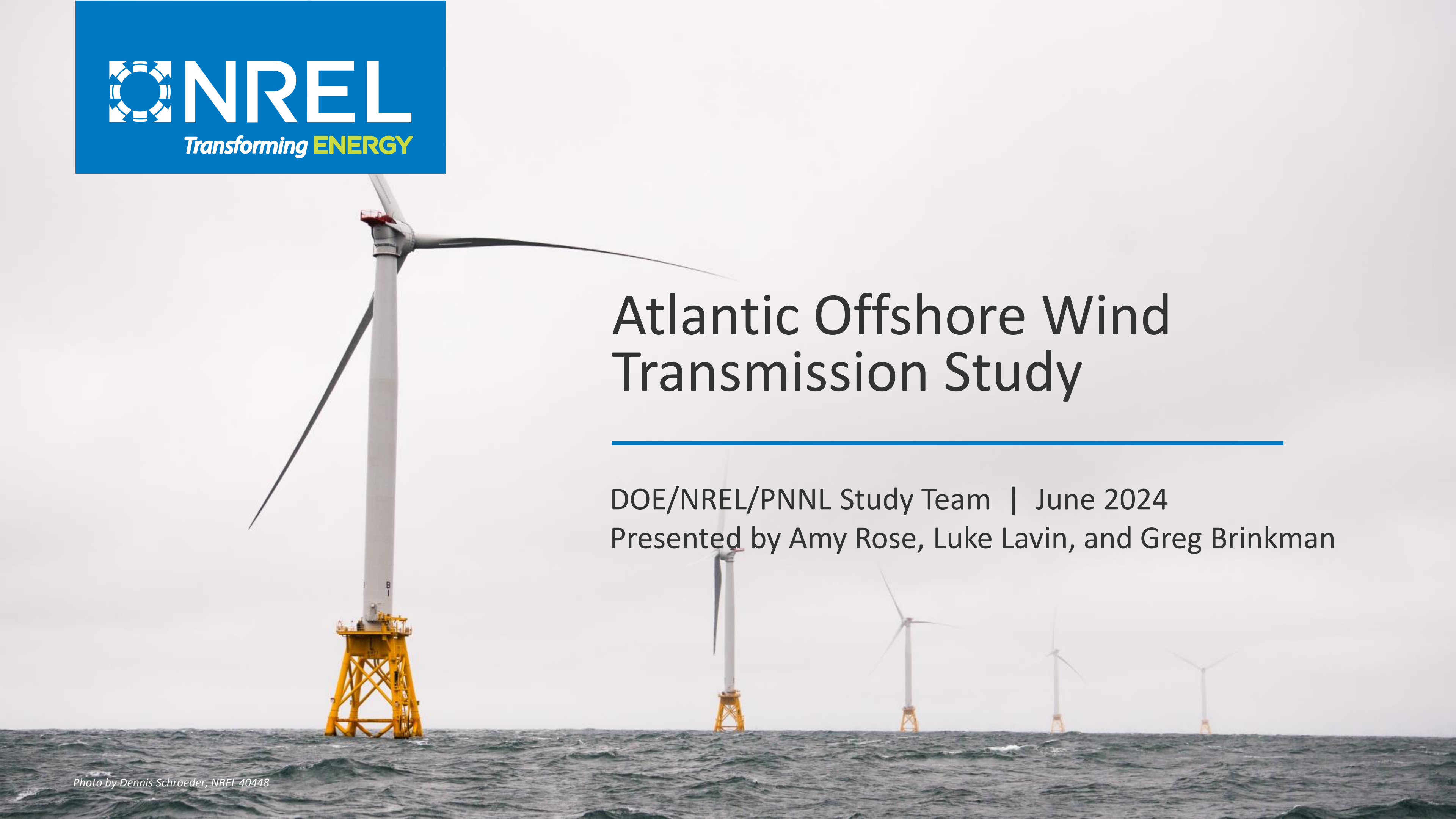


Atlantic Offshore Wind Transmission Study

DOE/NREL/PNNL Study Team | June 2024
Presented by Amy Rose, Luke Lavin, and Greg Brinkman

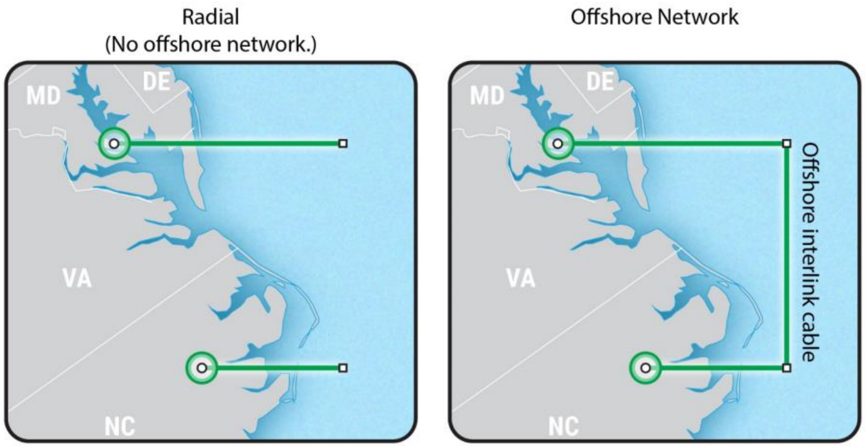
Photo by Dennis Schroeder, NREL 40448

Study Overview

We studied scenarios and pathways of offshore wind (OSW) and offshore transmission deployment **through 2050 with 85 GW** in the Atlantic, while respecting ocean co-uses

Key Objective: Determine what the potential costs, benefits, and impacts of offshore transmission networks are.

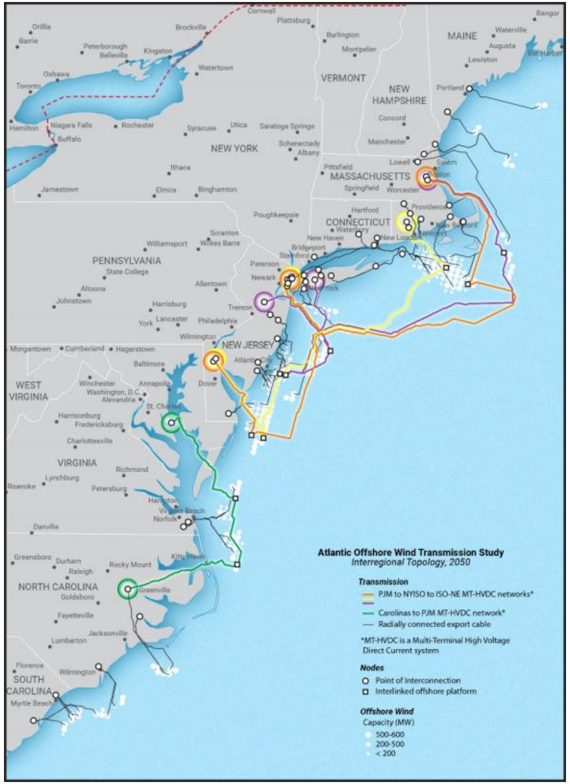
What is an offshore transmission network?



Topologies We Studied

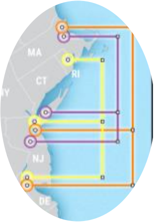
The team studied five topologies (and sensitivities):

- **Radial:** Planned connections from offshore substations to onshore grid
- **Interregional:** Specifically designed to take advantage of opportunities to connect diverse regions by interlinking offshore platforms
- **Intraregional:** Within-region connections that could complement (and come before) interregional solutions
- **Inter-Intra:** Combination of interlinks from Interregional and Intraregional
- **Backbone:** Larger, longer version of interregional build



Methods for Major Questions About Future of Transmission Complementing OSW Development

Question	Method
What is the cost of interlinking offshore platforms?	Bottom-up analysis of offshore substation and cable costs in the topologies
What are the economic benefits of different offshore grid philosophies?	All topologies simulated in a 2050 low-carbon grid with 85GW of OSW, plus sensitivities using PLEXOS
How could offshore transmissions impact reliability and resilience?	Resource adequacy, power flow and contingency analysis using PRAS, CPAGE and PSS/E
Could there be a sequence that achieves benefits without adding near-term hurdles?	Considered pathway that is consistent with current trajectories and technology readiness



Study is...

- An analysis of the operation, economics, and reliability implications of different types of offshore wind transmission networks
- A long-term planning analysis of the grid in 2050 in a low carbon scenario
- A focus area from Maine to South Carolina
- Cable routing analysis

Study is *not*...

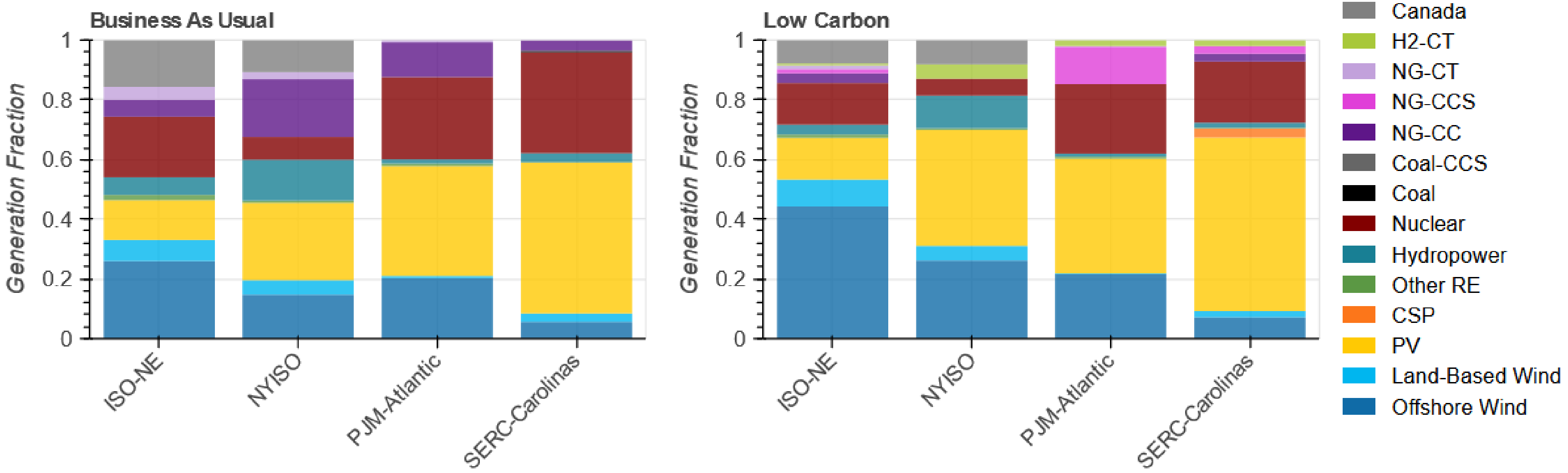
- A level of detail similar to interconnection studies for offshore wind injections
- An analysis of impacts of electrification (approximately doubling electricity demand) on the transmission system at all voltage levels
- A detailed siting or permitting analysis
- A prescription or suggestion for Points of Interconnection or exact interlinks

Scenarios

Offshore Wind Projected to Play a Critical Role in Helping Atlantic States Achieve a Low-Carbon Future

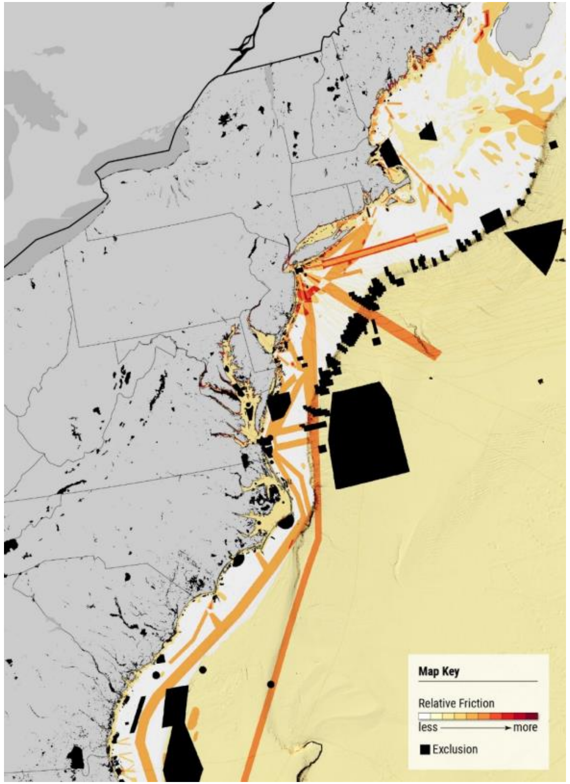
- Regional Energy Deployment System (ReEDS) model used for developing a Business as Usual (BAU) and Low Carbon (95% CO_2 reduction and electrification) scenario through 2050
- Low Carbon was chosen for analyzing the transmission topologies in 2050 with 85 GW of OSW

2050 Generation Fraction:



Offshore Transmission Can be Planned While Considering Ocean Co-Use and Environmental Constraints

- 26 data layers help identify a set of challenges to cable laying, including shipping, military, conservation, and other considerations
- Similar, but not identical exclusions for generation
- Not as comprehensive as a siting study, but can help identify large-scale issues
- Developed hypothetical cable routes based on those layers to produce the radial and other topologies.



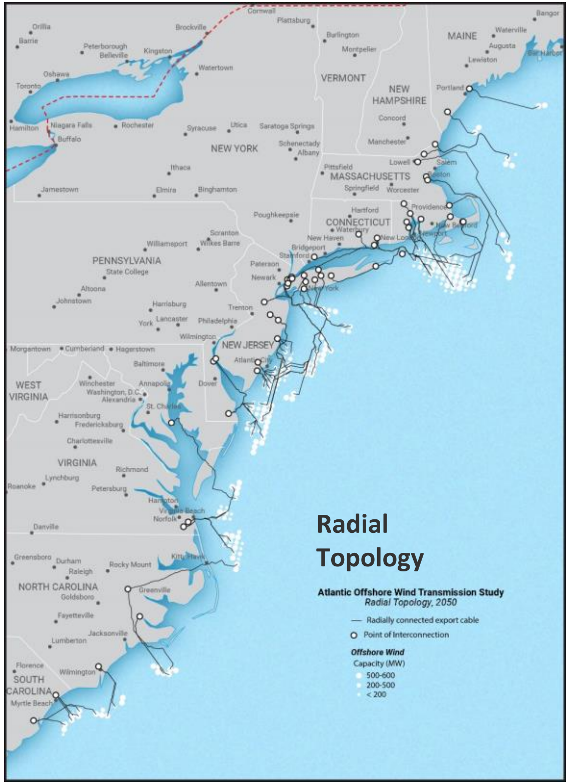
Topologies

REMINDER:

- Points of interconnection and connections are *not* intended as specific suggestions or prescriptions, but to form illustrative comparisons between the topologies.
- This is *not* intended as a siting nor permitting study.

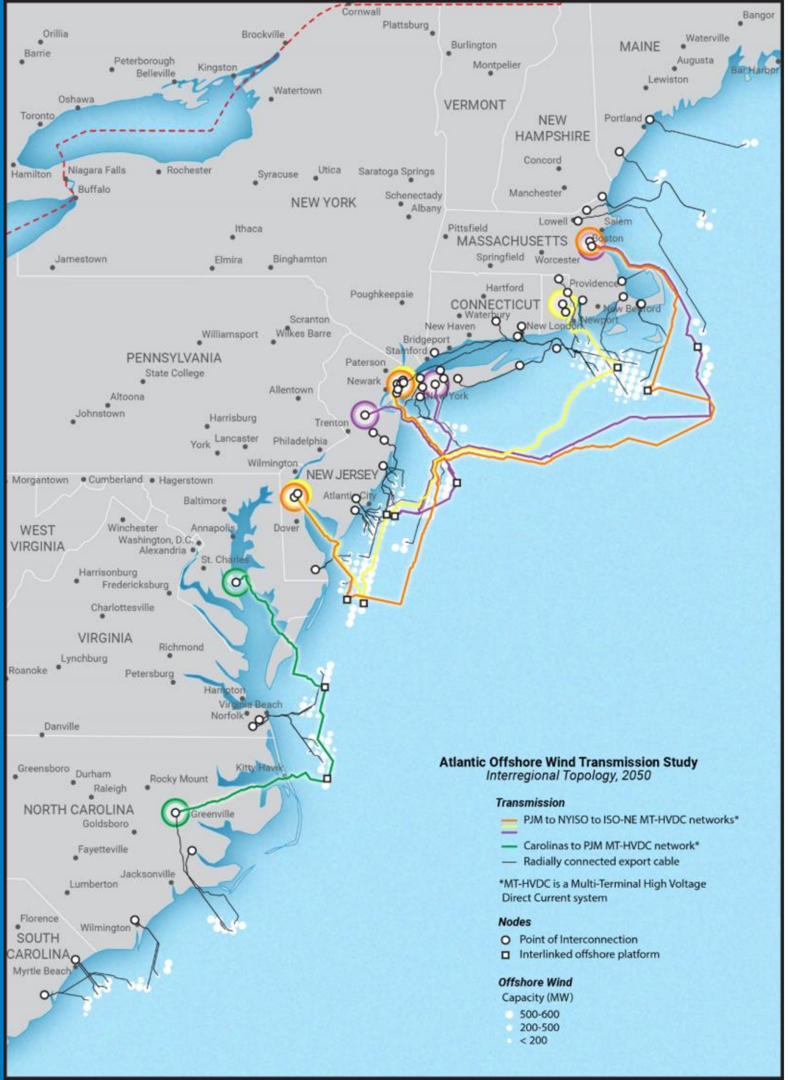
There is a Unique Opportunity with Offshore Wind to Add Transmission Capacity Offshore That Also Provides Value to the Grid

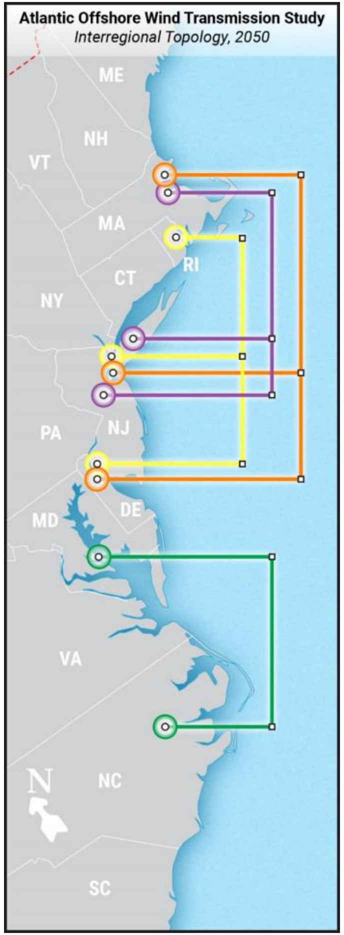
- 85 GW radial connections developed by optimizing levelized cost of electricity and export cable distance to suitable Points of Interconnection
- Wind development from Maine through South Carolina
- We considered how could this be leveraged to create value by interlinking.
- Analysis of modeled price differences helped define other topologies.



Interregional: What could a topology that links regions look like?

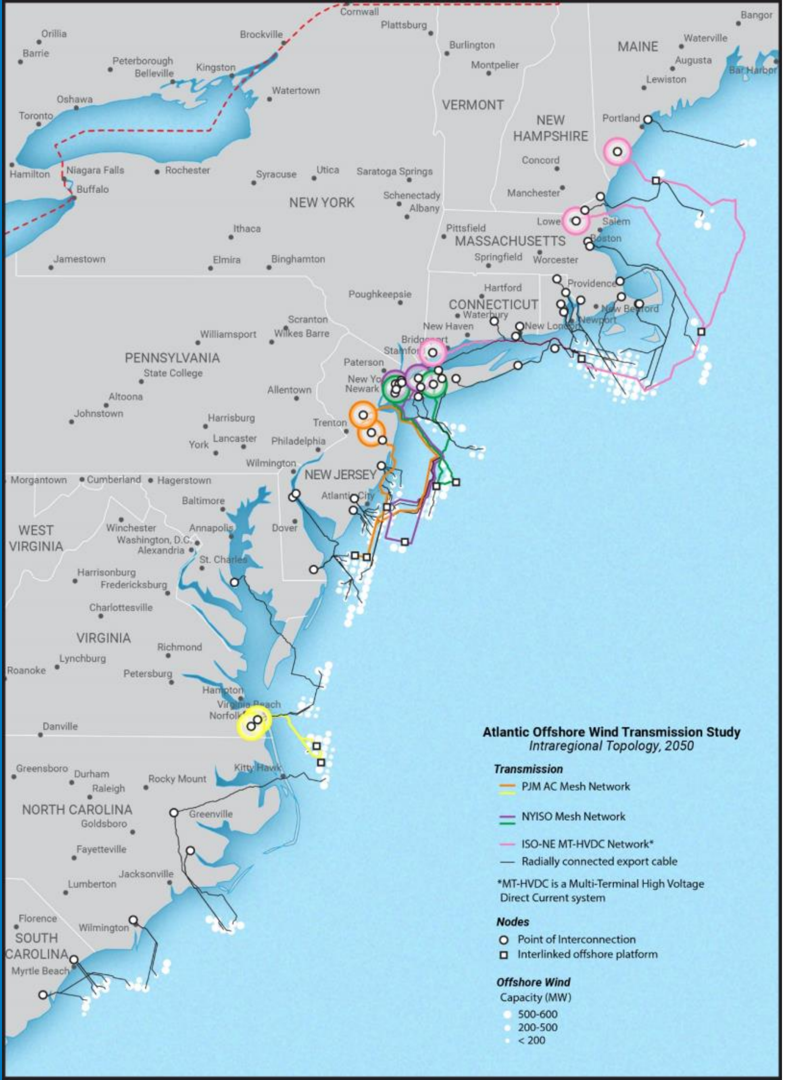
- Seven new cables, interlinking 11 platforms
- 14 GW interregional capacity
- Designed using price differentials from initial grid modeling

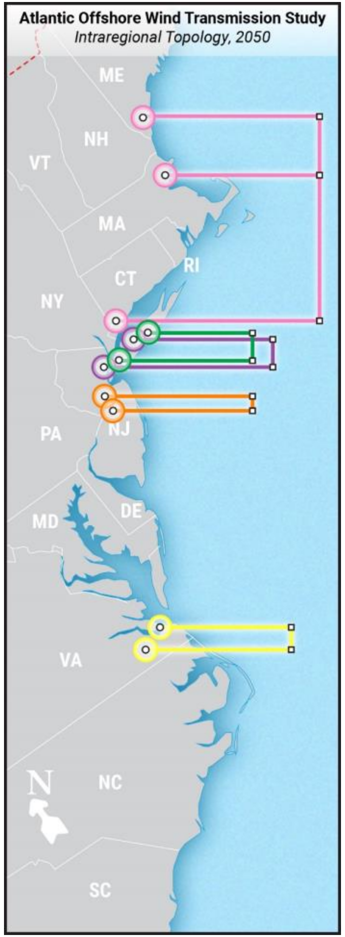




Intraregional: What an Interlinking Topology Could Look Like Within Regions

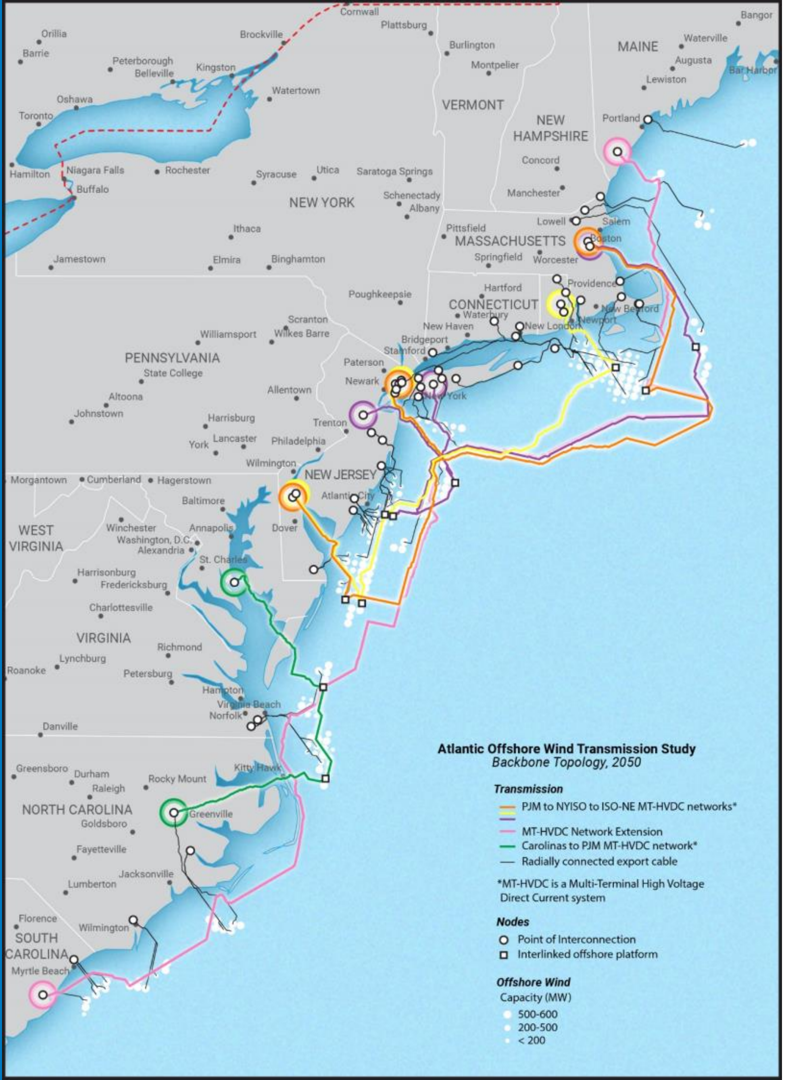
- HVDC in New England, HVAC elsewhere based on existing proposals
- Designed using platform locations and to be complementary to Interregional
- The Inter-Intra is all the interlinks from Interregional and Intraregional combined

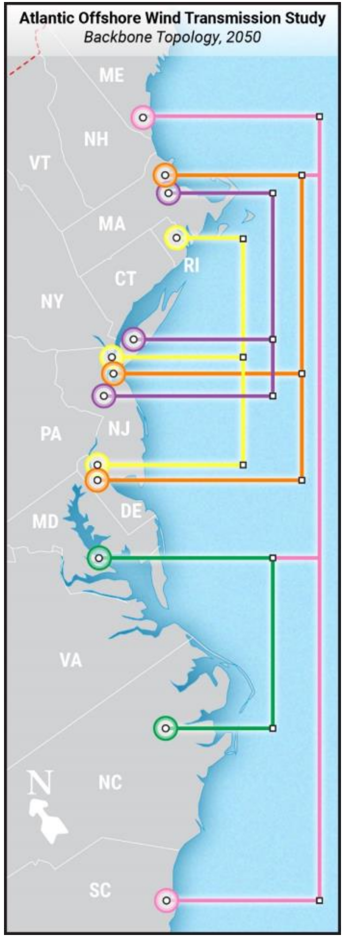




Backbone: Spanning the entire domain

- Start with Interregional…
- Add corridor from South Carolina to Maine to the Interregional



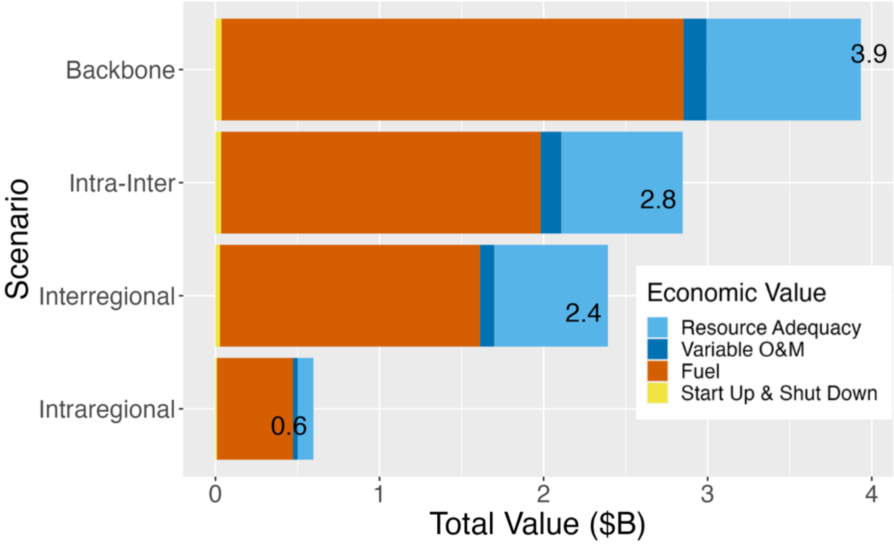


Key Findings

Annual Benefits of Offshore Transmission Networking Could Be Billions

- Reduced curtailment, reduced usage of higher-cost generators, and contributions to resource adequacy.
- Operation of the grid were simulated for all topologies in 2050 using PLEXOS production cost model
- Offshore wind curtailment is reduced by 1-2 percentage points in scenarios with interregional interlinks

***Annual* production cost and resource adequacy value in 2050**

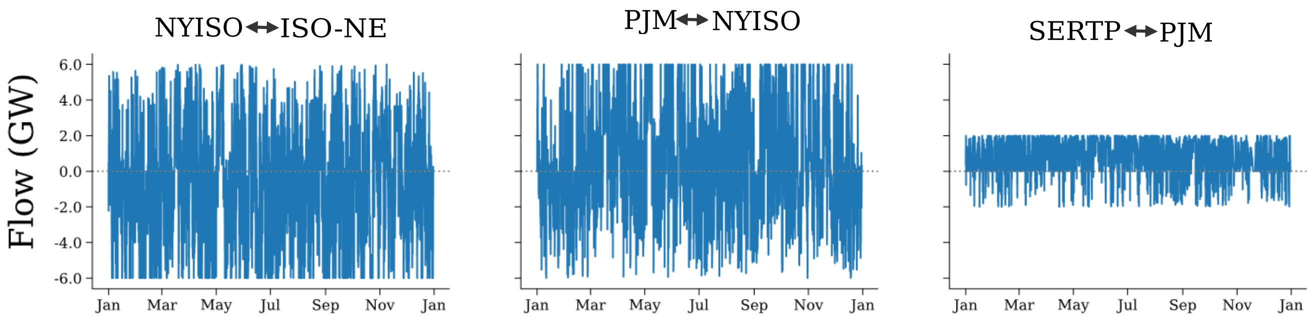


Markets don't currently exist to fully capture value streams

Offshore Transmission Benefits from High Utilization of Interlinks with Bidirectional Flow

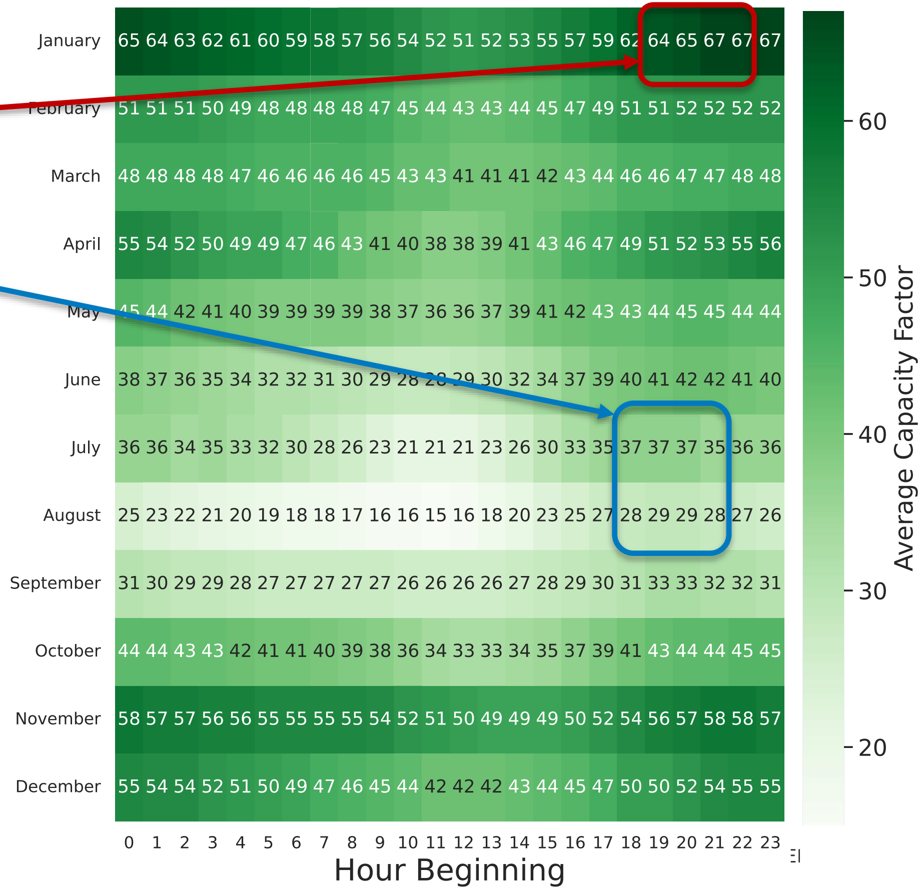
- On all interlinks, flows go both directions every season, reducing overall generation costs and curtailment
- Utilization of each line is 50% – 60%

Hourly time series of flow on interlinks (interregional topology)



Offshore wind contributes to peak demand, especially in an electrified, winter-peaking future

- Offshore wind contributes more during winter-peaking conditions than summer-peaking conditions
- Many regions, including New York and New England, become winter-peaking with electrification in these scenarios
- In this study, we assessed the contribution of the transmission topologies towards resource adequacy in 2050…



Offshore Transmission Networks Enable Resource Adequacy

- Transmission can contribute to resource adequacy, especially by exchanging power between regions that peak in different seasons
- Interregional interlinks can contribute to serving peak demand similar to **between 4 and 6 GW of Equivalent Firm Capacity** (EFC)[1], depending on scenario
- Estimated using Monte Carlo resource adequacy tool (NREL PRAS)

Scenario	Quantity of Offshore Interlink Transmission Built (MW)	Equivalent Firm Capacity Result (MW)
Intraregional	7,600	565-664
Interregional	14,000	4,062-4,726
Inter-Intra	21,600	4,453-5,000
Backbone	20,000	5,859-6,250

[1]EFC is a measure of how much hypothetical "perfect" generation capacity it would require to enable identical resource adequacy as adding the offshore transmission.

Benefits of Offshore Transmission Networking Outweigh Costs By a Ratio of 2 to 1 or more

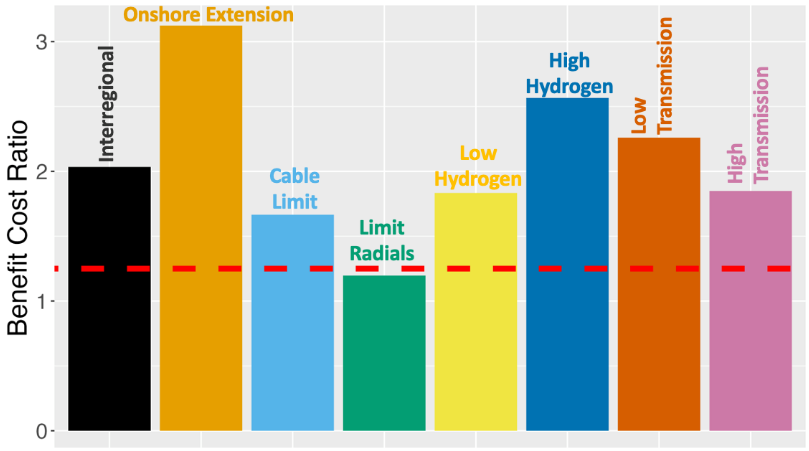
- Offshore networks with **interregional interlinks** provide the highest value.
- Offshore wind investment in HVDC converter stations, interconnection, and platforms can be leveraged by interlinking between platforms
- Inter- and intra- strategies can be mixed
- Majority of interregional costs are cables.

Scenario	Net Annual Value ($M) [Benefits – Costs]	Benefit Cost Ratio
Intraregional	330	2.3
Interregional	1560	2.9
Inter-Intra	1760	2.6
Backbone	2470	2.7

Positive Benefit to Cost Ratio In a Wide Range of Sensitivities

The interregional topology maintains benefit to cost ratio above one with a variety of scenarios:

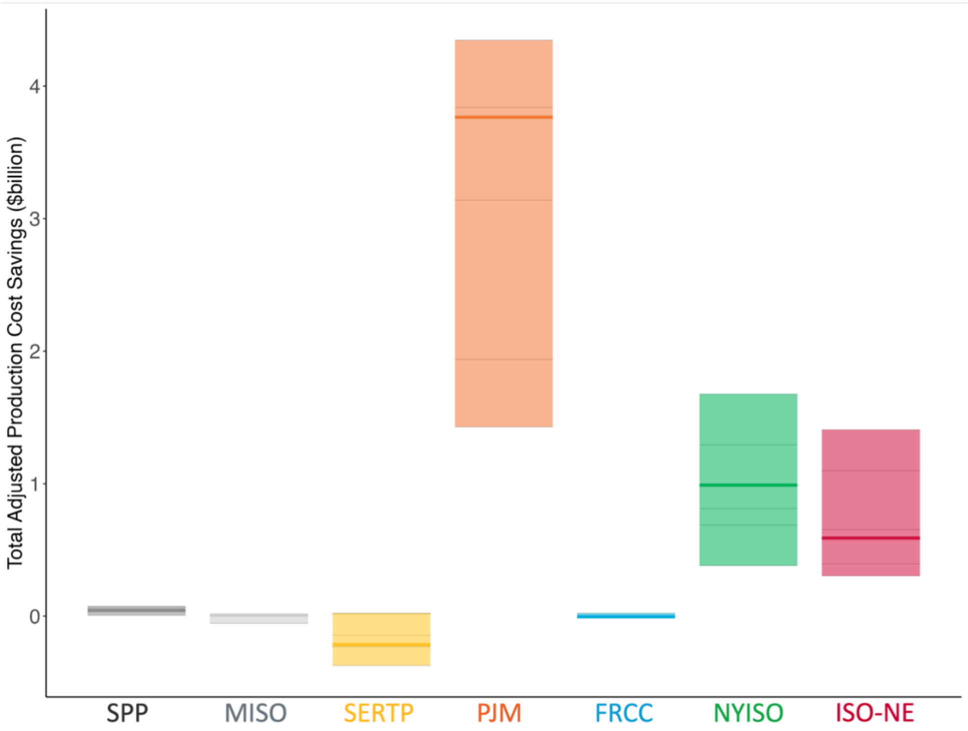
- *Onshore Extension*: More east-west transmission exists in PJM to access lower-cost renewable power
- *Cable Limit*: Interregional flows limited to 1200 MW
- *Limit Radials*: Radial export cables only flow from offshore to POI
- *Hydrogen prices*: $20/mmbtu in Interregional, $10 in Low and $30 in High
- *Transmission costs*: +/- 10%



Red line represents 1.25 benefit to cost ratio.
Values do not include resource adequacy.

Value to Individual Transmission Planning Regions Varies

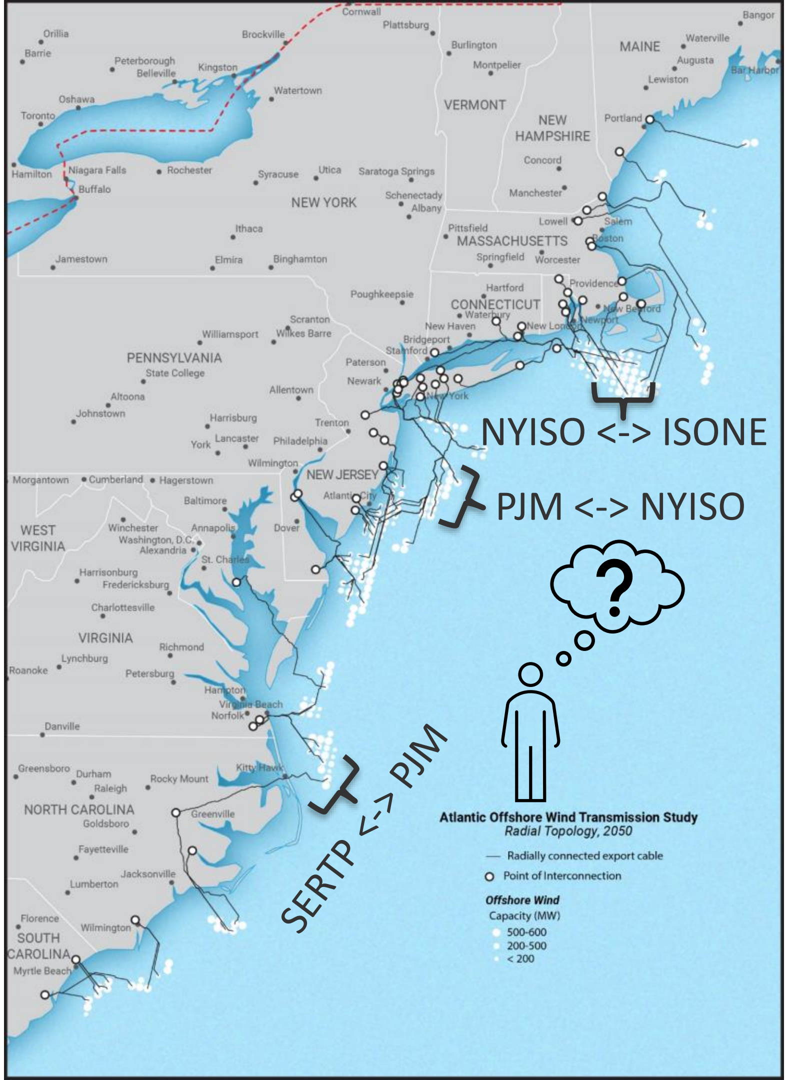
- Regions anticipated to have more points of interconnection (PJM, NYISO, and ISO-NE) see the highest value
- As a share of total costs, NYISO and ISO-NE have the largest savings
- Variation in regional value is driven by:
  - Hydrogen prices
  - Connectedness and power flow constraints among regions



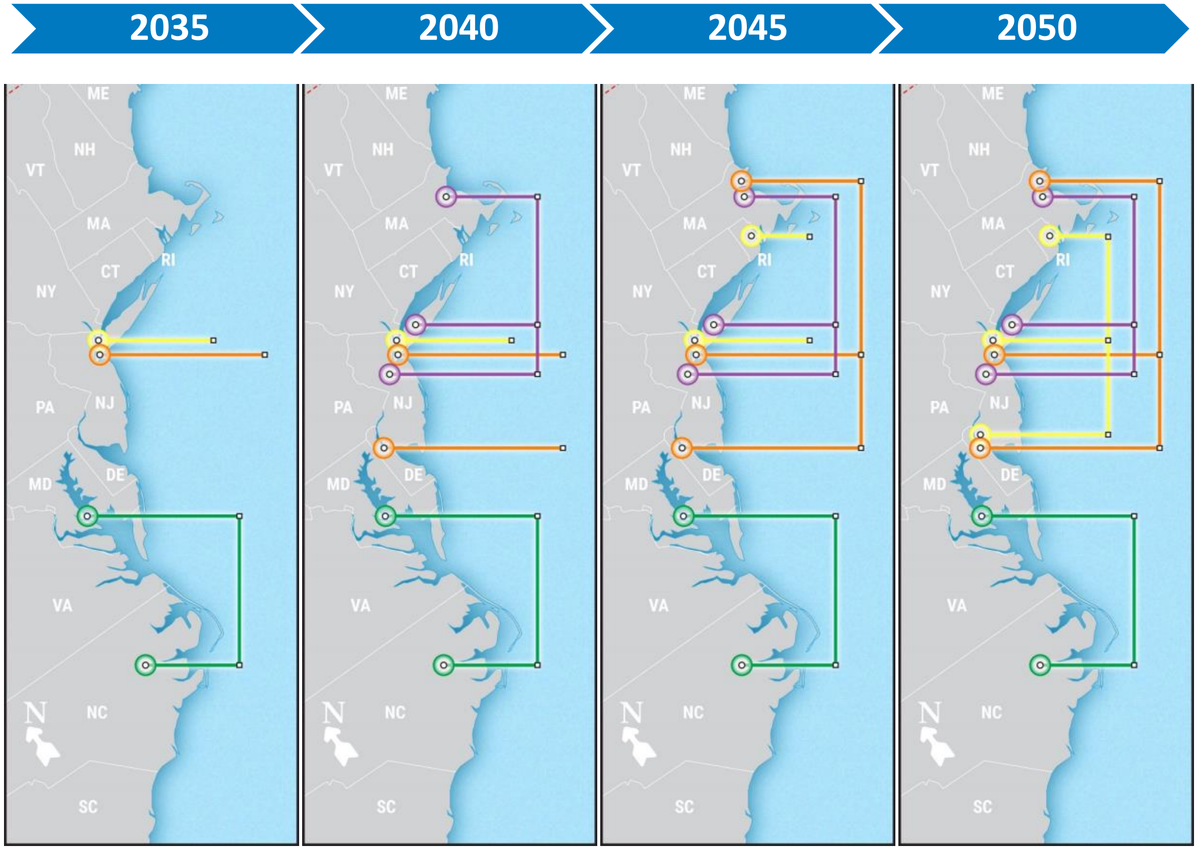
Total adjusted production cost savings in absolute $ billion for the interregional topology (bold line) and interregional sensitivities

Can linking nearby platforms reduce cost & maintain interregional benefit?

- We made a Short Distance Interregional scenario that focused on the shortest possible connections
- Five interregional connections, less than 100 km on average
- Benefits are one-third smaller than Interregional, but costs could be more than one-third lower
- There are limits to how many of these opportunities will exist, and many are in currently existing lease areas.



Transition from 2030 to 2050 (Interregional)

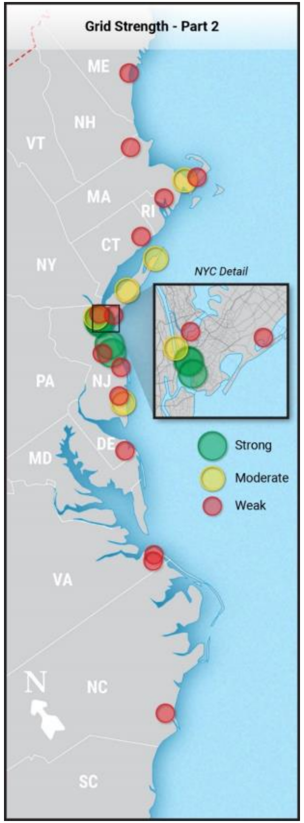


Offshore network can be developed in phases if offshore platforms are **installed with standards** that allow for future interlinking with multi-terminal HVDC

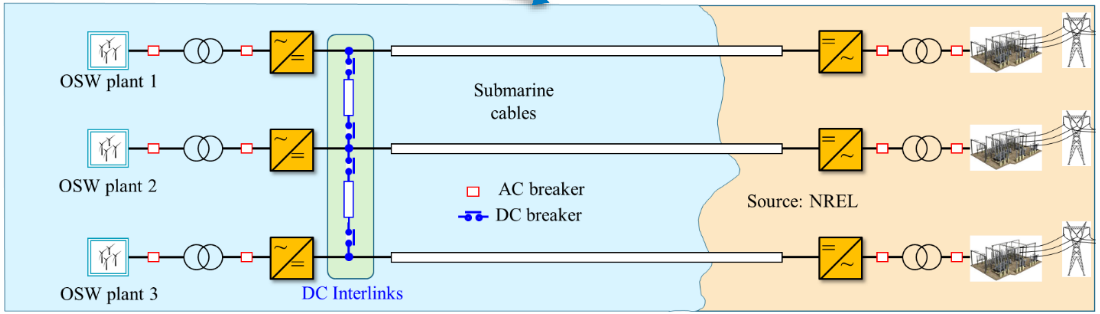
Reliability Explorations

AOSWTS demonstrated some methods/models/concepts but was not a comprehensive reliability assessment

Grid strength analysis using NREL Automated Systemwide Strength Evaluation Tool (ASSET) to determine which POIs may be weak and need more in-depth studies (and possibly additional equipment) to ensure stable and reliable operation



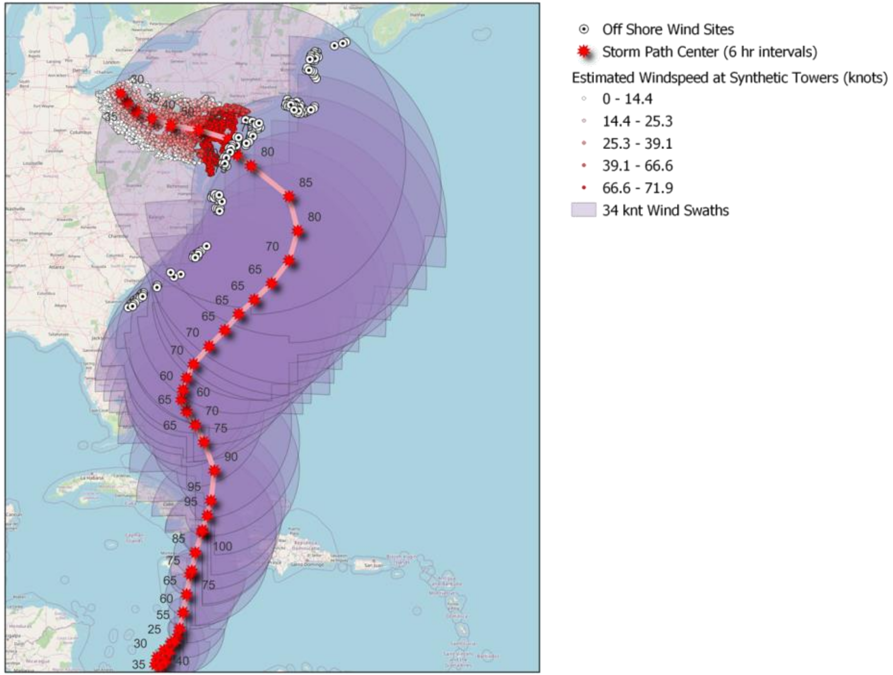
Ongoing work to understand the protection needs for multiterminal HVDC systems, see DOE WETO FOA 2828

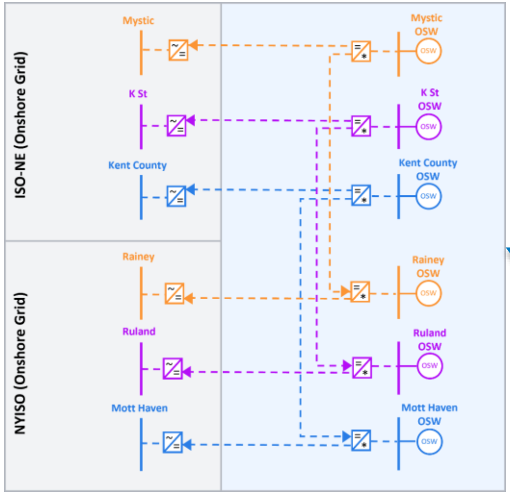


Reliability Explorations

AOSWTS demonstrated some methods/models/concepts but was not a comprehensive reliability assessment

PNNL's Offshore Wind Integration Tool (OSWIT) and Chronological AC Power Flow Automated Generation Tool (CPAGE) for powerflow case preparation, and Electrical Grid Resilience and Assessment System (EGRASS) for extreme event proof of concept





PNNL MT-HVDC redispatch to demonstrate how network could help manage on- or offshore contingencies

Future work

- This study helps to understand some of the benefits of interregional offshore transmission interconnections
- The landscape for offshore wind and offshore transmission is rapidly evolving, and this study demonstrates further research is warranted
- Outside potential future study by system operators and others, DOE is also funding several relevant projects, including the National Transmission Planning Study and HVDC standards work.

Questions?

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Thank You!

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