U.S. DEPARTMENT OF
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Atlantic Offshore Wind Transmission Study

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DOE Efforts on OSW Transmission

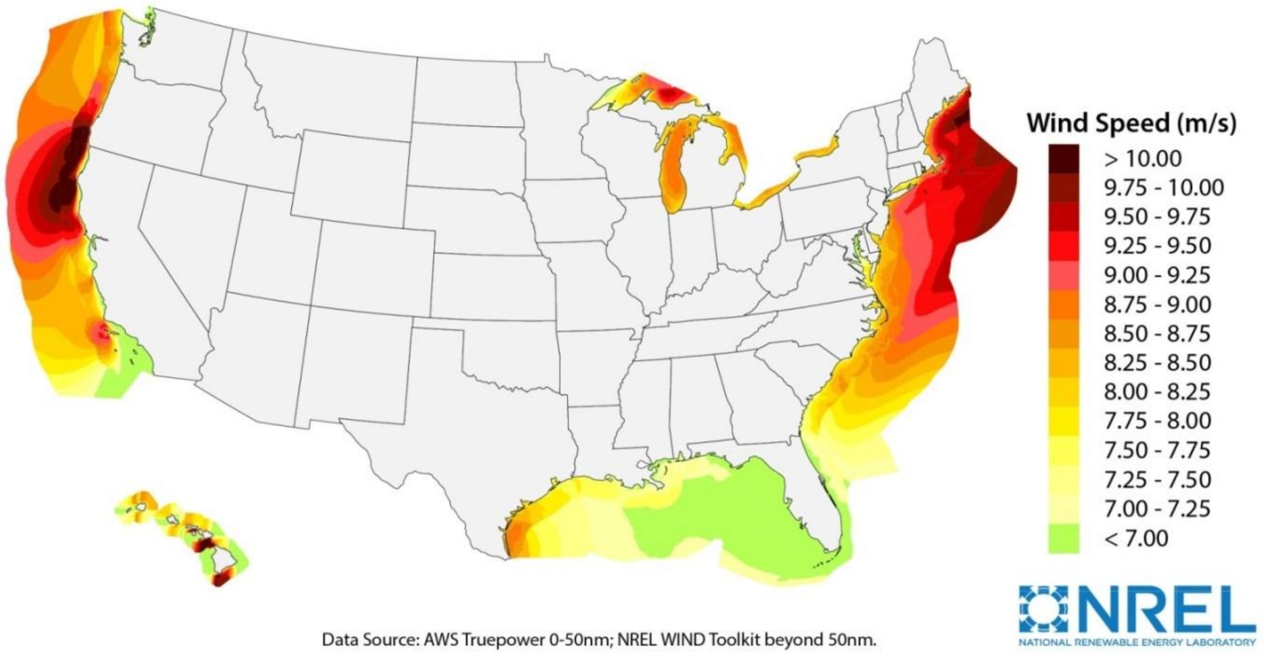
Convening Workshops: DOE and BOEM conducted a series of convening workshops, in consultation with FERC and other federal agencies, and developed a set of recommendations for OSW transmission development, planning policy, and permitting policy for the Atlantic Coast.

Transmission Analysis: DOE completed the Atlantic Offshore Wind Transmission Study with the final report released in March 2024. West Coast Offshore Wind Transmission Study is underway.

Action Plan & Recommendations Report: These final recommendations and a time-bound action plan for the Atlantic region was published in March 2024.

R&D and Standards: DOE selected 3 projects to develop standards and controls with the intention to enable the expandability of future HVDC grid for OSW deployment at scale. R&D programs are under development to reduce the cost of HVDC converter systems and support HVDC breaker needs.

Workforce Development & Others: HVDC Curriculum development and Technical Assistance to Tribal Nations are ongoing.



Atlantic Offshore Wind Transmission Study

Nov 2021 – Oct 2023

The Study intends to answer those questions:

- How much offshore wind could be deployed in 2050?
- What are the coordinated transmission solutions to accommodate offshore wind in 2050?
- What are the benefit and cost for different offshore transmission topologies?
- Could there be a sequence of build out that achieves benefit without adding near-term hurdles?
- Can we consider environmental and ocean co-use constraints in designing transmission topologies?
- How could the build out impact reliability and resilience?

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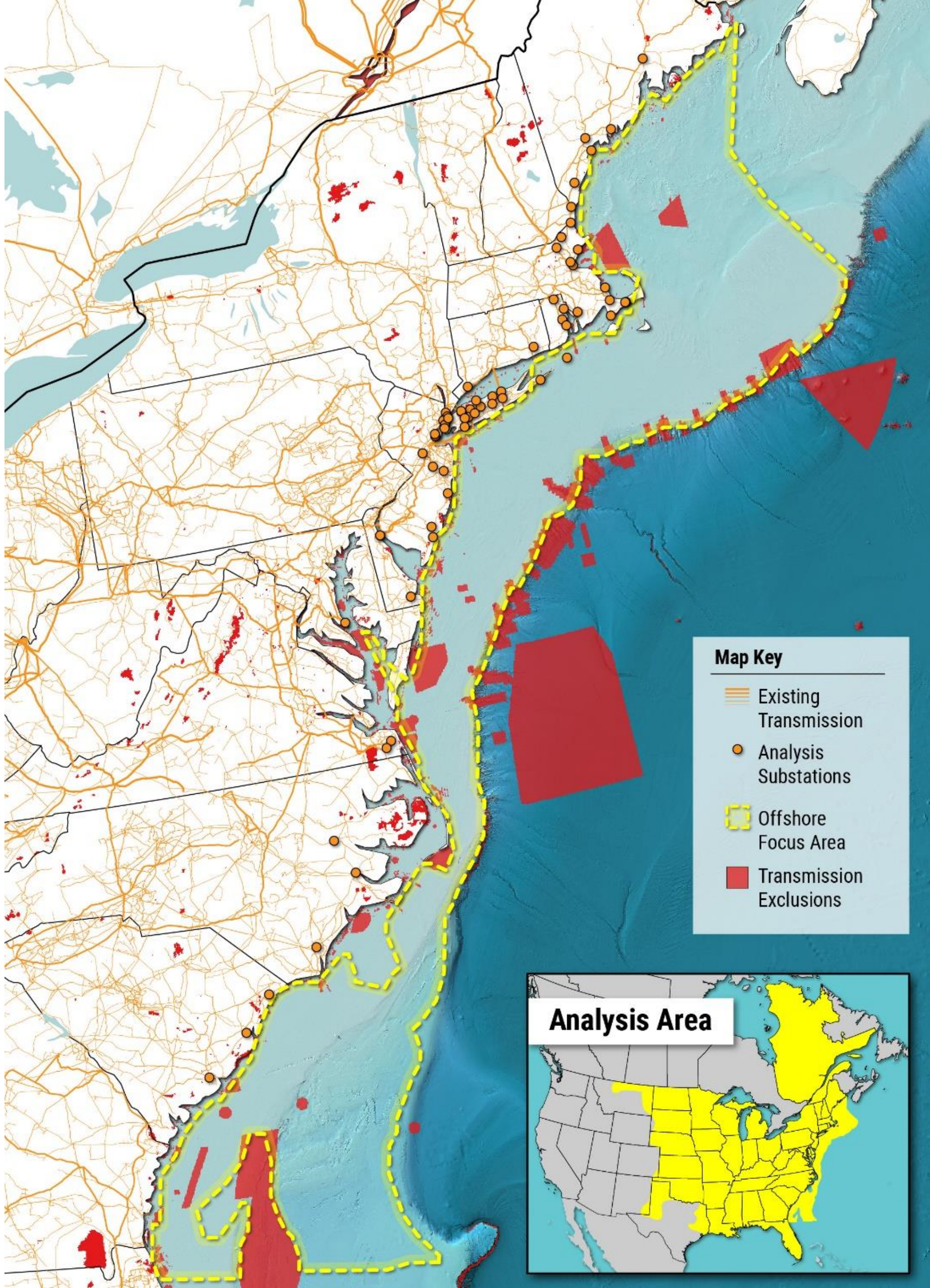
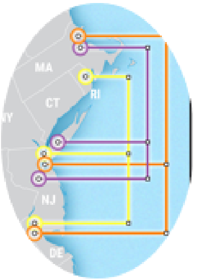
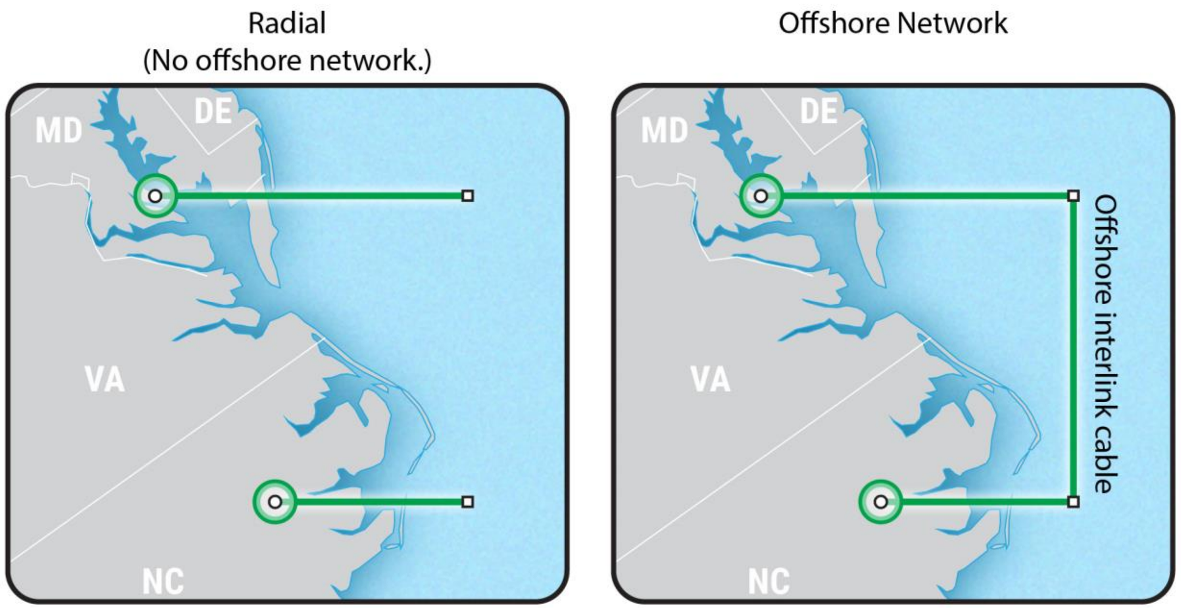


Major Questions and Study Methodologies

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?	10+ annual scenarios of offshore transmission build operated on 2050 low carbon grid with 85GW of OSW
How could offshore transmission impact reliability and resilience?	Resource adequacy, power flow and contingency analysis of 2050 grid using PRAS, CPAGE and PSS/E
Could there be a sequence that achieves benefits without adding near-term hurdles?	Consistent with current trajectories and technology readiness



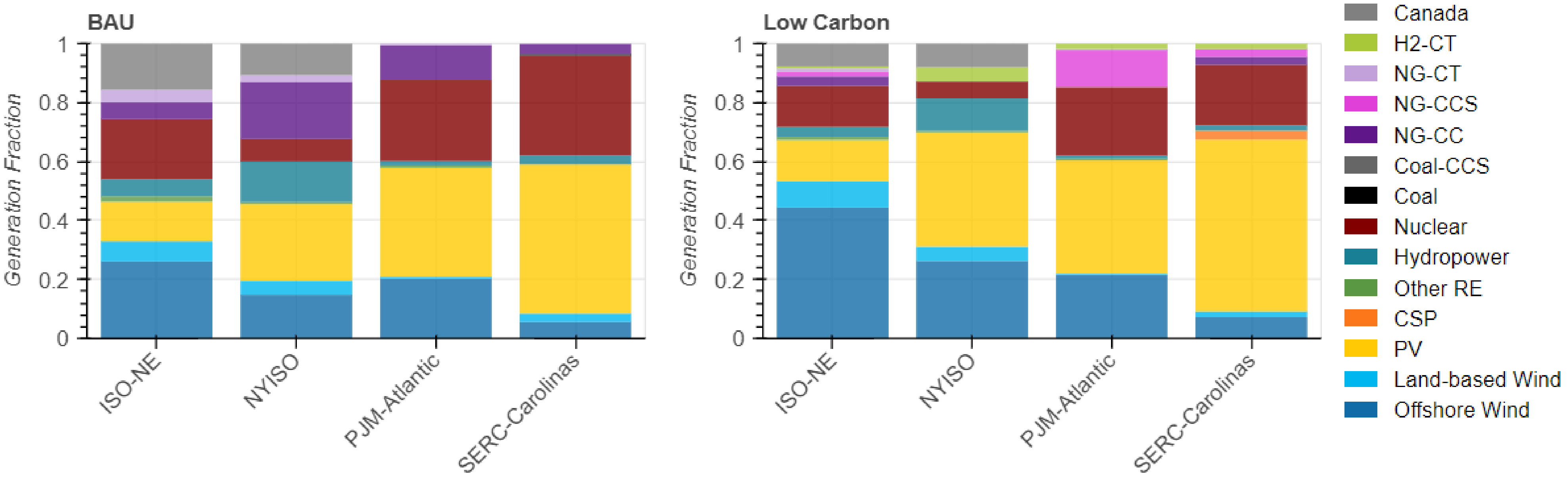
Offshore Transmission Topologies



- **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

Offshore wind is projected to be a key part of achieving low carbon future for the Atlantic States

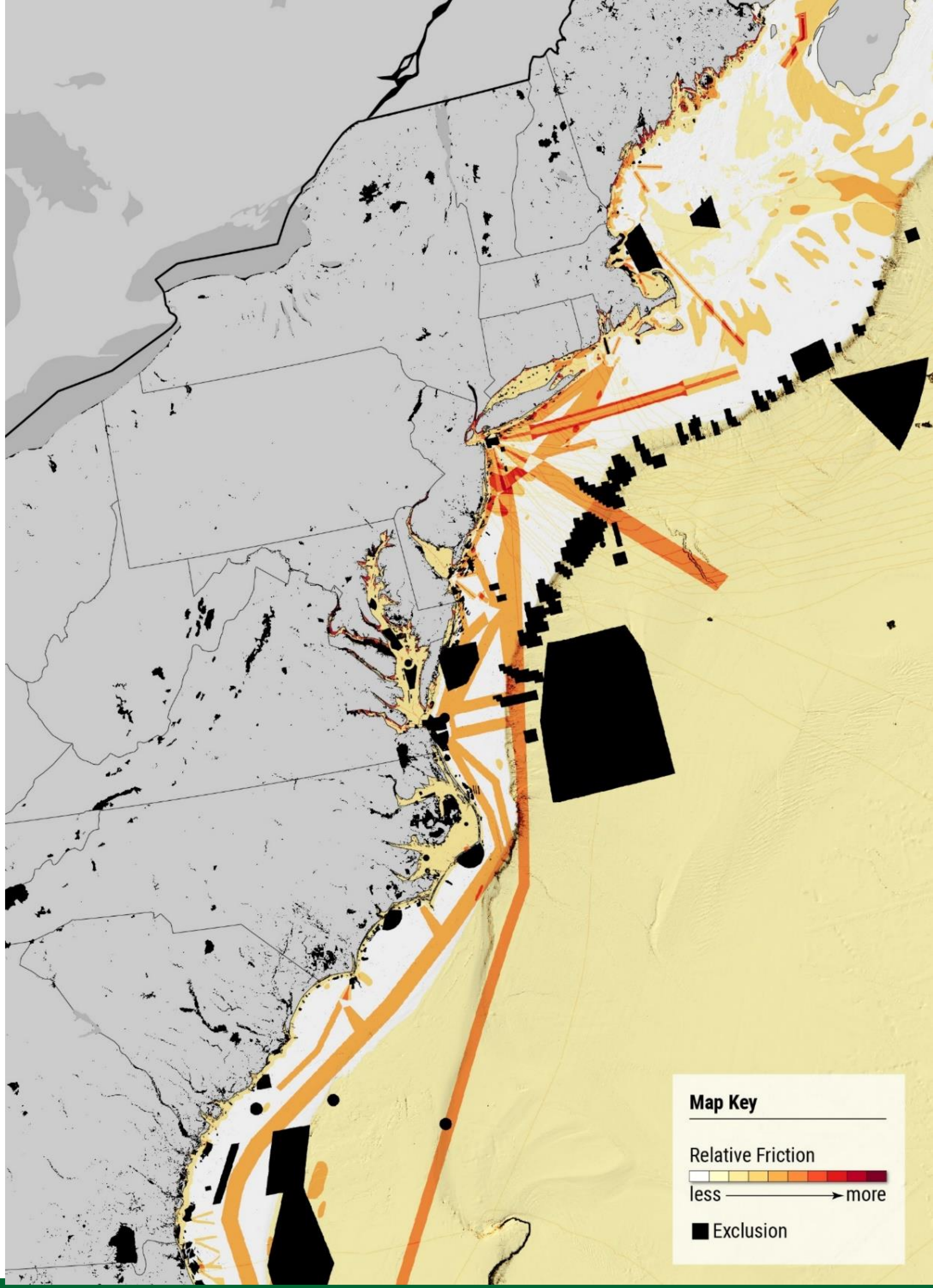
- Two future scenarios:
  - Business as Usual (BAU)
  - Low Carbon (95% CO_2 reduction and electrification) scenario through 2050.
- Low Carbon 2050 scenario deploys about **85 GW** of OSW and was selected for analyzing the transmission topologies



2050 Electricity Generation Fraction by Resources

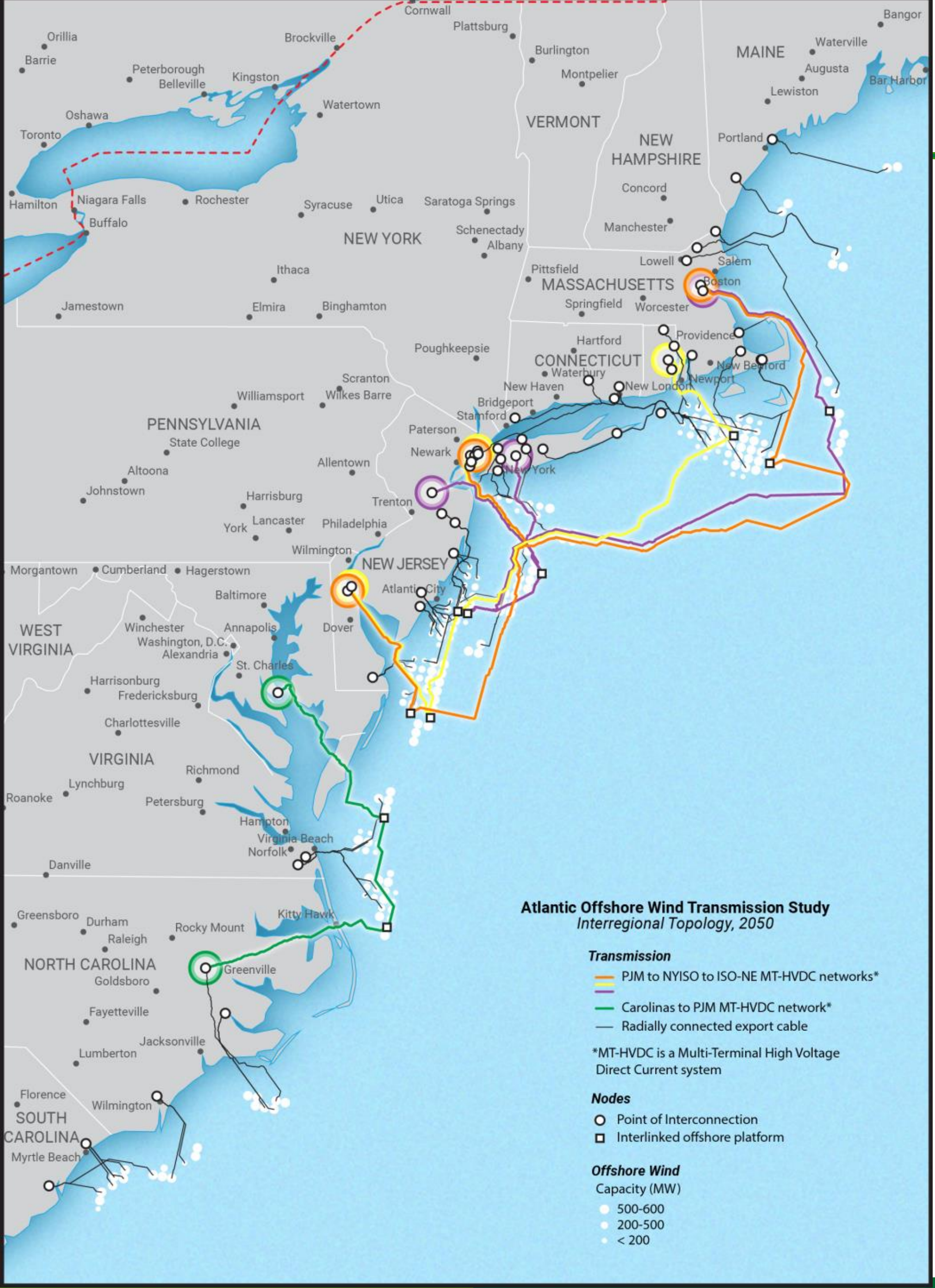
Offshore Transmission can be planned while considering ocean co-uses and environmental constraints

- 26 data layers help identify a set of challenges to cable laying, including shipping, military, conservation, and other considerations
- Not comprehensive siting study, but can help identify large-scale issues
- Hypothetical cable routes were developed based on those layers to produce the radial and other topologies.



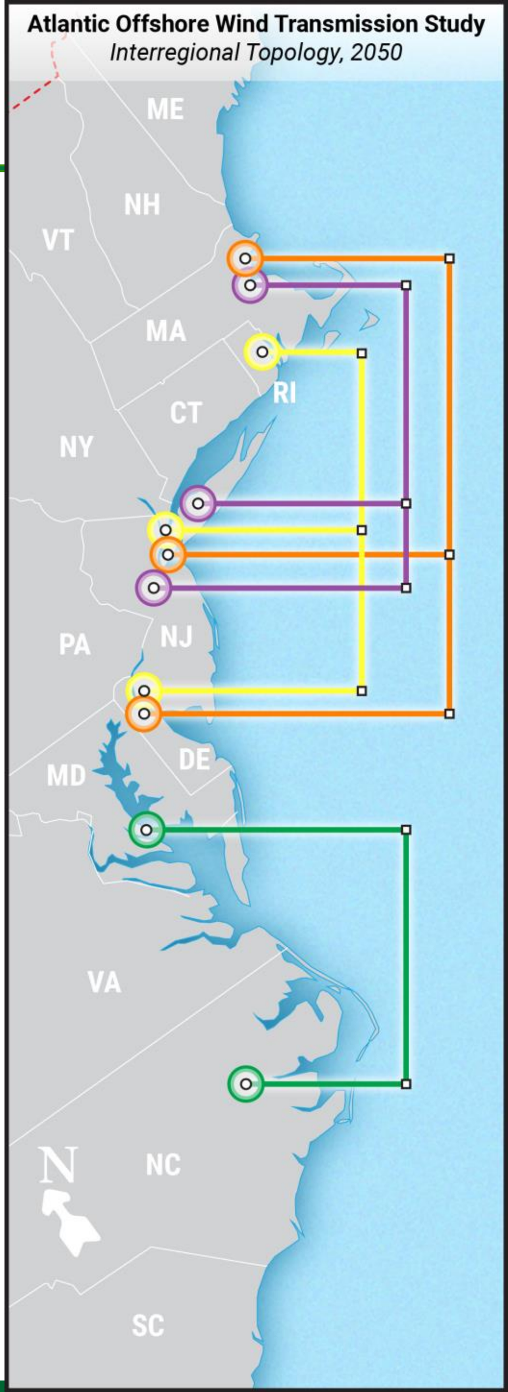
85 GW Radial Reference Topology

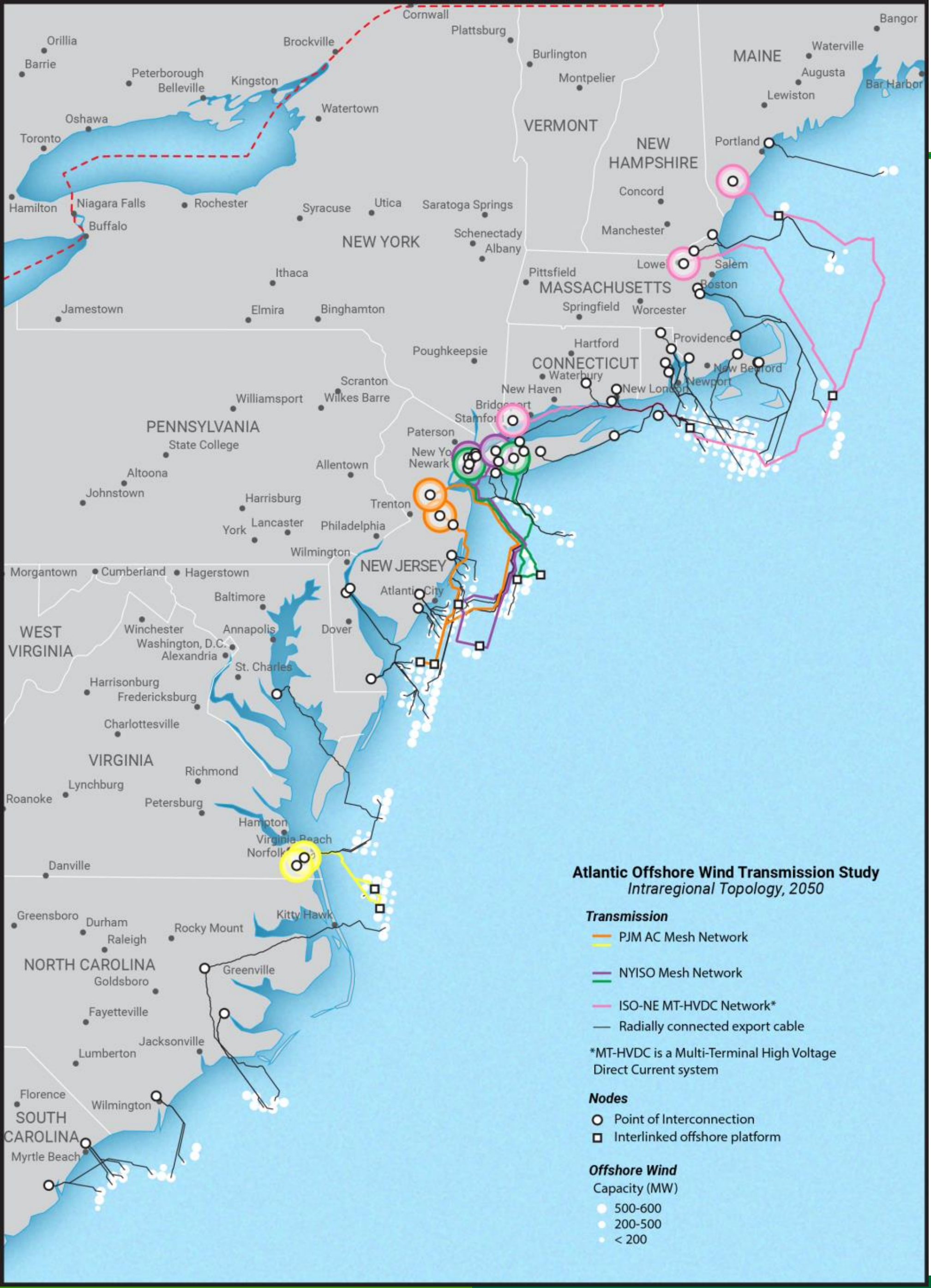
- Radial connections developed by optimizing levelized cost of electricity and cable distance to suitable Points of Interconnection
- Wind development from Maine through South Carolina
- Total of 51 POIs from New England to South Carolina selected



Interregional Topology

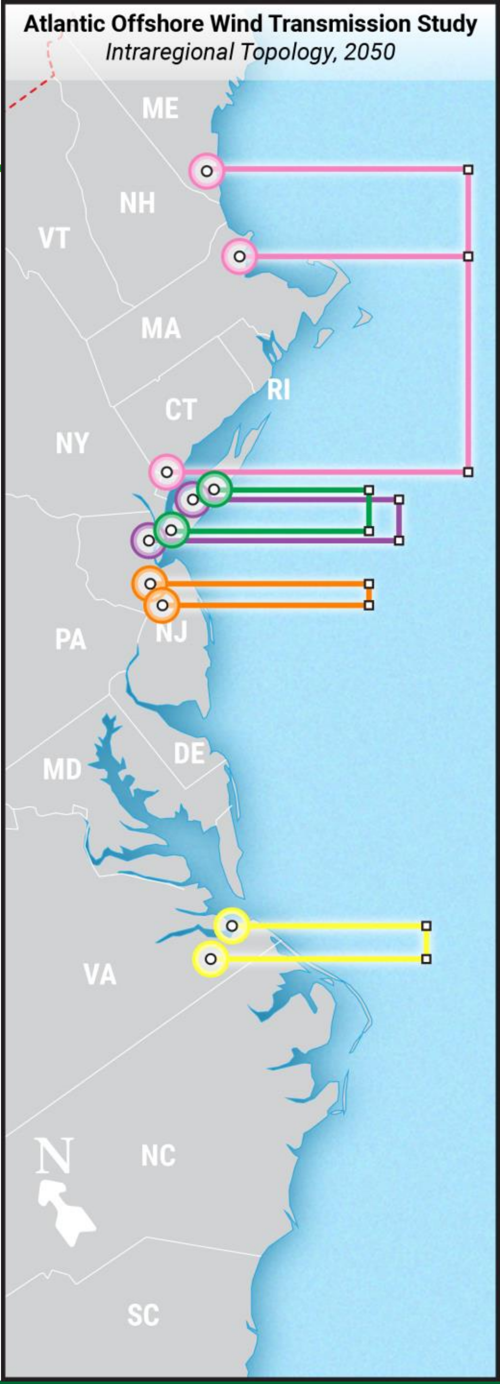
- Seven new cables, interlinking 11 platforms
- 14 GW interregional capacity
- Designed using price differentials from initial grid modeling

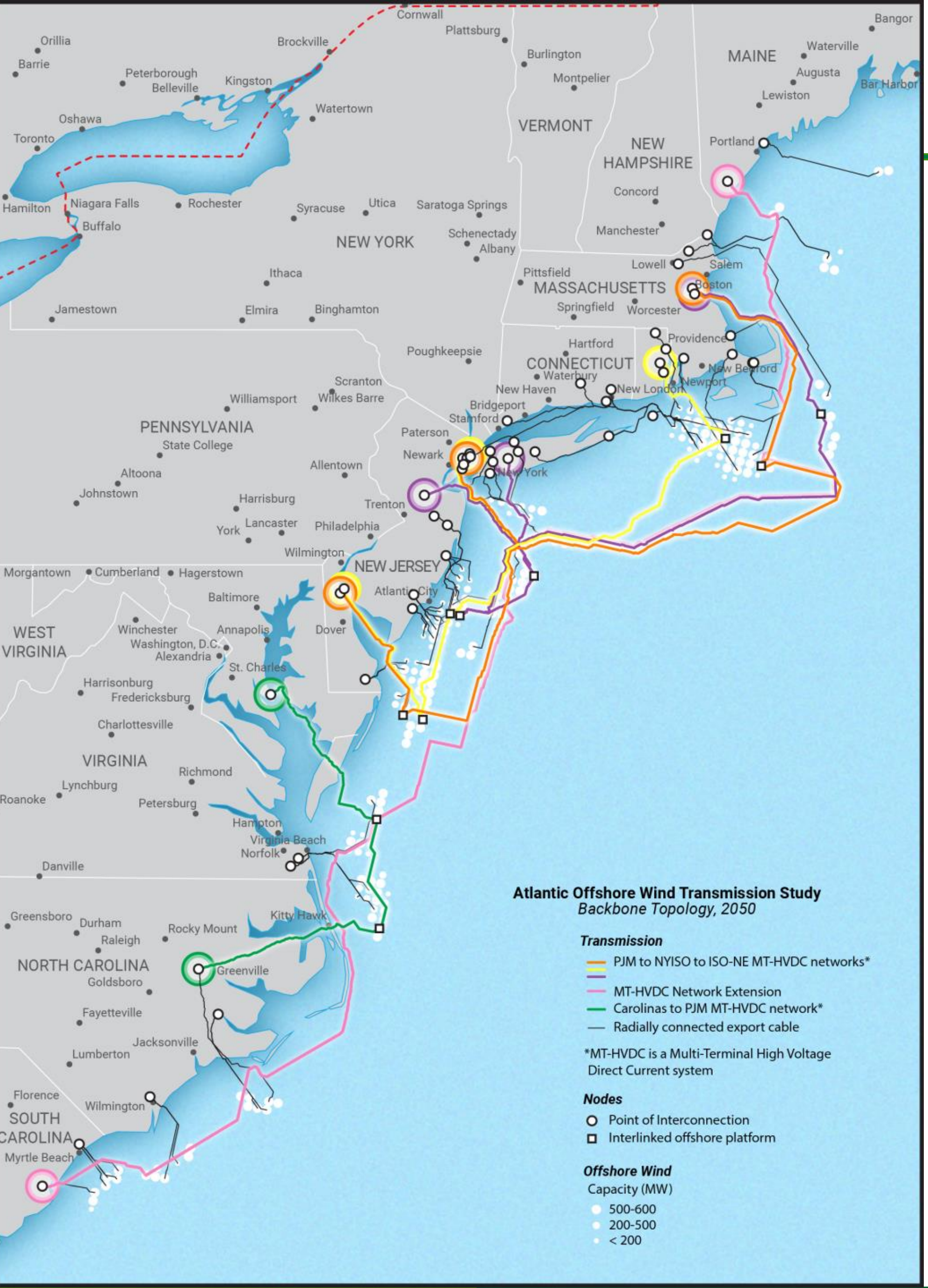




Intraregional Topology

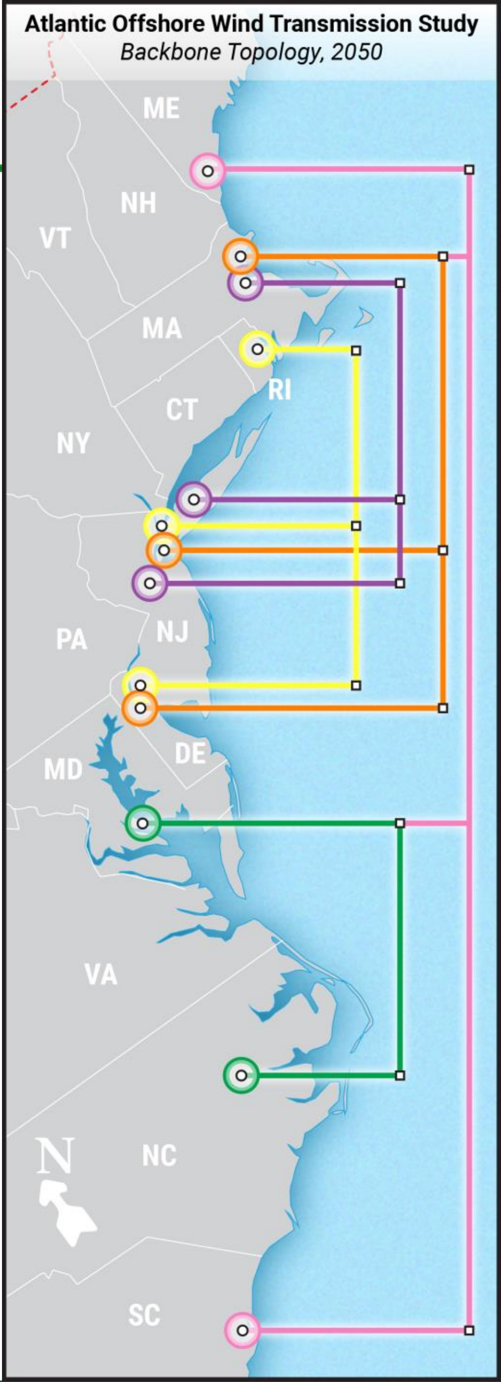
- Six new cables, interlinking 11 platforms
- HVDC in New England, HVAC elsewhere based on existing proposals
- Designed using platform locations and to be complementary to Interregional



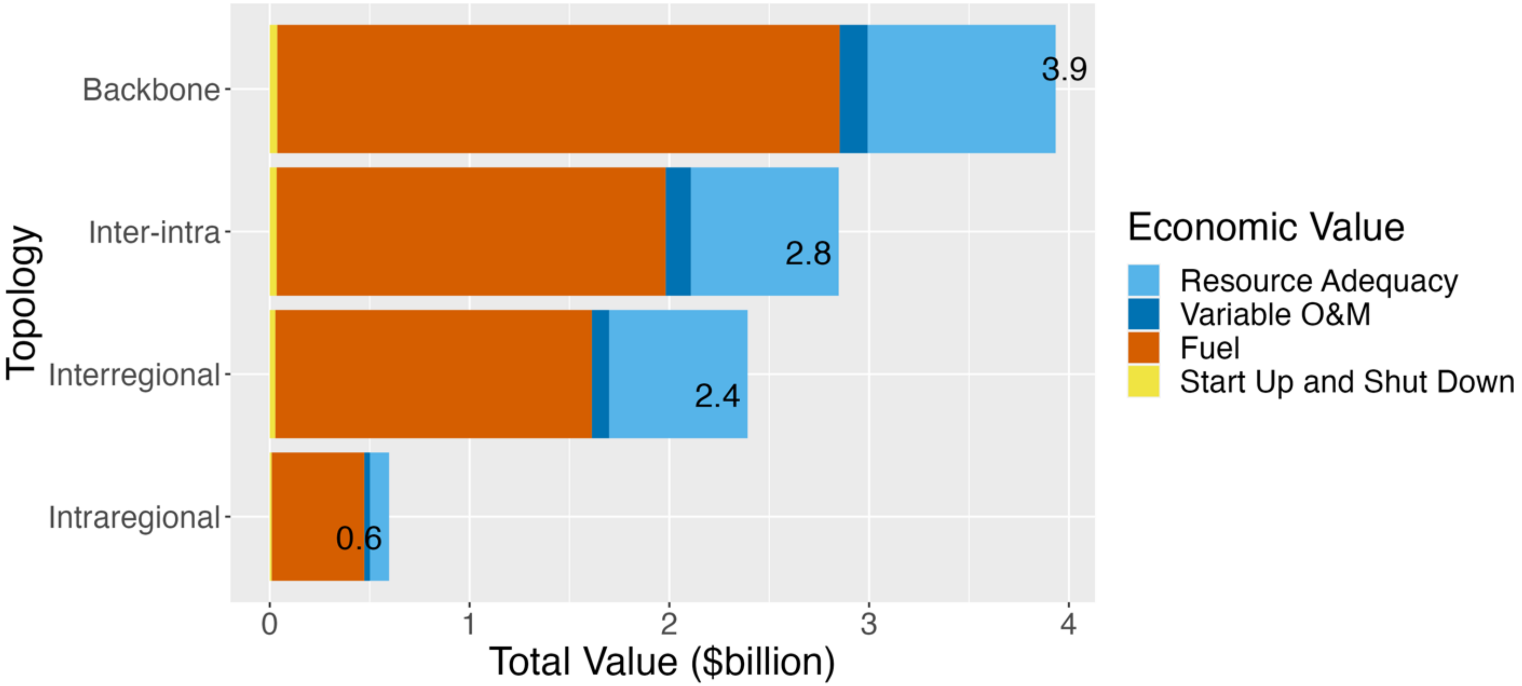


Backbone Topology

- Start with interregional
- Added corridor from South Carolina to Maine to the Interregional



Benefits of networking offshore transmission come from reduced curtailment, reduced usage of higher-cost generators, and



Annual production cost savings and resource adequacy value in 2050

- Production cost modeling was conducted for all topologies in 2050.
- On all interlinks, flows go both directions every season, reducing overall generation costs and curtailment
- Offshore wind curtailment is reduced by 1-2 percentage points
- Utilization of each line is 50% - 60%

Markets don't currently exist to fully capture transmission resource adequacy value

Offshore transmission networks contribute to grid reliability by enabling resource adequacy and helping manage the unexpected loss of grid components

- Transmission enables 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), depending on scenario

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

Benefits of offshore transmission networking outweigh the costs, often by a ratio of 2:1 or more. Offshore networks with Interregional interlinks

- 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.

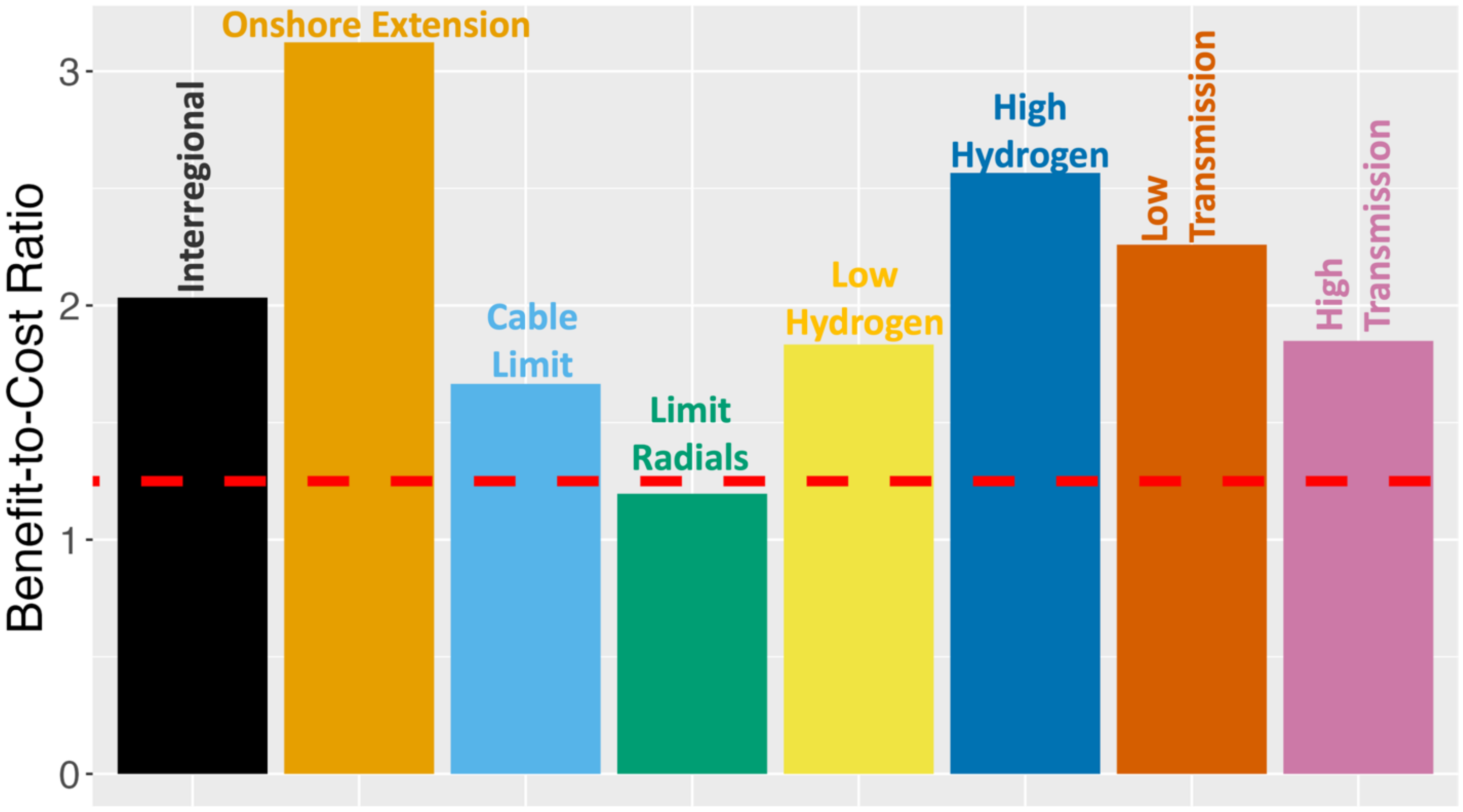
Net value (2050 benefits minus annual costs) and benefit to cost ratios:

Scenario	Net Annual Value ($M)	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 to wide range of sensitivities

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

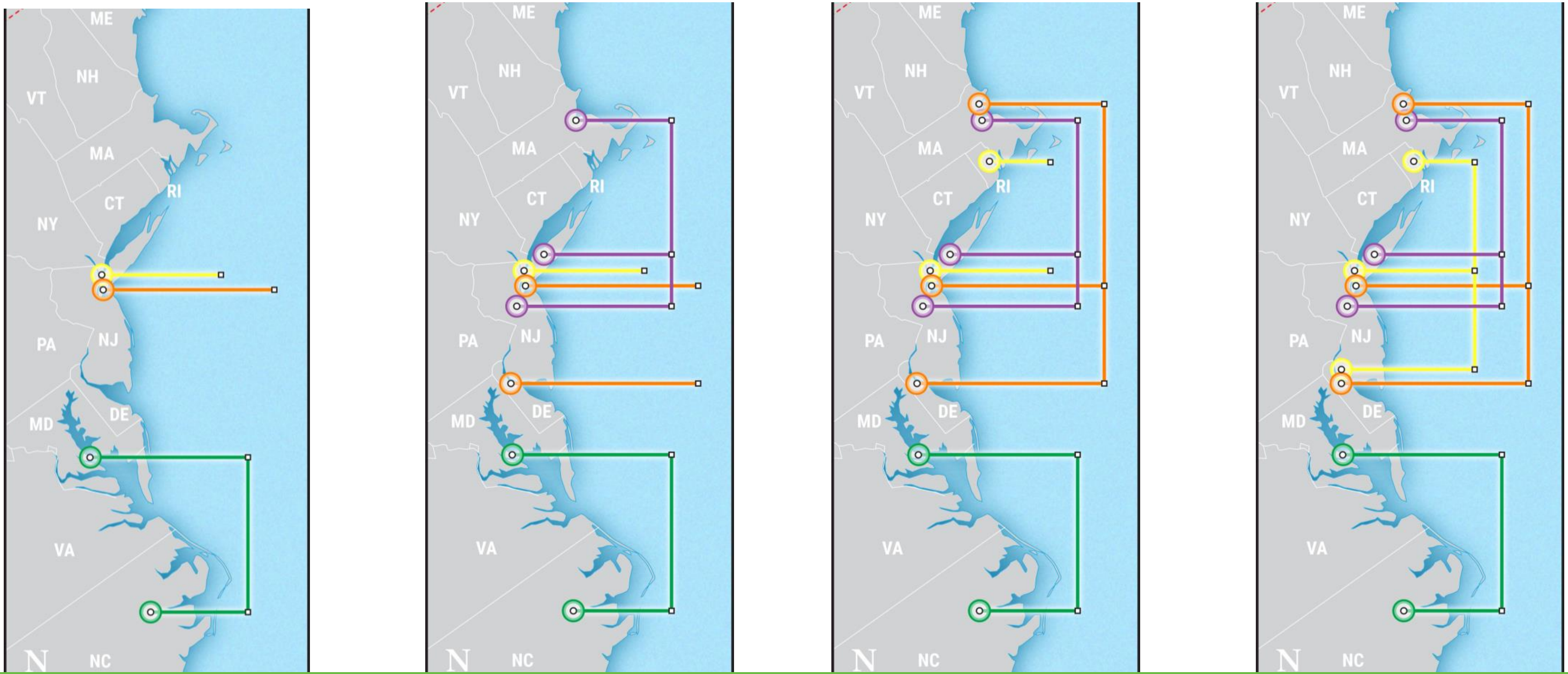
- *Onshore Extension*: More east-west transmission exists in PJM to access lower-cost renewable power
- *Cable Limit*: Interregional flows limited to 1200 MW
- *Limit Radials*: Radial export cables only flow from offshore to POI (note this is below 1.25)
- *Hydrogen prices*: $20/mmbtu in Interregional, $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

Transition from Radial 2030 to Interregional 2050

2035 | 2040 | 2045 | 2050



Building offshore transmission in phases can help reduce development risk, but early implementation of HVDC technology standards is essential for future interoperability.

Next Steps

- 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.

Thank you!

Image source: Equinor

Other Reliability Assessment

- Grid strength analysis of 30 GW of offshore wind capacity in 2030 shows that 14 of 24 considered POIs experience weak grid strength conditions. This does not mean the evaluated POIs are infeasible but indicates further studies (and possibly additional investment) are needed to ensure stable and reliable operation of the offshore wind power plant (or any inverter-based resource) under weak grid conditions.

- Dynamic and AC contingency analyses for 30 GW of offshore wind in 2030 do not indicate any widespread issues with maintaining reliability.

- Contingency analysis for 85 GW of offshore wind in 2050 indicates potential benefits of interlinked offshore network topologies to system reliability by enabling mutual support between the onshore and offshore networks during contingency events.

- Developing 85 GW of Atlantic offshore wind capacity may expose the power system to additional resilience risks resulting from extreme weather events occurring in the ocean and at the landing point. To enable improved planning for resilient offshore wind energy integration, the team developed datasets and methods to translate extreme weather events into simulations for both steady-state and dynamic analyses.