U.S. Offshore Wind Generation, Grid Constraints, and Transmission Needs

PRESENTED TO

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THE Brattle GROUP

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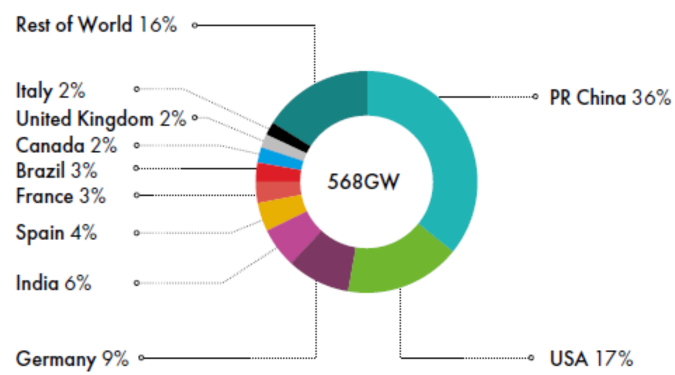
Global Context of Wind Generation

The U.S. now has 100 GW wind generation … but little offshore wind because focus has been developing abundant low-cost onshore wind resources (though often far from major load centers)

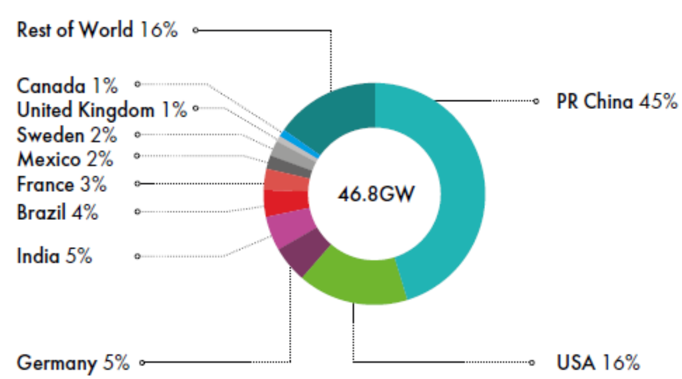
Total Installed Wind Capacity

Dec 2018 (GW)			
Country	Onshore	Offshore	Total
PR China	206.8	4.8	211.6
USA	96.6	0.03	96.7
Germany	53.2	6.4	59.6
India	35.1	0.0	35.1
Spain*	23.5	0.0	23.5
UK	13.0	8.0	21.0
France	15.3	0.0	15.3
Brazil	14.7	0.0	14.7
Canada	12.8	0.0	12.8
Italy*	10.0	0.0	10.0
Rest of world	87.4	3.9	91.3
TotalTO P10	481.0	19.2	500.2
World Total	568.4	23.1	591.5

Total Onshore (2018):



***New* 2018 Onshore Installations:**

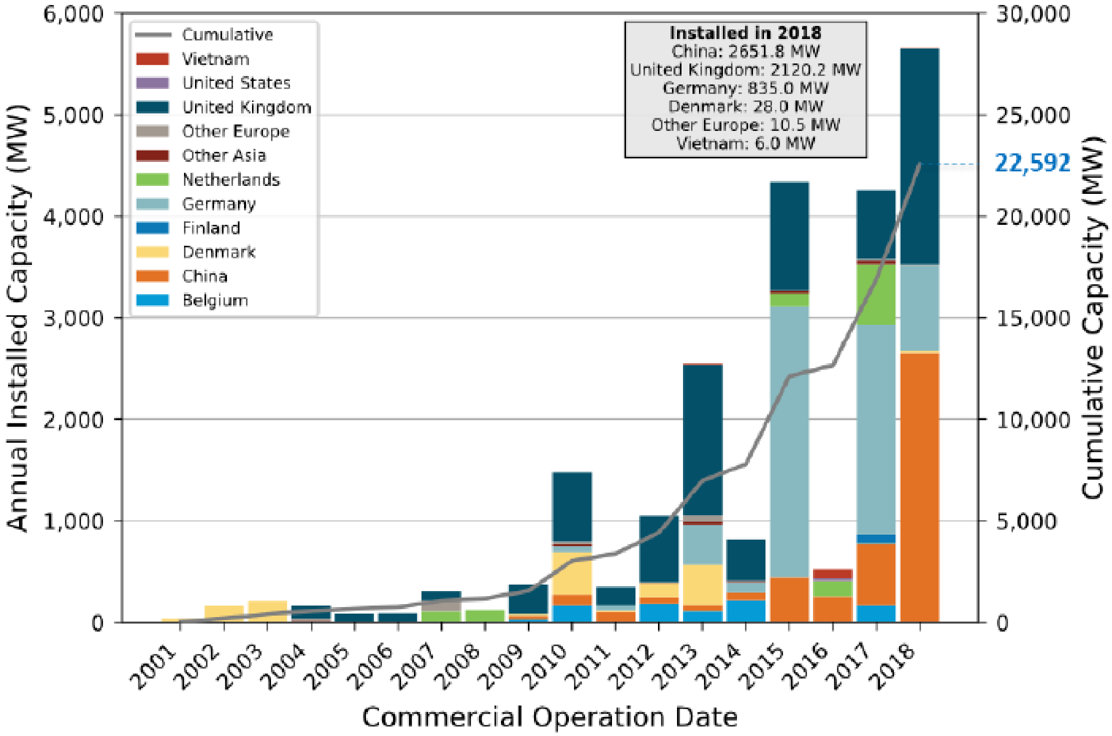


Source: GWEC (2019) 2018 Global Wind Energy Report. https://gwec.net/wp-content/uploads/2019/04/GWEC-Global-Wind-Report-2018.pdf

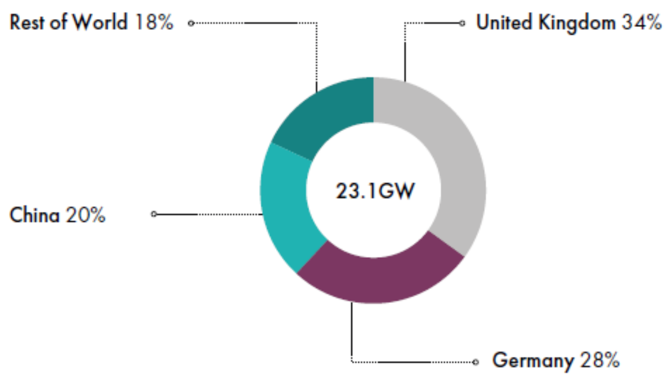
Global Offshore Wind Market

The installed global offshore wind capacity has reached 23 GW by the end of 2018 (up from 19 GW at the end of 2017) … mostly in China and Europe

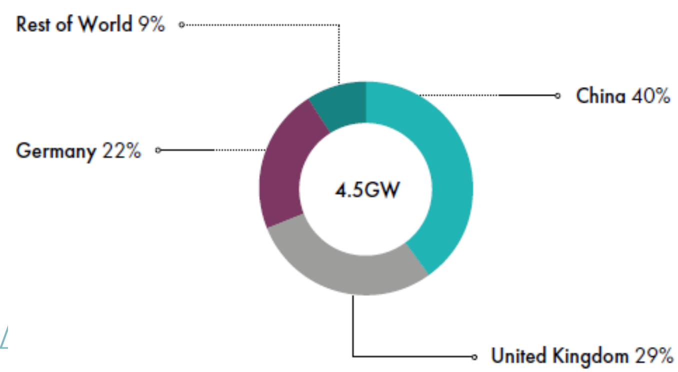
Global Offshore Wind Installations



Total Offshore (2018):



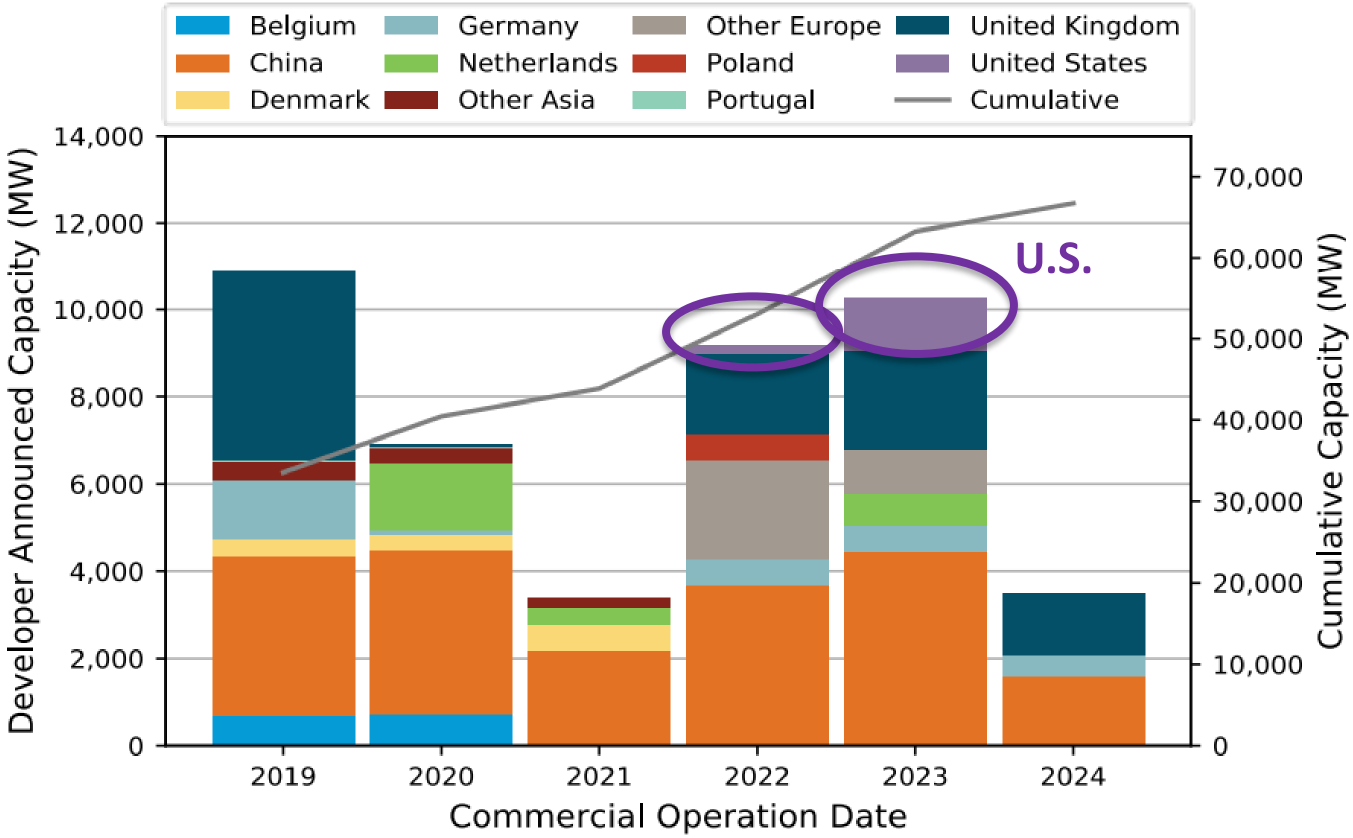
New 2018 Offshore Installations:



Sources: GWEC (2019) 2018 Global Wind Energy Report. https://gwec.net/wp-content/uploads/2019/Global-Wind-Report-2018.pdf,
US DOE (2018). Offshore Wind Technologies Market Report. https://www.energy.gov/sites/prod/files/2019/08/f65/2018%20Offshore%20Wind%20Market%20Report.pdf

U.S. Relative to Global Offshore Market: 2019-24

U.S. offshore wind development is expected to increase significantly, but "financially closed" projects still account for only a small share of the global industry growth over the next five years

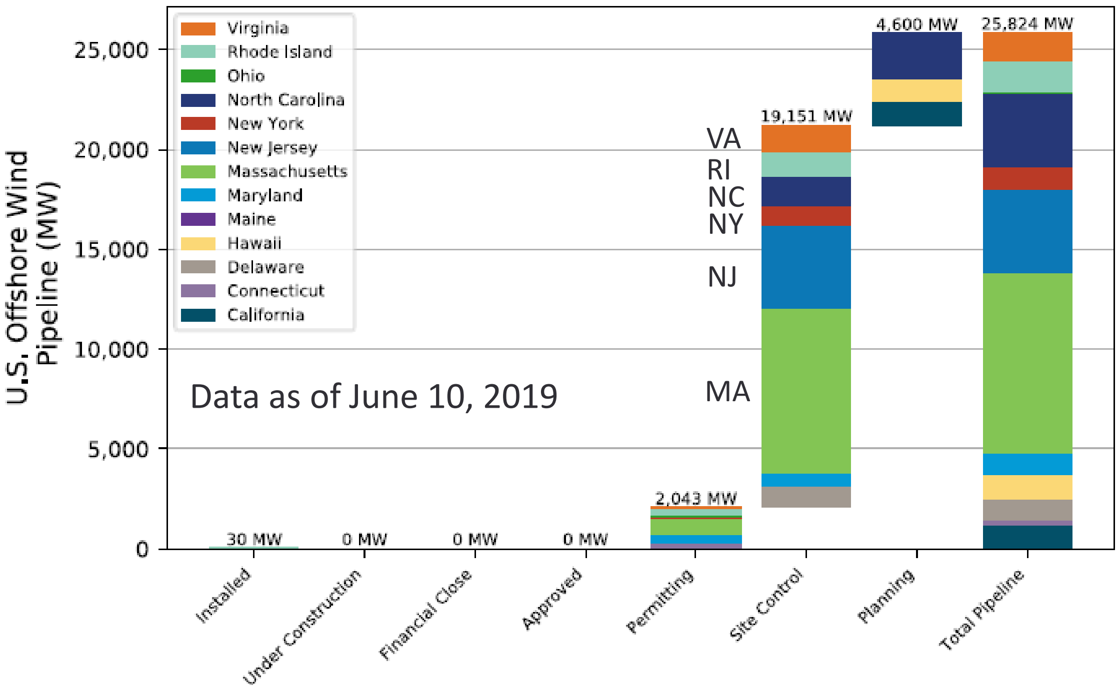


Source: US DOE (2018). Offshore Wind Technologies Market Report, https://www.energy.gov/sites/prod/files/2019/08/f65/2018%20Offshore%20Wind%20Market%20Report.pdf

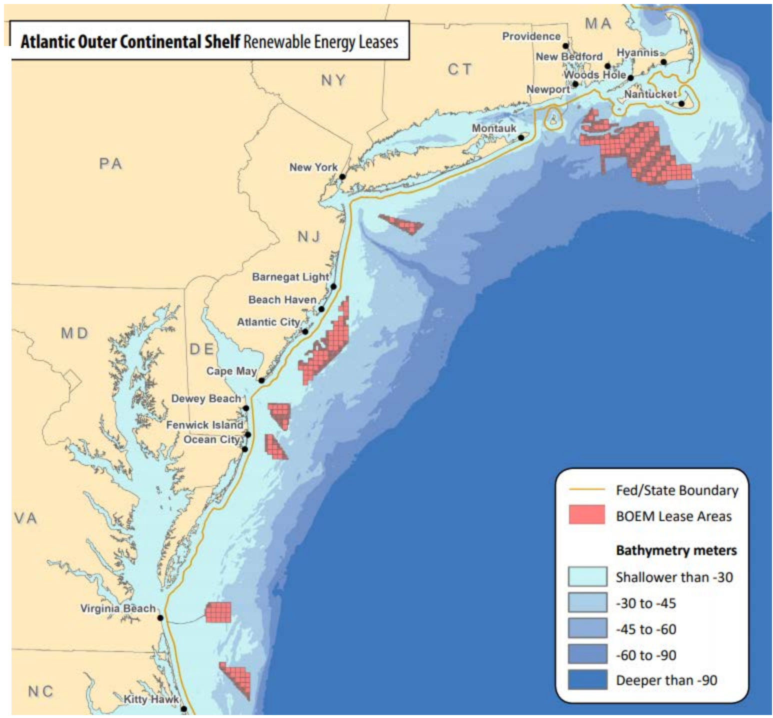
Currently Proposed U.S. Offshore Wind Projects

30 projects "under development" (28,464 MW*)… mostly in North Atlantic

- Backed by 19,968 MW of commitments from U.S. States (at end of 2018)
- Seven with power offtake agreements (1,300 MW)
- 1,700 MW under contract negotiation in NY



Source: US DOE (2018). Offshore Wind Technologies Market Report, https://www.energy.gov/sites/prod/files/2019/08/f65/2018%20Offshore%20Wind%20Market%20Report.pdf



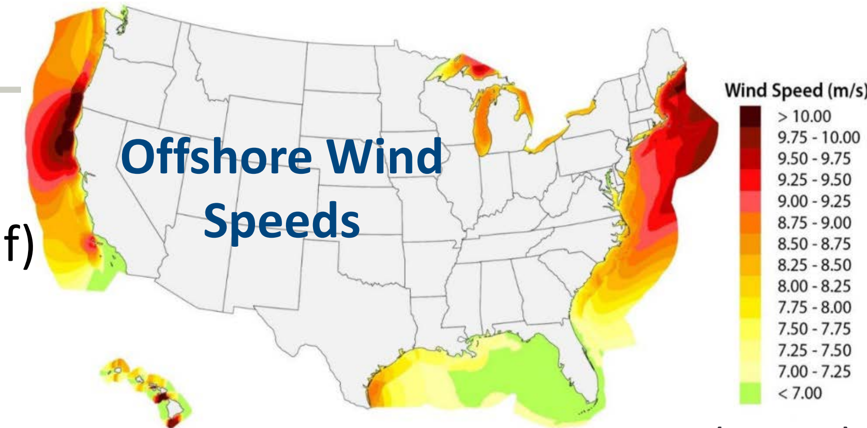
Source: Outer Continental Shelf Renewable Energy Leases Map Book, March 2019, BOEM https://www.boem.gov/Renewable-Energy-Lease-Map-Book/

*This number includes the 25,824 MW from the figure above and Dominion Energy's 2,640 MW VA project that was announced in September, 2019.

U.S. Offshore Wind Quality

Highest-quality U.S. offshore wind:

- East and Northeast (shallow Atlantic shelf)
- Northern California and Oregon



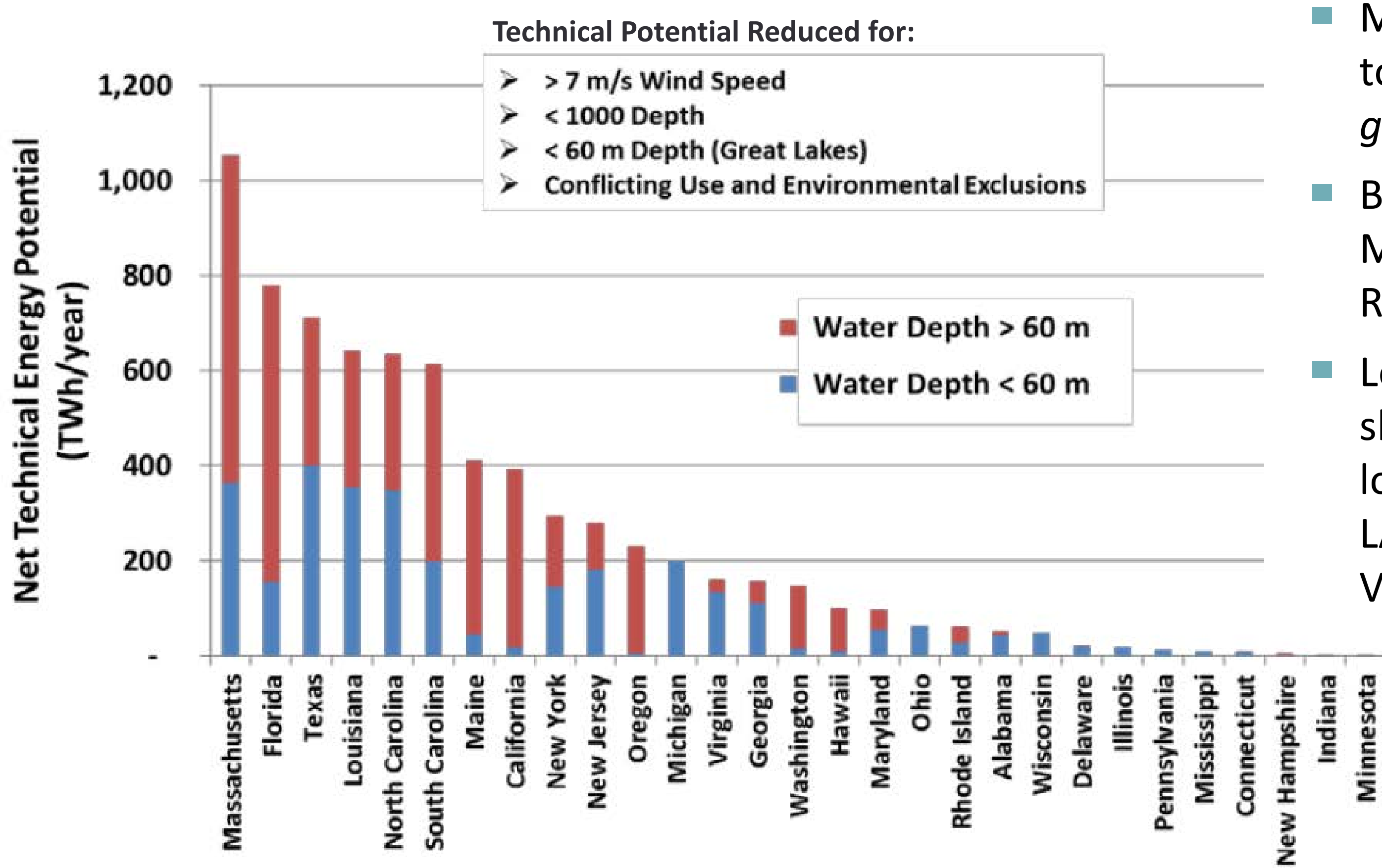
(At 100 m)

Highest capacity factors for U.S. offshore wind about equal to of onshore wind in Great Plains

Source: NREL (2016). Computing America's Offshore Wind Energy Potential. https://www.energy.gov/eere/articles/computing-america-s-offshore-wind-energy-potential

Enormous "Technical Potential" of U.S. Offshore Wind

Considering technological, land-use, environmental limits, the U.S. is estimated to offer 2,000 GW (7,200 TWh) of offshore wind potential



- More than double total installed U.S. *generation*.
- Best quality: MA, ME, CA, NY, NJ, OR RI
- Lower quality but shallow water and long coast lines: TX, LA, NC, SC, FL, MI, VA

Source: NREL (2016). Computing America's Offshore Wind Energy Potential.
https://www.energy.gov/eere/articles/computing-america-s-offshore-wind-energy-potential

BOEM Issued 21 GW Worth of Offshore Wind Leases

<u>Recent BOEM Lease News:</u>

- **BOEM leases now support 21 GW**
  - Up from 17 GW in 2018
- Massachusetts (February, 2019)
  - Record auction price of $135 million for each of three leases
  - Estimated 4.1 GW of potential capacity for all three leases
- Several **new BOEM "Call Areas"** in NY, NJ and SC to gage additional industry interest
- BOEM delaying EIS for Vineyard for additional cumulative impact studies
  - Will delay Vineyard wind project and result in lost tax credits (increased costs)
- Five Pacific-based projects have submitted unsolicited applications to BOEM

Source: 2018 Offshore Wind Technologies Market Report, U.S. Department of Energy
https://www.energy.gov/sites/prod/files/2019/08/f65/2018%20Offshore%20Wind%20Market%20Report.pdf

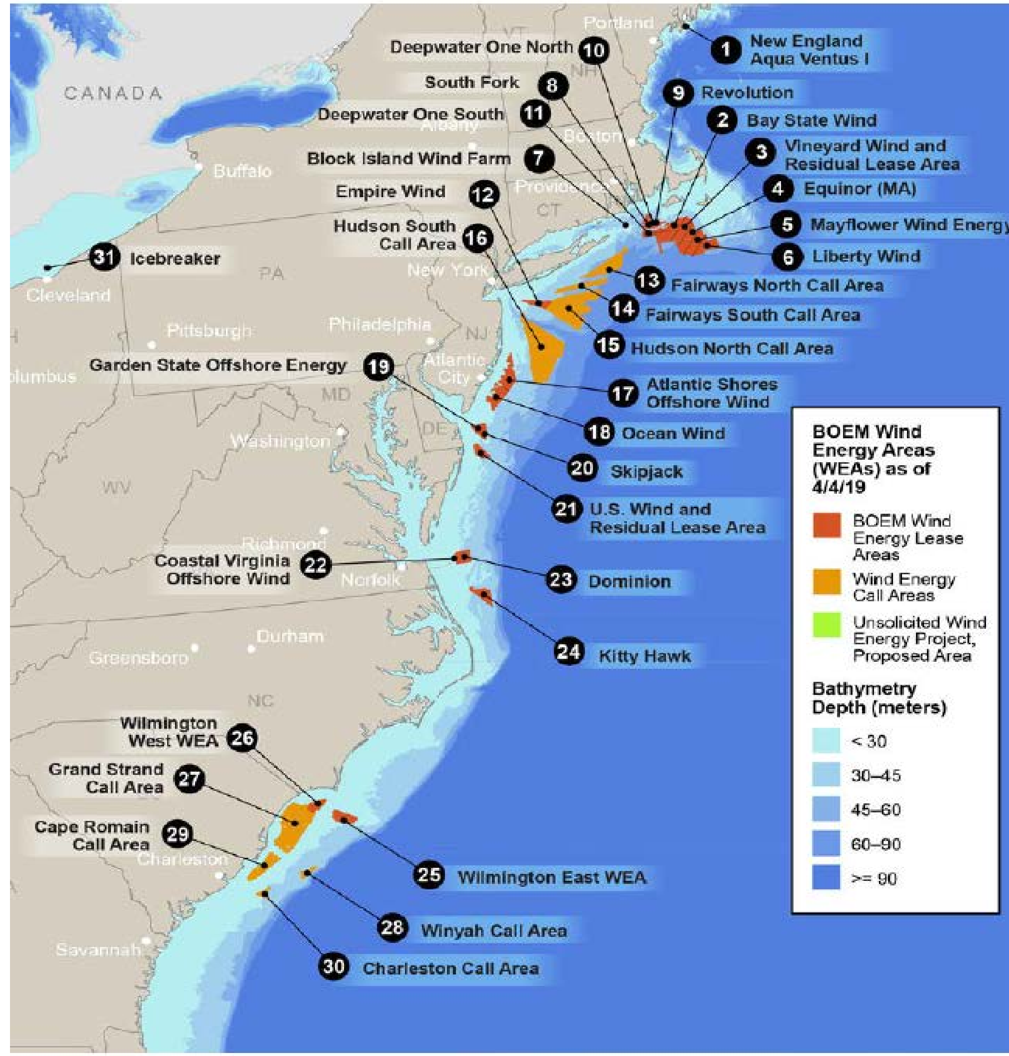


Figure 4. Locations of U.S. Atlantic Coast offshore wind pipeline activity and Call Areas as of March 2019. *Map provided by NREL*

U.S. Offshore Wind Generation News

At the end of 2018, committed offshore procurements by U.S. states totaled <u>19,968 MW by 2035</u> (up from 5,300 MW by 2030 as of the end of 2017)

New or expanded state initiatives since end of 2017:

- **RI:** Selected 400 MW project winner in collaboration with MA
- **MD:** Passed bill with 1,200 MW offshore wind carve-out that adds to previous 368 MW commitment
- **MA**: Passed 3,200 MW by 2035 bill (up from 1,600 MW by 2027)
- **CT:** Passed bill to solicit 2,000 MW of offshore wind in addition to 300 MW previously solicited
- **NY**: Passed bill for 9,000 MW of offshore wind by 2035 (up from 2,400 MW by 2030)
- **NJ**: Issued executive order for 3,500 MW by 2030 (up from "ambitious goal")

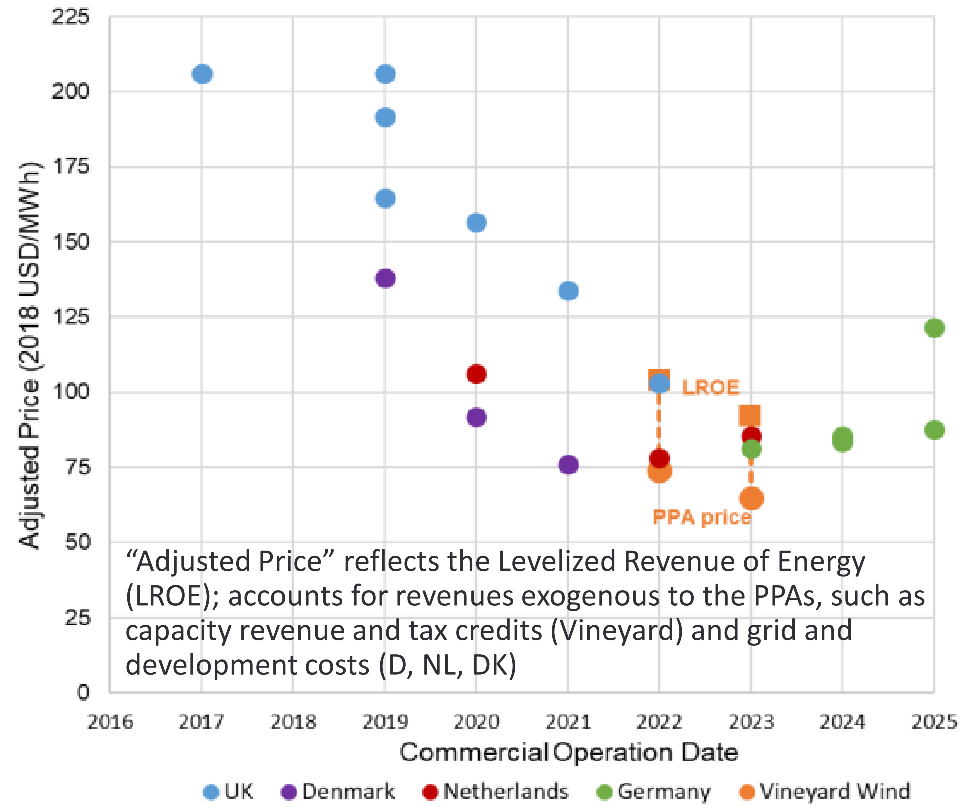
Examples of developer initiatives:

- **Deepwater Wind:** Revolution Wind 400 MW (MA, RI, CT); 120 MW (MD) and others
- **Ørsted**: Ocean Wind 1,100 MW (NJ); Baystate Wind 400-800 MW (MA); Sunrise Wind 880 MW (NY)
- **Avangrid Renewables**: Vineyard Wind 800 MW (MA); Kitty Hawk 1,500 MW (NC)
- **Equinor (Statoil):** Empire Wind 816 MW (up to 1,500 MW) (NY)
- **US Wind**: 248 MW (MD); up to 1,500 MW (NJ)
- **Dominion:** 2,640 MW (VA), first 880 MW phase to come online in 2024
- Others include: Eversource, GE, CIP, RES, Neptune Wind, Virginia Power, Georgia Power…

The Cost of Offshore Wind in the U.S. vs. Europe

2018 saw large cost decreases for U.S. offshore wind projects, decreasing gap with Europe (despite $0/MWh premiums in Europe)

- 2016 Block Island (RI): 30 MW at $244/MWh
- 2020-23 Revolution Wind (RI): $98/MWh for energy+RECS
- 2020-25 Vineyard (MA): **$74/MWh** for first 400 MW **$65/MWh** for second 400 MW.
  - Includes energy + RECS
  - Capacity value ($5-10/MWh) and ITC stays with developer
- Ocean Wind (NJ): Levelized OREC price estimated to $46.46/MWh
  - Does not include energy and capacity revenues
- NY prices are expected to be similar

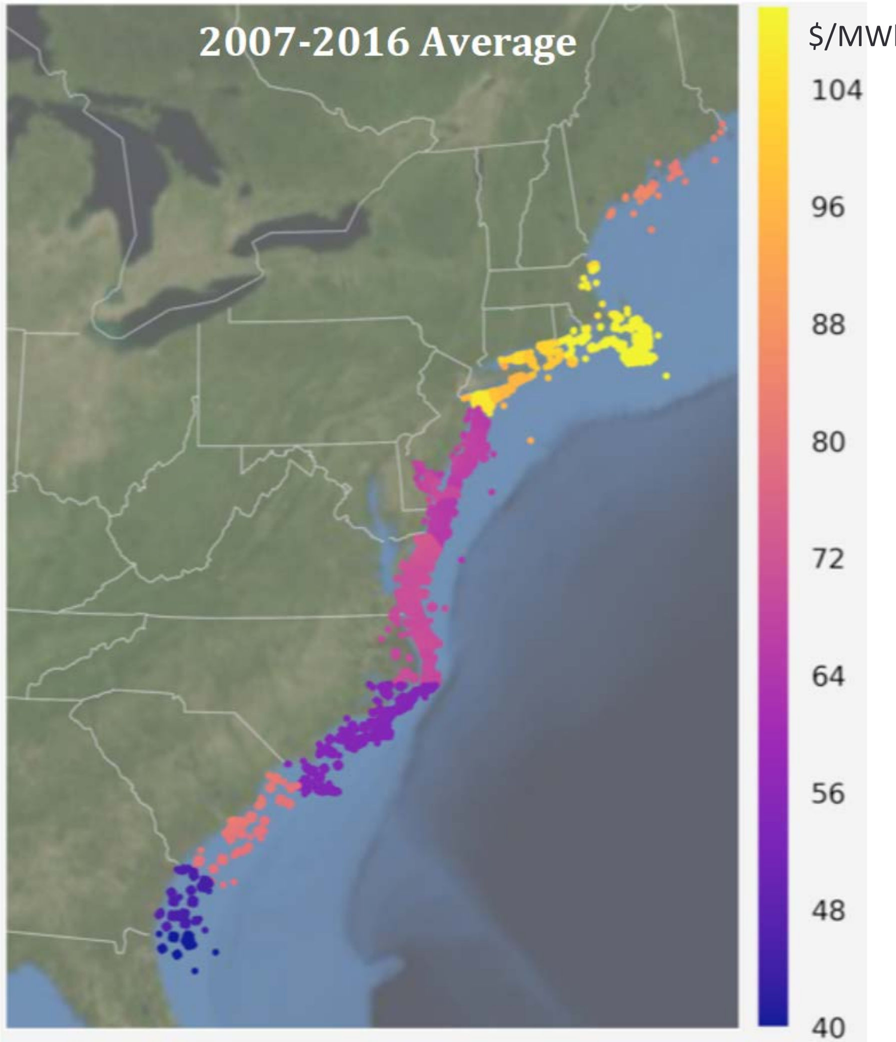


Source: Beiter (2017), The Vineyard Wind Power Purchase Agreement: Insights for Estimating Costs of U.S. Offshore Wind Projects, National Renewable Energy Laboratory https://www.nrel.gov/docs/fy19osti/72981.pdf

The Value of Offshore Wind in the U.S.

LBNL estimated the total market value of offshore wind generation based on historical market prices for energy, capacity, and RECs in various U.S. wholesale power markets:

- Highest value in New England at $100-110/MWh
- New York: $100/MWh
- Mid-Atlantic (PJM): $70/MWh
- South of PJM: $40-55/MWh



Source: LBNL (2018). Estimating the Value of Offshore Wind Along the United States' Eastern Coast
https://emp.lbl.gov/publications/estimating-value-offshore-wind-along

Offshore Project Procurement Models

Expected cost and risk of U.S. offshore wind development depends on contract and investment model:

Contract/Investment Model				
Model	**PPA**	**Indexed OREC**	**Fixed OREC**	**Market/Merchant**
Mechanism	Fixed contract for energy+ORECs	Fixed price minus energy/capacity index for ORECs	Fixed price for ORECs	No premium for "clean" attributes
Implications for Owner/ Developer	Fixed revenue stream (capacity market risk may remain)	Basis risk and shape risk relative to energy and capacity index	Energy and capacity risk	Relies on market prices, potential for hedges with banks or insurance companies
Example	Vineyard Wind (MA) (excl. capacity)	NYSERDA Solicitation	Ocean Wind (NJ)	Zero premium in Germany and NL (w/o transmission costs)

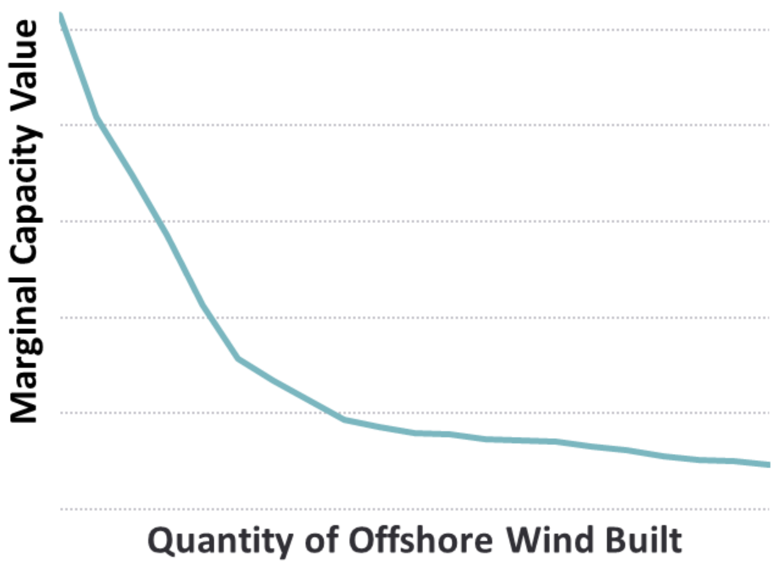
More risk for owner/developer →

Offshore Project Development Risks

Expected value and risk of U.S. offshore wind depends on many factors:

- Where the owner faces some market price risk (incl. the Index OREC):
  - Basis and shape risk not only add risk but also reduce the expected value of a project
  - Especially for large additions or if correlated with large amounts of similar resources at similar locations
- Capacity market risk can be high as future UCAP ratings could be substantially derated with increased off-shore wind development

Indicative Analysis of the Marginal Capacity Value of Adding Offshore Wind



Strategic Implications of Offshore Transmission

Locations of onshore interconnection points have important implications for offshore project costs, bids, and bid evaluation

- The choice of landing points is a major strategic decision, affecting both the project costs and revenues
  - Bidders will have to propose a landing point before they know what all the required network upgrade costs will be
  - Under OREC approaches, the bidder must evaluate different costs and "basis risk" associated with different landing points
  - Under PPA approaches, the bid evaluator must compare the value of resources at different landing points
- An offshore grid would create level playing field for competing projects
  - Positive recent experience in Germany, where transmission system operator owns and manages offshore grid while the substations are owned by developers
  - Offshore grids being developed in Belgium (1,030 MW) and the Netherlands (3,500 MW)
  - UK coordination study showed cost reductions offered by offshore grid transmission

Offshore Gen-Ties vs. Offshore Grids

Advantages of gen-ties to individual offshore wind plants:

- Offshore wind plant and transmission can be synchronized and integrated in development effort of individual companies (reduced project-on-project risk)
- Development of individual wind plants does not depend on common offshore transmission infrastructure becoming available in time
- More cost effective for limited wind development and short distances to shore

Advantages of off-shore grids to integrate multiple wind plants:

- More cost effective for large-scale wind development that are far offshore or in locations with few onshore landing points (or sensitive shoreline)
- Reduced risk that gen-ties of first several wind plants inefficiently use up available rights-of-ways, blocking subsequent developments
- Better coordination with and reinforcement of onshore grid
- Added offshore redundancy due to meshed configuration
- Open access to enable more competition among wind developers
- Competition between experienced transmission developers

Choosing between Gen-ties and Offshore Grids

Factors favoring offshore grids to serve multiple wind plants

- Large size of total wind generation commitment with sizable individual steps
  - More than 1600 MW 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

Factors favoring gen ties to individual offshore wind plants

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

Implications for U.S. Offshore Transmission Needs

U.S. offshore wind development will require substantial offshore transmission infrastructure

- The ~20,000 MW of committed off-shore wind development in the Northeastern US will require about **3,000 miles of offshore transmission** plus significant onshore reinforcements
  - For example: to integrate 20,000 MW with single 220kV HVAC **gen-ties** for every 400 MW of wind plants (up to 30-60 miles offshore) would require **50 landing points** with associated onshore grid interconnections reinforcements
  - **Off-shore grids** to integrate multiple wind plants—such as used in Germany, the Netherlands, Belgium, and proposed by Atlantic Wind in NJ and Anbaric, Bluewater, and Ørsted in MA—would **create scale economies and reduce the number of necessary landing points**

Integrating the already proposed offshorewind plants will almost certainly require the development of offshore grids

- Networked offshore grids can also reinforce the onshore network and reduce the cost of onshore-interconnection-related upgrades
- Additionally offers scale economies and competitive advantages

Offshore Wind Transmission Options in ISO-NE

ISO-NE: 40 to 90+ miles from interconnections with on-shore grid

	State	Owner	Approximate Total Cable Route Length (Miles)	Approximate Land Cable Route Length[32]	Approximate Submarine Cable Route Length	Substation Improvement for a 1,000 MW Project	Proximity of Potential Converter Station Parcel	Rank
Brayton Point	MA	National Grid	45 – 95	<1	45 – 95	$10M	Close	Tier 1
Canal	MA	NSTAR	60 – 100	10	50 – 90	$2.5M	Close	Tier 1
Kent County	RI	National Grid	51 – 96	1	40 – 95	$2.5M	Close	Tier 1
Carver	MA	NSTAR	65 – 105	20	45 – 85	$2.5M	Not Close	Tier 2
Oak Street	MA	NSTAR	50 – 60	10	45 – 60	$2.5M	Not Close	Tier 2
Millstone	CT	Northeast Utilities	60 – 120	<1	60 – 120	$2.5M	Close	Tier 3
Montville	CT	Northeast Utilities	65 – 130	<1	65 - 130	$2.5M	Close	Tier 3

Source: https://www.cleanegroup.org/ceg-resources/resource/northeast-offshore-wind-regional-market-characterization/

ISO-NE estimated that each of these interconnection points should be able to accommodate the injection of 1,000 MW of offshore wind generation, with a cumulative total of 6,000 MW

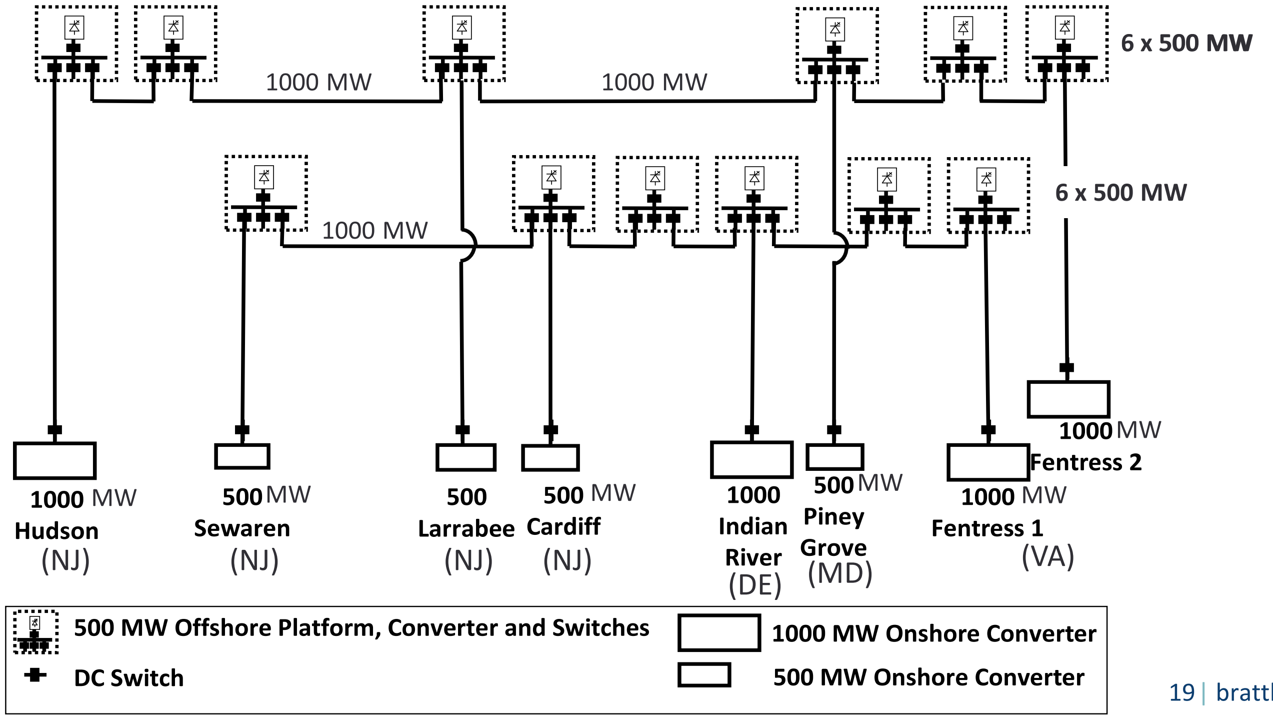
- Injections at these points will also benefit onshore grid by reducing north-south congestion and within south-eastern ISO-NE
- Injections in ME and NH would require north-south onshore grid expansion

Offshore Transmission Needs for NJ and PJM

New Jersey: wind areas in southern NJ, approx. 17 miles from shore

- Beyond Oyster Creek, the onshore grid in southern NJ is fairly weak, likely requiring:
  - Reinforcements of the on-shore grid at local landing points in southern NJ; or
  - Off-shore connections to more robust but distant landing points (in northern NJ)

PJM: Atlantic Wind Connection previously outlined example of how to integrate 6,000 MW of offshore wind into PJM, reinforcing the onshore grid between NJ, DE, MD, and VA



Offshore Transmission Needs for NY

New York wind energy areas located 14-30 miles offshore

- Limited by shipping lanes emanating from New York City
- Very limited interconnection opportunities with on-shore grid

As part of Governor's earlier commitment to develop 2,400 MW of offshore wind by 2030, NYSERDA begun the Master Plan process:

- Conducted a Cable Landfall Permitting Study to consider potential cable landfall sites
- Hard constraints were identified: National Priority List sites, DOE Conservation remediation sites, and hardened shorelines (Newtown Creek, Harlem River)
- Suggests very limited interconnection opportunities, particularly for a gen-ties model

NYPA's recent offshore wind study analyzed European case studies of offshore wind development, highlighting the opportunities and challenges of offshore wind development:

- "Long-term grid planning for both on and offshore, coordination and performance incentive alignment are really important so parties are incentivized to finish projects in a timely manner."

NYSERDA also taking the lead on interconnecting 9,000 MW by 2035

Planning Onshore Transmission for Offshore Wind

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 generally work for interconnecting an offshore grid

ISO "regional transmission planning" processes are not set up well to develop cost-effective plans for offshore grids in timely fashion

- ISO stakeholder-based regional planning processes are time consuming and often take several years to complete; frequently undefined for addressing public policy needs
- Limited ISO and stakeholder expertise with "wet" transmission facilities and offshore transmission technology options
- NYISO's solutions-based process for public-policy projects may be a good model
- Developing a cost effective offshore grid would require:
  - Phased-in plan that aligns timing of transmission investments with generation development
  - Project-on-project risk mitigation for generators (e.g., compensation for delayed transmission)
  - Coordination to use offshore transmission to also reinforce the on-shore grid
  - Tap into synergies from coordinated inter-regional planning

Takeaways

The U.S. is relying less on offshore wind resources to meet clean energy goals than some parts of Europe, but is poised to make major developments in the next decade

- **U.S. Onshore Wind**: Abundant low-cost, high-quality locations (many greater than 50% capacity factor) … but often far from major load centers.
- **U.S. Offshore Wind**: just 30 MW installed now, but 19,968 MW of existing state-level commitments and 28,464 MW of proposed projects
  - Closer to major load centers and higher-priced wholesale power markets

The U.S. will require substantial offshore+onshore transmission infrastructure investments to integrate the proposed projects

- **Gen-ties** to individual offshore wind plants that are 30-60 miles from shore (and far from other plants) can be cost effective
- **Offshore grids** with open access can offer significant cost and competitive advantages for (1) large plants far from shore and relatively close to each other; (2) limited onshore interconnection opportunities

ISO transmission planning processes work reasonably well for interconnecting individual generators (with gen ties) but are not set up well for offshore grids

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Note:
The views expressed in this presentation are strictly those of the presenter and do not necessarily state or reflect the views of *The Brattle Group, Inc*.

Johannes (Hannes) Pfeifenberger is an economist with a background in power engineering and over 20 years of experience in the areas of public utility economics and finance. He has published widely, assisted clients and stakeholder groups in the formulation of business and regulatory strategy, and submitted expert testimony to the U.S. Congress, courts, state and federal regulatory agencies, and in arbitration proceedings.

Hannes has extensive experience in the economic analyses of wholesale power markets and transmission systems. His recent experience includes the analysis of transmission benefits, reviews of RTO capacity market and resource adequacy designs, testimony in contract disputes, cost allocation, and rate design. He has performed market assessments, market design reviews, asset valuations, and cost-benefit studies for investor-owned utilities, independent system operators, transmission companies, regulatory agencies, public power companies, and generators across North America.

Hannes received an M.A. in Economics and Finance from Brandeis University and an M.S. in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.

Examples of Brattle Offshore Wind Experience

Evaluation of Offshore Wind Contract Terms

For the Massachusetts' Attorney General's office, Brattle experts submitted testimony before the Massachusetts Department of Public Utilities, comparing the proposed contract price and terms of the Cape Wind offshore wind project with the price and costs of other U.S.-based and European offshore wind projects. The testimony also estimated Cape Wind likely project costs and evaluated the potential ratepayer value of various proposed contract terms.

Locational and Zonal Long-Term Pricing for Off-shore Wind in New York

For an offshore wind developer participating in an offshore wind procurement by NYSERDA, Brattle prepared a number of price forecasts to help the client understand risks associated with the two PPA structures under the offshore wind procurement. To do so, we used nodal market simulations to forecast near-term (five years out) as well as longer-term energy and capacity prices in New York for various zones and nodes. The forecasts included assumptions about the development of demand in line with broader greenhouse gas policy goals and relaxed transmission constraints for longer-range forecasts.

U.S. Offshore Wind Generation and Transmission Needs

For a transmission developer Brattle experts developed a grid framework to evaluate the relative advantages and tradeoffs between using individual gen-ties versus offshore grids to interconnect offshore wind projects of different sizes and configurations.

Atlantic Wind FERC Testimony

Brattle experts testified before the Federal Energy Regulatory Commission (FERC) in support of the public policy, reliability, congestion relief, and economic benefits of the Atlantic Wind Connection Project. The project proposed to construct an offshore transmission grid to integrate 6,000 MW of offshore wind farms to the on-shore grid in the Mid-Atlantic region from New Jersey to Virginia.

Economic Stimulus of Offshore Wind Generation Investments

Brattle experts conducted several studies estimating the economic stimulus and employment impacts of major offshore wind generation investments.

Assessment of Market Design Improvements for Interconnecting Wind Generators

For a large regional transmission organization, Brattle assessed the potential risks associated with existing procedures for interconnecting wind generators on wind generators with different types of interconnections agreements, and proposed recommendations for improvements to the RTO procedures.

Transmission Planning for a Carbon-Constrained Future

In a report for the WIRES Group, a transmission trade association, Brattle analyzed the impact of accelerated decarbonization efforts on the transmission grid. In their study, Brattle experts took a comprehensive look at the rapid changes occurring in the electricity industry, particularly as they relate to the impact of environmental regulations, market forces, and new technologies on the generation fleet. Their analysis found that anticipatory transmission planning, which moves beyond the standard 5 to 10 year planning horizon, is key to addressing the next generation of electricity supplies and consumption in an effective manner.

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