

Atlantic Offshore Wind Transmission Study Overview

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U.S. Department of Energy

Wind Energy Technologies Office

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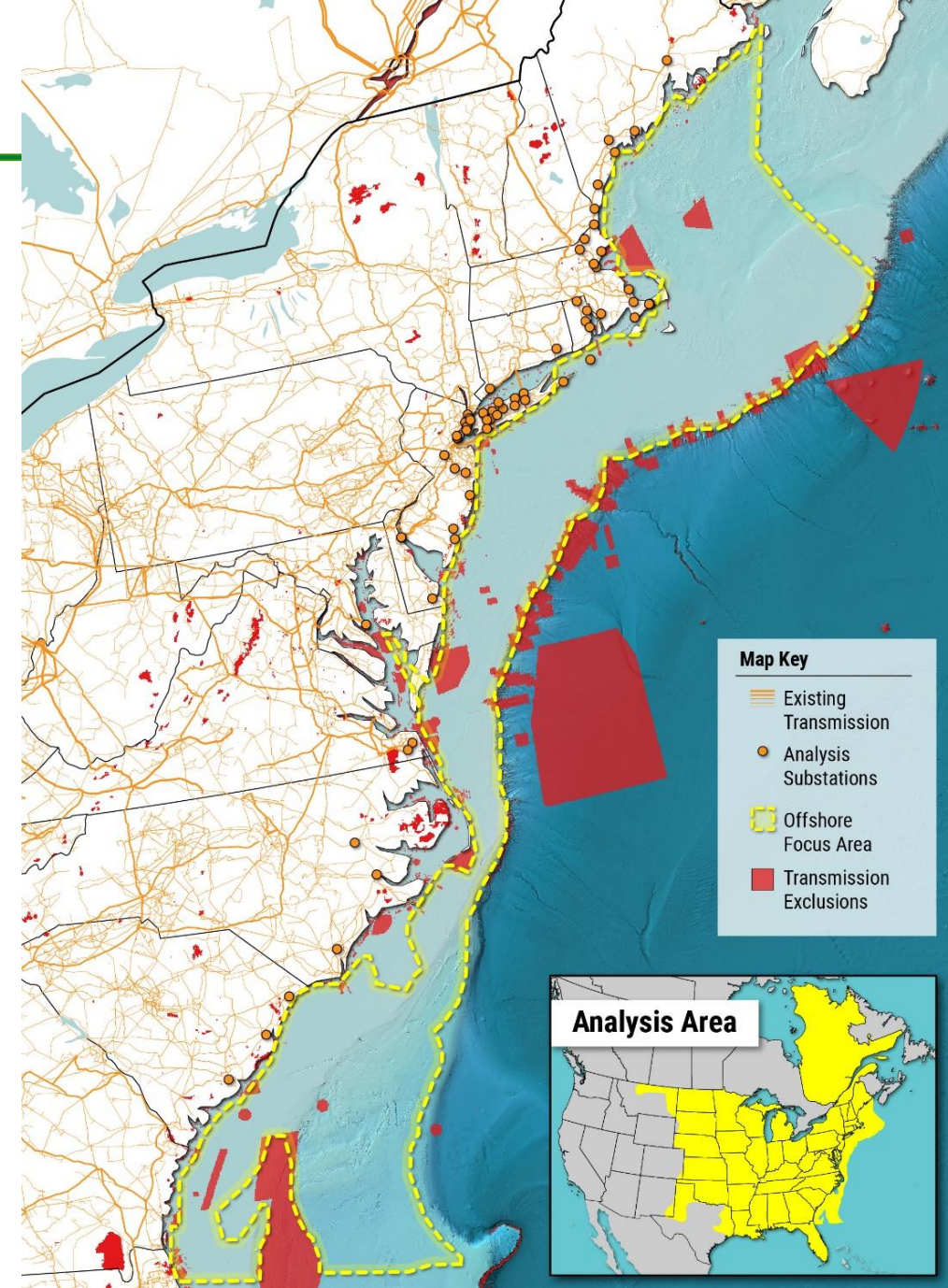
Background

Offshore wind deployment goals:

- Biden-Harris Administration offshore wind deployment goals of 30 GW by 2030, unlocking a pathway to 110 GW by 2050
- State renewable energy goals and procurement activities

Federal activities:

- DOE Atlantic Offshore Wind Transmission Literature Review and Gaps Analysis (2021)
- DOE-BOEM Offshore Wind Transmission Scoping Meetings (2021)
- DOE-BOEM Atlantic Offshore Wind Transmission Convening Workshops (2022-2023)



What is the Atlantic Offshore Wind Transmission Study?

- 2-year study (November 2021 – October 2023)
- DOE Wind Energy Technologies Office, with analysis led by the National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL)
- Atlantic Coast regional scope from Maine through South Carolina
- Evaluate coordinated offshore wind transmission solutions for offshore wind deployment
- Alignment with federal and state offshore wind goals
 - Near-term (2030) and Long-term (2050)
- Economic, reliability, and resilience analyses
- Environmental and siting factors and ocean co-use considerations
- NREL website: <https://www.nrel.gov/wind/atlantic-offshore-wind-transmission-study.html>

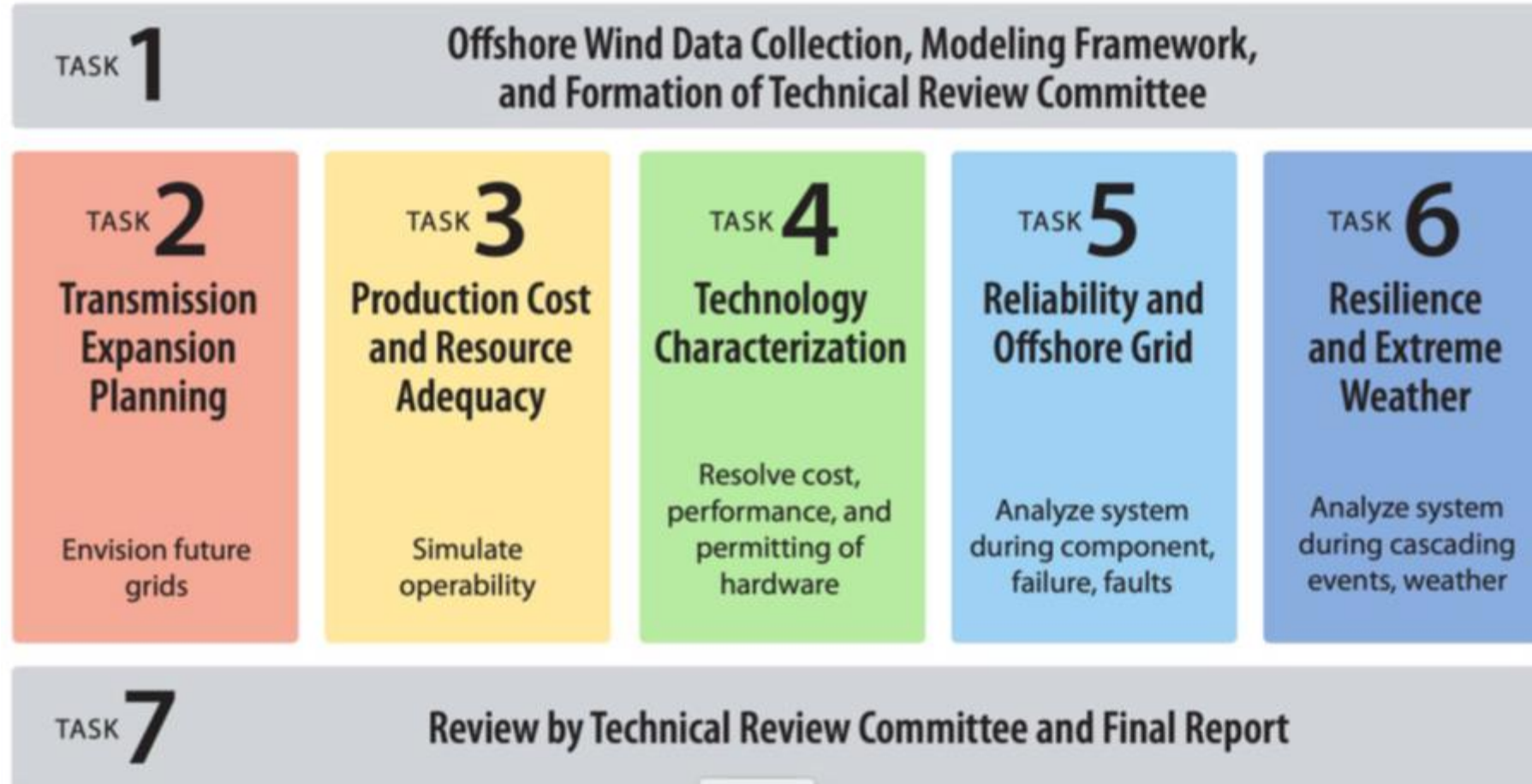
Study Objectives

- Identification of **pathways** for offshore wind deployment
- **Transmission topology scenarios**, sequencing, and build-out in the Atlantic Ocean for 2030 through 2050
 - Five offshore wind transmission topologies: radial, within-region (i.e., intraregional), interregional, within-region + interregional, and backbone
- Comparison of costs and benefits of different transmission build-out scenarios under various combinations of electricity supply and demand while considering reliability, resilience, and environmental and siting constraints
- Consideration of periods of system stress under typical and extreme weather conditions
- Characterization and comparison of **transmission technologies** for different scenarios, including onshore and offshore substations and cabling, and tradeoffs and costs for high voltage alternating current (HVAC) and high voltage direct current (HVDC) scenarios
- Collection of data and models that are **readily useable by ISO/RTOs** and industry for accelerating their own planning studies.

Schedule

- **In Year 1 (November 1, 2021 – October 31, 2022)**
 - Create a Technical Review Committee (TRC) with a wide range of stakeholders and expertise
 - Establish plausible onshore and offshore transmission expansion scenarios for 2030 and 2050 that consider the impacts of cable routing, points of interconnection, landing points, and environmental and siting factors
 - Begin to evaluate system operations, cost, and reliability of the plausible scenarios
- **In Year 2 (November 1, 2022 – October 31, 2023)**
 - Complete production cost modeling, capital investment estimation, and reliability studies
 - Perform stability analysis, transient fault behavior analysis, and resilience studies for the onshore and offshore grid
 - Continue to gather and incorporate TRC feedback
 - **Deliver the Final Report by end of year 2023**

Tasks



Extensive iteration and feedback loops among tasks

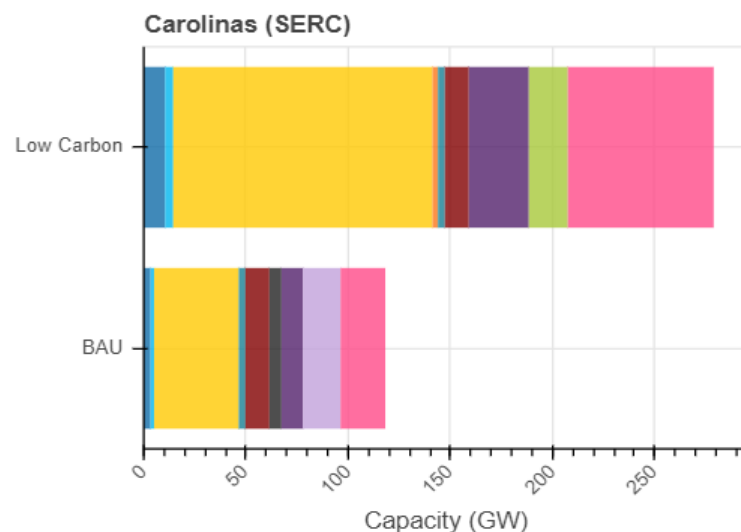
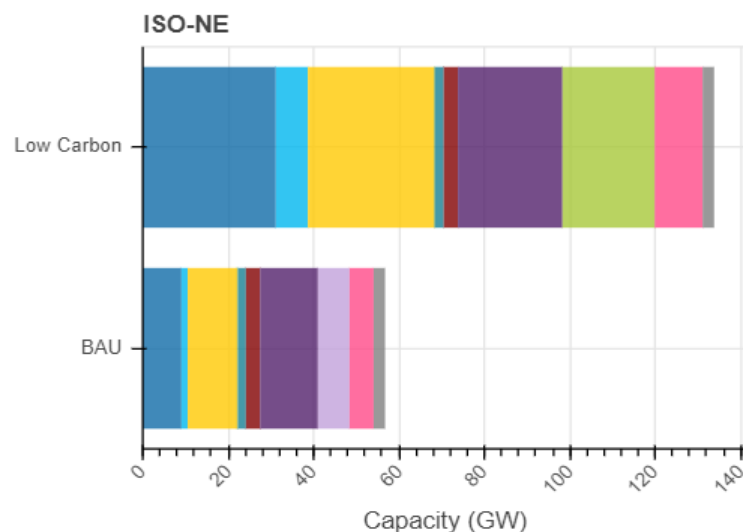
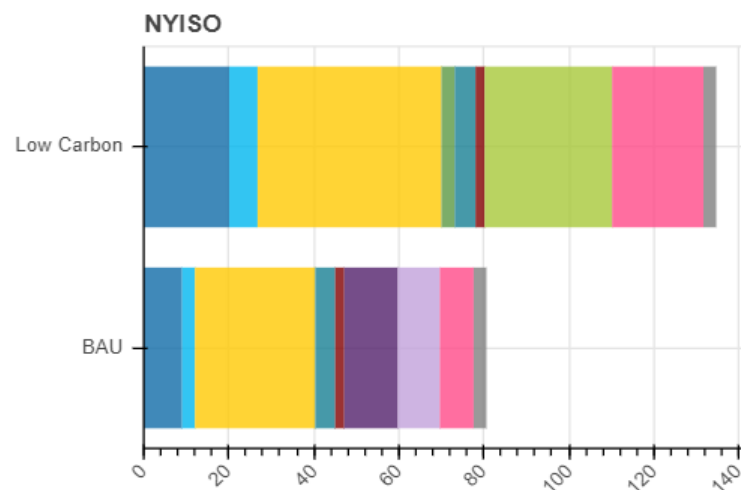
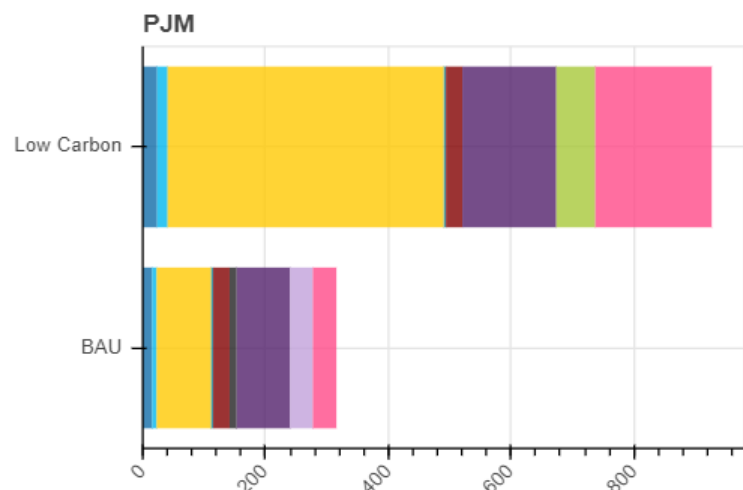
Transmission Expansion Planning

- Proposed Scenarios

	Business as Usual (BAU)	Low Carbon
Demand	Less electrification	More electrification
Carbon emissions (key driver for generation infrastructure)	State policies only	80% carbon reduction in electricity sector by 2035, 95% by 2050
Ability to build onshore wind and transmission	Limited access siting regime for onshore wind and limited new transmission	Limited access siting regime for onshore wind and limited new transmission

- All scenarios will include 30 GW OSW by 2030, and Low Carbon scenarios will include at least 85 GW in the Atlantic

Preliminary Results: Capacity 2050



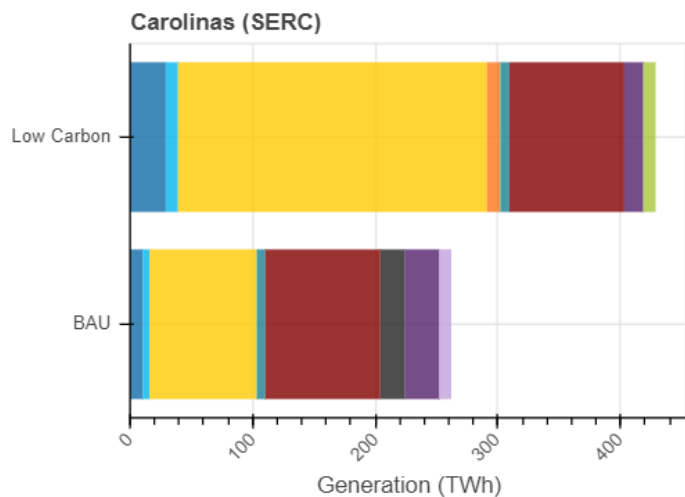
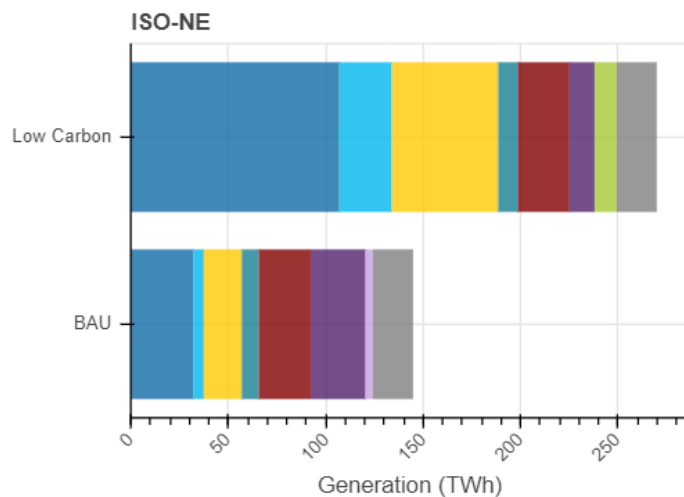
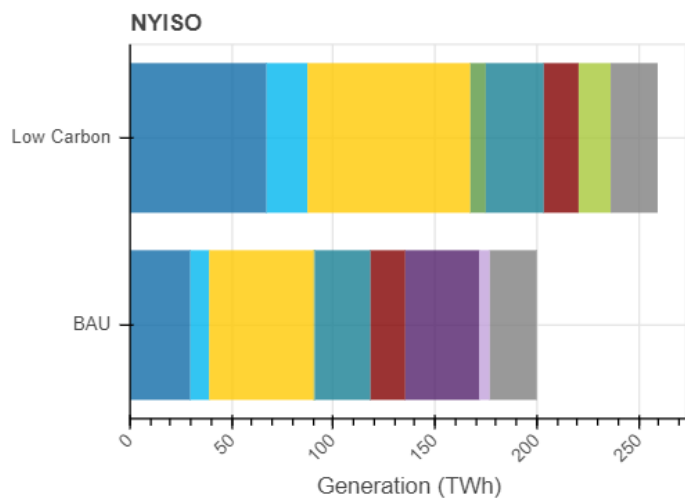
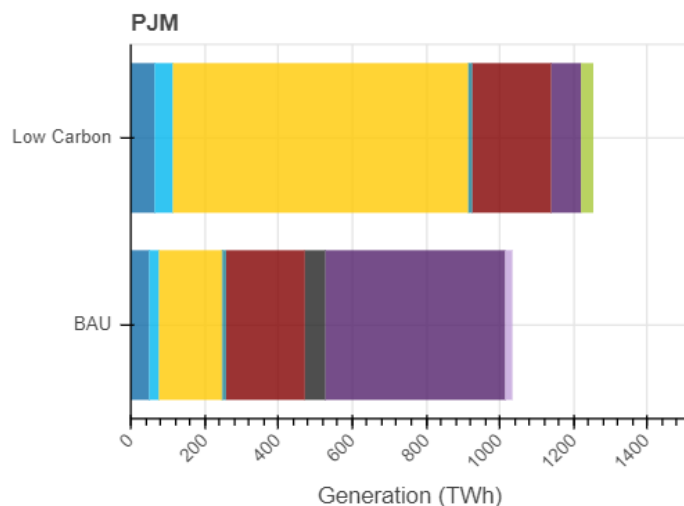
NG = Natural Gas
CC = Combined Cycle
CT = Combustion
Turbine
H2 = Hydrogen

Canada
H2-CT
NG-CT
NG-CC
Coal
Nuclear
Hydropower
Other RE
CSP
PV
Land-based Wind
Offshore Wind

Region	BAU Offshore capacity (GW)	Low Carbon Offshore capacity (GW)
Carolinas (SERC)	3.3	10.4
ISO-NE	9.0	31.2
NYISO	9.0	20.1
PJM	15.2	23.3

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Preliminary Results: Generation 2050



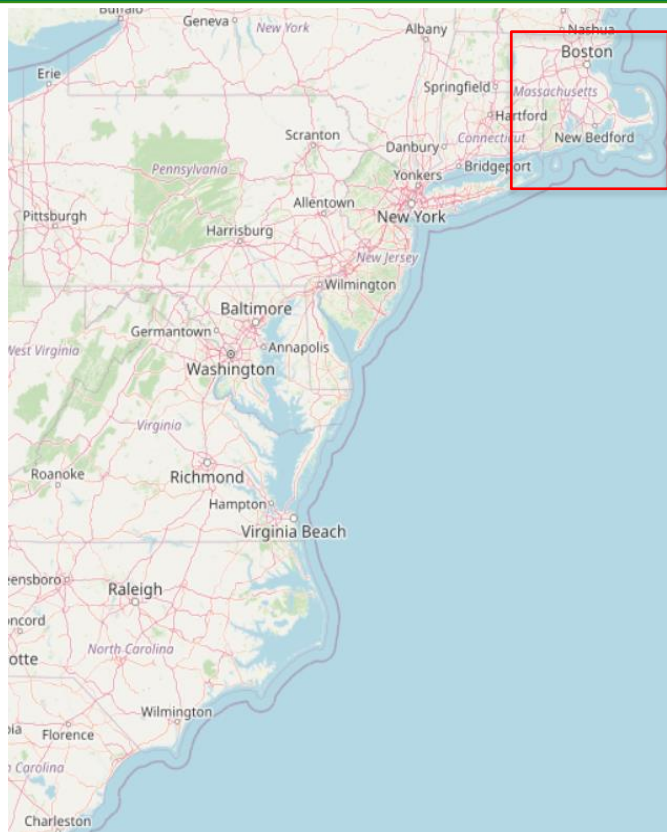
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- Canada
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- NG-CT
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- Coal
- Nuclear
- Hydropower
- Other RE
- CSP
- PV
- Land-based Wind
- Offshore Wind

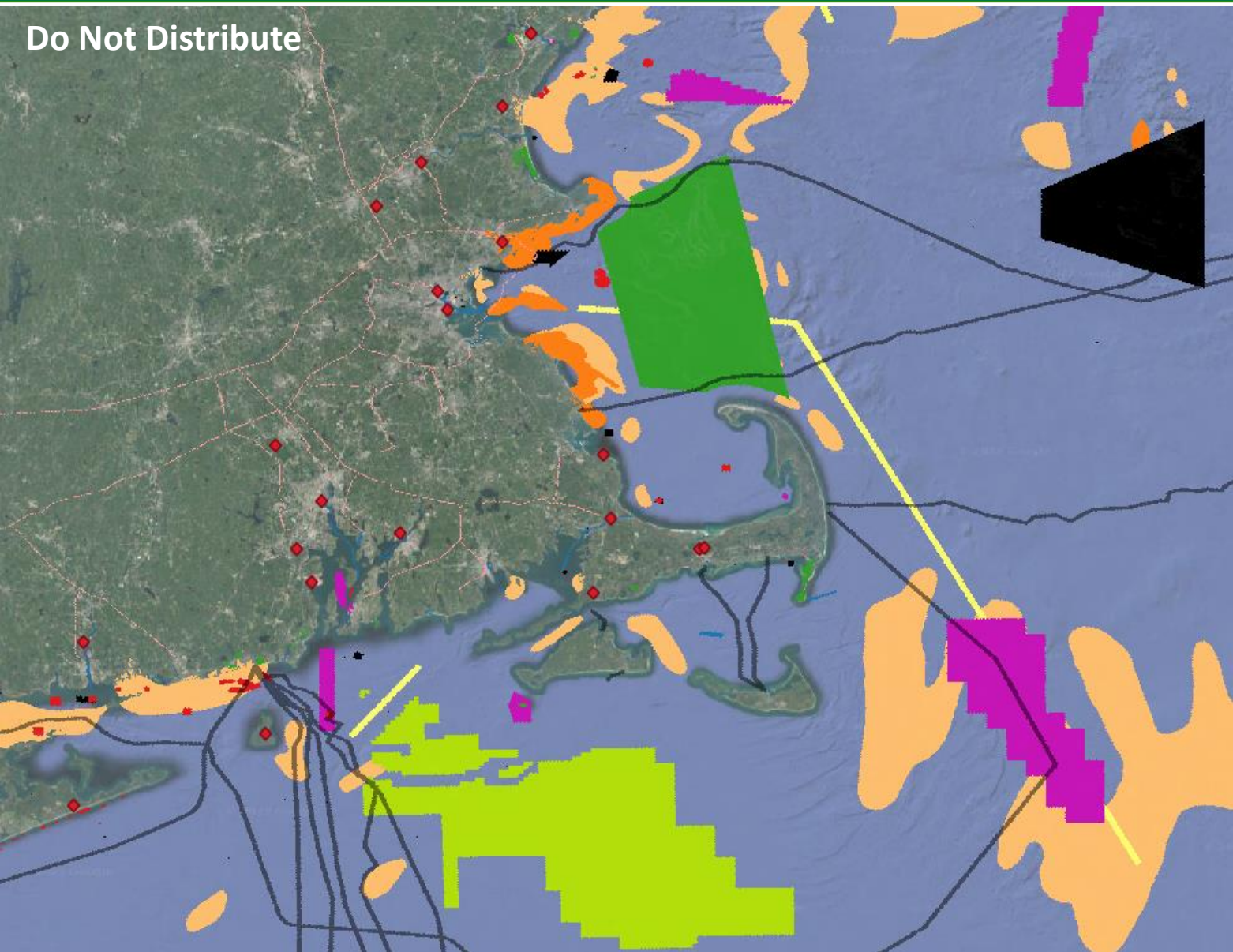
Region	BAU Offshore generation (TWh)	Low Carbon Offshore generation (TWh)
Carolinas (SERC)	10.4	29.1
ISO-NE	32.1	107
NYISO	29.6	67.1
PJM	49.8	64.7

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Siting Map (example)



- | | |
|------------------------------|-------------------|
| POI | Submarine Cable |
| Wind Lease | Conservation Area |
| USACE Borrow/Placement | Gravel Sediment |
| DoD Danger or Wind Exclusion | Bedrock |
| Ocean Disposal Site | Shipping Lane |



Path Routing Methodology

- A geospatial/image processing analysis that defines a path from a destination to a source - from a prospective OSW plant to a land-based point of interconnection.
- Path routing (typically called “least-cost-path”), uses distance and user defined criteria to determine areas of higher “cost” and then finds the least-cost route.
- We refer to “cost” as friction in our analysis as we are not applying real costs. Friction is in relative terms for this analysis
 - Example: 0% slope has less friction than 10% slope
- Path routing also includes user-defined out-of-bounds definitions referred to as “exclusions”
- Performed using raster (image) datasets, each pixel is assigned either as having friction or as being excluded.



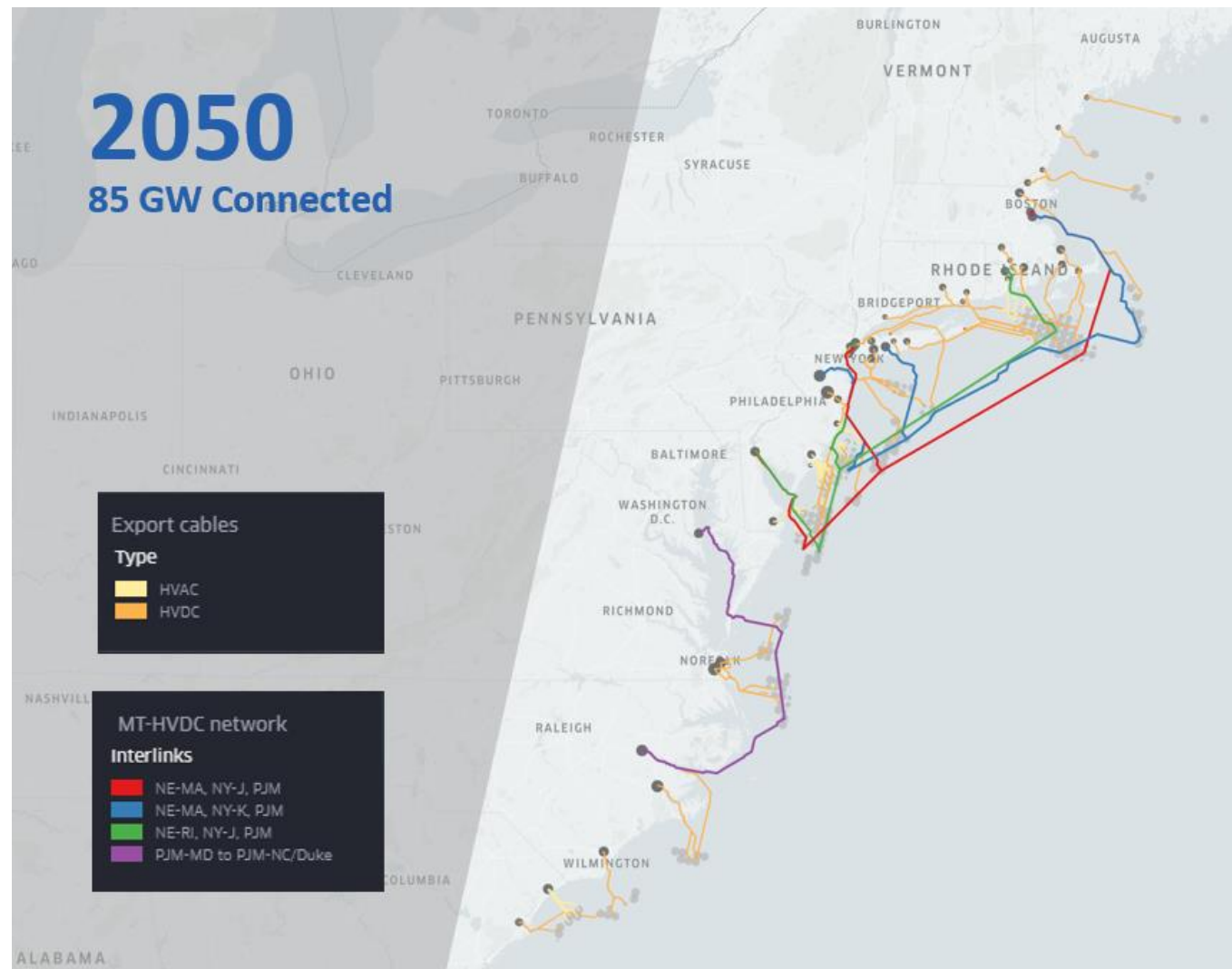
Preliminary Analysis

Preliminary findings indicate that connecting large volumes of offshore wind along the Atlantic Coast in the next several decades provides a unique opportunity for interregional connection.

The study analyzed five transmission topology strategies: radial, within-region (meshed connected within planning regions), **interregional (meshed connected across planning regions)**, within-region + interregional, and backbone (running the length of the coast).

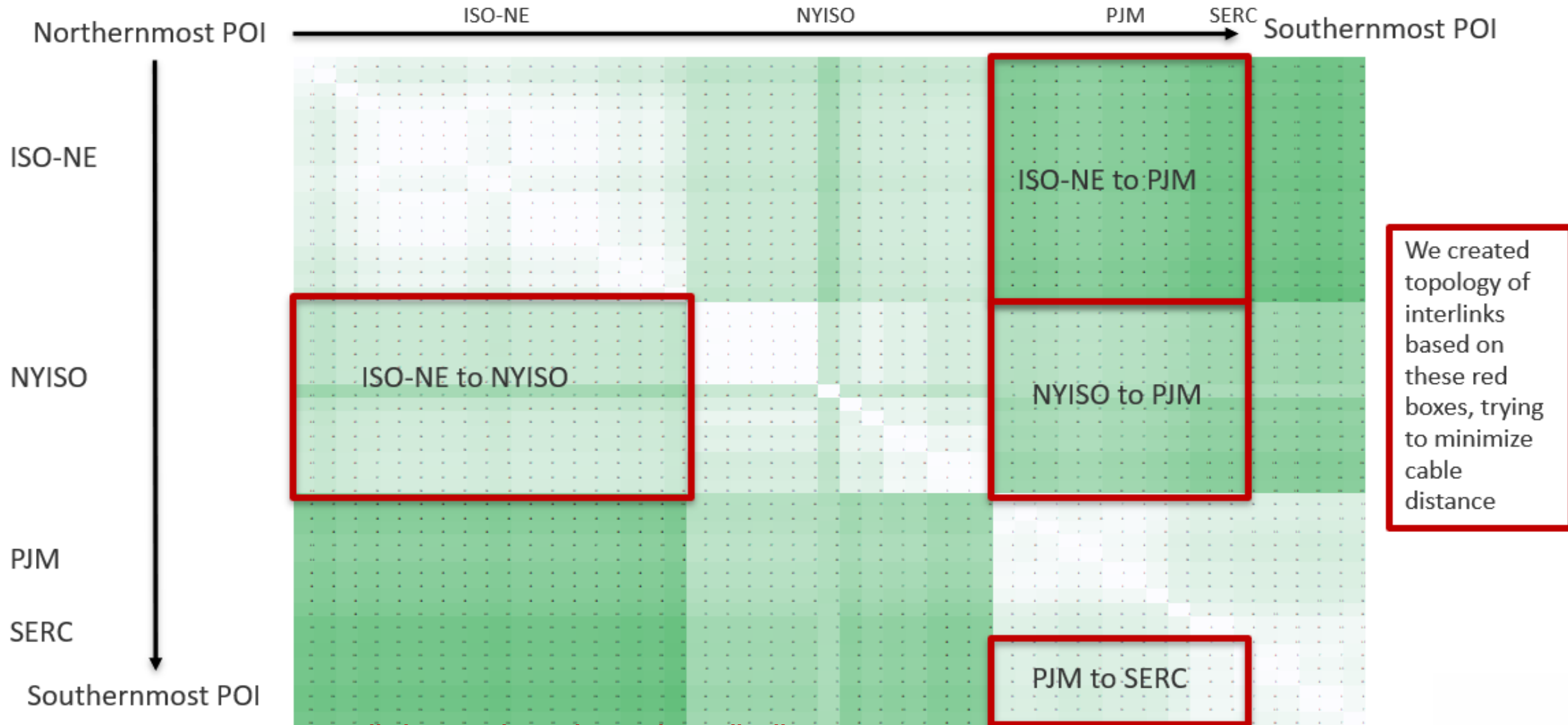
The interregional meshed connection is designed to maximize the benefit-to-cost ratio.

This transmission build-out connects regions with large electricity price disparity to create value for neighboring regions and improve overall system reliability and resilience while minimizing cable length relative to other configurations of interlinks.



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Biggest price diversity is interregional



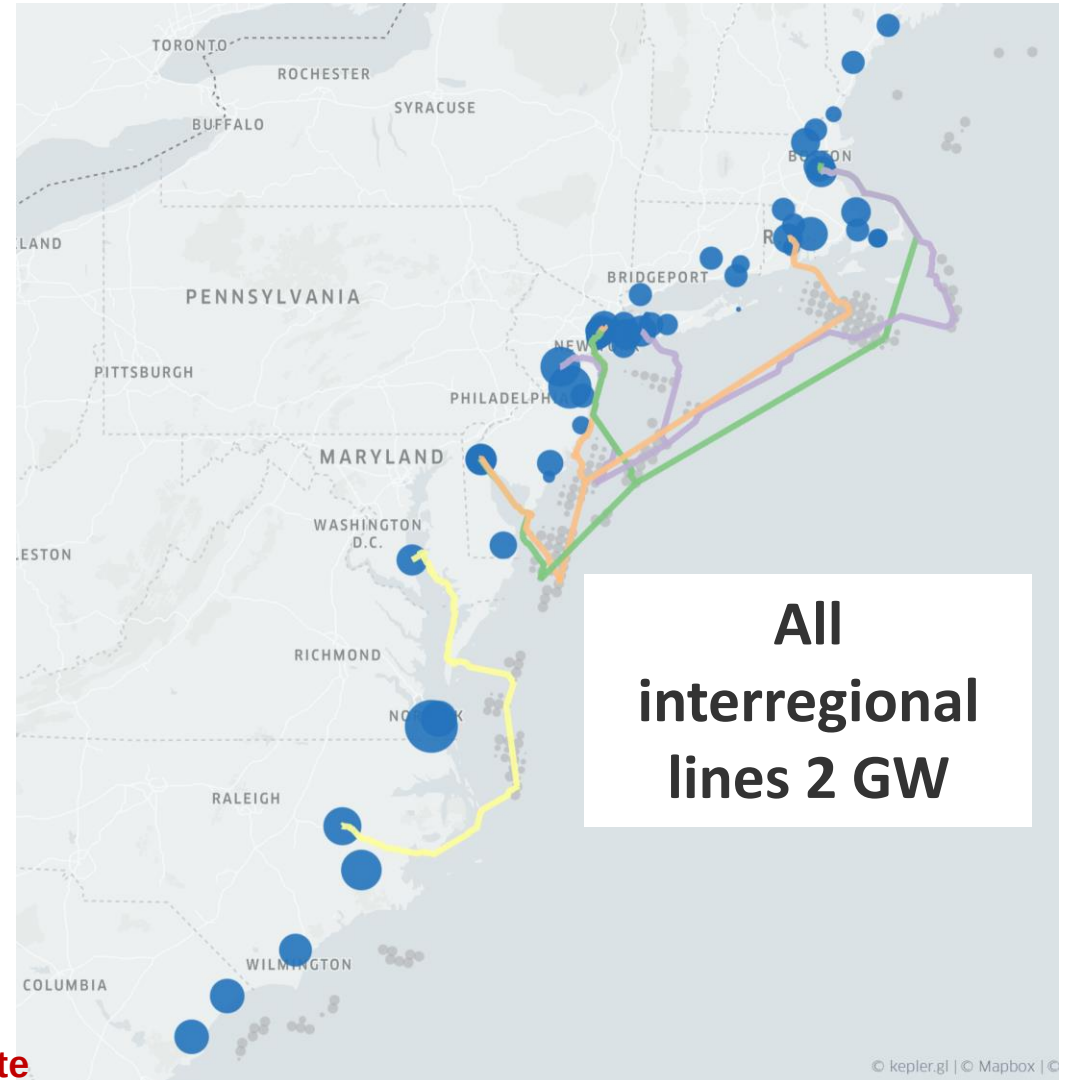
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2050 Production Cost Modeling Results

Radial



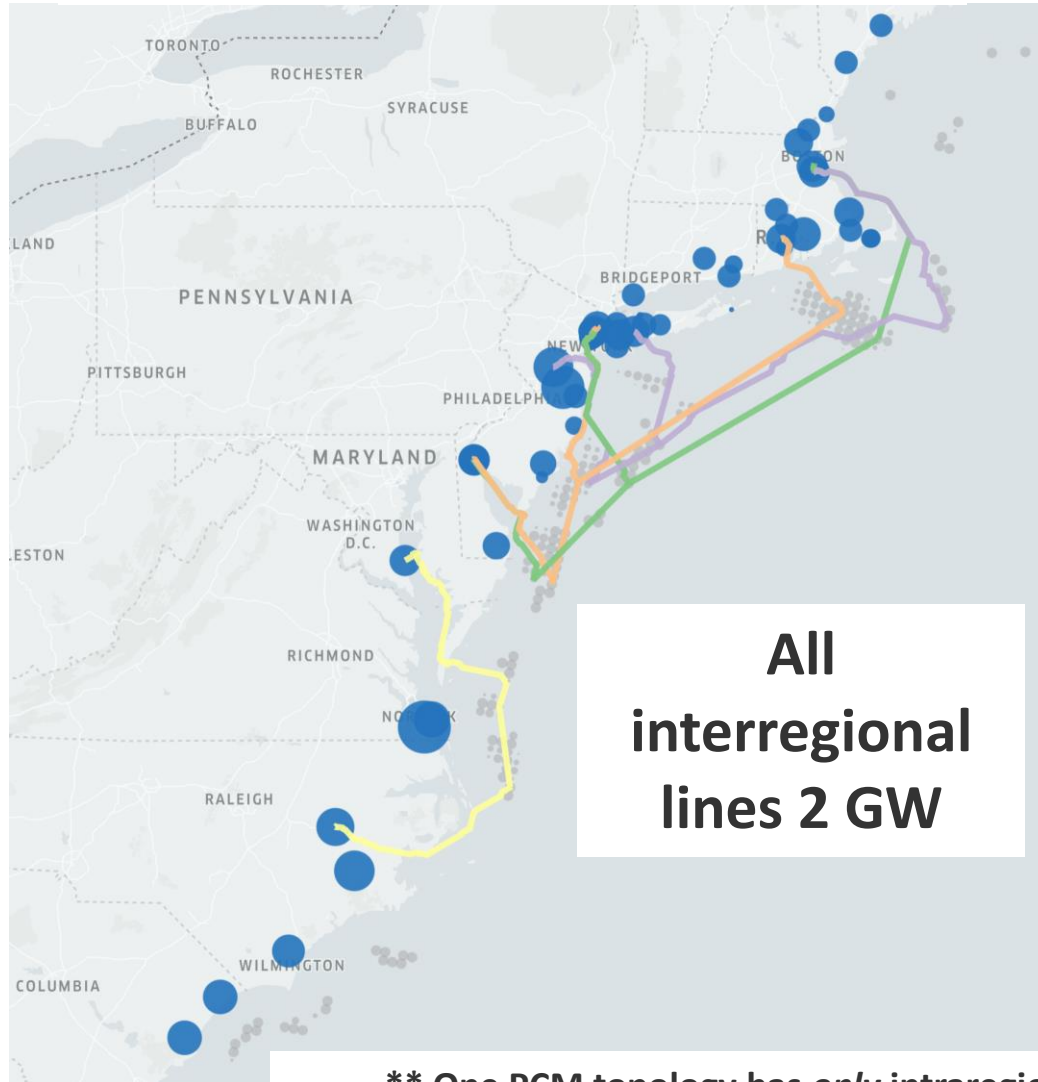
Interregional Network



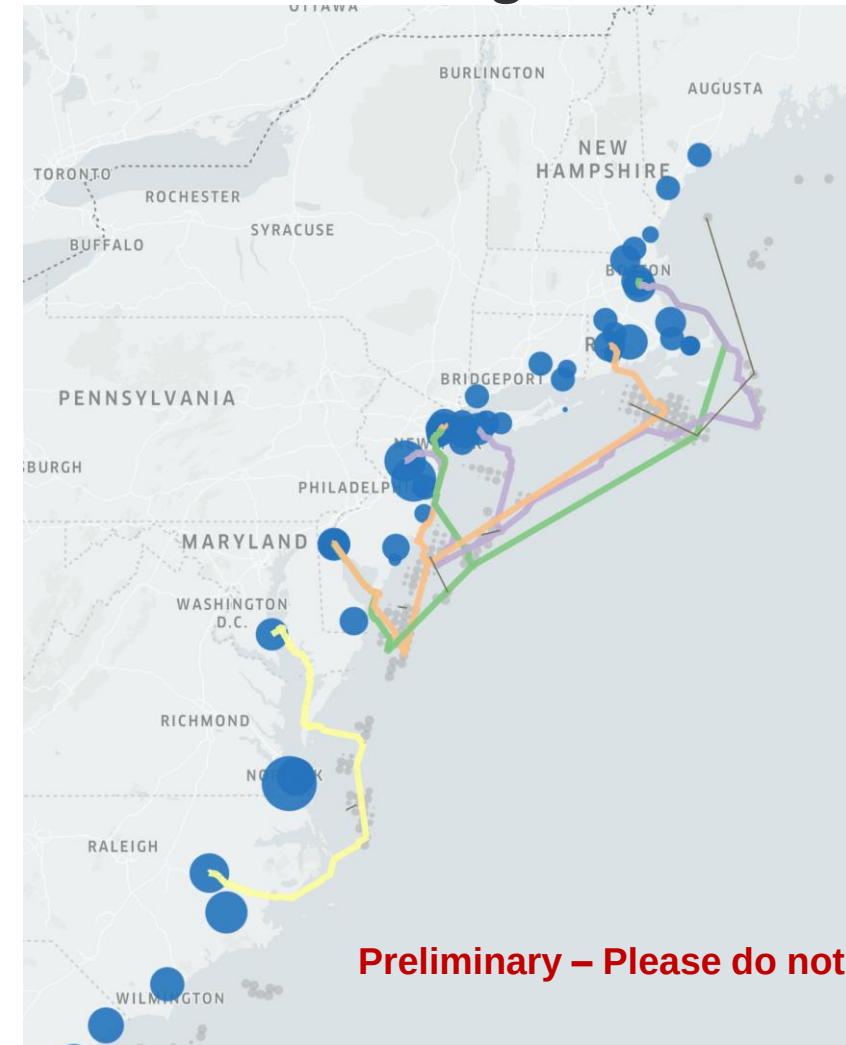
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2050 Production Cost Modeling Results

Interregional Network



Additional Intraregional lines**

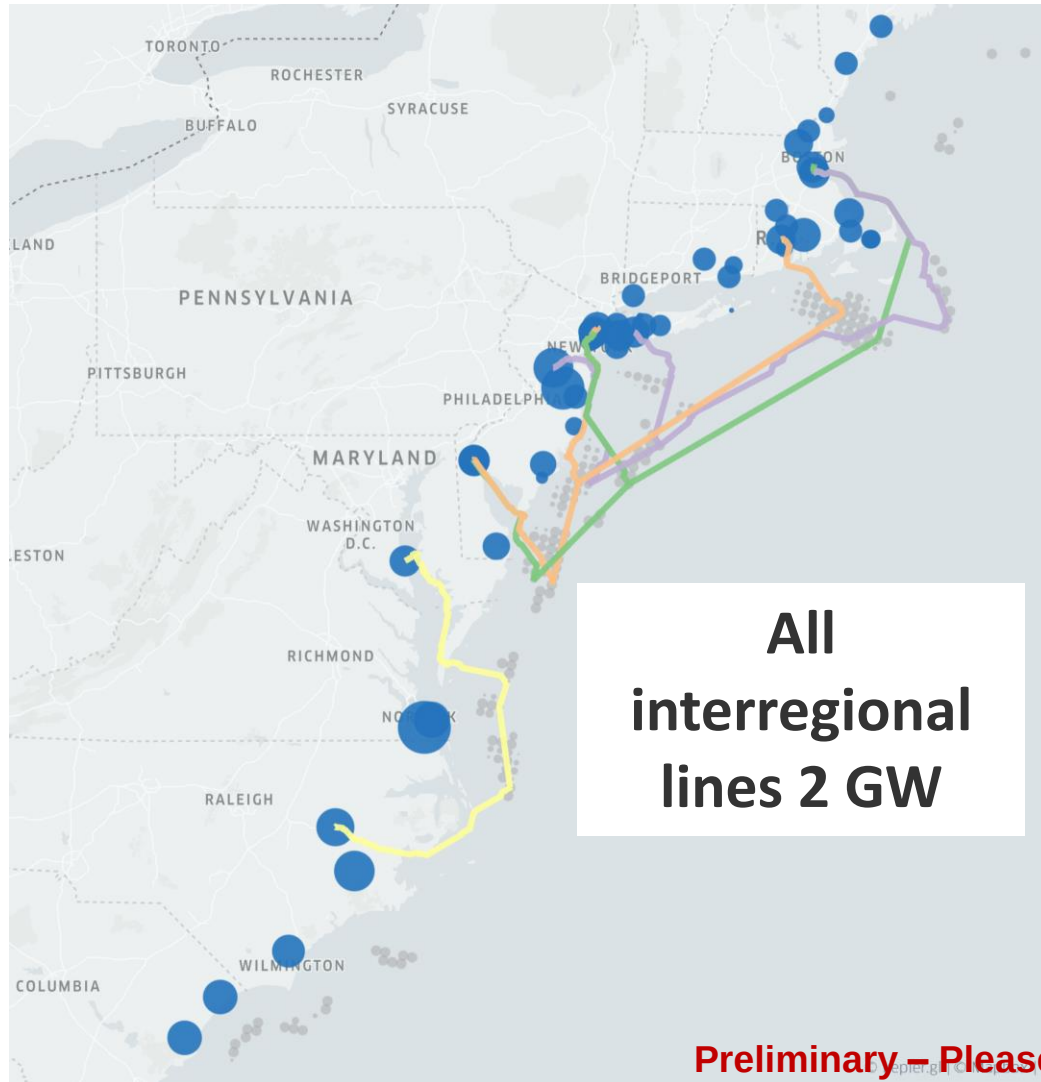


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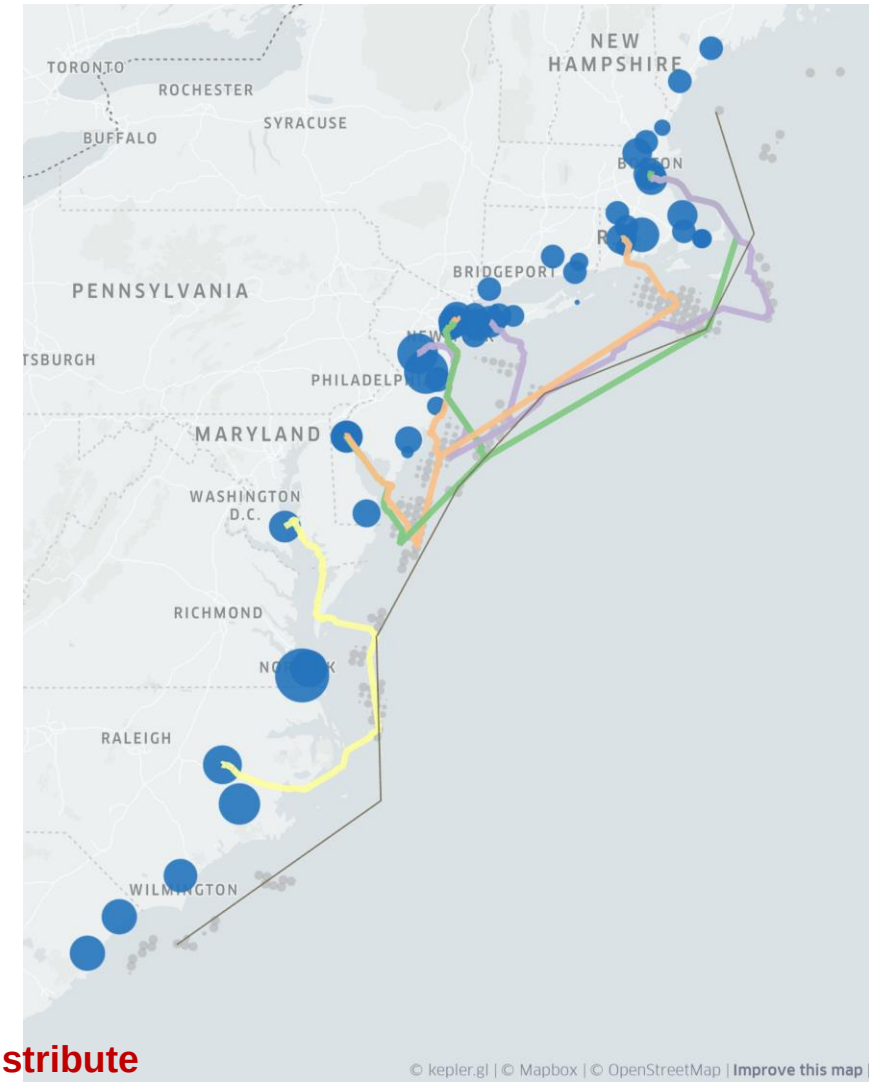
** One PCM topology has *only* intraregional, one has inter *and* intraregional topologies (as shown in figure)

2050 Production Cost Modeling Results

Interregional Network



Additional Backbone (2GW)



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Next Steps

- Finalize production cost modeling assumptions
 - Finalize fuel prices
 - Changes to offshore topologies
 - Updates to transmission assumptions
- Ongoing cost allocation analysis
- Ongoing dynamic contingency analysis

Siting Layers

• Sediments and slope

Layer Description	Include, Exclude, Friction	Citation / Source	Notes on Constraints
Underwater Slope (>15 degrees)	Exclusion	GEBCO Gridded Bathymetry	Global Marine guidance for slope restrictions.
Underwater Slope	Friction	GEBCO Gridded Bathymetry	Global Marine guidance for slope restrictions. 0-10, 10-15, 15-20, >20 groupings.
Atlantic Seafloor Sediment (CONMAP) Bedrock	Exclusion	USGS	Low: sand/silt/clay, sand-slit/clay, clay, sand-clay/slit, clay-slit/sand, sand. Medium: gravel-sand, gravel. High: Bedrock
Atlantic Seafloor Sediment (CONMAP) Gravel-sand & Gravel	Friction	USGS	Low: sand/silt/clay, sand-slit/clay, clay, sand-clay/slit, clay-slit/sand, sand. Medium: gravel-sand, gravel. High: Bedrock

• Conservation

Layer Description	Include, Exclude, Friction	Citation / Source	Notes on Constraints
Conservation Areas <ul style="list-style-type: none"> Habitat Areas of Particular Concern National Marine Sanctuary Marine National Monument National Wildlife Refuge Wilderness Area 	Exclusion	NOAA NMFS, USFWS, DOI	Consider protection levels, governance, and related management criteria
Atlantic Canyons	Exclusion	DOI	Previously identified by BOEM as an exclusion area
Coastal Critical Habitat Designation	Exclusion	NOAA NMFS	Land-fall exclusion
Artificial Reefs	Exclusion	Marine Cadastre	Derived from multiple state websites

Siting Layers

- BOEM, DOD, and USACE

Layer Description	Include, Exclude, Friction	Citation / Source	Notes on Constraints
Wind Planning Areas	Inclusion	BOEM	Siting considerations assumed to be minimal within planning areas.
Active Renewable Energy Leases	Inclusion	BOEM	Siting considerations assumed to be minimal within lease areas.
Danger Zones and Restricted Areas	Exclusion	DoD	Restricted Areas outlined in Code of Federal Regulations and Raster Navigational Charts. Areas used for target practice, bombing, ricket firing, or other hazardous operations.
Military Ship Shock Boxes	Exclusion	DoD	Underwater explosive tests.
Unexploded Ordnance Locations	Exclusion	DoD	100 m buffer.
Federal Outer Continental Shelf (OCS) Sand resource areas/borrow areas/marine minerals lease areas	Exclusion	BOEM	Federal OCS Sand and Gravel Borrow Areas.
USACE South Atlantic Division (SAD) Sand Sources/Borrow Areas	Exclusion	USACE	SAD SAND Study conducted by USACE. For the SAD region (NC-MS), consider this a more comprehensive version of the BOEM MMIS sand resource layer, as it includes many more areas in state waters.
USACE Borrow Areas	Exclusion	USACE	USACE borrow areas in state and federal waters nationwide. Using this layer to supplement those listed above.
USACE Placement Areas	Exclusion	USACE	USACE placement areas in state and federal waters nationwide. Using this layer to supplement those listed above.

Siting Layers

- Shipping, Vessels, and Channels

Layer Description	Include, Exclude, Friction	Citation / Source	Notes on Constraints
National Channel Framework	Friction	USACE	Guidance to avoid running parallel. Can cross.
Shipping Lanes and Regulations	Friction	NOAA Office of Coast Survey	Note that some COPs have proposed export cables running through lanes.
Fairways and Anchorages	Friction; Exclusion	USCG	Fairways as friction; Anchorages as exclusions.

- Physical Structures

Layer Description	Include, Exclude, Friction	Citation / Source	Notes on Constraints
Gas Pipelines	Friction	ABB	Avoiding spatial coincidence with existing pipelines.
Ocean Disposal Sites	Exclusion	Marine Cadastre	Historical dumping grounds.
Automated Wreck and Obstruction Information System (AWOIS)	Exclusion (In progress)	NOAA	>10,000 submerged wrecks and obstructions in the coastal waters of the United States

2030
30 GW Connected

Export cables

Type

- HVAC
- HVDC

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2035
42 GW Connected

Export cables

Type

- HVAC
- HVDC

MT-HVDC network

Interlinks

- NE-MA, NY-J, PJM
- NE-MA, NY-K, PJM
- NE-RI, NY-J, PJM
- PJM-MD to PJM-NC/Duke

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2040
55 GW Connected

Export cables

Type

- HVAC
- HVDC

MT-HVDC network

Interlinks

- NE-MA, NY-J, PJM
- NE-MA, NY-K, PJM
- NE-RI, NY-J, PJM
- PJM-MD to PJM-NC/Duke

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2045
70 GW Connected

Export cables

Type

- HVAC
- HVDC

MT-HVDC network

Interlinks

- NE-MA, NY-J, PJM
- NE-MA, NY-K, PJM
- NE-RI, NY-J, PJM
- PJM-MD to PJM-NC/Duke

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2050
85 GW Connected

Export cables

Type

- HVAC
- HVDC

MT-HVDC network

Interlinks

- NE-MA, NY-J, PJM
- NE-MA, NY-K, PJM
- NE-RI, NY-J, PJM
- PJM-MD to PJM-NC/Duke

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