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Request for Information:

Regional Transmission Initiative
Connecticut, Maine, Massachusetts, New Hampshire, and Rhode Island

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Background

While the U.S. has committed to building 30 GW of offshore wind by 2030, transmission development for currently planned projects is proceeding on a project-by-project basis. While individual states and systems operators are conducting analyses regarding the integration of large-scale offshore wind into their jurisdictions, plans for the system have yet to be developed. The signatories of the following RFI response constitute a multi-disciplinary research team that is currently engaged in a two-year research project entitled *Transmission Expansion Planning for Offshore Wind Energy* funded by the National Offshore Wind Research and Development Consortium (NOWRDC) and the Massachusetts Clean Energy Center (MassCEC). Our team is developing transmission expansion planning scenarios for 30 GW, 60 GW and 100+ GW offshore wind buildouts on the U.S. East Coast using both a full 90,059 bus power flow model (full-model) and a state-of-the-art reduced bus model (reduced-model) for the Eastern Interconnection (EI).

The full-model enables both AC and DC power flow analyses, providing detailed information related to POI selection, land-based upgrade requirements and costs, as well as assessments of grid support functions and ancillary services like voltage support, frequency regulation and reactive power support. The reduced model allows us to engage in coordinated expansion planning (CEP) exercises that include not only power flow analyses but also demand growth, multiple renewable resources such as wind and solar, resource variability, and investment costs.

The 30 GW, 60 GW, and 100+ GW scenarios in our study contemplate the use of advanced VSC-HVDC multi-terminal technology, coordination of points of interconnection (POIs) between regions, and the design of optionality for an integrated onshore/offshore grid that can grow with this new U.S. industry and with a future U.S. macrogrid. Our study is independent of and complementary to the U.S. Department of Energy's (DOE) Atlantic Offshore Wind Transmission Study (AOWTS) under development by the National Renewable Energy Laboratory (NREL) and the Pacific Northwest National Laboratory (PNNL). Our team meet regularly with the AOWTS team to share insights and results for purposes of providing independent checks on each study and deepening each research team's overall understanding of the role of East Coast offshore wind within the larger U.S. energy transition and grid modernization.

The responses here represent the views of the signatories and should not be understood as representing the views of the research institutions where the signatories are employed, the views of the DOE or the national labs running the AOWTS, the views of NOWRDC, or the views of MassCEC. Any opinions, errors, or misunderstandings within the following document are entirely our own.

Comments on Changes and Upgrades to the Regional Electric Transmission System Needed to Integrate Renewable Energy Resources:

1. Comment on how individual states, Participating States, or the region can best position themselves to access U.S. DOE funding or other DOE project participation options relating to transmission, including but not limited to funding, financing, technical support, and other opportunities available through the federal Infrastructure Investment and Jobs Act.

We recommend that the Participating States work together to create a regional vision and plan for the energy transition and articulate clearly how this vision is situated within a vision for the entire country that includes interregional transmission planning and projects. The Participating States have an opportunity to lead by example, and in so doing develop experience and expertise that will allow the region to grow economically through sharing with other regions.

2. Comment on ways to minimize adverse impacts to ratepayers including, but not limited to, risk sharing, ownership and/or contracting structures including cost caps, modular design, cost sharing, etc.

We recommend that the Participating States undertake a methodological review in both qualitative and quantitative terms as to what constitutes "adverse ratepayer impacts." While these would vary among the states, it would provide clear guidance for policy, regulatory and planning. Without clear numerical grounding, there are too many ways to interpret impacts and whether they are adverse or beneficial and could be combined with other metrics like the social cost of capital (SCC) and the approved cost/benefit metrics used in state proceedings. We published a study earlier this year showing that Levelized Nominal Prices (LNP) for offshore wind, considered in 2022 dollars, varied by $40.76 per megawatt-hour (MWh) among nine projects studies from New Jersey to Massachusetts, with an average price of $95.36 / MWh.[1] This variation is 2.87 times the weighted standard deviation of the nine projects in question and can be attributed mostly to specific putative economic benefits or lack thereof to the states for the contracts in question. Of secondary importance is the question of capacity market payments which can be argued to range between $4 and $11 / MWh depending on the calculating entity and its approach to the calculation.

Converting the $95.36 / MWh into ratepayer terms yields 9.536¢ / kWh, which is substantially less than the approximately 26¢ / kWh which New England rate payers have observed on their own electricity bills. Furthermore, cursory evaluation of New England electricity prices during Spring 2022, with Falmouth, MA as a case study, yielded the following observations for January through May 2022:

- Mean wholesale electricity price = $92.35 / MWh (higher than the U.S. average price of OSW)
- Standard deviation = $61.94 / MWh
- Maximum hourly wholesale price = $604.89 / MWh
- Minimum hourly wholesale price = -$151.12 / MWh
- The three-day rolling average wholesale price went above $200 / MWh in February 2022.
- The three-day rolling average wholesale price remained above $50 / MWh for most of May 2022.

These observations demonstrate that electricity prices are complicated, volatile, and must be understood from multiple perspectives. Therefore, it is difficult to consider prices rising or falling without giving proper context.

Based on these observations about price, we recommend the following:

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[1] Hines, E. and Kates-Garnick, B. (2022). *U.S. Offshore Wind Prices (2018-2021)*. OSPRE-2022-01. Tufts University. February 28.

- Establish a consistent numerical standard between all states for reporting offshore wind prices.
- Clearly indicate within this pricing standard the price of:
    - electricity generation and delivery to the relevant point of interconnection (POI)
    - land-based transmission system upgrades
    - capacity market payments
    - ITC benefits
    - putative economic impacts and their specific value in present dollars
- Make all pricing information publicly available and easily accessible, including payments to existing fossil fuel plants under all conditions, including peaking plants.
- Within this context, develop a common understanding between the Participating States of long-term transmission upgrades and negotiate sharing of these costs in a manner that clearly delineates the funding coming from:
    - Rate payer surcharges for each state / region
    - Taxpayer dollars from each state
    - Federal taxpayer dollars.
- Provide a common methodology to ascertain adverse ratepayer impacts

3. Identify the advantages and disadvantages of utilizing different types of transmission lines, like alternating current (AC) and direct current (DC) options for transmission lines and transmission solutions. Should 1200 MW / 525 kV HVDC lines be a preferred standard in any potential procurement involving offshore transmission lines?

- We are of the opinion that a hybrid network, with some shorter interconnections and collector systems of the offshore network should be AC, but that most of the interconnected system needs to be part of a Multi-Terminal HVDC (MTDC) network.
- A MTDC interconnection network may be developed in modular blocks but needs to be at the highest possible DC voltage of 525 kV. This voltage level will make the different sections compatible with the different states and multiple vendors have technology at these voltage levels.
- In Europe several studies and standards have developed over the last few years and consistently show that 525 kV / 2,000 MW would be the preferred modular offshore station configurations
- Furthermore, this 525 kV MTDC offshore network needs to be developed with Voltage-Source Converter (VSC) HVDC technology. VSC-HVDC is the most flexible and have superb grid support functionality.
- We believe that inter-regional collaboration and planning as well as Remedial Action Schemes (RAS) could raise this 1200 MW limit.

4. Comment on whether certain projects should be prioritized and why. For example, should a HVDC offshore project that eliminates the need for major land-based upgrades be prioritized over another HVDC offshore project that does not eliminate such upgrades?

- From the voltage level perspective, the North American MTDC grid should be planned for 525kV instead of 325kV. We recognize that the offshore grid protection systems for 525kV DC are relatively new and have not found wide adoption in HVDC projects yet, but these technologies are already used in international HVDC DC side protection, lab tested and are expected to mature more from a market perspective in the coming years. The cable cost is a significant portion in the overall offshore grid investment. Therefore, the offshore cables rated at 525kV could be laid and operated at 325kV, if need be, till DC protection technology is mature enough to replace the 325kV equipment in a modular design approach with HVDC breakers as an enabling technology. This approach will save significant upgradation costs and increase capacity in the future. It is also important to evaluate VSC-HVDC converter operation over a wide voltage range (>15%) to accommodate voltage drop and POI voltage constraints across the region.

- VSC-HVDC converter technology should be utilized in the onshore and offshore and onshore converter stations and platforms. This will help in providing advanced control features and grid support functions necessary for realization of meshed grids when transformation from radial networks into meshed grid occurs in the future. Furthermore, they will be able to provide ancillary services to the onshore AC grid.
- HVDC projects should be evaluated within a framework that appropriately values their long-term compatibility with the grids of 2050, 2040, and 2030. [Reverse order: 2050, 2040, and 2030 is intentional in this comment.]
- Local USA-based high voltage and high-power testbeds for HVDC converter technology and Power Hardware-in-the-Loop (P-HIL) are needed to perform validation of converter and DC circuit breaker technology for successful integration.

5. Identify any regional or interregional benefits or challenges presented by the possibility of using HVDC lines to assist in transmission system restoration following a load shedding or other emergency event and particularly from using the black start capabilities of HVDC lines in the event of a blackout?

- As proposed using VSC-HVDC converter technology in the onshore and offshore converter stations will provide ancillary services for the land-based transmission assets.
- The VSC-HVDC converter stations will provide valuable black-start capability to the regional power system should be utilized in the onshore and offshore and onshore converter stations and platforms.

6. Identify the benefits and/or challenges presented by using land based HVDC lines or other infrastructure to increase the integration of renewable energy (other than offshore wind) in New England to balance injections of offshore wind.

- The benefits of having a parallel land based HVDC network with a HVAC network will be valuable to interconnect more transmission connected solar and wind power for power flow control and grid support functions. This will support more renewable energy generation that may even be wheeled to other inland regions and states through an overlay HVDC grid for the future.
- An HVDC overlay transmission network will have VSC-HVDC converter technology in the converter stations will provide ancillary services benefits for the land-based transmission assets.

7. Comment on the region's ability to use offshore HVDC transmission lines to facilitate interregional transmission in the future.

- An HVDC overlay transmission network with VSC-HVDC converter technology will provide a backbone across the region and interconnect other regions to transmit wind and solar power across several regions and states.
- The capacity of existing AC transmission networks is near the limit and forms the bottleneck of integrating large numbers of remote wind and solar generation. Most of the high wind and solar production areas are far from load centers and need
- generation for ancillary services benefits for the land-based transmission assets.

8. Comment on any just-transition, environmental justice, equity and workforce development considerations or opportunities presented by the transmission system buildout and how these policy priorities are centered in decisions to develop future infrastructure.

Coordinating landing points for the full 2050 build-out is essential to ensuring a just-transition and environmental justice. Hundreds of independent generator lead line landings on the East Coast that are permitted and negotiated on a project-by-project basis will likely damage our fragile coastal environment and take unfair advantage of underserved communities.

Consider the following thought experiment. Within the context of the U.S. Energy Transition, which will require between 3000[2] GW and 4700[3] GW of renewable electricity generation capacity and storage, we estimate the East Coast offshore wind build-out to be approximately 300 GW, which is three times larger than the current DOE 2050 target. Separately negotiated lead lines for 300 individual 1 GW OSW projects presents a level of chaos that will make it very difficult to attend to environmental and community concerns. Conversely, if we imagine an East Coast transmission backbone as the first leg of a North American macrogrid, as show in response to Question 9 below, we can imagine 10-30 landing points ranging in size from 10-30 GW. In this case, there would be few enough landing points and each point would be significant enough that they could be carefully and wisely designed, permitted and negotiated with host communities. In turn, the federal government, state governments and the private sector could work with this handful of host communities to make sure they get high quality jobs, environmental mitigations, and economic development in return.

9. Comment on how to develop transmission solutions that maximize the reliability and economic benefits of regional clean energy resources.

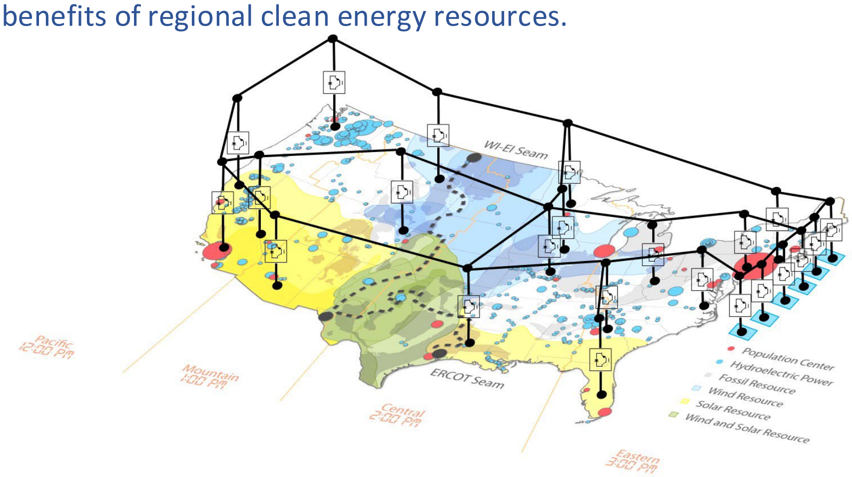

Figure 1: US Macrogrid/Offshore System. (J. McCalley and Q. Zhang., "Macro Grids in the Mainstream: An International Survey of Plans and Progress," Americans for a Clean Energy Grid, November 2020. [Macro-Grids-in-the-Mainstream-1.pdf (cleanenergygrid.org)](Macro-Grids-in-the-Mainstream-1.pdf)).

A macrogrid/offshore system, as illustrated in Figure 1 above, provides the ability to share energy and grid services over a 24-hour timeframe across regions and on a transcontinental scale, taking advantage of the temporal/spatial differences in demand due to time zones. Such sharing is also attractive with peaking capacity, taking advantage of the fact that different regions peak at different days of the year, providing opportunities for very large savings in avoided capacity procurement.

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[2] E. Larson, C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, EJ Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan, Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final Report Summary, Princeton University, Princeton, NJ, 29 October 2021.

[3] Denholm, Paul, Patrick Brown, Wesley Cole, et al. 2022. Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035. Golden, CO: National Renewable Energy Laboratory. NREL/TP6A40-81644. https://www.nrel.gov/docs/fy22osti/81644.pd

An example of this kind of network is the 1964 Pacific Northwest-Southwest HVDC Intertie which operates in parallel with the EHV AC lines. This intertie was designed to provide Northwest hydropower to the Southwest during summer months and Southwest electricity sources to the Northwest during winter months. It is important to recognize that this project hinged on the collaboration of multiple state, federal, and private entities. It also involved an international treaty with Canada.

Regardless of technological developments since the 1960's, deeper knowledge of U.S. experience in planning and constructing major energy and grid infrastructure will be instructive and helpful to our work on the coming energy transition. This transition will require infrastructure planning and construction that exceed any previous U.S. infrastructure developments in scale and speed.

Without a profound cultural recognition of this fact, the transition will remain elusive. For this reason, it is critical that our region speaks with one voice on this issue. DOE's role and the role of the research community in this effort is to create information that is simple, clear, and actionable. Research must be motivated by and pursued in the service of the practical realities of the energy transition. This also means that the federal government must be profoundly aware of the details driving each region's needs, history, and politics.

A north-south transmission leg along the U.S. Atlantic Coast (see Figure 1) is essential to the overall macro grid/offshore design to satisfy basic reliability requirements. Building this leg onshore will likely be prohibitively complex from a permitting point of view due to the population density and shear number of affective stakeholders and jurisdictions in this area. Constructing this leg off-shore can proceed under the sole authority of the U.S. federal government if coordination with states and RTOs prioritizes long-term planning for the use of POIs and land-based transmission expansion capacity.

VSC-based HVDC may be utilized to develop both onshore and offshore macrogrid segments, offering converters with control capabilities that can significantly strengthen the grid.

AC transmission cannot be connected trans continentally without deploying very high capacity to provide stable synchronization to what are today asynchronous grids. In addition, underground and undersea AC transmission is limited in distance. The need for HVDC arises from the long distances in the US—especially the distances for long north-south offshore transmission links.

Comments on the Draft MOWIP:

10. Identify potential Points of Interconnection (POIs) in the ISO-NE control area for renewable energy resources, including offshore wind. What are the benefits and weaknesses associated with each identified POI? To the extent that your comments rely on any published ISO-NE study, please cite accordingly.

We have developed automated procedures for identifying the cost of supporting a given power injection at a POI. Attractive POIs in the ISO-NE control area include Millstone 345, Brayton Point 345, Seabrook 345, Pilgrim 345, K Street 345, Maguire Rd 345, Yarmouth 345, Woburn 345, and Newington 345. These POIs tend to minimize the sum of two costs:

(i) reach circuit cost (the cost of connecting the offshore transmission system to the given substation) plus (ii) onshore transmission expansion cost (the cost of reinforcing the onshore transmission grid to accommodate the injection at the given POI).

11. Similarly, comment on whether there are benefits to integrating offshore wind deeper into the region's transmission system rather than simply interconnecting at the nearest landfall (e.g. using rivers to run HVDC lines further into the interior of New England). If there are enough benefits to make this approach feasible, please comment on any obstacles, barriers or issues that Participating States should be aware of regarding such an approach.

Benefits of integrating offshore wind deeper into a region's transmission system depend on the location of the displaced generation relative to the location of the POI. Such benefits will be most pronounced if the direction from the POI to the region having most of the displaced generation is opposite to the prevailing direction of flow.

12. Identify likely offshore corridor options for transmission lines. Please comment on the potential for such corridor options, include size of the corridor footprint and potential number of cables that can be accommodated, to minimize the number of lines and associated siting and environmental disturbance needed to integrate offshore wind resource. For any offshore corridor identified, please indicate how the corridor avoids or minimizes disturbances to marine resources identified in the applicable plan, including the Connecticut Blue Plan and the Massachusetts Ocean Management Plan.

We refer the Regional Transmission Initiative to the DOE-AOWT study.

13. Identify strategies to optimize for future interconnection between offshore converters, either AC or DC, to permit power flow between converters to facilitate the transmission of power from offshore to multiple POIs as needed. Similarly, comment on the ability of offshore converters from competing manufacturers to communicate with one another in this future case.

An offshore HVDC backbone transmission design enhances optionality for further development and interconnection as offshore wind grows in future decades. Such a design will have high-capacity HVDC connections to shore (landfalls) from which onshore connections to existing AC substations may be made. The number of landfalls should be limited to minimize necessary permitting and related infrastructure development on the coast. To avoid violating single source contingency limits set by the RTO, such designs should have at least three high-capacity landfalls so that most, if not all, of the offshore power may still be delivered under loss of one landfall.

14. Comment on the benefits and/or weaknesses of different ownership structures, such as a consortium of developers with transmission owners or use of U.S. DOE participation as an anchor tenant through its authorizations in the federal Infrastructure and Investment Jobs Act, for new offshore transmission lines.

We believe that the U.S. DOE as an anchor tenant is essential to making a project of this magnitude work.

15. Comment on cost allocation mechanisms that would prevent cost-shifting between the states based on their policy goals and ensure that local and regional benefits remain quantifiably distinct. How should any future potential procurement identify and distinguish local, regional, and state-specific benefits (e.g., reliability) such that ratepayers only pay for services that they benefit from?

16. Comment on the benefits and/or weaknesses of using a public-private partnership that might include one or more states or U.S. DOE as part owners with private developers or other sources.

We believe that useful public-private long-term investment and ownership models have been developed in the realm of infrastructure. For instance, there has been a lot of progress in such models with respect to toll roads. It is essential to think about this new energy infrastructure as "infrastructure" due to its size, cost and role as a critical public asset. It is imperative to have the best "infrastructure" thinking at the table along with the best "energy" and "environmental" thinking.

17. Comment on the co-benefits of landfalling offshore transmission lines, such as improvements to reliability and/or resilience (*i.e.*, through the use of HVDC converters or otherwise), economic development (*e.g.*, port development, hydrogen production, *etc.*) and any local system benefits. Identify ways to measure and maximize these co-benefits when evaluating transmission buildout.

There are many benefits to thinking holistically about transmission landfalls in coordination with port infrastructure, storage, and hydrogen production. A 300 GW OSW build-out represents an approximately $1Tr investment to be made on a very short timeframe (27 years). The U.S. has only one chance to get this right, and it is essential that we view this massive challenge with the respect it deserves. Interregional collaboration and planning with input from state, federal and RTO personnel is essential to working these issues out on a holistic level. These personnel must be highly trained in engineering, policy, economics, finance, law and other disciplines and will have to work together to create a new energy infrastructure under a new system of governance. They must be well-paid, have excellent career opportunities and stability, and must commit to working together over the long term to create this new system. The education for these personnel is still being invented and it is imperative that we come together to understand this new language of the energy transition along with its new body of knowledge so that we can help the next generation work competently and effectively in this space.