Power Systems and Markets Research Group

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Tufts Power Systems and Markets Research Group
Tufts University School of Engineering
The Fletcher School of Law and Diplomacy

By E-mail

Marian Swain
Energy Policy Analyst

Massachusetts Department of Energy Resources
100 Cambridge Street
Suite 1020
Boston, MA 02114

Subject: Comments on Offshore Wind Transmission

Ms. Swain:

In response to a Request for Comments on Offshore Wind Transmission from the Massachusetts Department of Energy Resources (DOER) to be presented at a technical conference co-hosted by the Massachusetts Clean Energy Center (MassCEC) on March 3, 2020, a team of students and faculty mentors at Tufts University submits these comments.

Best regards,

Tufts Power Systems and Markets Research Group

Introduction

We submit this filing in response to a Request for Comments on Offshore Wind Transmission from the Massachusetts Department of Energy Resources (DOER) to be presented at a technical conference co-hosted by the Massachusetts Clean Energy Center (MassCEC) on March 3, 2020.

For this response, we have assembled a team of Tufts University students and faculty mentors with expertise in power systems, civil engineering, and energy policy to address several questions relating to the costs and benefits of coordinated offshore wind energy (OSW) transmission and a potential independent transmission procurement in Massachusetts.[1] As a student-led team, we aim to provide an impartial perspective on relevant technical and policy considerations based on a long-term view of the renewable energy transition and its relevance to mitigating climate change. Our youngest contributor was born in 1998; that is to say, we have grown up learning about climate change, and know we will bear its impacts.

Our response is organized into an introduction, responses to specific questions, and a description of our team. We have illustrated the key ideas behind our responses in Figures 1-3 and refer to these figures throughout this document. These key ideas can be summarized as:

1. New OSW generation must be connected to an existing land-based grid. The land-based grid must be modified to accept this connection, and this connection will occur within the public commons, consisting of the ocean environment, coastal environments, and coastal communities, as shown in Figure 1.
2. A fundamental question related to this connection is whether it will consist of several independent lead lines or a networked transmission system, as shown in Figure 2.
3. The costs related to ideas 1 and 2 above exceed the costs of offshore wind energy generation plant construction alone and must be recognized in order to be handled responsibly, as show in Figure 3.

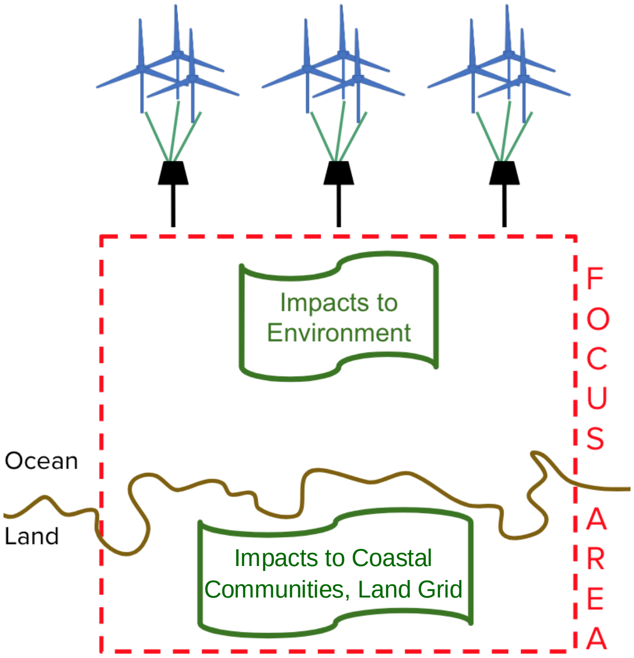

Figure 1: General Areas of Impact related to OSW Transmission

Thus far, OSW transmission has not received the same level of attention as project procurements and state commitments to purchase offshore wind power. However, transmission development is critical to success of the

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[1] This student-led document was developed within the interdisciplinary spring 2020 *Power Systems and Markets* seminar at Tufts University, comprised of students and faculty from the departments of Civil & Environmental Engineering and Electrical Computer Engineering within the School of Engineering, and from The Fletcher School. Any and all views expressed herein represent the opinions of seminar participants and do not represent official positions of Tufts University or its Schools. Please refer to the final pages of this document for a list of contributors.

industry, and examples throughout history have shown how difficult and time-consuming transmission can be to site.[2, 3]

Figure 1 depicts the focus area for this conversation in the context of the OSW industry. OSW developers require new infrastructure to inject their power into the existing, land-based electric grid. At stake are the long-term functioning of the grid, the collective interests of coastal communities, and marine ecosystems. The two options under consideration are generator lead lines and independent transmission. As depicted in Figure 2, the first option represents a radial approach, whereas the second option could take the form of a network.

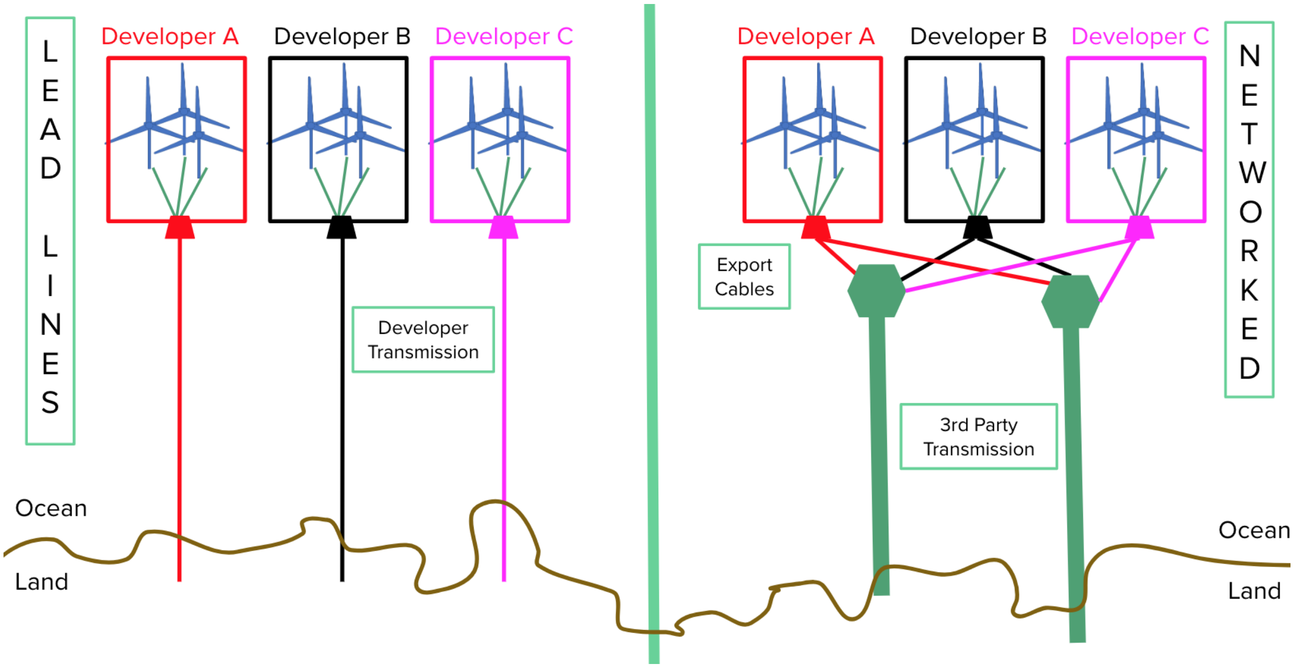

Figure 2: Generator Lead Lines vs. Networked Generation

Our response is based on comparative analysis of radial and networked transmission under a 16-gigawatt (GW) buildout of the Massachusetts and Rhode Island Wind Energy Areas (WEA). We have concluded that a networked offshore grid with fewer, larger transmission corridors would benefit all parties in the long-term. We have qualitatively analyzed four market externalities; each of which point to the superiority of a networked approach over radial interconnection:

1. **Long-Term Health of OSW Industry:** In order to accomplish full decarbonization of the energy system by 2050, OSW energy must be integrated into the grid with incredible and unprecedented speed, sustained over a period of decades. Honest and robust stakeholder engagement with long-term objectives early in this process will set the industry up for success. In acknowledgement of the tension between the objectives to move quickly and to move thoughtfully, we encourage an adaptive management approach that allows the earliest projects to move forward while an exploration of independent OSW transmission gets underway as quickly as possible.

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[2] The Northern Pass, a proposed 1,100-megawatt (MW) transmission project connecting hydropower in Québec to consumers in Massachusetts, failed after an investment of $300 million and nearly a decade of effort.[2] An alternative project, the New England Clean Energy Connect (NECEC), is still working its way through Maine regulatory bodies.

[3] Ropeik, Annie. *In Unanimous Vote, N.H. Supreme Court Upholds Northern Pass Denial*, New Hampshire Public Radio, (2019). https://www.nhpr.org/post/unanimous-vote-nh-supreme-court-upholds-northern-pass-denial#stream/0

2. **Grid Reliability, Resilience, and Redundancy:** Cost-benefit analyses that fail to quantify the benefits of reliability, resilience, and redundancy for the future grid will demonstrate their inadequacy within a period of years, robbing the energy transition, and our generation, of valuable time right now to get the system right. Once developed, a networked grid would reduce the risk of stranded OSW generation assets. Added redundancy, as shown in Figure 2, could substantially increase the availability of transmission to shore for each developer. Networked connections could provide more paths to deliver power to shore in the event that an export cable line goes down. These three Rs are essential to a functioning grid and a vibrant economy. They must be weighted as highly or higher than short-term rate payer benefits in any serious decision-making framework.

3. **Environmental Impacts:** By channeling the generated power into fewer lines, the OSW industry could reduce impacts to the benthic environment, fisheries, and marine mammals by shortening the total distance over which export cables must be installed.

4. **Social Impacts to Coastal Communities:** Reducing the overall number of lines would result in fewer landfall locations and less disruption to coastal communities. Additionally, a centrally planned network would lend itself to a broader and more comprehensive stakeholder engagement process, which could prioritize equitable distribution of these lines. Lower income communities and communities of color are disproportionately required to bear the social costs of facilities deemed undesirable by the public.[4] In our view, legislation focused on independent OSW transmission would encourage stakeholder engagement by driving a discussion around siting considerations for multiple WEAs.

With the aforementioned externalities in mind, we have provided responses to questions 1, 7, 8, 11, and 13 in the subsequent discussion.

Question 1

What are some of the benefits, challenges, and risks of pursuing independent offshore wind (OSW) transmission, whether supported through a separate transmission procurement or not, and what are the highest priority concerns or issues? How do these benefits, challenges, and risks change with the scale of OSW generation development?

As shown in Figures 1 and 2, many of the ***benefits*** of a networked OSW grid emerge from the bundling together of lines and their simultaneous installation. These benefits can accrue to the offshore wind energy developers, the land-based transmission grid, and the environment and coastal communities in between that comprise important but voiceless stakeholders in the public commons. If each generator builds its own lead line, each lead line project will need its own installation process. An independent transmission system would minimize environmental disruption and cost by bundling lines together. Fewer transmission routes would mean less construction time and less seafloor disruption through line installation. Furthermore, an offshore grid would streamline the permitting process. A streamlined permitting process, in turn, could put OSW on the grid faster. Therefore, it is arguably in the interests not only of the public in general and disadvantaged coastal communities in particular, but also the developers themselves. Furthermore, if an offshore transmission network negotiates interconnections into the onshore grid, developers will be relieved of the need to do so themselves. A sufficiently sized offshore grid means that all of the OSW resource would have space to interconnect and the construction of uneconomically long lead lines could be avoided after the nearer and easier interconnection points have been claimed.

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[4] Billias, Christopher. *Environmental Racism and Hazardous Facility Siting Decisions. Noble Cause or Political Tool?* Washington and Lee Journal of Civil Rights and Social Justice (1998). https://scholarlycommons.law.wlu.edu/cgi/viewcontent.cgi?article=1059&context=crsj

The short-term benefits are compelling, but perhaps more important from our perspective are the ***long-term benefits*** that may otherwise not be considered in the comparisons of alternatives. An independent transmission system stands to serve as an extension of the onshore grid, reducing congestion and increasing reliability and resilience in the halo of New England's largest demand center. In the long term, this stands to facilitate a more flexible, less expensive, and more renewables-ready grid. This grid will provide increased control, reliability, resiliency, and redundancy to organizations responsible for grid operation, and the independent transmission developers will provide a clear interface between existing land-based grids and OSW generation assets. Focus on OSW connections to and integration with the land-based grid will allow for comprehensive preparation and improvement of the existing land-based grid to receive larger amounts of offshore power than if planning is engaged through the perspective of OSW generation on a project-by-project basis.

We acknowledge several ***challenges*** to an offshore electricity network, such as: coordination and dispute resolution between independent transmission developers and OSW developers; planning and financing public-private assets that will be underutilized in the near term; timing between projects; payment mechanisms; regional coordination; and evaluation criteria for winning bids. Nevertheless, we believe that all of these challenges can be overcome, and we would prefer our decision makers to look ahead at them so that governments and transmission contractors can work with and around them towards suitable solutions.

The primary ***risk*** to such an approach is that of stranded offshore electricity generation assets. Independent transmission development presents a risk that turbines may be in the water and spinning before independent transmission is complete. Other risks include development of permanently underutilized transmission assets and the maintenance of offshore collectors and inter-array cables, which would be necessary for a sufficiently networked offshore grid. Technology changes and differences may increase the maintenance burden of the transmission. We also acknowledge the risk of public backlash to the perceived added cost of transmission upgrades. As stated, however, we believe it is better to anticipate these issues, and to work to address them before they become major problems. The future disaster of a poorly functioning grid cannot be discounted properly in any reasonable financial assessment. Both the decision makers and the public must understand the large-scale physical character of the coming energy transition. In order to preserve our way of life, we must build a new public infrastructure.

The ***highest priorities*** of the Massachusetts State Government ought to be to support both OSW generation and independent transmission buildouts. Effective immediately, both buildouts must be enabled to proceed with enough independence from one another to be equitable and efficient, and enough coordination to take advantage of near-term opportunities. It is critical that our government publicly recognize transmission as central to the renewable energy transition and recognize grid integration as infrastructure which must serve the public interest. Decision makers must publicly recognize rate payer concerns as only one aspect, among many, of the public interest. Other aspects of the public interest include: a successful energy transition; grid reliability; environmental protections; jobs; humane and equitable infrastructure buildouts; and resiliency and longevity of the new energy system. Finally, it is critical that the Massachusetts State Government convene the relevant experts and communities for transmission at the taskforce level and identify the key technical and political challenges that require knowledge, foresight, and deliberation.

The importance of independent transmission planning increases with the ***scale*** of OSW buildout. As the scale of the OSW buildout increases, transmission may become the rate-limiting factor in future growth. Therefore, the new grid must be constructed both with a plan in mind and with the ability to adjust for unforeseen circumstances.

Question 7

What steps or provisions could be made in generator lead lines for early OSW projects that would facilitate networking or conversion to independent OSW transmission at a later date?* (a) *What are the potential costs, benefits, and risks of networking multiple OSW generator lead lines?

We understand this question to have two parts. First, what should be done with respect to previously awarded OSW generation projects? Second, what are the costs, benefits and risks of deliberately networking multiple OSW generator lead lines after the fact?

In our opinion, it is important to allow both Vineyard Wind and Mayflower Wind to proceed with their existing 800 MW projects independently. They ought not to be required to coordinate with a future independent transmission plan. The window for this opportunity has already passed. These projects number among the first wave of utility-scale OSW projects in the U.S. and will be constructed primarily with European expertise and technology. U.S. priorities during these projects ought to focus on learning as much as possible from them and preparing the U.S. supply chain and electricity system for the second and third waves of development.

Future independent transmission scenarios ought to accommodate projects after Mayflower Wind and up to a full-scale buildout of the WEAs. While early stage independent transmission projects may not be awarded to accommodate the full WEA buildout, their planning ought to demonstrate a clear path to such a full buildout with special emphasis placed on future flexibility and expandability.

In the event that there may be opportunities for future integration of early projects such as Vineyard Wind and Mayflower Wind into an independent transmission system, coordinating the use of Alternating Current (AC) or Direct Current (DC), identification and understanding potential interconnect points, and basic stability studies of lead lines converted into network branches may be engaged as preliminary assessment tools for future decision making about offshore grid interconnects.

Attempting to facilitate later conversion from a radial system to a networked system imposes serious risks for the environment, local communities, industry players, and Massachusetts ratepayers. While networking OSW export cables would provide benefits to the overall system, the process of turning an already-built radial system into a networked one would be costly for developers.

We recognize that some entities may believe that networking existing lead lines at a later date could provide an effective way to eliminate stranded assets. It is our opinion, however, that building a networked system from the beginning is a better way to address this issue in the long run. Stranded assets ought to be minimized but cannot be eliminated entirely from any scheme. Under independent transmission scenarios, stranded assets can be accommodated if managed effectively. In this dynamic environment, it is reasonable to assume that there will be times when generators will not be able to send their power to shore. Recognizing this reality, the state governments, OSW developers, and Independent System Operators (ISOs) can take steps to understand and manage that risk. Risk management approaches for stranded assets must be developed to the satisfaction of multiple stakeholders regardless of the type of transmission built. In negotiating these terms, key priorities in addition to rate payer impact should be the four externalities referenced in our introduction: Sustainability of the OSW industry and the renewable energy transition; reliability, resiliency, and redundancy of the new grid; the welfare of environment; and the welfare of coastal communities. Networking OSW lead lines with some redundancy increases the availability of transmission to shore for each developer. The most effective way to take advantage of the benefits of networked transmission is by planning it before generator lead lines have been built to shore.

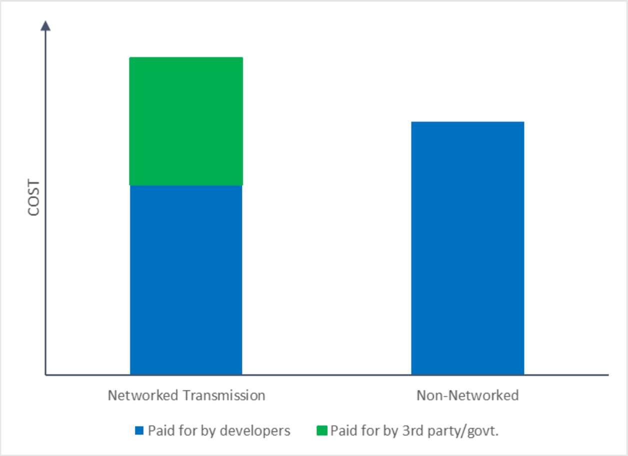

Figure 3: Qualitative Comparison of Relative Costs Between Networked and Non-Networked Transmission

It is difficult to fully compare the costs of different system topologies. We can be relatively certain a network will cost more than a lead line approach—though it is also unclear to what extent current development proposals have advertised their full transmission costs. In 2010, the Brattle Group estimated that the Atlantic Wind Connection (AWC) transmission backbone would cost around $5 billion, while individual lead lines to shore could cost between $3.5 and $5.3 billion for 6,000 MW of offshore generation.[5] In Europe, developers have seen a 17% to 25% decrease in project costs when generator transmission is networked.[6] Figure 3 qualitatively shows how a networked grid could cost more overall but less for developers.

Because the industry is still in its infancy domestically, developers may be skeptical of independent transmission owners, and Germany's stranded asset debacle is fresh in developers' memories. Once the developers connect to shore independently, these lines will probably be used for the life of the project, barring government intervention. Vineyard Wind and Mayflower Wind plan to utilize this lead line approach—we recognize this is likely unavoidable due to timing and investment constraints. However, this reality evidences that timing is of the essence: without a plan for a networked offshore grid, developers will chart their own courses to shore in an uncoordinated tangle of generator lead lines.

Question 8

What provisions or conditions should be developed to ensure that separately procured OSW transmission meets the technical needs of current and reasonably foreseeable OSW energy projects, given the evolution of technologies?

With OSW turbine sizes increasing every year, it is hard to put a number on exactly how much wind energy will need interconnection once the WEAs are fully built out.[7] Given the potential for the full wind energy area to have a higher nameplate capacity than we can foreseeably predict, an independently solicited and operated transmission network should be easily upgradeable to accommodate future expansion. If and when an upgrade to the offshore transmission system is necessary to install greater capacity, the selection of a developer for that project will need to be determined through a competitive bidding process. To keep the bidding process fair, any transmission developer should have an equal opportunity to submit a proposal.

A modular approach to networking is the best way to ensure future technical needs of an offshore network are met. Modularity of a networked grid requires standardization of cables, voltages, collectors, connections, and other common pieces within the transmission system with the goal of making the system expandable in the future.

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[5] Pfeifenberger, Johannes and Newell, Samuel Newell. *An Assessment of the Public Policy, Reliability, Congestion Relief, and Economic Benefits of the Atlantic Wind Connection Project: Executive Summary* 1, Brattle Group, (2010).

[6] Fox, Benjamin. "The Offshore Grid: The Future of America's Offshore Wind Energy Potential." *Ecology Law Quarterly* 42.3 (2015): 671. Web.

[7] Wiser, Ryan and Bolinger, Mark. 2018. U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. "2018 Wind Technologies Market Report."

This process of standardization for reliability purposes falls upon the Federal Energy Regulatory Committee (FERC) and the North American Electric Reliability Council (NERC). In this case, however, standardization should consider future upgradability in addition to reliability in order to prepare for the growth of the industry. An example of NERC standardization onshore is the use of 345 kilovolt (kV) lines and associated tower specifications for high-capacity backbones in the northeastern grid. The actual offshore standards will likely differ from onshore standards; however, all transmission developers should be subject to rules regulating system components and must follow an established framework for interconnecting offshore grid components.

In determining standards for offshore transmission components, special consideration should be given to the process of deciding cable corridors and standardizing large infrastructure components. While electrical standards like cable voltages are crucial for a functioning system, large components such as collector stations and cables can be disruptive to their surroundings. As such, they will require separate measures to ensure an appropriate and equitable agreement between project stakeholders and host communities. We think conventional “decide, announce, defend” infrastructural siting processes often only consider input from the public in a perfunctory manner, and an equitable process would meaningfully incorporate the wants of the public. One alternative method is consent-based siting, which begins with outreach for a site volunteer process, and narrows sites from there. This has the additional benefit of protecting against municipal filibuster later in the process.[8] Working with these groups in the initial siting process will help avoid crowding the ocean floor with cables, and it will help minimize impacts related to landfall points in onshore communities.

Question 11

When weighing benefits, costs, and risks to Massachusetts ratepayers, how could potential bids be analyzed to compare a separately procured OSW transmission project to project-specific interconnection through generator lead lines? **(a)** ***Are there specific interconnection locations, public interest factors, or other transmission project benefits that should be specifically weighted in an analysis of independent OSW transmission bids?***

This question seems to indicate that on a project-by-project basis, DOER may evaluate bids for generator lead lines against bids for independent transmission. While it is reasonable to introduce competition at each stage of the process, regulators and decision-makers must not lose sight of the relevant externalities that could easily be ignored through a piece-wise process.

Networked transmission offers advantages associated with system planning that are captured by the following market externalities: reduced environmental impacts; reduced social impacts to coastal communities; and improved grid reliability, resilience, and redundancy. The benefits of networked transmission are long term and system wide, making it challenging to fairly compare to radial transmission on a project-by-project basis.

The process for evaluating and comparing bids should include project-specific criteria as well as criteria that take a long-term view of the system. Each stage of the WEA buildout must maintain a focus on long-term objectives for carbon-neutral energy and grid reliability, resilience, and redundancy. Projects should be evaluated and compared based on cost, timeline, environmental impacts, local workforce development, and social justice considerations associated with project siting. Longer-term criteria should focus on cumulative effects. In evaluating proposals, regulators should consider how well the following questions are addressed:

- **To what degree can the proposed transmission project be augmented and built upon in the future?** Proposed offshore transmission, whether developed by a generator or an independent third party, can be

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[8] Dicks, Norman et al., *Moving Forward with Consent-Based Siting for Nuclear Waste Facilities*, Bipartisan Policy Center Nuclear Waste Council, (2016). https://bipartisanpolicy.org/wp-content/uploads/2019/03/Nuclear-Consent-Based-Siting.pdf

strategically over-designed to accept additional generation capacity in the future. Project costs for design, permitting, public engagement, and construction mobilization are significant contributors to the total budget. Over-designing would add upfront equipment costs, but if done strategically, the savings from avoided future project costs would pay off. The capacity of and necessary improvements to onshore transmission infrastructure should inform the design of offshore transmission systems. Otherwise, the offshore grid risks overloading the onshore grid, leading to congestion. Preference should go to bids that incorporate additional capacity in export cable bundles and converter stations. The degree to which such proposals are favored should depend on the ease of future offshore interconnection and whether the option to interconnect is available to outside parties, not just the entity building the project.

- **To what degree does the proposed transmission project improve overall grid resilience?** Grid resilience refers to the grid's ability to withstand and recover from disruptive events.[9] Networked offshore transmission could provide multi-faceted improvements to grid resilience. As shown in Figure 2, the networked cables provide equipment redundancy, which means that if one cable fails, electrons can still find other paths through the wires.[10] The decentralized distribution of a networked approach also improves resilience by lowering the probability that a natural disaster or targeted event would strike all critical assets at once. Offshore transmission that interconnects different urban load centers will further improve resilience of the land-based grid while offering the additional benefit of reduced congestion, which smooths local energy prices.

Question 13

What other questions, concerns, or issues have you identified relating to a separate OSW transmission solicitation?

The discourse around OSW transmission has primarily focused on business and financial considerations. If transmission is developed independently, developers worry that incentives would not align, and their generation assets could be stranded. Risks, whether perceived or realized, affect market confidence and project financing. These business concerns are valid, but they should not obscure other considerations of equal importance.

A separate OSW transmission solicitation should be taken as an opportunity to account for market externalities related to the environment, social equity, grid function, and the long-term industry outlook. In each category, we see value added through networked transmission. The four externalities presented in our response introduction are restated here for further consideration:

1. **Long-Term Health of OSW Industry:** In order to accomplish full decarbonization of the energy system by 2050, OSW energy must be integrated into the grid with incredible and unprecedented speed sustained over a period of decades. Honest and robust stakeholder engagement with long-term objectives early in this process will set the industry up for success. In acknowledgement of the tension between the objectives to move quickly and to move thoughtfully, we encourage an adaptive management approach that allows the earliest projects to move forward while an exploration of independent OSW transmission gets underway as quickly as possible.

2. **Grid Reliability, Resilience, and Redundancy:** Cost-benefit analyses that fail to quantify the benefits of reliability, resilience, and redundancy risk underselling the benefits of a networked grid. Once developed,

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[9] Clark-Ginsberg, Aaron. "What's the Difference Between Reliability and Resilience?" Stanford University Center for International Security and Cooperation, (2016). http://www.aaroncg.me/2016/04/21/whats-the-difference-between-reliability-and-resilience/

[10] Silverstein, Alison, Gramlich, Rob, and Goggin, Michael. "A Customer-focused Framework for Electric System Resilience." Grid Strategies, LLC, (2018). https://gridprogress.files.wordpress.com/2018/05/customer-focused-resilience-final-050118.pdf

a networked grid would reduce the risk of stranded OSW generation assets. Added redundancy, as shown in Figure 2, would substantially increase the availability of transmission to shore for each developer. Networked connections would provide more paths to deliver power to shore in the event that an export cable line goes down. These three Rs are essential to a functioning grid and a sustainable future. They must be weighted as highly or higher than short-term rate payer benefits in any serious decision-making framework.

3. **Environmental Impacts:** By channeling the generated power into fewer lines, the OSW industry could reduce impacts to the benthic environment, fisheries, and marine mammals by shortening the total distance over which export cables must be installed.

4. **Social Impacts to Coastal Communities:** Reducing the overall number of lines would result in fewer landfall locations and less disruption to coastal communities. Additionally, a centrally planned network would lend itself to a broader and more comprehensive stakeholder engagement process, which could prioritize equitable distribution of these lines. Lower income communities and communities of color are disproportionately required to bear the social costs of facilities deemed undesirable by the public.[11] In our view, legislation focused on independent OSW transmission would encourage stakeholder engagement by driving a discussion around siting considerations for multiple WEAs.

In addition to these four externalities considered, a plan for the future capacity and reliability of OSW integration should address the intermittency of OSW generation. This intermittency necessitates changing the types and amounts of ancillary services available to provide reliability to the grid. Flexibility reserves, which are designed to address the needs of variable generation, increase system ramping capacity and have been shown to reduce energy scarcity events that would otherwise raise customer rates.[12] Energy storage will also be a key factor in mitigating power shortages and reducing curtailment, and a variety of energy storage technologies are either on the market or at a high level of development.[13] An independent OSW transmission network provides an opportunity for long-term planning to address concerns around integrating large quantities of variable generation. Thus, a provision quantifying the need for ancillary services and considering future interfacing with energy storage should be included in a proposal for independent transmission.

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[11] Billias, Christopher. *Environmental Racism and Hazardous Facility Siting Decisions. Noble Cause or Political Tool?* Washington and Lee Journal of Civil Rights and Social Justice (1998). https://scholarlycommons.law.wlu.edu/cgi/viewcontent.cgi?article=1059&context=crsj

[12] Ibanez, E. and Ela, E.. National Renewable Energy Laboratory. "Quantifying the Potential Impacts of Flexibility Reserve on Power System Operations." Presented at IEEE 2015 Annual Green Technology Conference New Orleans, Louisiana (2015).

[13] Alamri, B. R. and Alamri, A. R. Technical Review of Energy Storage Technologies when Integrated with Intermittent Renewable Energy. TVTC Brunel University, West London, UK (2009).

Contributors

Authors

Samuel Lenney is a master's student studying electrical engineering at Tufts University. Within the Tufts power systems and markets seminar, he focuses on trends in developing technologies related to offshore wind transmission and the challenges and opportunities they bring. His primary research studies novel semiconductor materials that will enable the next generation of photovoltaic and solar energy devices. He received his B.S. in physics from Tufts University in 2019.

Oliver Marsden is an electrical engineering senior at Tufts University. He competes in mock trial and is pursuing an economics minor. Oliver will stay for a 5th year to complete a master's in electrical engineering. His aim is to apply his specialized technical knowledge, public speaking experience, and financial proficiency to budding interdisciplinary fields within renewable technology. He spent the last two summers honing those skills: in 2018, at a mine in eastern Arizona operated by Freeport McMoran, and in 2019, at Community Energy Inc., a solar development firm in Philadelphia.

Sean Murphy is in the last semester of his undergraduate studies in civil engineering at Tufts University where he has focused his studies on water, transportation, and energy. Sean has worked on energy from government, utility, and now academic perspectives. He spent a summer in the Medford Office of Energy and Environment, which led him to explore the discipline academically, and gave him the opportunity to work for Central Maine Power as an intern in the high voltage lines projects unit in 2019. He is also researching water resources methods to develop optimal control rules for merchant energy storage systems. Sean hopes to continue his involvement with energy topics after he graduates with a B.S. in May.

Kelly Smith is pursuing a master's in offshore wind energy engineering at Tufts University, with an expected completion of December 2020. She also works as a part-time contractor for the National Offshore Wind Research and Development Consortium. Prior to her graduate studies, Kelly spent eight years working in water resources engineering and environmental consulting, most recently for Hodge Water Resources, LLC. Kelly is a licensed Professional Engineer in Massachusetts as well as a Certified Floodplain Manager and Envision Sustainability Professional. Her analytical expertise is in the numerical modeling of environmental systems. She currently serves on the board of New England Women in Energy and the Environment. Kelly holds a B.S., *summa cum laude*, in environmental engineering from Tufts University.

Academic Advisors

Eric Hines directs the offshore wind energy graduate program at Tufts University, where he is the Kentaro Tsutsumi Professor of the Practice in structural engineering. Dr. Hines has over 20 years of experience engineering innovative infrastructure and large-scale testing. Major projects include the Wind Technology Testing Center in Charlestown, MA, the New Bedford Marine Commerce Terminal, Beijing's Yin Tai Center, the digital twin verification processes for the new San Francisco-Oakland Bay Bridge and the Block Island Wind Farm. He works at the technology/policy interface to develop systems-level design concepts. He studied engineering and public policy as an undergraduate at Princeton University and a Fulbright Fellow in Germany. He holds a Ph.D. in structural engineering from the University of California, San Diego.

Power Systems and Markets Research Group

Barbara Kates-Garnick is a professor of practice at the Fletcher School of Tufts University. She recently served as Undersecretary of Energy for the Commonwealth of Massachusetts (EEA). Her prior work in public service includes Commissioner of Public Utilities (MA DPU)., Assistant Secretary of Consumer Affairs, and Director of Rates and Research (MA DPU). Dr. Kates-Garnick has been a Vice President of Corporate Affairs at KeySpan. She was on the founding team of NewEnergy. She currently sits on the Boards of Anbaric Transmission and PowerOptions. She also serves on the Energy and Environmental Systems (BEES) Board of the National Academies of Science, Engineering and Medicine. She has a Ph.D. in international political economy from the Fletcher School of Tufts University, an A.B., *cum laude,* in political science from Bryn Mawr College and was a pre-doctoral fellow at the Center for Science and International Affairs at the Kennedy School of Government, Harvard University.

Aleksandar Stanković, Ph.D., F.IEEE, is the Alvin H. Howell Professor of Electrical Engineering at Tufts University. Dr. Stanković has over 30 years of experience in power systems engineering and control. He has chaired the Power Systems subcommittee of the Institute for Electrical and Electronics Engineers (IEEE) Power Engineering Society and served as a distinguished lecturer for the IEEE Circuits and Systems Society. He has edited the IEEE transactions of Smart Grids, and co-edited a book series on Power Systems and Power Electronics for Springer. His work on power system stability and grid blackouts has over 2000 citations, making him one of the most sought-after voices on grid reliability in the Northeastern United States. Dr. Stanković completed his undergraduate and masters work at the University of Belgrade and holds a Ph.D. from MIT.

Editor

Chisaki Watanabe is a student at the Fletcher School, Tufts University, and her research focuses on climate change diplomacy and energy security. She was an energy reporter for Bloomberg News in Tokyo and covered power markets and renewable energy in Japan and other Asian countries. She has a M.S. in mass communication from the College of Communication, Boston University, and B.S. in journalism from Sophia University in Tokyo, Japan.