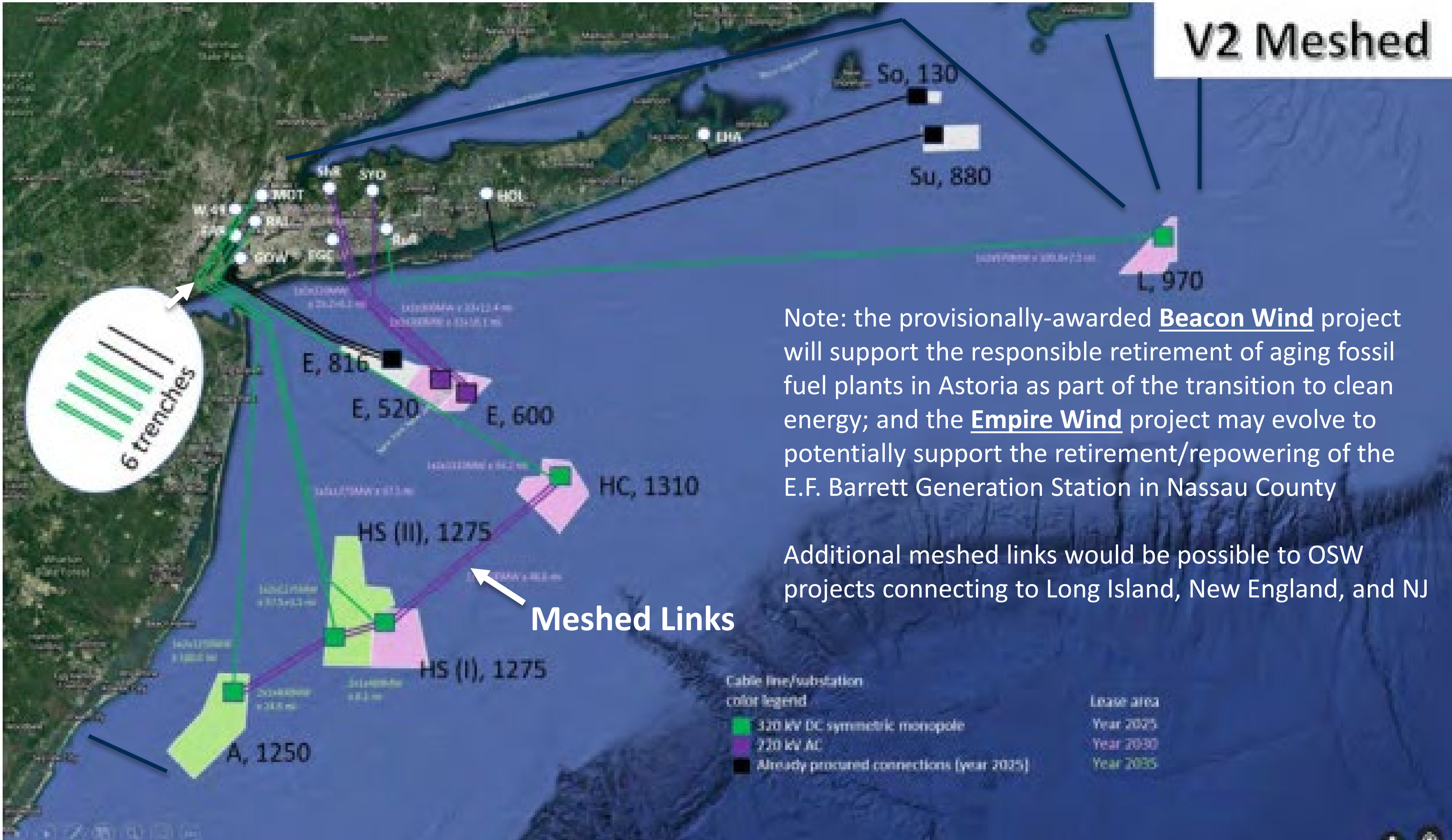


Lower Impact: Planned HVDC Grid



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:

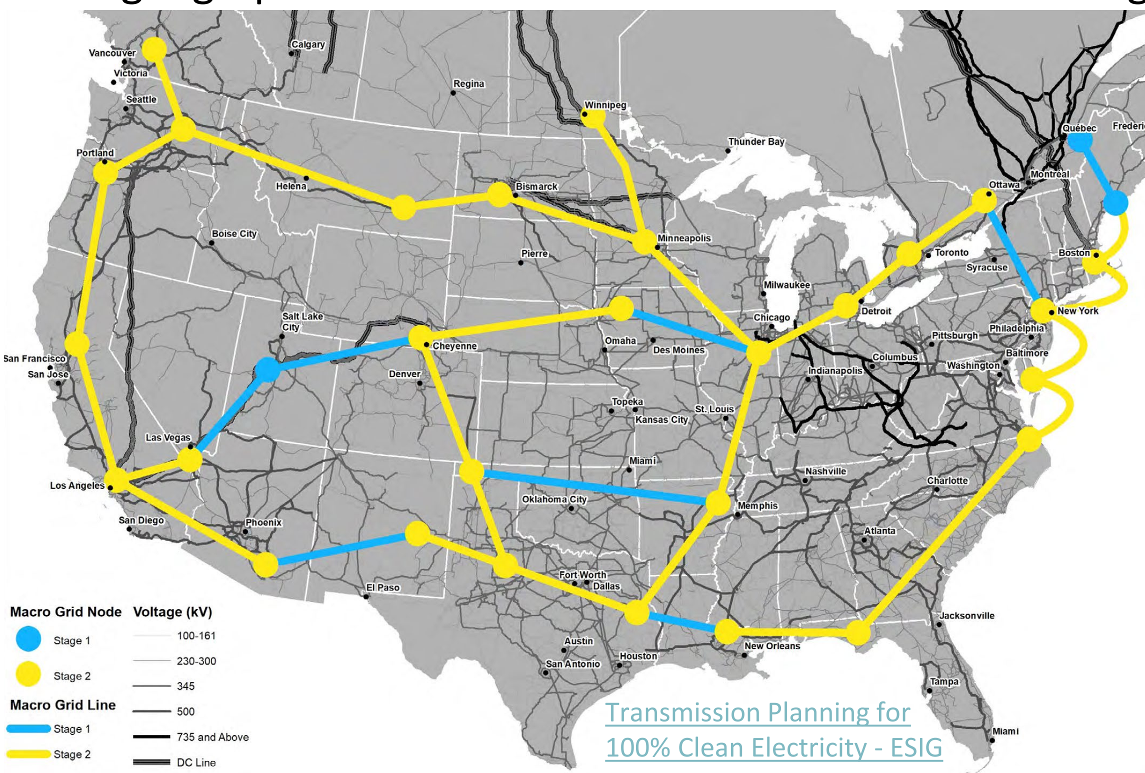
- Reduce number of cables and landing points
- Reduce the need for onshore transmission upgrades
  - Select more optimal interconnection points consistent with coordinated long-term plan (even if not lowest-cost in short run)
- Consider solicitations for OSW transmission (e.g., 7500 MW by NJ BPU)

Hybrid: create options that allow evolving from gen-ties to a meshed offshore grid

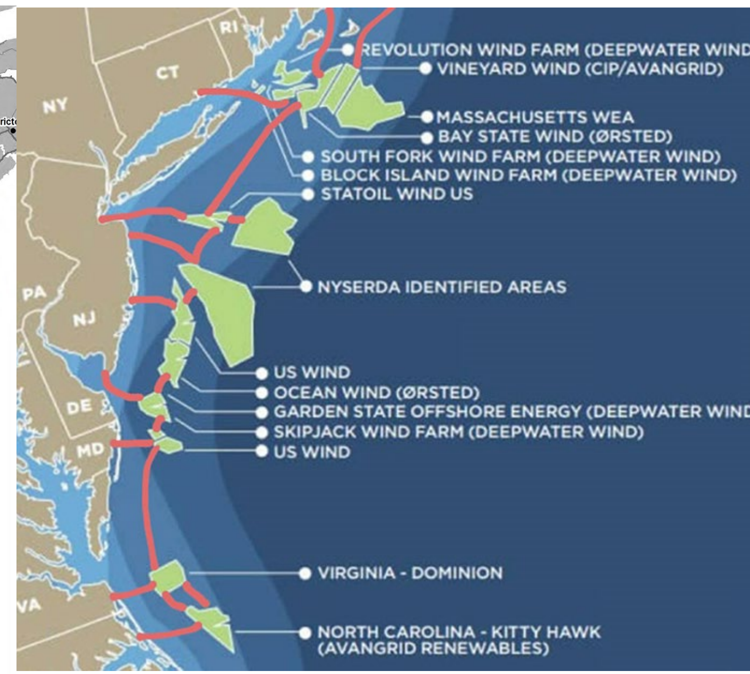
Long-term: OSW generation integrated into a more geographically-diverse national grid?

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]



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Additional Reading

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Johannes (Hannes) 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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