U.S. Offshore Wind Generation and Transmission Needs

SEPTEMBER 2018 UPDATE

PRESENTED TO

Offshore Wind Transmission, USA Conference

PRESENTED BY

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Agenda

Background

- Global Context for U.S. Wind Generation
- U.S. Offshore Wind Generation Policy & Developmental Efforts
- Costs

Current Regulatory and Permitting Issues

Onshore Grid Constraints and Solutions

Key Considerations for Offshore Wind Transmission

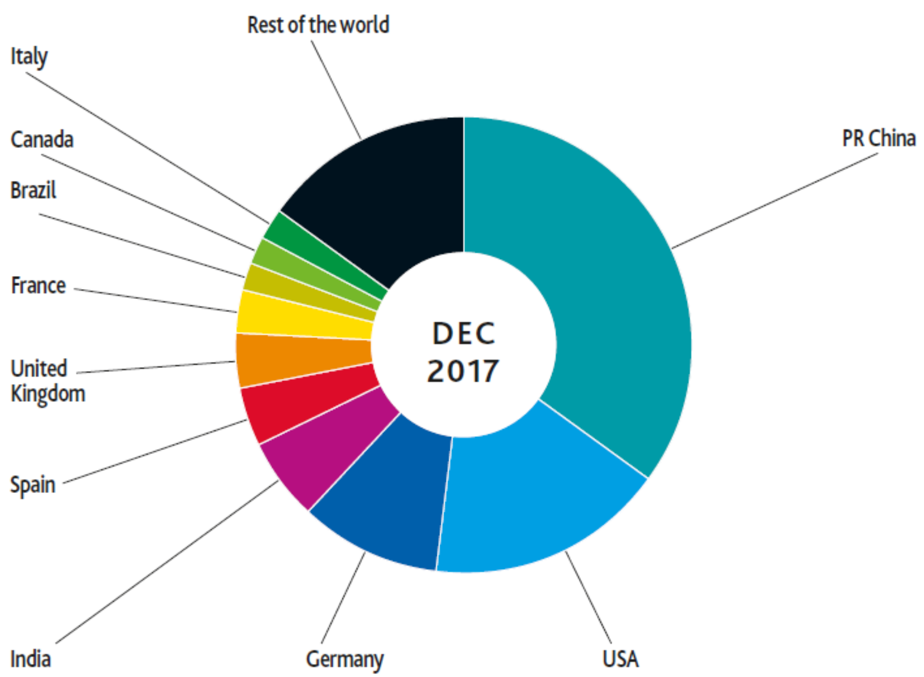
Takeaways

Global Context for U.S. Wind Generation

The U.S. has significant wind generation … but little offshore wind because of abundant low-cost onshore wind resources (though often far from major load centers)

Total Installed Wind Capacity
(Onshore + offshore)

TOP 10 CUMULATIVE CAPACITY DEC 2017



Total Installed Wind Capacity
(Onshore + Offshore)
Dec 2017

Country	MW
PR China	188,392
USA	89,077
Germany	56,132
India	32,848
Spain	23,170
United Kingdom	18,872
France	13,759
Brazil	12,763
Canada	12,239
Italy	9,479
Rest of the world	82,391
Total TO P10	456,732
World Total	539,123

Source: GWEC (2018), 2017 Global Wind Energy Report, http://files.gwec.net/files/GWR2017.pdf

U.S. Position Relative to Global Offshore Market

The installed global offshore wind capacity has reached 18.8 GW by the end of 2017 (up from 12.9 GW at the end of 2016) … mostly in Europe and China

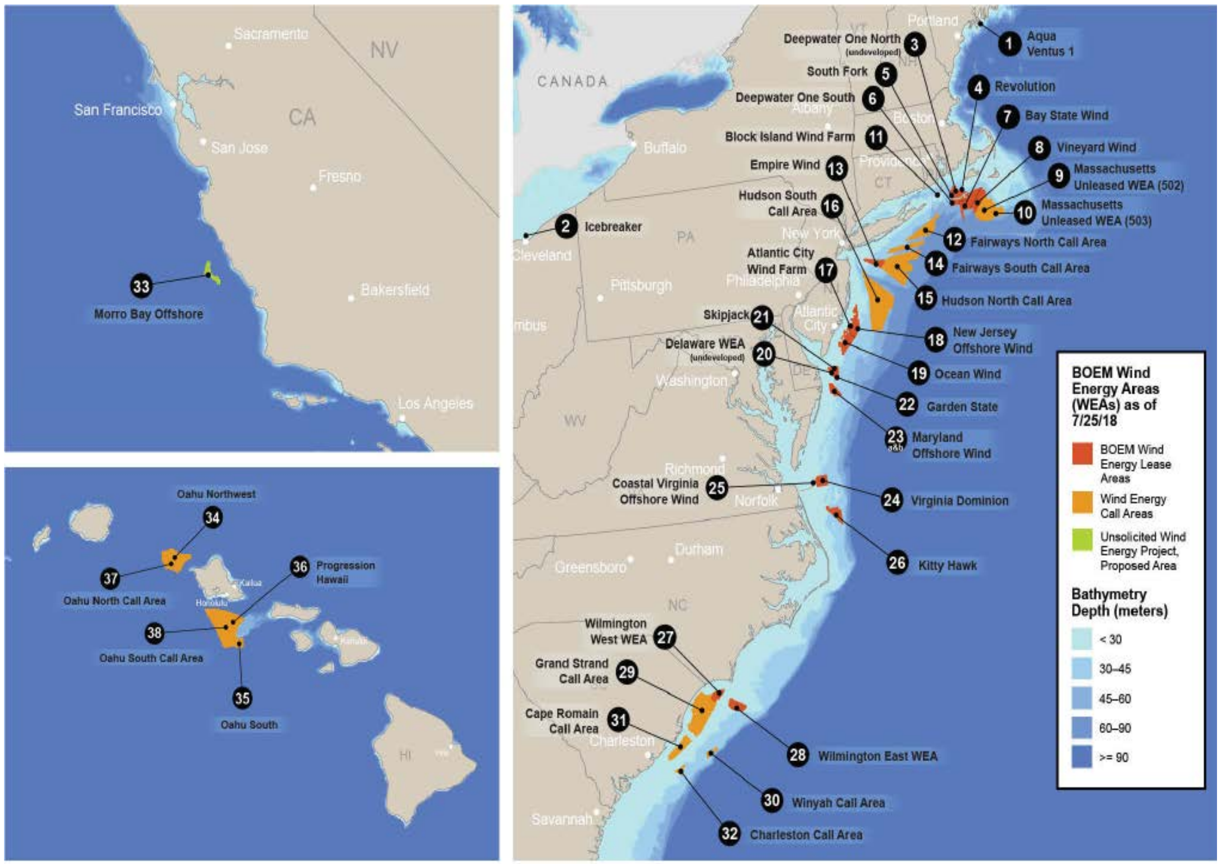
Total Offshore Wind Capacity	Commissioned (as of end of 2016 [MW])		Under Construction (as of end of 2016)	Total
United Kingdom	5,097	(6,836 as of end of 2017)	1,966	7,062
Germany	3,877	(5,355 as of end of 2017)	1,483	5,360
China	1,092	(2,848 as of end of 2017)	1,994	3,086
Denmark	1,271		0	1,271
Netherlands	520		600	1,120
Belgium	712		165	877
Sweden	202		0	202
Japan	38		12	50
United States	30		0	30
Other	75		80	155
Total (end of 2016)	**12,913**		**6,300**	**19,213**
Total (end of 2017)	**18,814**			

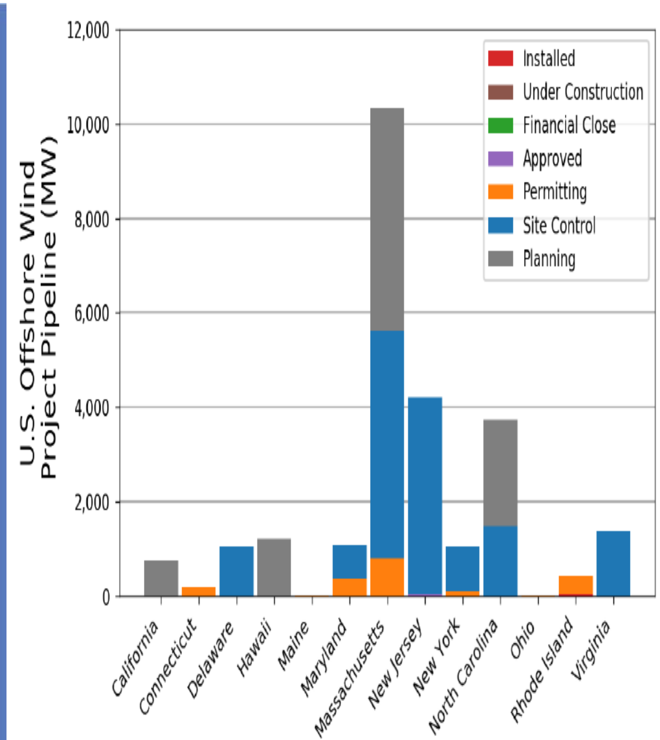
Source: Walter Musial, Beiter, Philipp, Schwabe, Paul, Tian, Tian, Stehly, Tyler, Spitsen, Paul, Robertson, Amy, & Gevorgian, Vahan. 2017. *2016 Offshore Wind Technologies Market Report. Table 2, Page 12.* United States, U.S. Department of Energy (DOE). DOE/GO-102017-5031. https://doi.org/10.2172/1375395.

Currently Proposed U.S. Offshore Wind Projects

28 projects “under development” (25,435 MW)

18 projects with site control (14,585 MW) … mostly in North Atlantic





U.S. Project Pipeline by State as of June 2018

Source: Beiter, Musial, et al. 2018. *2017 Offshore Wind Technologies Market Update. Figure “U.S. Offshore Wind Lease and Call Areas”; Figure “ U.S. Project Pipeline by States as of June 2018”*

Examples of Current U.S. Offshore Wind Initiatives

Examples of state initiatives:

- **RI:** 30 MW block island (operational)
- **MD:** 368 MW by 2020-22 (procured)
- **MA**: 1,600 MW by 2027 (mandate, 400-800 MW bid); 5,000 MW by 2035 (bill)
- **CT:** 200 MW RFP for offshore wind (including storage and fuel cells)
- **NY**: 800 MW (mandate); up to 2,400 MW by 2030 (goal)
- **NJ**: 1,100 MW (mandate); 3,500 MW by 2030 (goal); restarted review and approved Fishermen's Atlantic City Project (24 MW)
- Proposed projects also in: CA, GA, ME, NC, OH, TX, VA, (plus BC and ON in Canada)

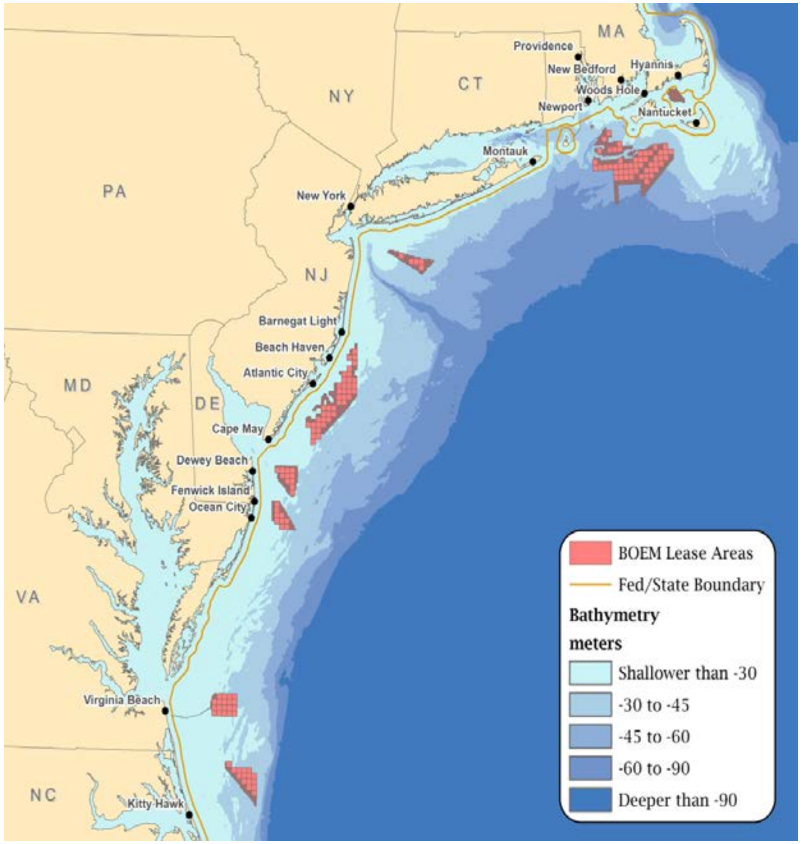
Examples of developer initiatives:

- **US Wind**: 248 MW (MD)
- **Deepwater:** Revolution 600 MW (RI, CT); Skipjack 120 MW (MD); Southfork 90 MW (NY)
- **Ørsted**: Ocean Wind with 1,000 MW by 2020-25 (NJ); Baystate Wind 400-800 MW (MA)
- **Avangrid Renewables**: Vineyard Wind 400-800 MW (MA); Kitty Hawk 1,500 MW (NC)
- **Equinor (Statoil):** Empire Wind 600 MW (up to 1,500 MW) for NYC & LI
- Others include: GE, RES, Neptune Wind, Virginia Power, Georgia Power, …

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.

- So far, BOEM has issued 17 GW worth of offshore wind leases.
- 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
- Individual BEOM Lease Sales:
- Rhode Island/Massachusetts (July 2013)
  - Commercial Lease OCS-A 0486
  - Commercial Lease OCS-A 0487
- Virginia (September 2013)
  - Commercial Lease OCS-A 0483
- Maryland (December 2014)
  - Commercial Lease OCS-A 0489
  - Commercial Lease OCS-A 0490
- Massachusetts (March 2015)
  - Lease OCS-A 0500
  - Lease OCS-A 0501
- New Jersey (February 2016)
  - Lease OCS-A 0498
  - Lease OCS-A 0499
- New York (December 2016)
  - Lease OCS-A 0512
- North Carolina (March 2017)
  - Lease OCS-A 0508

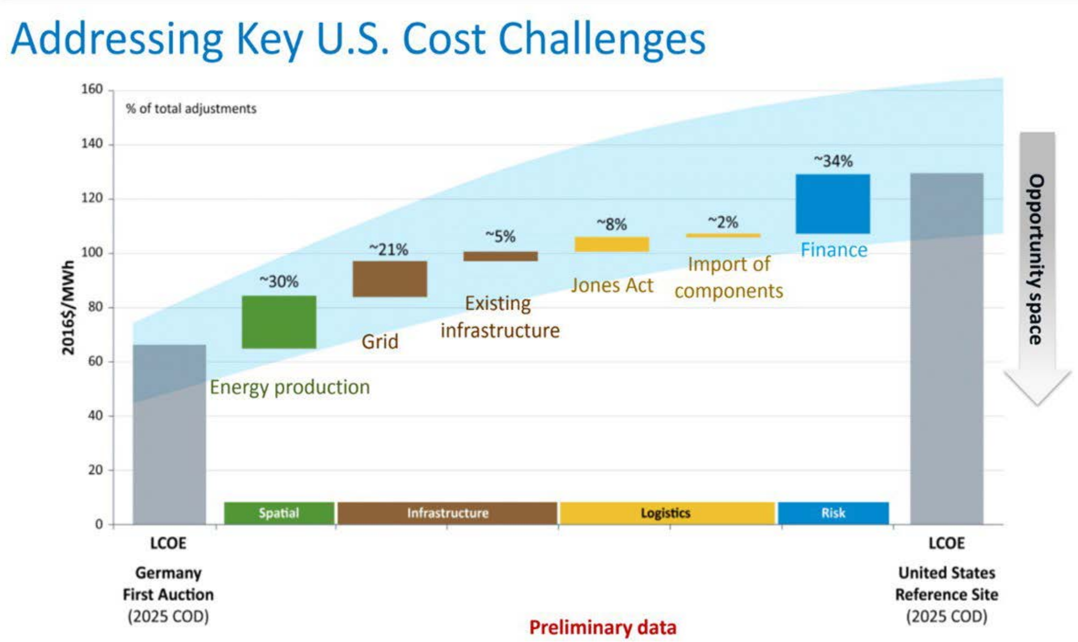


Source: "Lease and Grant Information", Bureau of Ocean Energy Management, accessed May 23, 2018, https://www.boem.gov/Lease-and-Grant-Information/.

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

Historically, there has been a large spread between the cost of offshore wind between the U.S. and Europe

- A 2017 analysis by NREL estimated the spread to be about $55/MWh between German and American costs for offshore wind procurements
- A recent German auction (April 2018) was conducted at $55/MWh (€46.6) for 1,610 MW (six wind farms)
- Using NREL's estimated spread, U.S. prices would be expected to be near $90-$110/MWh in near term
- Some previously observed prices in U.S.:
  - 2016 Block Island (RI): 30 MW at $244/MWh
  - 2020-22 Maryland: 368 MW at $132/MWh



Source: Philipp Beiter (2017). "Unlocking the U.S. Offshore Wind Cost Opportunity", NREL, p. 7. http://s23.a2zinc.net/clients/AWEA/OWP17/Custom/Handout/Speaker0_Session642_1.pdf

Recent Contracts Suggest the Gap is Not as Large as Previously Thought

Costs remain relatively higher in the U.S., but recent contracts show a significantly lower spread than NREL's estimated spread

- Using NREL's (2017) estimated spread, the U.S. costs would be around $110/MWh
- In a jurisdiction with a capacity market, such as Massachusetts, the PPA price could be lower since a portion of the cost can be recovered via capacity revenues. Assuming a capacity value of $5-$10/MWh, this suggests PPA prices in MA would be in the $100 - $105/MWh range
- In fact, Massachusetts 83C RFP recently procured 800 MW for $65/MWh, suggesting a smaller than predicted spread between Germany and U.S. offshore wind procurements
- This could in part be explained by a lower than expected risk premium for offshore wind development in the U.S. (e.g., following concerted efforts across the Eastern seaboard to address industry concerns surrounding the supply chain development and port access)

Source: Philipp Beiter (2017). "Unlocking the U.S. Offshore Wind Cost Opportunity", NREL, p. 7. http://s23.a2zinc.net/clients/AWEA/OWP17/Custom/Handout/Speaker0_Session642_1.pdf

New York State as a Case Study

In addition to obtaining a BOEM lease, there are various other permits or approvals needed for the development of offshore wind resources. In New York, for example:

- Siting of major utility transmission facilities is subject to the Department of Public Service, Public service Commission's approval in New York
- Title to the bodies of water is typically granted for a term of 25 years by the Office of General Services
- Various permits by the Department of Environmental Conservation are required for the installation of transmission cables through state waters that may impact water quality, stormwater, wetlands, or endangered species
- An architectural study is required to identify sensitive historical, cultural, and traditional sites (permitting agency: Office of Parks, Recreation, and Historic Preservation)

Source: NYSERDA (2015). "New York State Offshore Wind Master Plan: Table off Permits and Approvals", NYSERDA, pp. 3-5. "NY State Statutes and Regulations Applicable for Offshore Wind".

Implications for Offshore Transmission

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

- Even the 8,000 MW of committed off-shore wind development in MA, NY and NJ will require about 600-1,200 miles of offshore transmission plus onshore reinforcements
  - For example: to integrate 8,000 MW with single 220kV HVAC gen-ties for every 400 MW of wind plants (30-60 miles offshore) would require 20 landing points with associated onshore grid interconnections reinforcements
  - As discussed in the May 2018 conference, Ørsted estimated that transmission to shore can be 15%-20% of total off-shore wind capex. Also, Siemens discussed AC vs. DC technologies, and estimated the cross-over point from AC to DC technology to be around more than 300-400 MW and more than 60 miles
- Integrating 15,000-24,000 MW of already proposed offshore wind plants will almost certainly require the development of some (networked) offshore grids and approximately 3,000 miles of offshore transmission lines

Sources: Sunny Gupta (2018). "Developer's Perspective on Transmission", Orsted, p. 9. Kevin Pearce (2018). "Transmission Solutions for the U.S. Offshore Wind Market Global Transmission Offshore Wind Conference", Siemens, p. 5.

Offshore Transmission Needs for NJ, NY, MA

MA, RI, CT: 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

Sources: Northeast Offshore Wind Regional Market Characterization (2017) https://www.northeastwindcenter.org/wp-content/uploads/Northeast-Offshore-Wind-Regional-Market-Characterization.pdf ESS Group (2014) Offshore Wind Transmission Study: Final Report http://files.masscec.com/research/MassCECOSWTransmissionStudy.pdf

New York: wind energy area located 14-30 miles offshore

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

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
  - (1) significant reinforcements of the on-shore grid at local landing points or
  - (2) build off-shore connections to more robust but more distant landing points (e.g., in northern NJ)

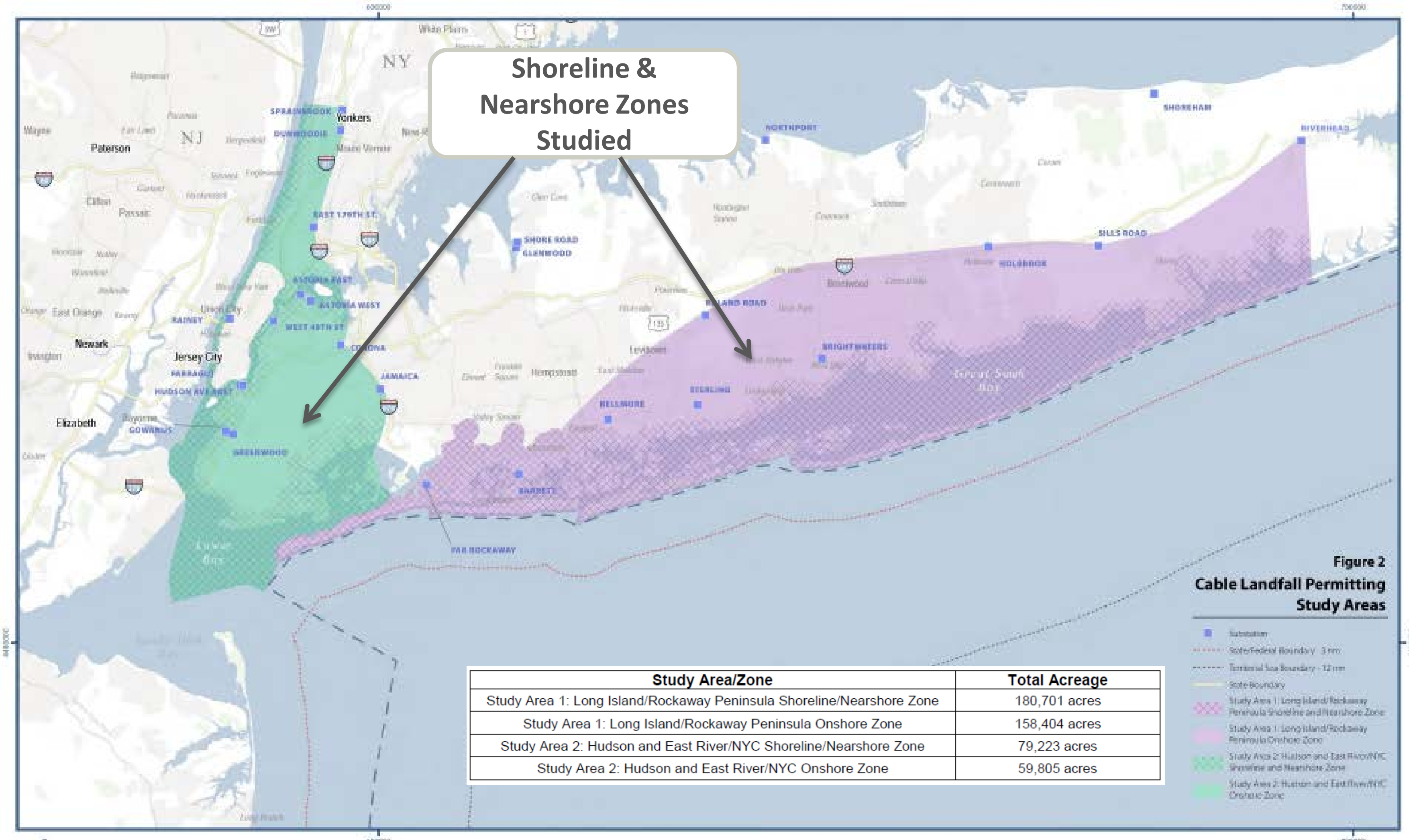
Offshore Wind in New York State

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

- Started with a 16,000 square mile study area for potential offshore wind
- Refined the area through analyses to maximise benefits/minimize conflicts to ocean users, and stakeholder feedback
- Conducted a Cable Landfall Permitting Study to consider potential cable landfall sites that could link an offshore wind farm to the onshore grid
  - Study focus was on Environmental, Physical and Social Resources to identify opportunities and constraints to permitting process
  - Hard constraints were identified, associated with National Priority List sites, DOE Conservation remediation sites, and hardened shorelines (Newtown Creek, Harlem River)
- Narrowed down the area of interest to 10% of the original study area (submitted the proposed area to BOEM in October 2017; BOEM published a Call for Information and Nominations for leasing in the New York Bight in April 2018)

Source: "Area for Consideration", NYSERDA. "New York State Offshore Wind Master Plan: Cable Landfall Permitting Study", NYSERDA, pp. 6, 7.

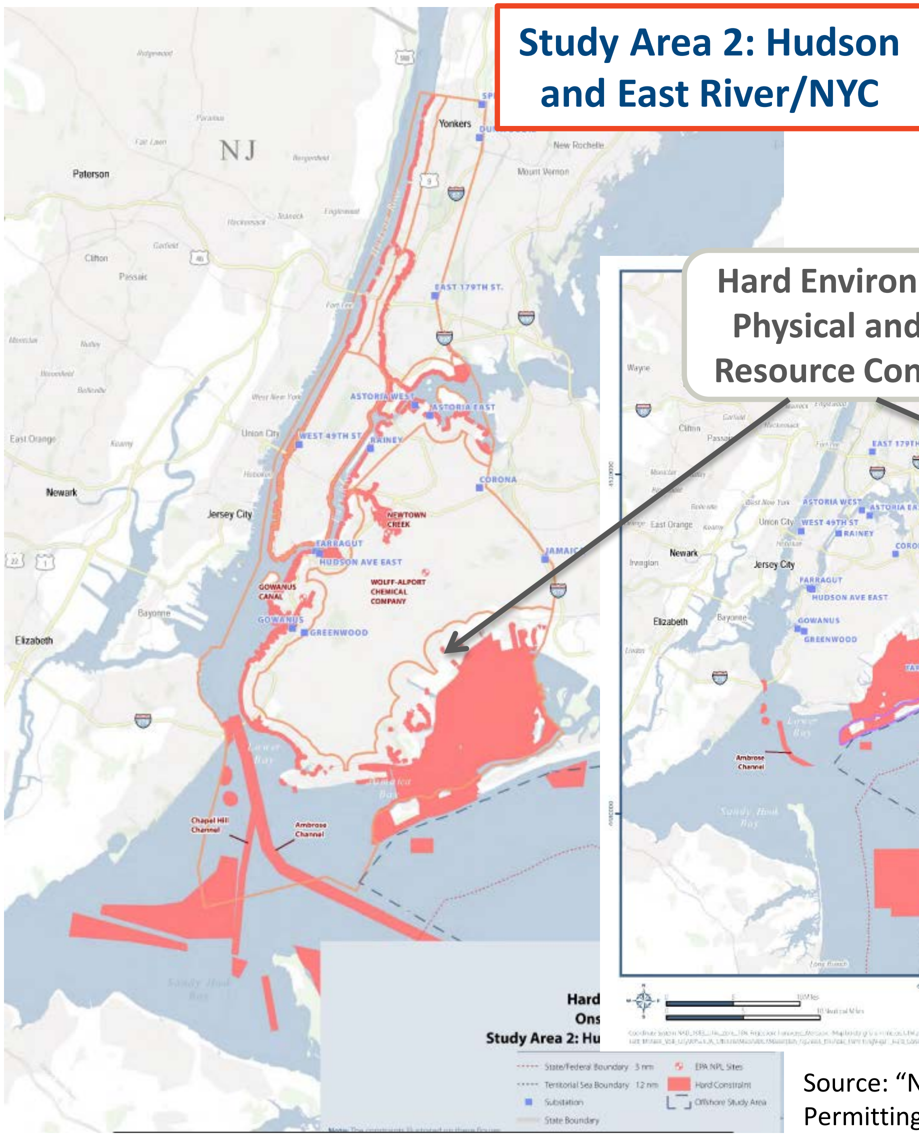
New York Cable Landfall Permitting Study Areas

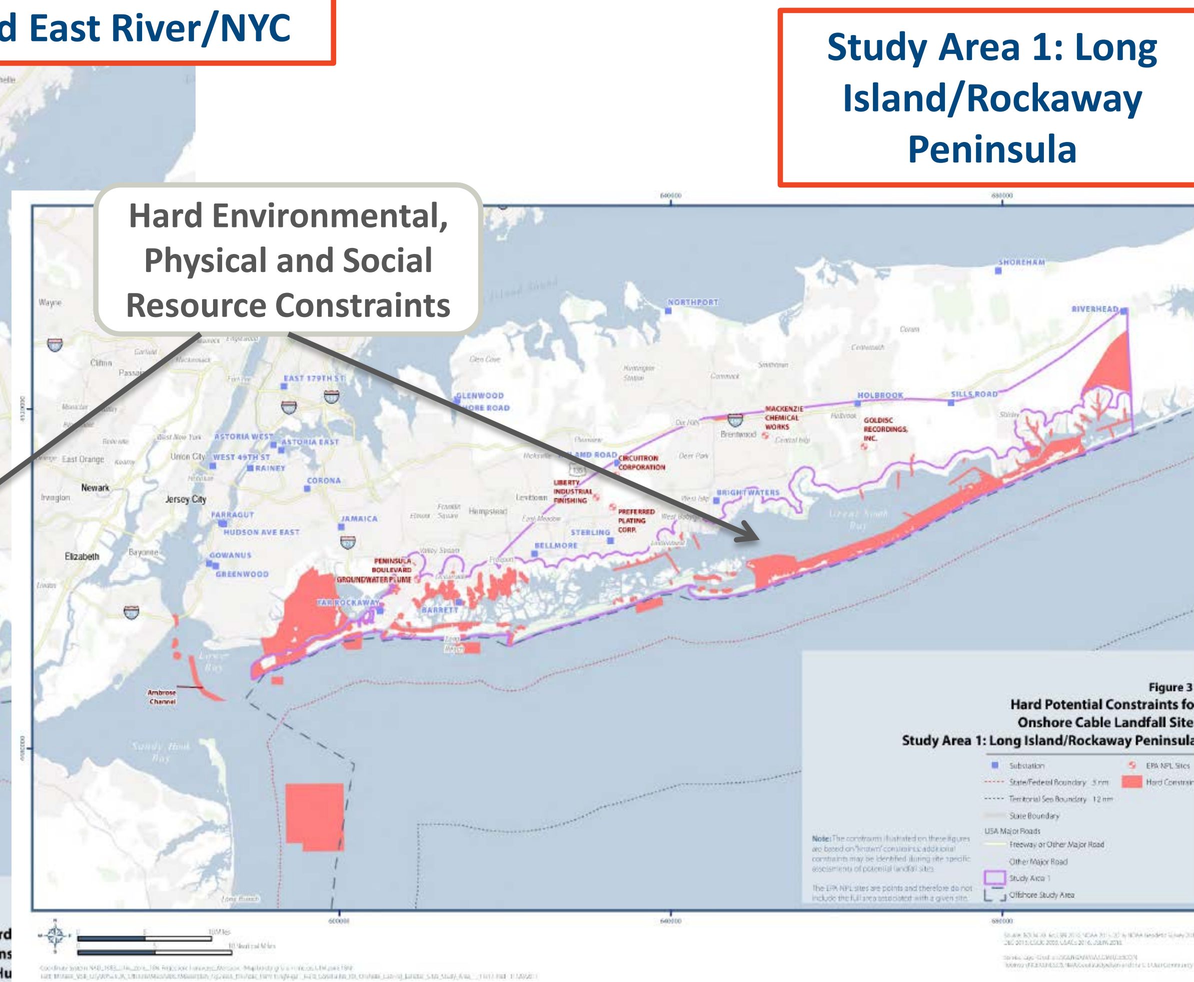


Study Area/Zone	Total Acreage
Study Area 1: Long Island/Rockaway Peninsula Shoreline/Nearshore Zone	180,701 acres
Study Area 1: Long Island/Rockaway Peninsula Onshore Zone	158,404 acres
Study Area 2: Hudson and East River/NYC Shoreline/Nearshore Zone	79,223 acres
Study Area 2: Hudson and East River/NYC Onshore Zone	59,805 acres

Source: “New York State Offshore Wind Master Plan: Cable Landfall Permitting Study”, NYSERDA, pp. 6, 7.

Hard Potential Constraints for Cable Landfall Sites





Source: "New York State Offshore Wind Master Plan: Cable Landfall Permitting Study", NYSERDA, pp. 164, 165.

Offshore Gen-Ties vs. Offshore Grids

Advantages of gen-ties to individual offshore wind plants:

- Offshore wind plant and transmission can be perfectly synchronized and integrated in development effort of individual companies
- 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 between 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 development commitment with sizable individual steps
  - Greater than 1,400 MW and procured 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 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 level playing-field 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
  - 200-400 MW plants only?
- Modest distance from shore
  - Less than 40 miles?
- Many landing points with robust on-shore transmission infrastructure
  - 4-8 for every 1,600 MW of total development?
- Long distance between offshore locations to be interconnected
- Easy permitting of landing points and interconnection study process
- Wind developers have significant offshore transmission experience

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 significant investments 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**: 30 MW installed with 8,000 MW of existing state-level commitments and 24,000 MW of proposed projects
  - Closer to major load centers and higher-priced wholesale power markets

The U.S. will likely require 600-1,000 miles (up to 3,000 miles) of offshore transmission infrastructure to integrate proposed projects

- **Gen-ties** to individual offshore wind plants that are within 30 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 interconnecting large amounts of wind generation
  - This is particularly the case with plants far from shore and relatively close to each other

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Mr. Sheilendranath is a Power & Utilities expert with over 10 years of consulting and business development experience, leading strategic analyses of large-scale renewables and transmission grid investments, strategic planning, financial valuation, electricity market modeling and public policy. He specializes in evaluating the economics of renewables and transmission grid investments, and has advised a wide range of clients, including Utility Executives, RTO/ISO Directors and Public Utility Commissions in strategic business and policy decision making. Mr. Sheilendranath also has extensive experience in regulatory finance and estimation of Cost of Capital for regulated utilities. At The Brattle Group, he assists a wide range of energy clients throughout North America and Oceania in business strategy, regulatory Corporate Finance, and all matters related to investments, valuation and integration of large-scale wind generation and electric transmission.

Mr. Sheilendranath holds an MBA From New York University's Stern School of Business and an M.S. in Electrical Engineering from Michigan Technological University.

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