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# Rapporteur's Report to the June 2023 Transmission Workshop

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OSPRE OffShore Power Research & Education Collaborative

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## Preface, Acknowledgements, and Disclaimer

This report reflects the discussion held in the June 2023 Transmission Workshop. The goal of this report is to provide a record of the conversations held in June 2023. The transcripts contained in this report have been kept as close to the original as possible. To protect the anonymity of the speakers, we have removed or summarized some parts. We have also made some small edits for clarity.

For ease of reading, we have added a summary of each session above each transcript. We have also identified the key themes in each session and listed them alongside the summary.

We take full responsibility for the content and discussion herein. Any mistakes, omissions, and opinions within this document are ours alone, and we will be glad to receive further feedback as this document reaches a wider audience.

Julie Harris, Eric Hines, and Barbara Kates-Garnick
Tufts University, December 2023

# Executive Summary

This report reflects the discussion held in the June 2023 Transmission Workshop. The report includes a short introduction of the main themes of the workshop. Transcripts from each session are also included.

The workshop focused on challenges at the technology / policy interface of offshore wind transmission in the United States. Main themes discussed included POI selection, siting, interconnection, the macrogrid, preparing for the future, and the role of the federal government. Participants identified several areas for reform.

## Contents

# 1 Introduction

On June 22, 2023, the NOWRDC research team for the project entitled "Transmission Expansion Planning Models for Offshore Wind Energy" held a transmission workshop at Tufts University. The goal of the workshop was to explore the technology/policy interface of offshore wind transmission in the United States with particular focus on planning, financing, and operating a reliable and resilient transmission system that protects our environment and benefits coastal communities.

The offshore wind industry is at a significant turning point. Individual states have been increasing their offshore wind commitment goals. The first commercially operable offshore wind facility in the country, Vineyard Wind One, is currently in development. The New England states have formed multiple groups to support the growth of renewable energy in the region, including the New England Energy Visions Initiative and the New England Energy Transmission Initiative. In January 2023, four New England states directly, with the other two supporting, filed a concept paper for the Joint State Innovation Partnership, which aims to proactively plan offshore wind transmission. In June 2023, the New England states, along with New York and New Jersey, sent a letter asking the DOE to facilitate an intra-regional planning initiative.

The growth of the offshore wind industry has also revealed areas for improvement in the current transmission and generation development process. The technology/policy interface is key to addressing these issues. There are few avenues for members of various sides of the offshore wind development industry to convene and speak freely. The June Transmission Workshop provided a space for this conversation.

The goal of this report is to provide a record of the conversations held in the June 2023 Transmission Workshop. The transcripts contained in this report have been kept as close to the original as possible. To protect the anonymity of the speakers, we have removed or summarized some parts. We have also made some small edits for clarity. The main themes of each session are summarized at the beginning of the transcript.

# 2 Keynote Address

### Themes: Energy Islands, HVDC, Permitting

*The keynote address focused on the creation of energy islands in Denmark. EnergieNet, the Danish TSO, is planning to build energy islands in the North Sea and the Baltic Sea. Initially they will connect to Belgium, with future plans to connect to other neighboring countries as part of a gradually built meshed grid in the North Sea. This session also included discussion of challenges in this area, including permitting complications and ensuring future interoperability of current projects.*

**Moderator**
First of all, thank you all for coming out. It's a pleasure to have you with us. I hope that everyone has a copy of this brochure that we created. This four-page brochure summarizes the work that we'll be talking about today. The way that the morning will unfold is that we have a keynote lecture and then we have two sessions to get a lot of ideas on the table. Then we'll have lunch and then the afternoon we'll come back and split into two sections: a technical discussion session and a policy discussion session. So, if you have questions or comments that you want to share, that don't happen in the morning, just know that there'll be a second opportunity in the afternoon to do this.

Another aspect of this workshop is that we've made a commitment to developing a rapporteur's report for the workshop. The report will be printed. It will be public.

I also want to point out my colleagues who have really been responsible for pulling this workshop together and making it happen. First of all, Professor Barbera Kates-Garnick from the Fletcher School. Our PhD students: Julie Harris, Rebecca Wolf, and Emma Hibbard. And special thanks to Jill Parlee from the Gordon Institute, who was really the mastermind behind pulling the whole day together for us. I also want to extend a special thanks to Mel Shultz, and to Carrie Hitt. Both of you have been involved in this project for years, funding it through NOWRDC (the National Offshore Wind Research and Development Consortium). The support that you all have given is very meaningful to us, and we very much appreciate it. At the same time, the Massachusetts Clean Energy Center (MassCEC), I believe, will also be attending. And we're very appreciative of the work that MassCEC has done to support and strengthen this project.

On Zoom, we have Peter Godt-Larsen with us from EnergieNet in Denmark. We've been talking with Peter and his colleagues for several months now, specifically about their work on energy islands. And as a theme of this workshop today is about getting past levels of gigawatts – low levels of gigawatts and the much higher levels of gigawatts – three gigawatts, six gigawatts –

understanding this as a potential language and a necessary language for the energy transition. It is very helpful and instructive for us to look to Europe and to the North Sea to see that this is already happening. So, without further ado, I will ask Peter Godt-Larsen just to say a few words of introduction to himself and then launch into his presentation. It's about a 15-minute presentation and we'll have 15 minutes for questions. Okay, thank you. Peter, over to you.

**Peter Godt-Larsen**

Thanks, Eric. Hi everybody, just a few words of introduction from me before I give my presentation. So, I'm Danish, hence the accent. Hope you can hear me and understand me. I work as a Senior Manager in charge of the development of Energy Islands in Denmark. Looking both on the two projects that we have in the pipeline, and also on a more longer-term for how we intend to work with this. EnergieNet — is the Danish electricity, gas, and also, recently, hydrogen Transmission System Operator (TSO). And we are an independent, State-owned company with our own board and organization, owned by the Danish State and thus, serving the greater public, in securing electricity, gas, and hydrogen supply at affordable costs, and also catering for the green energy transition.

Let me see if I can share my presentation with you.

[Appendix A – slide 1]

Now, I can't see you. So, I'll just run through my slides. And then, I guess, we will take questions afterwards, Eric, at your preference. I'm also fine to have questions as we go along the presentation, as you prefer.

[Appendix A – slide 2]

So. It's on the other side of the pond from where you are, currently. Denmark is at the top center of the slides. And then, we have the UK to the west of where we are in the North Sea. Norway on the top, to the north, and then continental Europe towards the south. So, we have this great enclosed sea, in a sense, where we know that we have the possibility to deploy large scale of offshore wind. It's relatively shallow waters and it's close to large consumption centers, and also between countries. So, this is our primary focus for large-scale offshore developments.

But also, in the Baltic Sea, to the east, and you'll see there's a circle around an island in that area. A Danish Island in that area, called Bornholm, where we will have one of two Energy Islands situated. So, the difference there is that that is already an island. We don't have to build anything out in the open sea. And that one will be 3 GW of offshore wind with the possibility of a bit more than that, if the developers see a business case in increasing that number. It won't affect the transmission capacities. It will go to the greater Copenhagen area: the capital of

Denmark, and also a large consumption center. And then also a connection to our southern neighbor, Germany.

In the North Sea, we'll have a phased approach for the Energy Island there. The main difference, of course, is that we are in open sea, so we will have to establish an artificial energy island. And we will build that in phases with an initial phase, which is – here it reads 3 GW, but more likely, you will have an increased ambition, so it will be 4 GW of offshore wind in the first phase. And then gradually building it up to towards the full build-out of 10 GW capacity.

In the in the first phase, we will connect to Belgium. So, quite a distance from Denmark. And in later phases, we also envision connections to other neighboring countries and as part of a gradually built meshed grid in the North Sea, offshore.

[Appendix A – slide 3]

We have been working with this in EnergieNet for quite some time. We started out looking at Energy Islands as a concept back in 2017, where I also, myself, joined EnergieNet. And we started looking at this as a purely development explorative concept, together with Dutch and German colleagues in what we call the "North Sea Wind Power Hub Consortium", a group consisting of TenneT in the Netherlands and Germany, and Gasunie in the Netherlands, and EnergieNet in Denmark, still up and running. And we do cooperation in that group. So, we are resting on many of the analyses that we have done in that group.

And out of that, we have developed, sort of, the concept around Energy Islands, looking at an optimal sizing of approximately 10 to 16 GW, as it reads in this slide. And with the offshore wind being connected to an energy island or hub, it could take many forms. And then, at that point, the current is being converted into direct current (DC) and brought to shore, where it is linked to the power grid onshore, where we have onshore AC current existent. There is also the possibility to have some of that production capacity coming offshore being converted further into hydrogen, either onshore, so near the coast, or near an infeed point. Also, we don't see that as something that is likely to be the case in the first phases. But in later phases, we might see, also, offshore conversion into hydrogen by electrolyzers.

[Appendix A – slide 4]

This is not anything like what we have done before at EnergieNet. The combination of offshore winds and transmission lines between countries is not something that we have done before. And not at all in this scale.

And it is also new in terms of the stakeholders in this. So, we have the offshore wind developers. We have EnergieNet, that's our TSO. And then we have our counterparts in the neighboring countries, the TSOs there. And last, but not least, we also have the countries Denmark, Belgium, and the other countries that we discussed this with. And all these stakeholders need to be able to see a case for it to mature. And then, it's also new for us, as EnergieNet, that, in this case, it's the countries and the political ambition that takes the first move into this. And we are more in the role as facilitators, making it possible and finding the best solutions in this. But the word on the wall is an increased ambition in more renewables and faster. So, rather today than tomorrow, that's the reality that we are in.

[Appendix A – slide 5]

This is an illustration of the Energy Island, the artificial Energy Island in the North Sea, where you'll see we have the connections to Denmark, and onwards to Belgium. And we have the offshore wind – in the first phase, we expect 4 GW of offshore wind to be connected and the voltage level to be increased and afterwards, converted into direct current, and then directed to, in the first phase, Denmark and Belgium. And with the DC breaker in place.

[Appendix A – slide 6]

In the following phases, we will have more of the same. So, more DC-breakers. And we will have them on the platform structure. We must become more cost-optimal. And then we will also see a further development, once we also have more countries being interested in linking up to our development. And perhaps for background, Denmark is a relatively small country. We are 6 million people. And here we are building something that could cater for 10 million households. And even taking account that we will have more power demand, both directly and indirectly, to convert it into other energy carriers that could help us in industry, shipping, aviation, etc. We primarily see this as something that will serve a power demand also in our neighboring countries and larger consumption centers, such as Germany and the United Kingdom and the Netherlands.

[Appendix A – slide 7]

This is just to illustrate. You see Denmark there in the middle, and then we have our neighbors around us. We have agreements with Germany for the connection in the Baltic Sea, and with Belgium for the Energy Island in the North Sea. But we have talks with all the remaining neighbors in the North Sea and in the Baltic Sea for potential connections to them, to see whether there's a fit, also, with their national plans. And as all our steppingstones towards gradually build-out of a meshed grid in those two seas.

[Appendix A – slide 8]

That's basically what you see here as a more long-term mission, where you also see similar developments in our neighboring countries. And we actually see that, already. So, our connection to Belgium, for instance, is a connection via an energy island, also, in Belgian waters. And then onwards to the Belgian mainland. And in our talks with Norway, our northern neighbor, we are also looking at a connection via an offshore wind development far from the Norwegian coast. And that will also, everything there will also be POI and direct current and high voltage direct current. There are similar talks in Germany and in the Netherlands, and also, to some extent, in the UK. So, this is an emerging meshed grid, as we see it. And we envision that that hydrogen, and also offshore pipelines for hydrogen, is going to be a significant part of this, out of demand in the relevant countries here, but also, that it would otherwise be difficult to imagine that we could transmit the full, say, 200 GW of offshore wind capacity in the North Sea via HVDC cables and a meshed grid alone.

[Appendix A – slide 9]

This is just for you to see where you can get further information about what we're working on and get in contact if you are interested in more information on this. I think I'll stop sharing now and then I'll open the floor to any questions from the room.

## Q&A

**Moderator**
All right, thank you very much, Peter.

[audience applause]

And are there any questions for Peter? Yes, [audience member].

**Audience Member**
Sure. My question relates to the suppliers of HVDC multi-terminal. You know, what's the relationship with both products? Manufacturing and who's supplying those? What's their outlook in terms of delivering on time?

**Peter Godt-Larsen**
Thanks for that question. That is a whole work stream looking into that and quite a difficult nut to crack. We are in dialogue in the Bornholm Energy Island. We are in a market dialogue that is running as we speak, with potential suppliers for the converters and the other equipment that we would need for that Energy Island. And obviously, what's at stake here is that, with the phased approach, which goes for both energy islands, we need to make sure that what we build in the initial phase will also be able to fit with what we will build later on.

And also, should there be a case, a likely case, where we will have different offshore wind farm turbines manufacturers. And we will have different manufacturers of the converters, as well. We need to establish a common language that works on that. And we've known that to be a challenge for quite some time. And what we have done is that we have approached our neighboring TSOs to combine the expertise and to try to solve how we could go about this. Basically, providing a common language and a way to control this and to expand it. We have established a project together that we call InterOPERA, interoperability, where this also sits. And I believe there's also more information on this on our website. And if not, I'll be happy to direct you to colleagues specifically working with this. It's outside of my personal expertise, I should be quickly to say.

**Moderator**
[More audience questions] in one second. I'm just going to interject a question, real quick. Peter, what is the largest capacity corridor and the largest capacity substation, in terms of gigawatts, that you all are currently imagining within the next 10 years? Can you just give us some numbers as a baseline?

**Peter Godt-Larsen**
Yeah. So, the offshore wind that we're talking about here will be 3 GW in Bornholm and 4 GW in the North Sea. And those offshore wind capacities will be brought to the Energy Islands via area cables 66 Kv, and with the possibility for all of it to be area cables bringing it to the Energy Islands. Some of it, when we build it up, will also be via substations where we'll increase the voltage level and then bring it into the Energy Island with an increased voltage level, and of course, with less cable to the actual Energy Island.

**Moderator**
Okay, thank you. And we'll go to [another audience member] now.

**Audience Member**
Thank you. Can you talk about the permitting situation? I would imagine creating a brand-new island in the North Sea, is not a trivial undertaking. I am curious about the island that exists in the Baltic. How did you gain possession? What sort of regulatory authority did you have to get approval from? And do you see that as, maybe, straightforward, or complicated?

**Peter Godt-Larsen**
Everything is complicated. And in terms of permitting, it's also complicated. But we also think that it is manageable. And we have a plan for this. And we're also in dialogue with our colleagues in the countries that we are doing these two projects with. And in the North Sea, we also, we're looking into that, that we will cross German, Dutch, and British territorial waters on our way from Denmark to Belgium. So, we also need the permits from those countries.

In Europe, all countries to some extent have offshore plans, and with designated areas. Some have established cable corridors, such as Germany. So, we know where we would have to pass through. And we also know which bodies that we need to approach to get the permits.

In that sense, doing a cable between countries, that's something that we have quite a bit experience with. We have done cabling to the Netherlands directly. And so, point-to-point connections, and to the UK and Norway and Sweden and Germany in the Baltic seas as well. So, there's quite some experience to drawn on there. And then, of course, the artificial islands is something new. And that will be, that will run its process in Denmark, itself. And we expect that that will – special law on that will be passed through the Danish Parliament to, for that to have its proper framework established.

**Moderator**
Okay, we'll take one more question.

**Audience Member**
You mentioned countries meeting on this effort. You just touched on a couple of examples. But I'm wondering if you can elaborate on how that's working.

**Peter Godt-Larsen**
Thanks for that question. Eric, could I ask you to repeat it? Because it was difficult to pick up from where I'm sitting.

**Moderator**
Yes. [Audience member], correct me if I'm wrong.  The question related to the states (governments) leading on this. And you're asking how that's going, in terms of the States leading? And how does that play itself out?

**Peter Godt-Larsen**
It's a new way of working. EnergieNet is packed with engineers, who are used to clear cut tasks. "We're going to build this. It's going to serve these purposes, and it's going to be ready by a certain date." And that has changed, with this being as politically driven as it is. And also, being an international project involving a more than just one country. So, that adds to the complexity, and also adds to uncertainties. And it adds to, things could take a turn in terms of planning, while you are along planning what you thought you were going to build. And these days, every time we hear from our politicians – irrespective of whether it's the Danish government and Parliament, or in our neighboring countries – they would like to have more faster than what they were, they are wishing for yesterday. And there's, of course, also out of the war in Ukraine, and the need to become more energy independent, and to secure a green energy catering for the demand side in Europe.

**Moderator**
Okay. Well, with that, Peter, we'd love to thank you very much for being with us this morning.

[audience applause]

**Peter Godt-Larsen**
Pleasure. It's on my side. Thanks, Eric, and I wish you a good a good day.

**Moderator**

Thank you very much, and we look forward to being in touch. All right, take care.

# 3 Policy Panel: "Connections"

Themes: Community Engagement, Queue Interconnection Process, Permitting Reform, Tariff Changes, Role of the Federal Government, Supply Chain, Meshed Grid, Macrogrid

*The policy panel focused on current challenges in transmission policy. In the first half of the session, panelists Bob Snook, Carrie Cullen Hitt, and Kelly Smith discussed issues they have experienced in their different industries. The second half of the session was a Q&A with the moderator and audience. Discussions focused on overarching issues in permitting, siting, and grid interconnection.*

**Moderator**
We're very excited that we are finally at this point where we can have this conversation and I know that Eric thanked our team but I, too, have to thank our team as well. We have Emma, Rebecca, Julie, and Jill: students and people who have made this conference possible.

And the other thing is, we're in an academic setting. So, we can really, I hope, sort of unshackle ourselves from some of our day-to-day constraints, and think creatively, and really think about the world, as we might like to have it. This conversation, and this presentation we just had from Europe, opens an amazing set of opportunities. And if they can do this internationally, we should at least be able to do this on the East Coast of the United States. So, that's what I'd like to say.

And, just in framing this conversation, one of the things that really strikes me as having been around for decades, is that the decisions we make today are what we continue to live with in the future. So, as we design an offshore wind grid and offshore wind transmission system, we really have to think long-term – we're designing for today, but we're also designing for the future, and I think that's the critical point.

The other thing that we have learned is this intersection of policy, engineering, technology is critical. We all live in our little silos, but how do we connect them, in a way that is useful for the actual building of an industry, and benefiting consumers.

And finally, to say that we are all driven by climate change and every state along the East Coast now has its own goals, and that is our driver as well. So, if we don't make our milestones, and my sense is, and some of the stuff we are not, what is realistic and how can we still be effective?

So, the order of our presentations will be Bob Snook from Connecticut. He's going to talk a little bit about the regional approach from the policy perspective. Carrie Cullen Hitt will talk from a developer perspective, but Carrie also has very strong policy roots and understanding and has been truly a path breaker. She and I worked together; I don't want to say how many years ago. She was dogged in the world of competition. And I can tell you that not only does she have a private sector perspective, but she does have a policy bent as well. And then we have Kelly, and for Eric and me it's a great honor to have our student come back, and so quickly after just having graduated. And so, it's a pleasure to see how the next generation and how we can be thinking about the future. So, I turn it over to Bob. Each person will speak for maybe about eight minutes. I have a set of questions and then we'll turn it over to the audience. So, Bob come to, he'll speak from his seat.

## Panelist 1: Bob Snook

**Bob Snook**

Thank you. Can you hear me? I'm very excited to be here. I want to give my thanks to Tufts, everyone who helped organize this. It's really exciting to be here. There are a lot of important things that are happening. This is a very timely conference. And I'll see if I can.

[Appendix B – slide 1]

Okay. Yeah. Bob Snook, Connecticut DEEP. I've been in the Connecticut state energy space for about 30 years now. I do have to have a little preparatory comment here – everything I'm saying today is my position, my opinions as a staffer at Connecticut DEEP. Many of you are probably aware, there is a New England Energy Visions Initiative, that started two a half years ago. There is also a New England Energy Transmission Initiative, which was an RFI that was issued a little over a year ago. And then there is the Joint State Innovation Partnership – in which four of the New England states are directly participating and the other two states are supporting – that filed a concept paper with the Department of Energy, which was approved this spring and then the participating states filed a funding initiative application in May. I cannot speak for any of those entities. I'm on the staff for all three of them, but on the other hand, these are my comments. If you want the official position of any of the member states of the New England Initiative, you'd have to go to the governor's office.

Having said that, this slide is just sort of caricature of why the New England states decided to come together. We started doing the same thing we have done for years, which is to go out to ask developers to come up with projects. We try to develop the area that you can see there, the BOEM leasehold, so that we can get some offshore wind. The problem was the developers were incented to go to the closest points of interconnection. And many of them were European companies without great experience in working with the very convoluted issues in the New England grid.

And so what happened is, we started having everybody interconnect on Cape Cod. Cape Cod is only a 600-megawatt load. So currently we have 2,400 megawatts of interconnected contracted energy going into a 600-megawatt load. And the result is chaos / disaster / curtailment / end of the world.

So, we then decided to look at some theoretical work that was done by Brattle Group, DOE, and others and the states decided to do something radical: we decided to talk to each other. Now, state officials are responsible to their constituencies and state planning authorities and regulators will always go for what is in the interest of their state's ratepayers. But that's not going to work if we're going to work cooperatively.

So, the New England Energy Visions is a deliberate effort for the states to go look proactively into future. Where do they want to be? And instead of having the developers design the grid, we're going to have the states working with the developers, the transmission owners, and our ISO New England.

In a minute, I'll explain what else we've been doing. So, we looked to a planned DC approach, which obviously can carry more power, with fewer environmental impacts.

[Appendix B – slide 2]

Here's some of the benefits. It's modular – by the way, we are looking at a 2,000 megawatt, 525kv base system for this. That becomes important – provides states with an off-ramp, because the states are controlling the procurement process. Say we decide we want to do more onshore or hydro to Canada. We can scale back as we wish. It was designed to access DOE funding, that's self-evident.

The states – this is unusual – the states would select the landfalls. And there are important diversity and environmental justice reasons for that. Equity is a central issue. And then, of course, DC lines minimizes the marine impacts because every DC cable can carry many times more what the ACs can. And it's designed to co-optimize with the land-based grid, because the states are doing the purchasing large amounts of the power. So, we are the ones who are deciding where we're going to do solar, where we're going to do batteries, where we're going to do hydro, where we're going to do land-based wind. Since we know that, we are trying to co-optimize the landfall points, and the injections from offshore wind, in such a way that it complements, as opposed to getting in the way of, our land-based options.

And then, we designed the grid so that in the future, we can link the DC lines and we call that the "meshed" grid. This is an old slide from two years ago. Currently, we're using the term "networked" because we're not really looking to an AC mesh grid like New

York, we're looking to a multi-terminal DC system.

[Appendix B – slide 3]

This is an interesting diagram. This was developed three years ago next month. It is already dated. You can see that, originally, we're looking at 1,200MW/320 kVs, because that was the common sort of architecture that was developed at the time. You can see the area in Cape Cod with the circle, we're avoiding that because that's already contracted with AC. We were looking at the idea of taking the DC lines – say the blue wants it first and then the red ones and you'll see the green one. That's a New York project. That's Beacon Wind. That goes from the same leasehold down to Queens. And then we're looking at the networking the DC lines once the fault clearing technology is ready and the circuit breakers are available. Thus connecting the DC converters to permit a full multi-terminal, DC controllable grid. That's the vision we're looking at.

So, we are not solving for just trying to get the power to land, that's the least of our problems. We know that's going to happen, the developers or the states will do that. What we're solving for is to see what other values we can layer on to the DC lines that are going to be built anyway. And that was the idea of interregional and intra-regional power flows. So, even if the wind isn't blowing, we have a fully controllable grid that we can move power from one part on the grid to another part.

[Appendix B – slide 4]

And this is sort of a rip off from a DOE paper. And what it is, this is the macrogrid concept. And the reason I'm including this is, if you look at the East Coast, that green circle off the East Coast, you'll notice they're not building a whole lot of DC lines on land because, I believe, and I'm pretty sure everyone in this room is aware that New England has demonstrated that is almost impossible to build major DC projects on land.

We have one project, Northern Pass, where a certain company spent eight years and 300 million dollars and failed to get the project built because of the opposition and difficulties. So, we are looking at these failed projects, and DOE is aware of this, because – by the way, full disclosure, I also work on the technical review committee for DOE, so they know I'm talking about this. We are looking at the macro grid for the East Coast – would it really be a marine macrogrid – that would connect with the land-based grid.

[Appendix B – slide 5]

And that's just within New England. If you want any official comments on where we're going, you must go to the New England Energy Visions website.

So, in short, and I'm sort of riffing off what Peter said in the first presentation, the critical issue here was the states getting together and agreeing to cooperate. That's, frankly, the hard part. The engineering – the people in this room can do the engineering, we're very confident of that. But the states have decided that we're going to cooperate and work together and it is my pleasure to tell you that last Friday, the New England states, all of them, along with New York and New Jersey, sent a letter to the Department of Energy, asking for DOE to facilitate an intra-regional planning initiative, which would include PJM, NYISO, ISO New England, and we're not forgetting our friends in Canada. The maritime provinces, the New England Maritime Offshore Wind Energy Corridor, we are speaking to them as well. This is official – I'm so glad we got the letter out so I can say it here – but we are deadly serious about this. That's the way forward, we believe. And we are hoping to get that moving within the next couple months.

[audience applause]

## Panelist 2: Carrie Cullen Hitt

**Carrie Cullen Hitt**

Okay, good morning, everyone. I should say, this is, those of you that do know me, I recently joined Vineyard Offshore, and this is my second time speaking publicly on behalf of Vineyard Offshore. So, please be patient. I have a couple colleagues in the room in the back who will correct me if I get something wrong.

[Appendix B – slide 6]

[Appendix B – slide 7]

First, I'm just going to take two minutes and just tell you who Vineyard Offshore is, because I think it's important to provide some clarification. So, Vineyard Offshore is newly created – well, in April 2021. We hold three lease areas. And I'm just describing this so as to distinguish from Vineyard Wind One, which is the project off the coast, that was referenced in the sides earlier. And we are part owner in that project. But Vineyard Offshore itself has two other lease areas, one in California and two additional ones here on the East Coast. We are owned by Copenhagen Infrastructure Partners, which many of you may have heard of, CIP, which is a broad infrastructure group. But Vineyard Offshore strictly focuses on offshore wind here in the US and in Canada. And that that may be expanded as well. But, for the moment, that's where my focus is, as well as the company's.

[Appendix B – slide 8]

So, these are the lease areas that we have. You saw Bob's map earlier, 501, 522, and 544. A couple sides later, I'm going to show you our lease area in California. Vineyard Wind One is in development right now.

Many of you might have seen that – I think it was two weeks ago, 10 days ago – our equipment was delivered in New Bedford. It's the first time, we'll be the first commercially operable offshore wind facility, which is great news. Things are moving forward. It's wonderful. Bob, like your news last Friday, it's wonderful to be able to now say that this is actually going to happen. And, of course, Block Island has been in place for a while. But this will be a commercially operable offshore wind facility.

We also have two other lease areas here on the East Coast right now. And we are determining where they will deliver into, whether they'll be into New York ISO, or New England, or even PJM. Maybe in the distant future, we might have the capability to deliver into one market but also be tied to another market, and operationalize that a bit better. That idea is music to my ears. So, if you have questions about where these are at, I'm happy to provide more information.

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Again, Vineyard Wind One is the first commercially operational facility. It will be interconnected – hopefully, and that's the plan – in 2024. An important piece of what we do: as mentioned, permitting is really important and that's usually the front end of the projects that take almost a decade to happen, here in the US.

Also, labor agreements are significant and important, both for the actual facility itself, but even transmission, etc. All that construction. Those are a key piece of our development work, up until, and after, once we're operational.

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I do want to mention our proposal overview for here on the East Coast. Excelsior Wind

and Liberty Wind with up to 2.6 GW of offshore wind capacity. We expect over 15 billion in direct economic benefits, 35 percent of which will go to disadvantaged communities.

Another important point, for all the offshore wind developers, is not only labor agreements, but the economic development benefits that we are delivering. They're often part of the power purchase agreements or the PPAs, that they might be called with the states that Bob mentioned earlier.

There's also the supply chain aspect, and the manufacturing aspect, which is 1.3 billion in turbines, nacelle, cable manufacturing, and the like. So, again here, just pointing out that while we are an energy company and will be delivering energy into New England or into California, we are also a construction company, an engineering company etc., as are my fellow offshore wind developers. There are so many factors that go into constructing these projects.

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I want to talk a little bit more about our community engagement activities and then finally talk about California and then just make a couple points to the conversation that we're having this morning. It's very important, as we develop these massive projects and infrastructure projects, that we think about community engagement and environmental justice. That's a key part of the development planning, there's significant outreach that goes to all stakeholders in the local communities here in Massachusetts. That's been down on the coast.

For me, I'm relatively new to offshore wind. I've been working in the space now for five years. This is one of the major learnings that I had, is the stakeholder engagement at the local level cannot be underestimated and the work that goes into that. Both for the siting the facility off the coast but also the interconnection point and the transmission line landing. It's a critical piece, and I'm sure that will come up a little bit today.

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Finally, I just wanted to draw an attention to the other lease area that we have, which is off the coast of California. And here, again, transmission will be a major challenge given the topical space, the geographic space out there, how deep the waters are, etc., and where Vineyard's lease, which is in northern California, which will come into Humboldt Bay, where there're very limited interconnection points. If we think the Cape is tough, it's even more challenging, could be more challenging there.

On the positive side, I think we are looking at an opportunity for, to take the time, over the next decade, before connection comes to really think over and about the transmission plans. I included the other leaseholder here, RWE, just so you could see that there are two leaseholders in northern California and we're working together to think about: how do we work with Cal ISO? How do we work with the state of California? How do we work with Humboldt Bay itself? The community, which is very small. In terms of our interconnection, what is that going to look like? Is it going to be a land-based solution, offshore solution, etc.? Very complicated. Also very exciting, because we sort of have a clean slate to think about.

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So, I just want to make a couple of substantive points before we sit down for conversation. As I think most of you know, developers have challenges – whether you're doing solar or battery storage, whatever – and they always are permitting, it's always permitting. It's always transmission and it's always how do you get your revenue, right? Those are the things that we think about the most, and making sure we mitigate risk in each one of those but also moving forward with each one of those. And those challenges are here in New England. And, you know, they exist in California as well.

What we're trying to figure out when it comes to transmission is how do we take those challenges and this overarching public policy challenge that we have here in terms of building out our infrastructure? And I think the news is fantastic, that New England has proposed through this DOE process, what's called – I don't know, the acronym I'm using is the GRIP Proposal.

And then, second, the announcement that was made Friday. But I continued to be challenged, at least personally, and I know professionally for our company, too, by: what is the regulatory and legal path forward for those ideas? They sound good, it's great that there's collaboration happening, but we need a firm – how do I say? – path or process that ensures that those ideas are actually put into practice and actually installed or built at the end of the day.

My week is bookended a little bit this week. I was at the FERC wholesale conference, which was up in Maine, on Tuesday, where the focus was on winter capacity issues. But transmission came up a lot, and again, it's the same questions are being asked for the energy market. I'm really pleased to see transmission be at the forefront of the conversation, finally, but we need a path forward and I hope we can talk more about that.

And then finally, I just want to draw your attention to – and maybe we can talk about this, too – on Tuesday, New York approved what's called the Public Policy Transmission Need (PPTN), which I think is an exemplary process – I mean it has its faults, of course – an exemplary process for identifying places to interconnect, and what the cost recovery is going to be for that interconnection, which is another challenge that we all have, getting back to the revenue challenge.

The PPTN process, again, has its faults. But the outcome is that developers know where New York wants us to go. What's the most efficient way to do that, perhaps, and also what the cost recovery is going to be for the upgrades that are needed onshore to ensure that we can interconnect. So maybe, we can talk about that. Thank you.

[audience applause]

## Panelist 3: Kelly Smith

**Kelly Smith**

Hi, everyone. It's nice to be back at Tufts.

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My name is Kelly Smith. I'm the onshore package manager for South Coast Wind, working on the Ocean Winds side of the joint venture. I am a "double jumbo." So, I did do my undergraduate here and, thankfully, I also get to say I'm also a recent grad. Although, there was a decent gap in between, so I'm not quite as young as you might think.

So, Carrie's remarks transition, and Bob's as well, transition really nicely into what I wanted to introduce today, which is a little bit more detail into the mindset of the upfront development process here in New England, and what the regulatory frameworks are like and how developers are currently moving through the grid interconnection process and the permitting process. And, certainly, I think a big focus of the discussion today will be how to improve that going forward. But, I think it's useful to ground in where we're at right now.

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So, for development, there's really four major buckets that need to be secured for projects to de-risk to the point where we can take final investment decision. This is where you get bank financing in place to do the major manufacturing and the construction.

And so, the top one on this list is grid interconnection. That's the main subject for today. And, in the current process, what you need is, you need a queue position with "acceptable" – room for interpretation on that – but acceptable cost and schedule implications for your overall project. Because, in the current system, the developer is bearing the cost of those transmission upgrades and needs to factor in when they'll be available into their overall construction schedule. You also need a viable route from your lease area to your onshore point of interconnection and that means technically viable. That also means something that you think can get through the stakeholder and permitting processes for those jurisdictions.

Another big bucket that's been discussed today are the permitting and site control requirements. The route to market is also a critical piece in the U.S. It's really the state power purchase agreements that are dominating. And then the supply chain as well. So, as the interest in HVDC transmission technology grows, as the interest in offshore wind continues to take off, there's a lot of strain on the supply chain. And so, to secure your schedule, you really need to be doing early engagement with vendors. That is a lot of up-front work in order to secure the project to the point where it can move forward into construction, as Vineyard Wind is doing now.

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So, zooming in on the grid interconnection process. Here's just an overview of what it looks to step through that currently in ISO New England. Queue positions are currently studied in the order in which they're filed. If there are a lot of queue positions, like in Cape Cod, if there's a lot of interest in the same geographic area, ISO New England can move to a cluster study process. There has been a lot of discussion about queue reform, which I'm sure is something we'll get into today, with the proposal from FERC to transition to a first-ready system instead of the first in line. So, there's a lot of opportunities to streamline some of this. But, as it sits currently, you're looking at a multi-year process, with some pretty substantial financial commitments along the way.

For example, by the time you get to the system impact study, the developer costs are approximately a million plus, just invested in the grid piece of it. And at that point you're trying to juggle all your timelines. There's a significant additional amount of capital on the line across the development efforts; this is just a piece of it. The end goal is the contractual interconnection agreement, agreed between the developer, the utility, and ISO. And then in the current system, the developer is on the hook for all the enabling grid interconnection costs, which, in some instances, can easily be hundreds of millions of dollars and take four to ten years to permit and construct just those onshore upgrades.

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And just to compare against the same map that Bob showed for 2019, there were two studies done by ISO New England on economic implications of large-scale interconnection of offshore wind. This was the map. The base assumption showed, at the time, you've got about 7,000 megawatts of what I'll call "low hanging fruit" for points of interconnection, that don't require as substantial upgrades to bring the power online.

And so, here's where we are since then. A chunk of this has been claimed through interconnection agreements that have been executed. Vineyard Wind went first. Their process, from QP filing to interconnection agreement, took a little under four years. Park City Wind took a little bit longer. Revolution Wind was about three years. South Coast Wind acquired its queue position at Brayton Point and was able to progress to an interconnection agreement in 2022. So, it does take years, even just to move through this upfront process.

And then, once you've signed the interconnection agreements, you're more locked into cost and schedule for the grid upgrades, but the utility still must permit and build those. So, there's still a long time on the back end to get the onshore grid infrastructure in place.

All this is to say that projects are moving in the direction of being larger and larger in size. And so, a standard kit size these days for HVDC, which is the direction a lot of projects are moving in, is 1,200 megawatts, which maxes out the current ISO New England single source contingency limit. There are very limited locations that are feasible to route to and interconnect 1,200 megawatts at this point in New England.

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So, just quickly zooming in on South Coast Wind, specifically. Our first project, the first 1,200-megawatt project, is looking to interconnect at Brayton Point in Somerset, Massachusetts, which means we do have a lot of jurisdictions to pass through in Rhode Island as well as in Massachusetts. Just a snapshot of what we're looking at.

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And then, if you put that in context on a map, we're talking about the orange route on the left here. That's about 90 miles of cabling in federal waters, 20 miles in Rhode Island state waters, and two miles in Massachusetts, as well as a two-mile onshore segment in Rhode Island and then a short onshore segment at an industrial site in Massachusetts. So, quite a long distance to go, but if you really zoom in, most of this, we will look at a single HVDC cable bundle offshore, which, installed, has a width of just over a foot. So, long in scale, but narrow in footprint.

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And then, in terms of the permitting timeline, the graphics on the left show where we are in the federal process, currently. And, just to ground this, the BOEM federal process is the longest of the permitting processes. But, you really have to map them all out in advance if you're going to move through it as efficiently as possible. And there's a lot of technical work that goes into the front end of filing these permits.

So, if you're thinking about the front-end elements right now, you've got: a federal process, that's about two to three years. You have a grid interconnection process that can be anywhere from three to five. And, in order to file your federal permits, you're already making assumptions about your grid interconnection and your route to delivery. So, there's a lot of big assumptions that go in at the beginning that have increasing implications as you try to change and optimize them later. So, I think this is a timely discussion. I think there's a lot to consider. There's a lot of room for improvement and streamlining and where we are with the front end now, I would say.

[audience applause]

## Q&A

**Moderator**

So, this has been an incredible beginning way of laying the groundwork of the challenges that we totally have ahead. And I think it's good for the technical people to hear what the policy people are working with. This next session, we're going to be talking about a macro grid, we're going to be talking about a whole series of interconnections, so I think it's a great opportunity to meet of the minds.

Each of you have laid out amazing challenges. In the long term, I think we are going to get to where we need. We set deadlines. I'm not sure we're going to meet those deadlines. But, if you were sitting there, Bob, in your role on the policy side – and I know you don't speak for every state – what is the priority and the challenges that you feel need to be unpacked? And what is the policy structure, in your mind – because you spent many years thinking about this – that needs to happen to get the states to cooperate, given all of the complexities, the politics, of the set of governors? And in addition, I believe right now you have mainly democratic governors, except two, in New England. If you have a change of regime, what happens to this process?

So, these are a lot of questions you don't know the answer. But could you just sort of lead us in a direction that would be helpful?

**Bob Snook**

The New England Energy Visions is a flexible, a long-term proactive agreement between the states. It's been extremely helpful. We found – and it took three years to get the whole process moving – that what you needed to do is upstaff at the staff level and then reach out to other states. Connecticut is fairly new to this. Coming up with the technical staff so that we can understand some of the engineering issues and some of the development issues and really get to have more experience at DOE and FERC. Once we did that, staff will then go to the energy officers for each state and the governors and our legislators. I have found it takes about four meetings until people get comfortable with understanding the importance of offshore wind and the transmission issues.

Then we insisted that the state energy officers working with each other in the various states. Not all New England states even have a climate policy. New Hampshire does not. And not only did we get all the states to join, but even one of the states – the biggest state, Massachusetts – had a change in political administration, and the cooperation has been seamless.

All the states have committed to this joint approach to transmission development and there are several reasons why. We did point out, obviously, the climate issues. We also pointed out that New England's going forward with a major energy transition. The future’s coming, whether we like it or not. We are retiring the oil plants. The coal plants are, essentially, all gone. And the plants that are burning oil in New England, now, the only ones that I actually know of, were built 50+ years ago, and are, obviously, at the end of their useful life. To build new gas plants in New England is difficult. I don't think we will see any new ones in the future. None of the major nuclear plants are going to be built. Maybe some small modular reactors in the future if the technology goes that way.

The future's coming, no matter what party you're on. How are we going to build out for the clean energy transition, which is coming, which requires a significantly different transmission system? So, once we have the governors and officers realize this – and then the ISO study, which demonstrated that, by 2050, 50 percent of New England's bulk power supply lines will be overtaxed, and that will cost billions and billions of dollars. So, armed with that, we were able to get the New England governors of different parties to collaborate.

There is one way forward – and to keep this going, we need – FERC, DOE, and the states each have obligations: states need to continue to collaborate and work cooperatively with each other. And that requires frequent meetings – yes, it's a lot of talking in government, but it's necessary – as well as keeping ourselves informed with what's going on in Europe and elsewhere.

The second thing is to adopt a proactive, scenario-based planning approach, because the states never did that before. Because we know where we're going to be putting the clean energy resources, because under the Federal Power Act, it's our job to do that.

Now one state in particular, down south, has refused to do this. They said, "we're going to let our transmission companies do that." They're vertically integrated, that's their approach. That works in some cases. As I said, also, FERC has two things they have to do. FERC docket AD23-3 – I think that's the correct docket number – is the minimum interregional transfer capacity docket. That's an interesting forum for discussing interregional transmission. That docket is where we can start the real conversation going about inter-regional transmission, which is going to be very important with offshore wind.

The other thing FERC really needs to do, is to allow the ISOs and the RTOs to have the necessary tariff changes to find out who is going to operate an offshore, multi-terminal grid. Is it one ISO? Is it another? Is it a separate entity? That's a decision we need to make. As well as the regulatory authority for the control of the transfer of power. Because, between right now, with our AC interconnections to New York, power flows, between ISO-NE and NYISO, go the wrong way 40% of the time.

Last one is DOE. They have to come up with standardization protocols for the interoperability of HVDC equipment. One approach is for DOE to essentially mimic what InterOPERA organization is doing in Europe. In fact, I'm not hiding the fact that we're all looking at what InterOPERA is doing because it would make sense for the European and North American grids to use some similar equipment and standards.

**Moderator**
Thank you.

So, turning to Carrie. Now, you raised a lot of issues that are potential for discussion in your presentation and alluded to the fact that we are going to have these conversations. If you were to prioritize – you know, chewing gum and walking at the same time – how should we began to prioritize some of the decisions that we need to make? What do you think can happen simultaneously as we move projects forward? All of these issues need to come to the fore. So, you know, this is your opportunity to give us a sense of, just a direction, from the developer perspective. But also, using your public policy background to set a set of priorities to lead us forward.

**Carrie Cullen Hitt**
I think it's been pointed out that the conversation is now happening. The dialogue is now happening. Which is great, right? I've thought about transmission for the past 15 years and it's always been the thing that nobody really thinks about, unless you're in Holyoke or Guilderland or whatever. Or you're, in theory, thinking about it. So that's great news.

To be super wonky, here in New England, right now, we need tariff changes. That's one thing. We need the tariff changes, actually, in the open-access tariff, and the market rules that specifically think about the future, not just retroactive view – that's one thing – allows the ISO to use the data that's there, that's available to incorporate in future planning.

And second, to address cost recovery of how this is going to work. We have to, probably, make some changes on our cost-recovery mechanisms, both at the state level and at the federal through the wholesale level. It's not a super exciting thing. Because now that the conversation's happening, and there is momentum here in New England that we have goals, personally, I don't think we have a choice anymore.

I got asked this on a panel last week in California, why do you wake up every day? I say, because I was at South Brooklyn Marine Terminal two weeks ago and I honestly couldn't breathe, and it was scary and shocking and, you know. We all know we need to do something at this point, at least in this part of the country.

**Moderator**
Can you talk about tariff changes? Because those of us, those people who are not regulators, don't understand the wonkiness, but the importance, of the tariff change. What is it that needs to change? Just, more generally.

**Carrie Cullen Hitt**
So, I think there are two things. One is our states, themselves. The PUC (Public Utility Commission) of this – it's a lot, Bobbi. So, let me just say two things and try to leave it

at that and we can talk more later. Generally, state commissions – and I'm not a state commissioner, so this is just my perspective – are guided by a fundamental principal, which is "prudency for ratepayers." Achieve lowest cost. And even here in New England, where we have other goals, the fundamental thing is still prudency. But what does prudency mean? Is it the kilowatt hour cost, exclusive of all the benefits? Are you incorporating environmental benefits as well? What does that mean? So, at the state level, there's that aspect that is part of the rates. I'm not going to get into specific changes, but that's a fundamental thing that we need to think about, still.

At the ISO level – ISOs are generally guided by basic market principles and FERC orders and things like that. And the two things that I see – and this isn't just in New England – are that, first, often future planning is based on past data. So, unless there's a contract that says there's 3 gigawatts of offshore wind coming, they can't necessarily take that into account in their planning.

So, for example, yesterday we filed comments in California's integrated resource planning process, IRP. They still have an IRP in California. And their baseline numbers were based on 2022 NREL data, that assumed a 12 MW turbine. Well, by the time we construct a project in 2035, it's going to be a 20 MW turbine. So, we want to make sure they know that information but also can use that information with their future plans. Same thing is true for here in New England or New York as well. How do you incorporate what we think is coming, even if there's not a contract in place, in the planning process, so that we can get the transmission planning that's needed to make sure that those things can be interconnected in the timely manner? Or we build an offshore system that everybody can interconnect to, speaking very generally.

Then, second, even the open-access transmission tariff, OATT – for those of you that don't know, it's like about 1400-page document in every organized market RTO – there are certain aspects of that that address interconnection queues, things like that, that might need to be rethought. And, including cost recovery for upgrades and things like that to accommodate future planning as well. So, those are the three things that I think about, which, it alone, you could spend a week talking though.

**Moderator**
Right? And just to say that it's good that Bob heard this so that he can integrate this into his interregional conversation.

**Carrie Cullen Hitt**
Bobbi, can I just say one other thing? One other thing is that New England is particularly challenging because it's multi-state, right? So, I mentioned the New York PPTN, which is the transmission policy.

**Moderator**

Can you say what PPTN is?

**Carrie Cullen Hitt**

It's the transmission process that goes through the ISO and then the Department of Public Service approves. But it's a single state. California is, currently, a single state. It might not be forever. So, it's a little bit easier sometimes, and I'm sure you can appreciate that. And so, I think in New England, even the ISOs – and again, I don't want to speak for the ISO, and I know somebody is here from the ISO, I can see them back – is in a particularly challenging position sometimes, too, because who do you listen to? You have a board of governors, you have this and that. But, you have to put all the pieces together, which may make it difficult to make those tariff filings or market rule changes that you might think are needed to accommodate these different policy objectives.

**Moderator**

Just a question to you, Kelly. I mean, you have laid out, I think in very stark form, the permitting process, the cost of determining process, the issues in the challenges of the POIs. If you could also rationalize the process, in some form – and you also talked a little bit about energy justice and some of those costs. How does energy justice – how do all of those significant issues – which, ultimately, can kill a project at the end, after you have invested time and millions of dollars – where does that intervention happen in a meaningful way, so that you feel confidently that when you've gone through your processes, you actually were able to put cables in the ground?

**Kelly Smith**

That is an excellent question. Yes, hard for me to optimize, on the fly, 60 different agencies. There needs to be a federal process that's looking after all the jurisdictional elements from the lease area, all the way to the point of interconnection. Or, wherever that cutoff point in ownership is, depending on how the system evolves in the future.

Of course, there also needs to be state processes for looking at siting. And of course, you want a seat at the table for the local voices and the environmental justice communities. I think, the permitting system has already evolved, at least in New England, to include what's called the "Energy Facility Siting Board," which are, in most cases, the overriding state approval for new generation development and transmission level development. And they take a holistic look at the environmental and the community impacts, and also, certainly, factor in environmental justice as well.

With offshore wind, we cross so many different environmental resource areas that that brings a lot of environmental and other new stakeholders to the table. And, I think, it's finding a way to incorporate the right voices at the right time into an existing overarching process, rather than to have each stage of the way have its own priorities, that might be out of alignment, and could put the entire development effort at risk. So, I think the agencies are thinking about this and thinking about how to do it better. But this first set of projects is really testing how that system works and, I think, helping to identify future efficiencies. So, I guess what I would say is: incorporating more of the feedback into an overall process at the state and federal level.

**Moderator**
I totally agree with you. Having sat on an energy facility siting board – and this is not meant against any siting board – there is no more inflexible, difficult, arcane process. And you see all the intervention and then you say, "how did this decision come out of it?" But it is so legalistic and regulatory that my own recommendation really is – and again, now you're getting into legal precedent and all sorts of assumptions there. But that would really be an opportunity, creatively, to think about from an offshore wind perspective, how that gets rationalized.

So, I think that there are a lot of comments that we could open up. I saw a lot of people taking notes, so I'm going to open the floor. Why don't you begin?

**Audience Member**
For a long time, there has been discussion about how should a multistate level integrate with the RTO transmission planning process? And there's been discussion in the past that the transmission planning process for RTOs should be really different than the energy market planning process. And this really seems to bring that to a point, dealing with offshore wind. I would love your comments from a developer protective, and, Bob, from a multi-state perspective, about how we need to be thinking, not only of New England, but really of the eastern seaboard and, kind of, those conversations. Thank you so much, all of you.

**Bob Snook**
It's hugely important. So, we are in the process of integrating multistate planning now. NEPOOL meetings are also happening now for reviewing the changes to the ISO-NE tariff to permit states to come forward with proactive scenarios, which we will then give to the ISO to study. So, it's not what is currently in the tariff but it's where the states are going. And we're looking for a longer ISO-NE study period, 20 years instead of 10. These tariff changes are already moving forward. The ISO's already doing a lot of them, and they've been incredibly flexible.

The 2050 study, very helpful directionally. It's not a deterministic study, but it's directional and it gives the ammunition to the state planners to then go to our governors and legislators and work together on a multistate planning approach. Now, that has been hugely helpful.

In addition, if there is a first-ready first-serve interconnection reforms advanced by FERC which will help. Therefore, the states should come out with an approach whereby we select the POIs and pre-build them, basically, for larger injection levels of offshore wind.

I also point out that on March 27th, the ISO-NE sent a letter to the joint inter-regional planning committee (the JIPC) about increasing the loss-of-load first contingency level from 1,200 MW to 2,000 MW. So, we are moving in the right direction. Many people are frustrated with the NEPOOL process because it takes months of meetings and meetings. But those are important, and we are moving in right direction. But ultimately it is the states' job to give the data to the ISO, and the ISO to do its job, which is studying and planning.

And then there there's a Heisenberg problem. Specifically, if I start injecting 2,000 MW into a system like New England, that's going to completely change the rest of the topology of the system. So, we can't just do one study and pick the best POIs. We have to come up with a couple of POIs that states like. Then we need to consider injection levels. Then we go to the ISO and say, "Okay, how will this affect the grid? Is this even doable?" And then we go to the next step, for perhaps, a future funding opportunity at US DOE. So, we're looking at this as an iterative proactive process, whereby the states and the ISO – we're sort of bouncing the ball back and forth with each other – obviously including the existing transmission owners as well.

**Audience Member**
Do we need a new reliability standard for offshore wind?

**Bob Snook**
I think we may have a need for that. That's something I need to talk with DOE about. There have been conversations, but I'm not permitted to go into detail on those. But people are aware of the issues.

**Audience Member**
What do you mean by reliability standard may be a good question to ask there. We're using a term. Maybe we should define that term before we –

**Carrie Cullen Hitt**
I was going to offer just a couple of term things and then – I don't know if you were in Portland. You referred to MISO. It's a Midwest Independent Transmission System Operator (MISO) which is 11 states or something. So, they have new interconnection queue rules and things like that. And, again, I don't know if it's perfect. They've been progressing. I don't know if they're dealing with offshore wind, but.

I referred earlier to the FERC workshop that was in Portland on Tuesday, which was, sort of, the same old, same old to be honest with you. But on the other hand, for me, anyway, it was the first time – and it was great to hear it – offshore wind mentioned repeatedly by Secretary Tepper. But, I think ISO mentioned it as well, a recognition that significant injections will be coming from offshore wind within the next year to 15 years. And acknowledging that that needs to be taken into consideration, for transmission planning, but also reliability standards.

I know this is not the topic for today, Bobbi, but it is a component that we all think about, which is, what are the forward capacity markets going to look like? We're already talking about 2029, right now. So, the data is needed and the studies are needed to make sure that we model the best we can for what's going to happen in 2029 and beyond. And what their reliability rules are. And recognizing that offshore wind might be winter peaking, and if we have more electrification, it helps match that. All those things. So, just another whole bucket of conversation. Again, I am very encouraged by the fact that it's actually a dialogue that's happening now.

Where I still have significant concerns is that, if we want to build an offshore grid that's more efficient or provides efficiency and more cost effective for ratepayers and for developers and for all of us, that's still like 15 years away, because we still have to do all these tariff changes and things like that, that take at least five years. So, I don't want to be negative, but urgency is important. And I think guidance and leadership from both their states, which is coming, is great. And the federal level is really, really important. And from the investment community as well. I know, Kelly, you might have something.

**Kelly Smith**
It was on the previous topic.

**Carrie Cullen Hitt**
Oh yeah, maybe you were going to say this: Secretary Tepper has made no – and I know this administration in Massachusetts is thinking about siting board reform. I don't know where that stands, but I know it's a topic that's been mentioned a few times here in Massachusetts. So, something to pay attention to.

**Kelly Smith**
Since you've opened it, I'll add on to that one. I think also in Massachusetts – from what I've experienced, they've had a bit of a staffing issue and certainly need more folks to be involved in that process. And also, as Bobbi said, a key point, it's a very legal process and so everything's evaluated against precedent and how things were done before. And you really have to build your case to try and do anything different and to demonstrate the need for new projects in a way that is different from what's been done before. So, I think the siting board is open, they see the need for this new energy infrastructure, and they see the need for it, but we need to create the permission structure for them to allow it to move forward. So, unless the regulations are reformed or unless the lawyers on the developer teams can be creative in how

they're presenting these new ideas, that also tends to be a stall point.

**Moderator**
And just to build up on your point: one of the things that I'm very aware of is the power of incumbency, and that, how do you – the rules were made at a previous time, and yet, the energy bar in New England is very skilled at maintaining incumbency in various ways. Carrie and I have lived this in an earlier portion of our lives. So, I just want to point that out, too.

But I know there are other questions from you audience, so, yes.

**Audience Member**
I'm curious about the panel's view on the current status of how offshore wind lease areas are allocated in the BOEM process and how that matches with how POIs are now being fixed onshore. We're still in the situation where, even though the POI is fixed, you don't know where the offshore wind is going to come from. If you don't know that, you cannot plan for an offshore transmission grid, if that happens to be wrong. Which is what's happening in Europe, right?

**Carrie Cullen Hitt**
In an ideal world, which probably won't exist, you'd have better sequencing, right? Maybe a little bit to Kelly's point, if you win a lease area, it's provisional. And then a year later –you paid the money and signed the lease – then you go through your permitting process at BOEM, the initial filing. You say where you think you're going to interconnect, then – we're trying to figure that out in California right now. So, that's kind of tough, because if they state and the ISO, after they go through the process – which we welcome – for four years, later come back and say, "oh, you know, it would be better if he went here." I could go back to the start – kind of – make an amendment at BOEM to my COP, which then adds years and time and you have to do surveys and all that. So, I think that's the problem you're recognizing. I don't see anybody really talking about how to fix that problem right now.

**Moderator**
Why is that? We'll let Bob talk.

**Bob Snook**
I'm going to get ahead of my myself if I go too far. I'm going to get ahead of all of my commissioners' official positions for a moment. The BOEM leasehold off Massachusetts is already set. So, how should I phrase this? This has not gone up to our management. This is my position only as a staffer. But Connecticut's technical team is working with a certain New England state, at the staff level, in ahead of a Gulf of Maine BOEM process. And we wish to inform them of where we think the best POIs would be – so that we can address exactly what Dr. Plet is talking about. So that with the BOEM, we're trying to get the

cart behind the horse, which is a novel thing. In fact, I think we're the first doing it. So, we have made a preliminary evaluation of three points. And, hypothetically, one might be in another country that faces the Gulf of Maine. So that is – again, all at staff level. This has not been approved by anybody. But we are going to be meeting again next week to address this specific issue.

**Carrie Cullen Hitt**
Which I think is great. That's welcome news. We then must take into consideration the revenue impacts of – and I don't know if that's going into that thought process. So, let's say you deliver into another country, or a thousand miles away in northern Maine, but your power purchase agreement is in Connecticut. As a developer, we must take into account – do we have to pay for transmission rights, congestion rights, that sort of thing? So, there's then this revenue matchup thing that must happen, too, where physically, the interconnection might look great, from an engineering standpoint, from a power system standpoint, from an environmental standpoint. But then we must think about the economic aspect to that, too. And maybe it's fine to pay for that. But we must recognize that there might be cost along the way.

**Kelly Smith**
I think there's also a bit of work to do unraveling the political considerations, as well. In the current framework, the states are each doing their own solicitation process. You haven't seen it play out every time. So, the Connecticut project, for example, has POIs in other New England states. But there's definitely, from our understanding, an incentive to really put the economic advantages in the state doing the procurement, right? So that can lead to duplicate economic development efforts that can lead to developers trying to create the best sales package to whoever's buying the power, which is maybe not optimal for the rest of the system.

**Moderator**
[calling on someone in audience] Yes.

**Audience Member**
Thanks. And this goes to your point, Carrie, about the RTO tariff changes that are needed. In talking to people at PJM, they're limited by the Federal Power Act, currently, that they can't make changes for interregional and intra-regional policy transmission without federal legislation. And that's the big sticking point in their eyes for that those needed tariff changes.

**Carrie Cullen Hitt**
Yeah, there are limits. I agree. And the way that PJM got around it a tiny, tiny bit, is New Jersey went through the State Agreement Approach, right?

**Audience Member**
They accepted all the costs.

**Carrie Cullen Hitt**

And that was tucked into, you know, their interpretation of FERC Order 1000. Sorry, this is so acronym –

**Moderator**
No, you have to have these conversations. This is where the decisions get made.

**Carrie Cullen Hitt**
As I understand it – and others may know more than I do – PJM, when they filed their response to FERC Order 1000 – which, for those of you that don't know, was an attempt to require ISOs to have competitive transmission, which happened in some markets, a little bit, and not so much up here. But, in PJM, their response for their tariff had a little hook that states could do something like this. And New Jersey has proceeded with what's called the State Agreement Approach (SAA) – they've done one process with that – where the state itself said we want this and we will pay. Our ratepayers will pay for it. And the PJM tariff allowed them to do that. I don't think we have that construct here in New England. So, that was just a sort of a workaround to some of these challenges. But, yes, you're right.

**Audience Member**
There was a part of that SAA award that was transmission in Pennsylvania. And they accepted that. And it was a small project. But that wouldn't happen if it was a large project, and they need, kind of, a multi-state.

**Moderator**
[calling on someone in audience] Yes? And then we'll – and that'll be a great ending.

**Audience Member**
Hi. I'm really curious: you've talked a little bit about how the planning is going to get larger scope and the breadth across states is going to continue to grow, which I think is exemplified by the letter that was sent out on Friday. And, Bob, I think you mentioned that there's sort of an iterative nature that you see between states and the RTOs, sort of accommodating these waves of offshore wind lease areas. And I'm curious about the panel's opinions, both from developers and state, about the value of competitiveness in that process. Because I hear about the states and RTOs and I'm curious if the states are going to have a competitive transmission planning process, and what the developers think about the value of competition as the RFPs might become more prescriptive.

**Bob Snook**
I can say this: over the last eight years, Connecticut, working with up to 18 other states across the country, has filed, repeatedly, comments at FERC on the idea of competition, the importance of competition. We've been very successful in our procurement strategy, so far, over the last 10 years. We like our approach. It is a little unusual. I wish Eric from my office was here, because he's an economist, he's very good at this. It's a little unusual if there's only a handful of players that actually

have leaseholds. Because then is it *real* competition? And how would that play out? However, the states in New England so far, have done this, sort of, it's not a joint RFP. We did one for land-based things years ago. It was an absolute nightmare because we have different laws and things like that. We had been doing a, sort of, parallel play –we all go out roughly at the same time – and we allow contingent bids. So, while we favor competition, there has been some thought that it's a little bit hamstrung by the approach of having BOEM leaseholds. We only see a few companies having it. But generally, we like competition.

**Carrie Cullen Hitt**

My quick comment, on the transmission side of competition: if anything, a competitive process gets the states and then ISO information they may not otherwise have. So, if anything – and that was shown in New Jersey, through the SAA approach, there were 83 proposals received – that revealed a lot of things and different possibilities. And they ended up choosing one and that's it. And the same thing just happened with this PPTN in New York. So, at the very least, at least policy makers get the information that they might not otherwise see. And so, to some extent, does the public.

**Kelly Smith**

Just one other thing to think about as we think about the gold standard of competition and driving down prices and all of that. We're migrating towards an HVDC grid system, and there are very few manufacturers of HVDC equipment. So, that becomes the limiting constraint: how tied up are their books, and who's available to commit? And that is a big element to driving overall cost and schedule. We're seeing that now, and I suspect that's going to continue for a while, just because of how long it takes to develop companies that have that sort of expertise. As we look to European counterparts – TenneT, for example, working in the Netherlands and Germany – they're able to do volume procurements of HVDC. So, they just did up, I think they procured 14, I'll call them "kits" of offshore and onshore converter station systems, and, I think, another big solicitation for HVDC cable. But we are seeing that the big TenneT orders are – because it's such a volume system, it draws the attention of those manufacturers. And so, we're taking the slots in between. And that's what happens when we're going to the market as individual developers. Now, there is some buying power within – if you climb up the organizational structures, our companies have different lease areas, so there is some market leverage there. But, compared to what TenneT's able to do through a planned system and a bulk buying approach, it leaves us in a very different position in terms of driving competition.

**Moderator**

Well, thank you. Now, Jim McCalley, who is going to be in our next panel from Iowa State has a question. And I think it's great to end with him because that will provide us the transition after the break.

**Jim McCalley**

Thank you. I appreciate the comments of all of you. I'm indeed encouraged a bit by listening to the interstate, the interregional, efforts to coordinate. I've heard a few comments on that fact, there. But we're building, we want to build, a multi-regional transmission grid out there, right? And we've been here before. Not in this area of the country, though. 2,500 miles to the west. And Eric and company have captured that on the very bottom here [*gesturing to brochure*] – it's very interesting. It says, "a formal plan for a federally constructed intertie that served as the yardstick in motivating non-federal parties to participate in meaningful negotiations." So, the essence in 1964 was, they threw a plan down on the table and said, "we're going to build this. Do you want to participate?" And a lot of people came on board, instantly. Now, I don't know that that's the answer today, but on my question is this: do you feel like a stronger federal presence in leading this effort would be beneficial? Would you welcome that or do you say, "no, let us do it ourselves, please." I mean, I can see reason for going both ways, but what's your thoughts?

**Carrie Cullen Hitt**

I'm going to answer personally. I don't know how my company feels about it. Yes, but only if there's a very clear path and the outcome is almost guaranteed. And that is not the case in the US when it comes to these sorts of things, right? We have a change in administration in a year and a half: what happens? Does it stop something like that or not? So, that's my fear. The risk is mostly political risk. And as a developer, once we start a project, and we have commitments for PPAs – you know, we've been talking a lot about risk today – but all these things are about managing your risk. And if I think that federal path is most likely to get me interconnected when I need to be, and it diminishes my interconnection risk and my supply chain risk associated with it, yes. But I can't personally say, today, that I believe we could achieve that. I don't know. That's my concern.

**Bob Snook**

I'll say that the position of Connecticut staff – again, this isn't a question that's ever gone to our commissioners – but Connecticut staff feels that the federal highway system was not built by states. It was done by the federal government using a top down approach to highway planning. The majority view of Connecticut staff is that a federal like transmission corridor – there is some authority at FERC to do this – would probably not work on the eastern seaboard and that the opposition from the state governments would be very strong. Right now, the states believe that we can do the transmission planning. Primarily – and the closest thing we'll get to an interregional backbone transmission system, sometimes called grid 3.0, is probably going to be by interconnecting the offshore HVDC wind cabling and building out the grid that way. We're comfortable with that. The thing we'd like from the feds is having the Department of Energy give us the space so we can work together on some real joint interregional planning and, in addition, the funding, because that's been a huge thing that's been stimulating a lot of state effort. So, I personally don't think that the states – particularly on East Coast – would be agreeable, something which might work elsewhere in the country. But I don't I don't see it flying here. At least not in near-term.

**Kelly Smith**

Honestly, I don't have much to add to those points. I think Carrie took the words out of my mouth. I was going to speak for myself as well. I think there's a need for federal leadership on a lot of the issues. But, in order to make it a resilient solution in New England, you really need the buy-in at the state and local level, and I don't think it would be received well, if it came top down. I think the more resilient approach is probably by unwinding and correcting some of the legislative items and FERC as well.

**Moderator**

Great. Well, we have had an amazing panel. I thank our panelists. I thank our audience. We will take a quick break and technically be back here in 15 minutes.

# 4 Technical Panel: 85 GW Study

## Themes: macrogrid, HVDC, interoperability, 85 GW study

*The technical panel focused on the future of HVDC technology, the macrogrid, and the presentation of the 85 GW offshore wind injection study. The session began with presentations from panelists Jim McCalley, Cornelis Plet, and Johan Enslin. The session ended with a short Q&A.*

**Moderator**
I'll say a few words of introduction as we move into this next panel, and before we start the presentations. After my introduction, I'll ask the panelists to introduce themselves and then we'll be going in the order of: Jim McCalley will be speaking, and then Cornelis Plet will be speaking, and then Johann Enslin will be speaking. This panel will have a similar structure to the previous panel, and we're excited to share this with you. I also want to circle back to a theme that is apparent to us as we're thinking about all this, but I want to state it explicitly. First: today, we're following Chatham House rules. It's very important that people in this room can speak freely, able to speak candidly. This is an academic environment. It is meant to be a space in which we exchange ideas, in which we engage in spirited discussions and debates, and in which people can really listen to each other in an honest way. We recognize that most of the people in this room, when you speak in different venues, there are constraints upon you. We understand those. We respect those. We understand that, even in this venue, this isn't perfect and that these constraints still exist. But our job as hosts is to create a space in which we can have conversations that flow a little more freely, that possibly can iterate in different directions. Not everything everyone says must be right. People are not held to what they've said. This is a creative environment where we're able to stimulate and exchange ideas.

We're hoping that this panel – that this workshop today is the beginning of a series of engagements as we move from our aspirations to hit an 85 gigawatt study – consistent with the DOE's Atlantic offshore wind transmission project – moving towards a 200 gigawatt study and a 300 gigawatt study. And we intend to kick off a series of engagements and convenings – some in person, some virtual, each with different themes – over the coming months, so that we can continue to help steward this conversation forward and we look forward to all your feedback and to your engagement.

And so, with that said, I'd like to introduce the themes of this panel and the themes of our work. Again, our team, funded by the National Offshore Wind Research &

Development Consortium (NOWRDC) and the Mass Clean Energy Center, has been working, for several years, in parallel and very closely with the NREL and PNNL team running the Atlantic Offshore Wind Transmission Study. We have met monthly with key members of the team. We have met as teams to exchange information. We have participated on each other's technical review committees. And we have been very excited to have the opportunity to approach this enormous challenge from independent points of view that are coordinated and connected to one another. And I would say that the primary focus of our work has been on the land: the land-based upgrades. Simply put, how much offshore wind can you inject into the existing grid? Where do we run into issues? How do we think about that system?

And so, because of this, we have elected, in our study – and we've had the room to do this – to consider: what if we were starting from scratch in offshore wind? And there's some notes about this in the brochure. Even if there are already, you know, 18 plus gigawatts under permitting and procurement and all of these things, if you think about the number 200 gigawatts, 18 gigawatts is less than 10 percent of that. It's even a smaller portion of 300 gigawatts. And so, the question for us is: what is the Eastern Interconnect? What does it want? How does it behave? Where are the power flows? How do we think – conceptually and technically and numerically – about the entire East Coast? And why do we want to do this?

We want to do this because, in our mind, if we do not get the transmission right, this industry will stop short of its full potential. There is no doubt about that. And if we can minimize the number of points of interconnection, and if we can minimize the number of landing points, then we can treat each landing point as an important piece of infrastructure, that brings benefits to the communities who’s hosting it, that actually connects into the grid in a way that facilitates the energy transition, that has buy-in at the state, local, regional, and federal perspective. We think that this is the way to go. And there's a very clear technical challenge facing us in moving in this direction, which is that we have to go way beyond our current notions of single source contingency limits. Way beyond them. Today, we're going to talk about going up to six gigawatts. But, if you think about a macrogrid that's going to run the country in 2050 and actually accomplish the energy transition, 85 gigawatts is a small number. We're talking about three to five thousand gigawatts of renewable electricity that the country is going to have to be able to use. We're talking about a tripling of the capacity of the grid. And we are talking about macrogrid corridors that are upwards of 20, 30 gigawatts. And so, this is why we began the day with the discussion from Energinet. We didn't get into this, but we've heard discussions of a 10-gigawatt substation south of Hamburg in Germany. And we've heard these different discussions as they're developing. And so, I would really like to frame this discussion as: this is what we're thinking about and that today is a kickoff to a longer discussion. And we're excited to introduce to you several models that we've been developing over the last several years to handle the national question, the local questions, and the regional questions, together. And we are hoping that these models will find themselves in the service of the public sector, of decisionmakers. And that we are hoping, truly, in terms of the name of this workshop, to help the visualize the technology-policy interface. There's discussions about the legal frameworks, there's discussions about precedent, there are discussions about the need to think about things in a new way. And we believe that the ability to visualize these systems, these yardsticks – this idea of what are the scenarios that we're talking about – is going to help stimulate discussions. So, with that said, I'll ask Jim, and then Cornelis, and Johan, just to introduce themselves briefly and then we'll move into Jim's presentation.

**Jim McCalley**
Yeah, I'm Jim McCalley I work at Iowa State University, so I live over there. I grew up in Georgia and professionally spent five years on the West Coast. So, I'm happy to begin learning about the Northeast.

**Cornelis Plet**
My name is Cornelis Plet. I go by "Cees." I lead DNV's Power System Advisory group in North America. I'm based in Toronto, but I'm originally from the Netherlands. And I'm an enthusiast of all things HVDC. So, take my words with a pinch of salt.

**Johan Enslin**
Johan Enslin, I'm a professor at Clemson University. My accent is deep South.

[audience laughter]

Deeper South, actually. But anyway. I'm from South Africa originally. But, I do work most of my career in power electronics, integrating to the grid, including HVDC from South Africa and the Netherlands. We actually shared a company, at one stage. He just was much later than I was at KEMA. I'm a professor, for last 12 years now, in the U.S. But I'll talk a little bit about HVDC. Thank you.

**Moderator**
Thank you. One more comment before Jim takes the podium. I will say that we have looked long and hard to find this team and this panel sitting in front of you and they're all quite modest. But I think that this is really a very special group of people to be able to come together and knit together the power systems view, as well as the HVDC view. And everybody's coming from real experience. Jim has really been at the center of a lot of the work going on in MISO, and in the middle of the country, and bringing

these perspectives from other regions to New England, where our grid is so much of an organism that we sort of stand there and behold it and imagine these smaller injections. But now, we're about to do something with levels of power that we've really never contemplated in this part of the country. So, we're very grateful to have these perspectives from other regions and other parts of the world. Jim, I'll leave it to you to start the presentation.

## Panelist 1: Jim McCalley

**Jim McCalley**

Okay

[Appendix C – slide 1]

Yeah, so, grateful to be able to work with Eric and Per-Anders and Bobbi, Rebecca, and Emma, Julie. It's been wonderful. A lot of great interactions going on. Clemson folks are also just an integration of strengths here. And I have to recognize Ali and Abhinav – sitting at the back – have been instrumental in developing a lot of the results that you'll see here. I'll say a few things about assumptions behind the talk that I'm giving right now. And then, Eric mentioned these three transmission models. So, I do want to give you some insight about those and a few takeaways. So, if I can do that in 20 minutes, and if I don't, shoot me, and go to the next person.

[Appendix C – slide 2]

The onshore power system is the focus, here, of my discussion. We're talking about, you know, higher offshore wind. We're not talking about 30 gigawatts, but in the realm of 70 or 80 and upwards, is the focus as Eric mentioned. The assumption here, as the cartoon suggests, is that we'll have opportunity to develop a kind of a backbone transmission system. And we're thinking Maine to the Carolinas. It may not be – that corridor, itself, may not stretch that distance. But we're thinking about the onshore grid in that context and we're not asking the question: what can the grid do today? **But we're asking the question of: how do you achieve a certain target level of offshore capacity at the least cost?** And finally, again, it's already been mentioned, the single source contingency limit we recognize as an important metric for the Northeast, and there's good reasons for it. We think that you can design facilities in such a way to reduce that risk significantly. And if you can, then you can start to talk about six-gigawatt level POIs. So, we're sort of extending that limit. And have chosen this number as a reasonable number to think about in terms of identifying POI capacities.

[Appendix C – slide 3]

So, there's three models that I want to describe to you a little bit. Spend quite a bit of time on Model Number 1, I'm going to call it. And it is using a 93,000-bus Eastern Interconnection power flow model. And so, this is standard fare for what the industry uses. Representing a single snapshot in time: summer peak condition in 2031. So, you know, that's a limitation. We're not looking, in this model, over the course of many hours, of many days, of many years. And then, contingencies are included here. We're looking at normal conditions as well as n-1. Not n-1-1, though we can do it. And the method is optimization, but heuristic. So, I'm not using an optimizer – a formal optimizer – in this process and you'll see that in just a second. 13:12 The objective here is to identify the POIs.

Model Number 2 is a much smaller model. 720 buses instead of 90 something thousand, right? And we're looking at just one region. The model is smaller, not because we're looking at just one region, but because we have heavily reduced it. And the conditions in this case are much greater. It's looking at 2031 to 2046. 17 conditions per year. It's a representative set of conditions. So, there's a total of 255. So, you see the kind of trade-off that's going on right now, right, between Model 1 – a very detailed network model – and Model 2 is a higher-level model, many more conditions. And this is a formal optimizer. And the objective there is to identify POIs as well. And, in addition – although I won't show you anything about this part, today – we want to use it for the offshore transmission design and think it'll be very helpful in that direction.

Model Number 3, you see the number of buses is much less, but the geographical scope is much greater. It's a national model. We're interested in modeling the Eastern Interconnection and the Western Interconnection, together. Texas is not in there. And you think, "well they're not interconnected." Well, they are interconnected with a few DC threads that sum to about two gigawatts out of 1100 gigawatts capacity today in the United States. Two-gigawatt capacity that connects the two grids. So, there's no significant amount of interconnection, there, between those two grids. But we're modeling them anyway because we want to study the question: what if you do interconnect them in a substantive, high-capacity way? So, we're interested in studying what we referred to – and has been referred to this morning – as the macrogrid, MG. And it is a formal optimizer, as well. We're looking here, not at identifying POIs, but trying to say something about the relationship between offshore wind development and the national grid needs and the national energy requirements, and so forth. We want to look at that interaction.

[Appendix C – slide 4 – title]

I'm going to just go from there into the takeaways of the discussion. And I might go a little fast here on some of these things.

[Appendix C – slide 5]

So, if we have questions, we can come back to this this afternoon, for those of you who will be in the workshop that will be discussing this. So, here's a comparison, just for the ISO New England area, of the two models: Model 1 and Model 2. So, what are we doing here? **We're trying to identify the least-cost way to interconnect 20 gigawatts of offshore transmissions.** So, the number 20 gigawatts is a chosen number, for some reason. And Model 1 is identifying these POIs as the ones to interconnect with, in order to minimize the overall cost, where the overall cost is including the substation expansion costs, the onshore transmission costs, and what we refer to as the "reach circuit" costs, which is the cost of bringing from land to the POI, the cost of that transmission. It's not addressing the cost of the wind or the offshore transmission grid, right? And so, Model 1 gives us the answer that you see there: Millstone, Woburn, Maguire Road, Carver, Card Street. These are meaningful to people, I'm sure, that have studied this.

Model 2 gives a similar answer, but not the same – there's some differences, and there's some reasons for those differences. On the map, you'll see the red stars [are] Model 2. That's the small 700-bus model. And Model 1 is black dots with numbers in them. And you'll see that they do overlap in the first three POIs. And the other ones that are different – like, for example, Carver versus Canal, West Barnstable, are different – but you can see that they're all in the same area. So, we're definitely seeing some differences. The models are different – different sizes, and so on and so forth – but yet they're also telling us something similar. So, I'll be interested, if the ISO New England folks come walk up to me after the talk and say, "well, what about… ?" And I'm sure there's room for that kind of discussion. But a similar thing can be seen here, in the bottom two. You have Card Street, chosen by Model 1, and then the other one is Haddam, here. And so, there's, again, differences but similarities. That's a good thing, we're interested in that and – yes?

**Audience Member**
What are the blue marks on there?

**Jim McCalley**
So, these are the POIs that were considered. Thank you. So, some 15 or 20 different POI candidates that were considered in the in the process. So, the takeaway here is not a huge one, it's just to say that the result of the modeling seems to be consistent. That's not an absolute stamp of approval, but it's a suggestion that we're sort of in the right ballpark here, which is good thing. Another interesting feature is that the flows on this system – in this case that we modeled – tend to be, you know, from the north down to the Boston area and the South. And that becomes interesting in the next slide.

[Appendix C – slide 6]

So, here's the problem that Model 1 is solving. No mathematics here, I'm just going to tell you in plain English. Given a target level for a particular region – in this case, ISO New England – select the POIs and the capacities to minimize the cost of these four things. This reach circuit is the concept I mentioned earlier. It's the interconnection from landfall to the POI. And typically, we think of that as an HVDC interconnection. It's part of the multi-terminal DC grid. So, we also have this constraint: less than or equal to six gigawatts. And we have to satisfy all the power flow constraints under normal conditions as well as contingency conditions. A little bit, maybe, detailed here, but the process is an iterative one. And we're using this commercial grade tool called "TARA." Some of those people here in the room that are in the planning environment know about this tool. Very widely used tool. And then we run some homegrown code to assess that in an iterative fashion to identify the next least cost POI. The solution is the result of that effort. It's an interesting process, in the sense that it very much involves an engineer – a human decision maker – to understand the results as they come out and make good decisions associated with them. And I can talk more about that later this afternoon.

[Appendix C – slide 7]

Okay, busy slide here. Here's the result of this, having done it up and down the East Coast. ISO New England, New York ISO, PJM, and the South – basically, the Carolinas. The target values of capacity are there on the left. So, there's the one that I've been talking about a little bit about, in ISO New England. And then we have New York ISO, PJM, and the South Carolina / North Carolina area. So, this is a result of that iterative, heuristic optimization process that I mentioned. Kind of an interesting feature is that the process is sequential. So, you choose Millstone as the most attractive POI, economically. And then you go to the next most attractive. And we get an average cost per megawatt out of each one of those iterations. And it's interesting that the second chosen one is less than the first chosen one. This is a result of the reality that when you model four gigawatts at Millstone, because it's more in the south, it offloads that transmission that's seen by Woburn, and as a result, reduces the cost. And so, that's an interesting feature of the process. There are additional interesting features of the process that you get when you start interacting with it in an intimate way. Summarizing the cost numbers associated with the process. In ISO New England, we're figuring about $10 billion. New York: $16 billion. PJM: $18 billion. And the South, almost $5 billion. And it sums to a number that's easy to remember. And that is $50 billion, and it's probably low. So, I'm going to suggest this as a lower bound to achieving a 76-gigawatt design on the East Coast, in terms of the interconnection cost. Again, I'll emphasize: it's probably low. Whenever I do this kind of thing, first time is always low. $60 billion might be a little better – and it may even be a little more than that – but it gives you a ballpark feeling of what this kind of effort would require.

[Appendix C – slide 8]

This is in the folder that you have. So, I'm not going to say anything more about it. But it's interesting to look at the layout of all of these points that were identified in this process.

[Appendix C – slide 9]

One more communication that I want to make is regarding this Model 3. We've talked a little bit about this macrogrid idea. And so, here's the network model that we're using. It's 176 buses. This is a tiny number for modeling the entire United States. But, it's a reasonable model – a reasonable capture, at this level – of the western grid and the Eastern Interconnection. It is a so-called co-optimized expansion planning model. It's an LP optimizer. So, it's optimizing both generation resources as well as transmission investments. This is what our latest design for macro grid – we've been studying this for 10, 15 years now. And this one looks like there's some very strong reasons to feel like it's a very attractive design. This is a high-capacity HVDC interconnect that is clearly spanning multiple regions. So, we call it a multi-regional – not interregional, right? – a multi-regional transmission grid. The model that Abhinav uses here is going to build HVDC capacity in this topology if it's economic to do so. So, in other words, if it lowers the overall cost to spend the money on the macro grid, then it'll do that. And so, we see that it is indeed attractive from an economic point of view, in that sense. It builds on the order of 20 to 30 gigawatts per segment of capacity, which is significant. Benefits – the reason why it's doing that, the reason why it saves money – are basically two: because it's allowing / enabling multi-regional sharing of, not only energy, but also the services associated with energy, the ancillary services. And then, second, it is relieving the underlying AC system. This is a huge issue of relieving the underlying AC system. It's effectively buying you AC capacity at the expense of HVDC capacity on top.

[Appendix C – slide 10]

And there is a huge significant thought there to consider when you're thinking about offshore wind here on the East Coast. So again, it's a co-optimized model. It's doing both resources and transmission. So, this is the resource in 2050 that Abhinav found, the resource distribution. So, an interesting thing from this distribution, that you can see right away, is that offshore wind is not a huge component of the overall – at 85 gigawatts – is not a huge component of the overall national portfolio of resources. And it's a significant component for the East Coast, no doubt. But think nationally. It's a slice – it's a relatively small slice of the pie, something on the order of 2.6 percent of the 3100 gigawatts that are necessary in 2050 to do this. 3100 gigawatts. And if that number is not in context for you, currently – I said it before – we're at about 1100 – a little more, 1150, maybe – gigawatts of capacity in the US. So, we need to approximately triple that in order to use wind and solar in order to supply our energy needs, right? And if we do that, then 85 gigawatts will be about 2.6 percent of that U.S. national portfolio. That'll be 9, almost 10 percent of the capacity level associated with the needs of the areas that I'm studying here. So, it is locally significant, for sure. But the takeaway here, if I could say: nationally, it's small. Eric mentioned, we really are interested in looking at larger numbers here, beyond 85. And this is the reason. 100, 150, 200 is kind of a target that we think we might be able to do here in the next few months.

[Appendix C – slide 11]

The other thing that I mentioned already – and this is the last statement of my talk – this is a very small little carve out of Abhinav's result. When you model the offshore wind up and down the coast here, at 85 gigawatts of offshore wind, with the macro grid, you get about 100 billion dollars of line investment cost in the Eastern Interconnection. And without this macro grid – which, of course, spans to the West Coast – you get about $150 billion dollars. So, what's that saying? It's saying that when – it should be obvious in some sense – when you build this high capacity, multi-regional, transmission grid, you enable a lot of those underlying flows to move up to that HVDC grid, which frees up the underlying AC transmission system that is needed in order to handle the interconnect from the offshore wind and the load centers. Now, you can look at this – it saves me, you know, $46 billion – think of it this way: instead of 200 reinforcement projects, you got 40 or 50 or 60, in order to handle 85 gigawatts of wind. Every single one of those reinforcement projects is going to require multiple engineers over multiple years to think through it and deal with it, and I can't even think about how to articulate the loading on the regulatory system of all of those reinforcement projects. I don't know if you can see it, but I've tried to get a cartoon here of what I'm talking about. Here's without the macro grid, all of those little red lines. And here's with the macrogrid. You still have AC transmission to reinforce, but it's a lot less. There is real value in that. And of course, the trade-off is that then you've got to design and build this high-level transmission system. But my argument is that – and this is a discussion that we can have – the argument is that it might be easier, logistically, to build this high-level system, than it will be to build all of those smaller reinforcement projects. And if we can make that argument at the federal level – which I think needs to be involved here at this kind of macro grid project – I think it'll play well.

[Appendix C – slide 12]

So, the takeaways are summed here. Good modeling – I think we're doing good modeling. And $50 billion is sort of a lower bound for what 76 gigawatts of wind might cost, in terms of interconnection. We're aiming for a 200-gigawatt target, eventually, to study. Maybe we need to go to 300, I don't know. And the macro grid reduces offshore wind transmission.

[audience applause]

## Panelist 2: Cornelis Plet

**Cornelis Plet**
Okay.

[Appendix C – slide 13]

Thank you for that super interesting and inspiring presentation. I'm here to talk a little bit about multi-terminal HVDC technology. Professor Hines asked me, "can you say something about [the] maturity of multi-terminal HVDC technology?" And that's, kind of, answering the question that was posed earlier to the gentlemen from Energinet. Is multi-terminal HVDC technology – which a lot of those plans are based on – is it ready? Can you buy it? And I'm here to tell you that the answer is yes. But it depends on what you want to do, for the moment. I want to explain that by basically tackling those three words: **expandability**, **compatibility**, and **interoperability**, which are characteristics for HVDC systems to be able to be expanded into a multi-terminal system. But before we do that, I will say a little bit about what a multi-terminal HVDC system is, what the differences are. I'll explain a little bit about why it makes sense to use them. I'll give you some oversight on what the status is, today, of multi-terminal HVDC technology and then explain where we need to go, in my opinion.

So, as we probably all know, HVDC is the technology of choice for high-capacity and long-distance transmission. So, whenever you want to go more than 60 miles (if you're using cables) or more than 400 miles (if you're using overhead line), AC stops being technically and economically feasible and DC is the choice to go forward. And today, there are many HVDC systems in operation in the world. More than, I think, 140 gigawatts of capacity – probably significantly more than that. Most of those systems are so-called "point-to-point" systems. So, we have a DC transmission line with, on either end, a converter station, or a terminal, that converts AC to DC and DC back to AC on the other side. We can use those kinds of systems to realize the macrogrids. We can build many point-to-point HVDC systems, and it will work. It is not the most optimal way of going forward. And this is why, for example, the grid planners in Europe, like Energinet and TenneT, are proposing multi-terminal HVDC systems.

**Expandability:** What happens in a multi-terminal HVDC system is that, when you have more than one DC line, you connect them on the DC side, rather than on the AC side. What's very simple about that is that it allows you to skip at least one converter station, which saves cost, it saves you footprint, which – especially in Europe, but also here on the East Coast – can be a significant barrier to building new equipment. And importantly, it also saves a significant amount of losses because if there are power flows going from one DC line into another DC line through two sets of converters, through an AC link, you incur, let's say, one and a half percent loss, which you could avoid by using a DC connection. And that adds up over the lifetime of an HVDC link.

Different kinds of multi-terminal grids can be built. The simplest version is what we call a radial grid. So, this is where the DC grid, itself, has a radial topology. So, it looks like a tree or a star shape. There are no redundant paths. So, that means if a fault happens in one of those branches, it will take that branch out and it will not have a redundant DC path to reroute the power flow. A more complex version is what we call a meshed HVDC grid. So, this is where, on the DC side, we create DC connections that enable a redundant power flow path in case one of the links is out. But of course, in this case, we need to start thinking about: how do we disconnect the faulty path, using things like circuit breakers or other types of equipment?

One thing to note is that one of the disadvantages of DC is that we don't have DC transformers. So, in a DC grid, you just have one voltage level. Also, HVDC circuit breakers are not quite the same as they are in [an] AC grid. In an AC grid, they are quite compact, very mature, not so expensive equipment, which means that we can afford to put them at each line end, or each terminal of major components to realize protection and achieve this on-the-fly redundancy. HVDC circuit breakers, then, do exist. But they're significantly larger, significantly more expensive, and therefore we need to think differently about how we use them. And this is what is the discussion in meshed HVDC grids, where we typically don't try to put HVDC circuit breakers at each line end – it would get way too expensive – but in strategic locations, to make sure that, in case we have a DC fault, we can split the grid into different parts to make sure that we do not exceed the most severe single contingency of the connected AC grids. So, the function of an HVDC circuit breaker is not to protect different components in a DC grid – like AC circuit breakers really do – but it's really there to protect the AC grids that are connected to it from losing too much power infeed. So, that's a different way of thinking.

We see many opportunities for multi-terminal HVDC grids – especially in Europe, several developments are on the way, in places where, for example, the offshore wind that is being generated in the

North Sea comes onshore, and when it arrives onshore, it still needs to travel further to the load, which is quite often further down south. What we see happening is that different DC projects were being planned for this – one to bring the wind onshore and then another one to bring the wind South – which, the grid planners are now realizing, we can actually connect these on the DC side. So, the first multi-terminal plants are being realized that way.

And so, this is to say that multi-terminal technology is happening. Multi-terminal HVDC grids are being built – in fact, they have been in operation for a while, already. The first multi-terminal HVDC grids were being built in the late '80s. One of them is right here in your backyard, going from Quebec to New England. But these were based on a different technology: the LCC converter technology. The problem with this is that, to change the direction of power flow in a line, when you use this kind of technology, you need to change the polarity of the voltage. That makes it complex to decide: where does the power flow to in a grid like this? Now, LCC converters are basically on their way out, and being replaced by –

**Moderator**
Can you define what LCC is?

**Cornelis Plet**
My apologies. "Line Commutated Converter." So, this is a type of converter topology, which is based on a power semi-conductor called the thyristor. One of the defining characteristics of a thyristor is that you can switch it on, but you can't switch it off. You need to wait for the voltage on the AC line to change polarity – go from plus to minus – and it will then drop out of conduction. Hence, it's called a line commutated converter. And one of the disadvantages of that is that it creates a lot of harmonic distortion and produces a lot of reactive power, which means that you need to put a lot of equipment in place to compensate for that. And, because of those disadvantages – and new technology is being developed, or it has been developed, called voltage source converter (VSC). This is based on a power electronic switch, typically called an IGBT, but there are other versions as well. And this one, we can switch both on and off, and that allows us to basically create AC waveforms with negligible harmonic distortion. It's compact. You can create an AC grid with it, as in, you're not dependent on an AC voltage to be present but you can use it to create an AC voltage. For example, connecting an offshore wind farm or for connecting remote offshore loads. And the good thing about this technology is that we don't need to change the voltage polarity to change the direction of power flow in such a system. This makes it very suitable for building multi-terminal HVDC grids. In fact, several are in operation today. In China, there are four multi-terminal HVDC grids based on this VSC technology in operation with

HVDC circuit breakers. And one of them is even of the meshed kind. So clearly, technically, it's possible.

Also, in Europe, there are several projects being built today. So, one project is the Caithness-Moray link in Scotland, which will hopefully come online next year and be the first multi-terminal VSC system in operation. The system does not have a DC circuit breaker and all converter terminals are supplied by the same vendor. And I think that is probably the most important thing to mention: multi-terminal technology is ready from our western suppliers, let's say, if you just have one supplier. Out of all the suppliers that are there, there is one that can also deliver DC circuit breaker and I will get to it in just a moment.

There are a few things that we can do to be ready for the future, and those are the expandability, compatibility, and interoperability aspects. So, let's tackle the first one: expandability.

To make a multi-terminal grid, one of the very first things that you need to make sure is that you can, physically, make a connection to the DC system. And that's not a given. So, most point-to-point links today are designed as point-to-point links, and not – they don't have the physical connection points to be able to connect another circuit. So, in order to do that, you need to have a DC switchgear and instrumentation in place, a route for a cable or an overhead line to actually get in there. And that's really one of the prerequisites. It doesn't really matter whether it is AC or DC, in this case. You need to have an expandable system. So, this needs to be a requirement for DC systems going into the future, to have that option and maintain the future value option of being able to expand something.

Now, that then brings us to the second point: compatibility. **Compatibility** is really about aligning the physical aspects of different DC systems. So, for engineers, it's very clear that you cannot connect different lines that have different voltages, for example. So, if we want different DC systems to be connected into a multi-terminal system, they need to have the same voltage rating. There are other aspects, like, for example, the converter configuration. Are we using a monopole or a bipole? Are we using a return or not? How is the earthing point realized? What kind of operational configurations should it be operated in? And, very importantly, how are we going to deal with faults in the DC grid? Are we going to use HVDC circuit breakers or not? Are we going to use fault blocking converters – full bridge converters, which is another option of dealing with DC faults? Those different choices need to be aligned with one another, to make sure that we can build a multi-terminal grid.

And this is really where the difficulty comes in. We can probably align on voltage levels, we can probably align on converter configurations, but it becomes trickier when you start talking about how do we earth the system? How you earth a system is typically something that has been developed by different OEMs. They all have to have different patent bases. They are not necessarily compatible with each other. And if you, as a buyer, go out and say, “hey, I want to have this specific earthing system,” you might not be able to buy it from all the different vendors, which means that you have a less competitive offer, basically, coming into your procurement. So, that's where work is needed to make sure that we can have physical compatibility. When it comes to HVDC fault clearing, are we going to use full bridge converters, or DC circuit breakers? What kind of DC circuit breakers? How many? Where are we going to place them? This is something that, I think, is still quite in the academic domain. There's no clear reliability standard, for example, that tells us how available should an HVDC grid be, under what conditions? What fault should it be protecting against? This really needs to step out of the academic world – where a lot of work has been done – and be taken into the planning procedures and planning programs and documents that the TSOs and ISOs use. This is one of the things that, for example, the gentleman from Energinet was referring to earlier: the North Sea wind power hub. They started making the first steps to get such standardization out there and also accepted by the other system operators. So that's about compatibility – physical compatibility between different DC systems, where we are probably not quite there, if we're talking about systems of different vendors.

And the last point: **Interoperability** – and I always try to separate those two – is really about the functional interoperability. So, even if we specify converter stations from different vendors with the exact same physical specifications, it doesn't mean that they will work together. It doesn't mean that they can communicate with each other, which they need to do to be able to control the inputs and outputs. It doesn't mean that they behave in the same way under dynamic conditions. And that's really where this topic of vendor interoperability is the most pronounced and the biggest challenge. And that's what this project that was also earlier referred to – InterOPERA – is trying to address.

So, if you ask me: can we build multi-terminal grids? From an expandability perspective? Yeah. And it's up to grid planners to take a role here to make sure that we build expandable systems. Also, trying to make – as much as possible – choices to take control over the physical attributes of HVDC systems. So specify the converter configurations, voltage levels – not just a rated voltage, but also what could be permissible over voltages and for how long? All of those aspects to make sure that whatever we build now can be physically compatible with future expansions for HVDC grids. So, that's a maybe.

And the last point: vendor interoperability. Again, the Chinese systems, they are all multi-vender systems. So, also, that is possible. It's all about IP, about liability, about: How do we exchange information? Who is responsible for paying what, if something does go wrong? So, it's really more of a legal issue, in that sense, than a technical challenge. So, again, one of the things that the InterOPERA project is trying to tackle – they have one workstream dedicated to: how you do this from a legal perspective? But it's not an easy discussion.

I also wanted to mention that there's a lot of discussion here in the U.S. on expandability. For example, in New York, we have the meshed-ready requirements. In New Jersey, we have the offshore-transmission-network-ready requirements. Those are not multi-terminal HVDC grids. They are an AC connection between different DC grids. And, in my personal opinion, it's a missed opportunity that there isn't a little bit more attention given to defining some of the DC characteristics. Because it also means that we can't coordinate the planning of different DC links.

For example, in New York, there's going to be a situation where we have Clean Path New York, the DC link that's coming in from upstate. The Champlain-Hudson Power Express, which is also coming into New York from Canada. Then, the Beacon Wind, which we saw earlier, also coming into New York from somewhere north in the coast. And very soon, whoever wins the New York offshore wind solicitation, also has to use HVDC. Those onshore converter stations are going to be in spitting distance of each other somewhere in New York. There are probably conceivable configurations where you actually connect those on the DC side with each other, get more functionality with fewer converters and with better performance. And right now, these different lines can all have different configurations, different voltages, and will not have that option to be connected in the future. So, something to keep in mind for the grid planners around us.

So, coming back to, basically, my conclusion on this story: is it possible to build multi-terminal systems? Yes, it is. Today, if you go to a single vendor – even including DC circuit breakers – in anticipation of solving the challenges around multi-vendor interoperability, there are a lot of choices that you – as a buyer of HVDC systems, or as grid planner – can make to make sure that you are multi-terminal ready. And in Europe, at the moment, about 20 projects like that are in development, that have these multi-terminal readiness requirements being implemented, to make sure that at least we maintain the option value of connecting things into a DC grid in the future. Thank you.

**Moderator**

Thank you, Cees, and thank you for providing us that confidence and perspective from Europe that this is indeed happening. It is available. But the question is: how do you do this in the U.S.? And you've got to have interoperability and you've got to have a supply chain. We're going to need our own supply chain, which is a very familiar drumbeat, I think, in this industry in the United States. So, I'm going to turn this over to Johan, now, who is going to focus on the U.S. and: how do we do this in the United States?

## Panelist 3: Johan Enslin

**Johan Enslin**
Thanks, Eric. Next slide, okay.

[Appendix C – slide 14]

Right. So, good afternoon, everybody. As I mentioned, I'm from Clemson University. Moazzam Nazir is also from Clemson. [The] two of us were, sort of, the go-to guys for looking at the technology, at least, for this project. We have a great team. Eric and Jim already mentioned the team. I want to do the same. I think this is this great team to work with. All the high diversity parts of it make it very nice to work with.

[Appendix C – slide 15]

I do want to talk a little bit – it's nice to speak third, because you know whatever people spoke about. So, I do want to expand a little bit on this macrogrid idea. I think it's absolutely needed to have a sort of standardized interoperable standard. The multi-terminal readiness, which Cees mentioned, is fundamental at this stage. If we make that decision now, it's going to save us billions in the future. But I do want to talk a little bit about the readiness – maybe some duplication of what Jim said – and I want to focus a little bit longer on the project which we worked on: this so-called two-gigawatt standard. You know, we looked at, from our literature, what's happening in Europe. We looked at all those standards, and what they are focusing on to try to get this multi-terminal readiness network. And I think there is, really, a lot of good work which has been done in Europe, which I think we can definitely benefit from. I have some ideas about this multi-terminal grid – at least starting where we are now on the 76 megawatts. And actually – maybe more for this afternoon – I do want to discuss: what is the future for research and especially capability goals? For the US, not Europe. All the national labs, all the research activities, all the centralized activity around HVDC is in Europe or in Asia. It's not here. So, I think it is very important for us to get localized OEMs – even General Electric is not manufacturing their DC technology here, it's elsewhere, right? Which they bought a few years ago.

[Appendix C – slide 16]

But why do we need this backbone? I think Cees mentioned a lot of these. But the point is: we have to. We have no option. There must be a macrogrid built across the United

States, which will, basically, interconnect the new grid and make us ready for this fourth industrial revolution. It's going to be end-to-end electricity – you know, from your car you drive this morning, until your air conditioning you turn on at night. All of that's going to be electric, right? So, it's really that, this expansion of the grid is not just a fake idea. This is really happening. We need that macro grid as a super highway to really interconnect load and these generations of the future. We have 1.3 terawatts of interconnected generation right now, right? [It] all has to go before 2050. [It] all has to be replaced. All the nuclear – 104 gigawatts of nuclear – has to be gone. It has to be replaced – maybe with new nuclear – but it can't operate another 60 years. We have all the wind and solar – just saw the numbers from Jim. So, it is basically no option. And it is the lowest societal cost – and I think that's the bottom line here – it's the lowest societal cost to do the energy transition with a new grid. There's just no other way. We can talk about this a lot, how to integrate hydrogen – a new hydrogen economy is coming as well. I am glad to see some of the discussions this morning about what's happening in Europe with Energinet. The utility of the future is going to have hydrogen. It's going to have, maybe, natural gas, and it's going to have electricity. And natural gas is going to be replaced by hydrogen in the future. It's happening. So, we do have to see these things in a bigger picture when we talk about it.

[Appendix C – slide 17]

I'll come back to our own project. And, you know, this was one of the earlier slides where we just started sort of pulling down these BOEM areas, Eric did. Looking at, just on the East Coast, what's happening.

[Appendix C – slide 18]

And it may be 100, 150, maybe 200 gigawatts, but we have very few – this original slide came all the way from Boston / New England, all the way down to South Carolina, right? And actually, I like this picture a lot. Why? Because it shows ten interconnection points, right? So, if we look at all these thousands of lines going into the grid, it's just not feasible. We actually have to grow these points of interconnection to actually about 10 or 20 major interconnection points. Because that is what we need. Now, what will this buy us? We will buy, basically, a grid, which gives us the way to use – first of all, capacity factor, right? Capacity factor of wind is 40 to 50 percent. So, if we look at capacity factor, we overbuilt our transmission networks 100%, at least, because we can't use the capacity factor. If you build a line-to-line point-to-point connection, you have to overbuild. On top of that, you have, you know, seasonal, but you also have changes during the day and nighttime. So, utilizing a backbone grid for – I think somebody said – not just for interconnected generation, but basically use that as a bypass for your regular transmission grid. Really important piece of discussion there.

[Appendix C – slide 19]

So, this is an earlier picture from Jim, which shows that overarching HVDC grid. Yeah, maybe 10 or 20 of those major interconnection points – not at two gigabytes value, it may be 10, it may be 20 gigawatt interconnection points – we will really redesign this overhead grid.

[Appendix C – slide 20]

Focusing a little bit on the standard. So, we have to start somewhere, right? So that's bigger picture. Where do we start off with? Now, this is what the guys in Europe have come across and I show you some of these pictures to give you an idea of the size and the feeling of these offshore platforms. So, this is one of the offshore platforms, which do AC to DC, right? And they interconnect pretty much all the AC lines – the so-called connector systems of the wind farms – and they convert it into DC and to the underground cable –525 kV DC – and you can build this cable pretty much as long as you wish. You can interconnect on the DC side with DC breakers or DC switching stations. So, there's actually a lot to be done on the DC side with circuit breakers, switching stations, and maybe underwater switching stations. Why do we have to build it on platforms? Can we build these very highly integrated underwater switching stations? Which I think is possible. There are some researching it, but it really needs to be developed. I mean, if we look at onshore voltage source converters, now you're talking about a grid which [has], basically, [the] capability in that onshore space to do grid stabilization, to do all the ancillary services. So, you have a win-win situation. You can share capacity. You can actually build stability on the grid. And, by the way, you can, maybe in the future, build this stuff underwater and not in platforms.

[Appendix C – slide 21]

So, let's continue on this. The two-gigawatt standard goes into a way to build in natural redundancy in the design. Why do I say that? Because the so-called bipole design means it's a positive and a negative pole, and it has a natural reliability, because even if one of those lines are off, you basically have, still, some connectivity. So, you build into the cable, you build into a converter station, already, that resiliency and reliability number. So, these are a sort of a standard, which I think we spoke about, where you have multiple vendors, which you can actually build to one single standard, and they can know that these will operate together in a larger grid. And, thinking in the future, maybe having those switching stations as part of the cable. Build those switching stations in the cable rather than on platforms.

[Appendix C – slide 22]

Right. So, how would we do this? First of all, I think it has to be a standard where we can interoperable these different technologies, but also make it future proof. So, if we build one HVDC line today, we will probably want to build it point-to-point and have AC breakers – the green ones are AC breakers – which basically connect both sides: the offshore side and the onshore side – connect that interconnectivity, but, basically, with AC. It's not ideal, but it's a start. And then we can actually start this process and have a process of actually moving this forward.

[Appendix C – slide 23]

Obviously, the next step is to actually keep that AC breaker technology, but build the interconnections, now, on the DC side. And there we do need the breakers, we do need DC breakers, and these can actually now be built much longer. We can actually build reliability in that backbone to actually move power from north to south and vice versa. So, there's much more diversity in that.

[Appendix C – slide 24]

We started off with a first 30-gigawatt project up on the northeast, right? So, out of that, we got a few standards, which I think, for the U.S., make sense. First of all: voltage level. I think it was discussed – we don't want to have different voltage levels. We have to standardize the voltage levels. 525 [kV] is the international standard we can go on. I think, from the offshore platforms, the TenneT type of two-gigawatt standard right now is probably the best option. In the future, I would like to see that standard go to four gigawatts, maybe even to six gigawatts, which Jim mentioned as the ideal number for our interconnections. And then eventually, what is the price of this stuff, right? So just to give you an idea – because this is new, right? We have two or three of these terminals worldwide, really, in operation. So, the tag right now, the price tag of those things: about 1.5 billion dollars, right? So, what do we need to do? We must build more of them, get scale. We must make it cheaper. We have to make it more cost-effective. So, there's a lot to be done here. But we have to start somewhere, and I think that is what we're trying to show you.

[Appendix C – slide 25]

You notice how the 76 gigawatt one, which is in your brochure, which tells you a little bit: what are we talking about? There’s a bunch of these connections – both on the offshore side, but also on the grid side – and right now, if we don't do a lot of these diversity calculations and so on, we’re talking about around 40 onshore and 40 offshore platforms for HVDC. So, these are a lot. So, we do have to be careful what we wish for. But if that is just assuming what the price is now, that is, maybe, some of the future prices. But in a more detailed design, we’ll probably want to use wind probability density, capacity factor, and decrease the number of platforms, decrease the power levels of each individual interconnection, just because there is natural diversity there already. And why don't we utilize it?

[Appendix C – slide 26]

So, I think I can stop there, Eric. I do want to focus on the research side, but maybe we can do that this afternoon.

## Q&A

**Moderator**
Thank you. We will pick this up this afternoon. We do have time for one question and we'll take your question. We're having a late lunch today, so I'm sure everyone's hungry. We have 45 minutes for lunch and we'll take the next five minutes with a question, and then we'll break for lunch, okay? Yes?

**Audience Member**
Hello to everyone. My question is, what is the best strategy, you think, for maintaining reliability when there are corridors – when there are single paths – that are carrying, say, 20 or 30 gigawatts of power?

**Jim McCalley**
I can give you a response to that. 20 or 30 gigawatts of power in a single path. What that would mean to me is that there's a single path that would be subject to a single point of failure. And so, I'm thinking you're looking at the macrogrid and saying, "here's such a path." Yeah, so those designs, if you look at them carefully, they're using parallel paths of three. This is a very important feature, actually, and it's kind of a fundamental guideline in high-capacity design: design always independent paths of three.

So, for example, in this design there's an East Coast path, a West Coast path, and a Midwestern path from North to South. So, clearly, they are independent. You wouldn't think that they would ever fail together, so you need to design so that you could lose any one of those paths. And that you can do – if they are all approximately having the same capacity level – using a little bit of offloading, to begin with, and a little bit of emergency overload capability, after the failure. And of course, if you build parallel paths of four, it becomes even better. But then more expensive. And so, the rule of three is kind of suggesting that the most economic balance between the loss of the single path and the cost of the infrastructure comes in combinations of three.

**Audience Member**
And is there something similar for offshore wind connection points that might have as much as six gigawatts?

**Jim McCalley**
So, the six-gigawatt issue is, in my view, a little bit different. So here, this is getting at the heart of – and I'm not sure, it might have been the point of the discussion that we had earlier – but it's getting at the heart of the

single source contingency limit. That's really a major part, here, of the northeast that I think may be slightly different from one region to another – some of you can tell me – but something on the order less than two gigawatts. And so, we're saying six. There's very good reasons for that. If you don't take any action following the contingency, then I would not be surprised to see major voltage stability, major transient stability problems when you lose a two gigawatt injection and you don't take remedial actions. So, the keyword here is remedial action. And it's a fairly standard approach in the western United States to dealing with loss of high capacity single sources, where, what I mean is, the most common remedial action scheme is you lose a line and you drop the generator. So otherwise, if you don't do that, you have a transient stability problem. It loses synchronism. You have a major issue. So, you detect loss of the line. And within cycles, there's a communication and control scheme, which trips, let's say, one unit out of three in order to stabilize the remaining two. So, this is a typical scheme. Some people think it's a little bit risky, you know, because there's dependence on control and communication, but there's a cultural sense in the west, a historical sense in the west, that they're very effective. With appropriate design and operational oversight, they can be used with integrity.

**Moderator**

Okay. I'd love to continue this conversation. Let's do that after lunch, and we'll pick up on reliability in the technical session. There will be a policy session. Those are both on the second floor, and I'm sure there will be plenty of people to help you find your way into the session of your choice. So, please enjoy lunch and thanks again to our panel.

# 5 Breakout Session: Policy

*During this two-hour breakout session, participants continued discussions from the morning sessions, focusing on the policy challenges. The session began with each participant listing a point or question they would like to discuss. In order to protect the anonymity of the speakers, some sections have been removed or summarized. As a result, some sections have been reorganized so that the transcript is sorted by theme.*

Themes: Role of the Federal Government, Interagency Cooperation, Standardization, Offshore Grid, POIs, Cost

## Introduction

*Conversation began with participants bringing up issues they would like to discuss. Topics included main barriers and potential solutions, the role of the federal government, ways to change the current transmission procurement process, and discussion of risk.*

**Moderator**
I think we should go around the room and introduce ourselves, and just give a little overview of – a short overview of your focus, what you're interested in – because I think that'll help us, sort of, structure the conversation. And I just did have – it's a very basic, barebones PowerPoint, just thinking about things to structure our discussion. As you describe who you are, can you list a point that you really want to talk about today? Either based on the conversation we had or based on something that you're working on. And then we can make a list of the issues and start to see if we can unpack some things. So, that's a good way to begin.

**Speaker**
I guess if there's one question I would pose, it would be one that we continually run into, which is the tradeoff of dollars and risk. It's often left to the engineers. But I think it's fundamentally a policy question: how much risk we're willing to take. We will need to take risks to design a system this big. Big systems mean big problems. And it can be really expensive to insulate yourself from the big problems. We run into it at more micro levels now. But how are we going to design these systems where one bad day you could lose 6,000 megawatts of capability going into your system? And under today's system, you'd black out the whole Eastern Interaction, which seems like a bad day at the office. So, how do we manage that? And how much money are we willing to spend to protect against those sorts of things? And not that I expect the dollar value, but what process? Who should make those decisions? Should they be local? Should they be national? I'll tell you, if you do it locally, you're going to get a patchwork of stuff that doesn't match. It's going to be heterogeneous across lots of areas. And it's also going to take a long time, because a lot of local folks

don't want to make those difficult decisions. They want guidance.

**Speaker**
And, I guess, an area of interest: just curious what the role is that people see the federal government play in helping plan.

**Speaker**
I would love to understand more about the main barriers in this field and about its potential solutions.

**Speaker**
One of the things we always talk about is whether the size of your solution matches the size of your problem. And what struck me in all of the talks today is how our technological aspirations for where we need to go to get there are so out of step with our institutional and planning processes at the regulatory and decision-making level. And so, what I would like to talk [about] – what are the pieces we will need to build bridges to cross those gaps? What they will look like and how we could ensure that scholarship is targeted and helping give that kind of regulatory legal foundation for moving forward.

**Speaker**
And I've heard a lot this morning about the gaps. Adding on to what [a previous speaker] said, is what are the barriers to – how do we break the barriers down, for one? The time it takes to make things happen. And two, working together to make those challenges match the solutions.

**Speaker**
I think one of the topics I'm most interested in is understanding how a procurement, if it's – a lot will be competitively procured – how those can be defined to both meet what the states are doing – what the states want to see – but also create a manageable procurement process? To provide a specific example: [New Jersey's first procurement for offshore wind transmission] basically said, "We have a goal. We want you to propose solutions." And it led to bids for everything from couple $100,000 upgrades to the onshore grid to fully integrated multi-billion-dollar, multi-terminal HVDC offshore grids. And I think that was helpful in surfacing information. … But at the same time, I think it's created a bit of an unwieldy process where it was difficult for the States and PJM even to figure out: how do we evaluate these apples and oranges and Volkswagens? And selfishly, I think you want to enable innovation. But also, the more there are technical specifications, it just helps constrain and make the process more efficient.

**Speaker**
And it's interesting, too, because the whole issue of the procurement process – it has many different sides and levels to it. And now, of course, we're into a whole set of other issues of increasing costs. And how do you redo a contract? And all these other

issues. But I guess one of the good questions to ask is: is the procurement process that we're all part of the right procurement process for offshore wind? We went into it as a traditional procurement process. If we had an opportunity to either redo it or to revise it, what should be revised in the offshore wind procurement process, now that we've had the experiences that we've had up and down the seacoast? And that is a question that I'm really interested in, too.

**Speaker**
It's really interesting to hear the broader policy perspectives of how we see the overall planning coming together. I'm also very interested in the procurement conversation. So, looking forward to hearing from everyone else.

**Speaker**
What I'm interested – and I think it's brilliant that we're having, finally, this larger transmission discussion beyond just, "we're individual projects and we have to plug in." Really important. So, my question right now is somewhere between [the procurements we've discussed]. We have, on the one hand, upcoming transmission procurements for a planned transition. On the other hand, we have ongoing scheduled procurements for offshore wind projects that take many, many, many years to design and build. And at some point, we have to bring those together. And so, it's that interface between what we're trying to do right now, in terms of starting a planned transmission process, and how that interfaces with an ongoing offshore wind procurement process that we don't want to slow down – we don't want to stop – but somehow these two things have to come together in a way. So, how do we do that?

**Speaker**
I think all these questions are great. I'm fairly focused on: do we need a stronger federal role when it comes to offshore wind transmission? Do we need a federal transmission organization? RTO on steroids or Power Marketing Administration (PMA), an offshore wind PMA. I'm interested in how we accelerate permitting. Kelly's statistic in her presentation is disappointing, that these projects need 60 permits from 30 different agencies is – it's bizarre. I understand how we got there, but that can't stand. So, very interested in that. And the last thing is innovation. I see in the workshop title. There's so much innovation need in this space, and a lot of it happening. Are we finding it enough? And can we accelerate it and figure out how to get it into motion so that developers have these tools to cut costs and accelerate timetables?

**Speaker**
[I] fundamentally agree with the premise of the tagline of this [workshop]: no transition without transmission. So, [I'm] really interested in how to play a constructive role in approaching planned transmission in order to address permitting, mitigate environmental harm and risks, deliver

community benefits. It feels like the scale at which we need to try to move these things forward – we're trying to figure out how we can do that effectively all along the coast. I'm also interested in the idea of the federal role. Ultimately, our states are not going to – the idea of the feds driving this will not go down easily. However, the kind of push-pull of the specter of federal heavy hand can also be motivating for a region that is not planning very effectively. So, just sort of interested in what other regions are experiencing. Trying to understand how to use the opportunity we have before us.

**Speaker**
I'm interested in exploring what kind of policies or coordination framework can be flexible enough to accommodate different electric service models, more restructured states up here versus our vertically integrated states. As we move further down the coast, you have states that don't have any renewable mandates, or any real appetite for that. So how do we make this happen, given those things, is something I'm interested in talking about.

[conversational note: Alabama, Florida, Georgia, South Carolina, and Tennessee either have no renewable mandates, or have mandates that are so voluntary that they're meaningless. North Carolina and Virginia do have renewable mandates.]

**Speaker**
Although, one note is that all those states [listed above] raised their hand for the climate pollution reduction grants, which requires an inventory and targets for greenhouse gas emissions reductions. And so, I'm interested just to see – we're watching to see like, what are they going to say?

**Speaker**
One thing that I'd like to put in, is from the tip of the supply chain. This black line that runs down the East Coast, you know, represents thousands, if not tens of thousands, of kilometers of submarine cable. [One TSO's order can tie up a factory's cable-making output for multiple years.] I think what that shows is, keep going with the policy, but the practicality is tough. So, the gap between supply and demand is massive.

**Speaker**
My question is, who's the leader in the space? … What's transformational? How do we actually get more momentum behind the conversation? I think technical solutions are there. I think supply chain can be solved. But we need – again, I keep saying it: we need a path forward. And in my mind, it doesn't have to be a person. It could be a company or whatever. But who's actually going to make this happen? [On electric vehicles:] How are they figuring out their charging network? Well, there was a leader that said, "we're going to go with EVs." And it was a person, and it was Elon Musk. But

then some states followed and adopted, and, if not – demand was there to kind of create the supply chain. And now, hopefully, we will also get charging stations at work consistently, and there's enough there. So, I just point that out, because sometimes these things take leadership too.

**Speaker**
A big conversation point, earlier, was about inefficiencies in the process right now. So, how do we streamline? Where are the easiest places to try and get that more streamlined now? And in places where it's going to be a lot more difficult, what are the difficulties? And how do we start addressing them?

**Speaker**
I don't think technology is the issue. Planning it is part of it, but it's really: what are the policies and what must change, or has to be amended, or has to be adapted, to make it go? I think this can go, minus supply chain, and TenneT being the big gorilla out there, causing problems. But, what's the roadblock? What's the one that we need to go shift? And maybe we can't shift them all. But what are the first three steps that do it and keep it competitive? Because if it's not, it kind of falls back into – you know, what we'll say, the incumbent area. Also differences among states: one wants to burn coal, and one wants offshore wind. But there are the different policies. And how is it going to work throughout? Because if it's not done interregionally, it's just not going to happen. And I say this all the time: watching New England states is great, but it's putting, like, a family at an estate sale at the end. And who's making decisions? Who gets what? … So, who's the leader, as [another speaker] said. Who's going to push it? And does it need to be the government? Or does it need to be something that the developers could do on their side to push? But I don't think so, without policy change. So, what are the three policies we need to change to make it go? And did we miss the boat? Because at some point, you're looking at the Rhode Island leases. They're kind of consumed. And they're all going in, and they're all going to be a single export cable, right? So are we fighting a battle that needs to be fought further out? [unclear] Then again, there's some PPA discussions: do they get built? Do you really have it? How do you even achieve your goals right now? And then, the other big one is: how do we fix the Investment Tax Credit (ITC)? Because, for transmission to go, the ITC is one of the biggest holders. Because no one's going to take that burden on. Or I'd be impressed if a state takes that 30% burden on.

**Speaker**
[One] of the big issues that I've seen, or that I like to talk about – and I've already heard reflected upon today – is this issue of going from a small scale, community scale up to state and national transmission.

**Speaker**

Given what we've all said, there seems to be a range of questions about the first projects getting in, and then others about how do you get this to scale? And I'm wondering if that would be useful to have that first discussion and then going to broader topics as a way to go structure this. And it builds on your point of what do we do today?

## The Current Role of the Federal Government

*Participants discussed the current mechanisms DOE has, including the GRIP program and funding to work with national labs and stakeholders. In the past, DOE giving money to projects has been very effective, helping to motivate both states and developers. Participants also brought up the idea of a DOE study on the value proposition of an offshore wind grid, which was discussed in the next section.*

### Question: What can the DOE accomplish with the mechanisms it has?

*Either the mechanisms it has in pre-existing statute, or the mechanisms it has under the Infrastructure Investment and Jobs Act (IIJA), under the Inflations Reduction Act (IRA). And do we need different mechanisms? And if so, what are the implications of the idea that we need different mechanisms?*

**Speaker**

I think we should start with what DOE should do, based on the conversations of the various people in the room. What would be helpful? I think that's a really concrete outcome that can come from today's discussion. The other thing that I was interested in was the question that [another speaker] raised about risk and how we, as part of this, apportion risk today versus risk in the future. And that's another good question to think about. And finally, this notion of the offshore grid: Is this where we want to end up? I think that's a really important question. And if that is the case, what do we need to put in place today to get us to an offshore grid of the future? And we can just delve into some of that.

**Mechanisms DOE has in place**

The GRIP program (straight cash). When is that useful? When is that not useful? There is a mechanism in which DOE is the capacity holder on certain transmission paths in order to facilitate that project getting constructed. How does that play into facilitating projects coming online that otherwise wouldn't have been able to get over a financing hump? DOE has permitting teams looking at ways to navigate and ease permitting questions. DOE has funding under Transmission and Grid Modernization divisions, which can be used to work with national labs and stakeholders.

**Speaker**

So, two observations. One is: the most effective thing is [DOE] throwing money on the table and saying, "if you come to us with projects, we will give you a sliver of the money you need for that project." The number of people that has motivated has been remarkable. The states are all over that, and are working together, working across regions – it's just remarkable, especially because it's not that much money in context. In transmission planning … a billion dollars is, you know, "coffee money." It's sad, but that's what the region is looking at. I saw the number today of $50 billion in that study. And I'm like, "that's just a buy in. That's not going to get us anywhere where we want to go." New England's going to be more than $50 billion. So, that's been remarkably effective: putting money on the table and saying, "look, we'll give you 5 percent of your project costs covered. But, A) it's money, but B) it allows the political folks to say, "look, we got $100 million. Isn't that wonderful?" Like, it's a big win for them. And even if the total project costs $5 billion, $100 million is still a lot of money.

The other thing that I would say, in terms of things mentioned, but also that touch on the list, is: I would love to see a study maybe by DOE that says, "here is the value proposition of an offshore wind grid." Because I've asked around. I haven't seen it. Folks I've talked to have not seen one that looks at, not just the benefits, but also the costs. And for once, a study that was fairly detailed, that showed the benefits – so that we can actually start to think more seriously about an OSW grid. Because right now, I feel like it's mostly been in sort of pitch slide decks. And, you know, a lot of people talk about it and say, "Oh, it would be great!" It would be great. Lots of things would be great if we had unlimited money, but nobody actually compares the costs to the benefits. And will it help us curtail less wind? And are there real benefits to moving wind from New England to Virginia? In theory, I'm sure there's some, but do they outweigh the cost of laying that much cable? I'm certainly open to being convinced. But I'll tell you: the engineers who work with the ISO are skeptical. And since they're the ones who ultimately have to make it work, it would be good to see –

Question: What is the benefit of money from the DOE?

*While DOE funding is helpful in gaining political capital, it does not necessarily solve cost allocation, as the DOE can only fund a project once. What is more important to the ISOs is knowing the path forward. The ISOs need a policy in place that ensures they talk to each other when planning. Keep in mind, however, that DOE has limited regulatory authority.*

**Speaker**

I feel like I have to say this: but on the first point, on money, I personally don't think money is the issue – except it does help get political capital, and that's great. There's plenty of money to be invested, right now. People are – at least from my perspective – people will spend the dollars, they will invest in transmission, if they know what the cost recovery is, if they know what the risks are, and if they know what the regulatory path forward is. So, while I think it's great that DOE put some money on the table, and it helps with the issue that [another speaker] pointed out, I don't necessarily know that it's needed for investment, per se. What's needed for investment is knowing what the path forward is. And if people invest, they're investing in offshore wind facilities that are going to cost $2 billion, with very uncertain development paths. But we know that we're probably going to get a PPA.

**DOE funding**

DOE funding programs are very competitive. This is difficult for states, because they want some amount of certainty or confidence as they're putting together a project. States need to provide DOE with context on what projects exist, if they want those projects to be taken into account during the next round of solicitation. DOE can fund a project once. So, if DOE funds a project with a grant, that doesn't necessarily solve cost allocation. The likelihood is that the next time, the grant won't be there, because the DOE only has whatever funding is available under IIJA. More generally, grant programs are seeking to push forward into the next project and the next, rather than funding the same projects again.

**Speaker**

But is it the money? So, [DOE funds a project] once. It's not going to solve [the ISOs] for 10 years later, 10 years – it's a policy that is needed. What policy needs to be changed so that ISOs (PJM and NYISO) – talk? It's a policy. Right now, the ISOs' planning criteria are in a box. … It's multiple policies. But I'm focused on one, to make the statement that – for this, long-term, money will show up. It's being able to say, "hey, here's the guidelines that you need to do this study, and you need to not only look internally 10 years, 20 years out, but also regionally." Somebody has to demand that, or say, "hey, this is what we want." Because, if I'm the ISO, my policies are the policies. I'm here for reliability. I'm going to do that. Until someone says the ISO is mandated to really do this, I'm focused on what's going to fix what I need. This is what I'm here to do as a private company. So, the grants – we could put money on the table, and we could say, "go, do it." It's not going to help continuously.

**Speaker**

You're hitting the heart of it, which is, "who's on first here in terms of the national grid." And, by the way, I love how sanguine the developers are about money.

**Speaker**

People don't understand that the Department of Energy has limited regulatory authority, and I think that's [unclear]. It's very impressive, what the agency and the Grid Deployment Office and then the key offices – Wind Energy Technology office – do with limited statutory authority. And the kinds of mechanisms laid out are about leveraging enormous amounts of funding. It's about bringing people together. It's about envisioning and planning – all that stuff is important. And it goes a long way. But it's not the same as statutory authority. And that's a really interesting question, is: with what can we bulk up DOE? The other players – FERC: powerful, but primarily focused on the RTOs and the ISOs, who, in turn, are really, you know, suffering from the tyranny of – the tariff tyranny. But anyway, I did have a question buried in here: in the IRA, Congress gave DOE $100 million for interstate and offshore wind transmission: planning, modeling, and analysis and stakeholder engagement. And I'm curious: is there a plan for how those dollars are going to be used? $100 million, of course, is not a lot of money in an infrastructure context. It's a pretty good amount of money in terms of funding staff and processes, I would argue.

## DOE Facilitating Interagency Interaction and Cooperation

*Getting the RTOs to talk to each other is important for answering some of these bigger questions (such as integrating 85 GW of OSW on the East Coast). RTOs, individually, get more accomplished by working within their own region than across lines. So, there needs to be a forcing function to get the RTOs to talk to each other. Participants discussed whether this is something that DOE could facilitate. DOE cannot force the states to take actions they do not wish to take. The New England states, New York, and New Jersey recently sent a letter asking DOE and FERC to set the table for the RTOs and states to talk. However, it is unclear in the letter what the states hope to do after this.*

**Speaker**

I would say that there's an institutional piece here that this money could help to develop that capacity. And I would say that you have to play with at least two, probably three RTOs to get your money. Because I want PJM to talk to ISO New England, and I want New York to be part of that, because having of [the ISOs] learn to speak each other's acronyms is actually really important for figuring out some of these bigger questions. [RTO people] never really get a chance to be honest with each other outside of a lot of more formal meetings. And having venues where they can encourage institutional capacity-building across themselves can be really critical if we are talking about an Atlantic grid. And that institutional capacity – it isn't yet up for what we're talking about – needs to be built as well. So, I would say it's not the development of the infrastructure as much as their ability to have internal legitimacy to make those discussions and arguments within their frameworks with your engineers. I mean, I recognize that none of the wind regimes that we, today, do automatically – I mean, those were blocked out of the models 20 years ago, right? You couldn't have more than 20% wind, because your system would crash. We have developed our modeling and our operational capabilities as well, and that needs to happen for offshore wind, as well. So, I wonder if you had a grant program where you could require ISO New England to go in with two other RTOs and have that be part of a coordinated study as a way to, kind of, trigger those conversations that are institutionally important for DOE's goals.

**Speaker**
Generally, I would say, there does need to be a forcing function to get the RTOs to talk to each other. Working across political borders and RTO borders is a time sink. And, unless [there is] the same commitment on the other side – and it's unlikely – you're spinning your wheels. [An RTO is] going to get a lot more accomplished by applying [its] limited resources within [its region] versus trying to do stuff across lines, unless there's some forcing function, some larger political process – and it could be the States getting together. But, we definitely need something, if we're going to do that. Now, that said, I think there's a lot that that is useful being done in New England. So, it's not like we're wasting our time. But if you want to do 85 gigawatts on the East Coast, you've got to have that connection.

**Speaker**
[The] Governor of Massachusetts just sent a letter on behalf of the New England States, New York, and New Jersey, to ask DOE to help facilitate that kind of discussion that's difficult for them to have with the RTOs. Also, it's difficult for them to initiate themselves. So, they're looking for DOE and FERC to bring – to set the table for them to talk, as I understand it.

**Speaker**
[DOE] can't force the states to be willing to take certain actions that they're not willing to take. The states, by putting out this letter, have said, "we're willing to come to the table." I will say, just as a personal read, right? If you ask me, based on that letter: what are the states going to be willing to agree to coming out of this process? I would not know. I would not know what the scope is. You know, the states are not putting in that letter on the table something along the lines of, "DOE, if you convene us, we will sign on to all coming to an agreement on a cost allocation, that framework that we would bring to our ISOs." It's not at that level of specificity.

**Speaker**
Well, you know that they did that, because otherwise they couldn't get anybody to sign onto it. The more specific it got … you wouldn't get agreement on the sign off.

**Speaker**
Right. So, to that extent, it's a little bit of this question – not to say that that what the states are asking for in that letter is not useful or appealing in some sense – but it's a little bit of a, you set it up and kind of hope that

lightning strikes in the bottle. And maybe it will, and maybe it won't. As opposed to the states putting on the table, "we think that we need this specific type of leadership from DOE to get these specific types of outcomes." And yes, I agree, if they were outlining outcomes that they wanted in the letter, the letter wouldn't have happened.

**Speaker**
So, what is the solution to that problem? Because that, to me, is a lot of the essence of where we are on these issues today. In other words, how do you – you know, just taking New England. But you could also take PJM. The minute that you get into a state process – and you know this from the ISO – it becomes a very difficult process. So, what would be concrete steps for all of the people in the room if they were telling the states what they wanted to include in such a framework? I think we have to get pretty specific. I think it's a negotiation. No one is going to get everything they want, but there has to be concrete proposals. And, you know, I actually don't think the states are going to agree, and that there's going to be different mechanisms of putting out dissents. If they come to some agreement, there should be room for dissent statements within. But, I mean, what is the process to have this be more successful? And it's all of you in the room that would have that to happen.

**Speaker**
Yeah, I kind of like that you took it back to the states. And we're sitting here in New England, so.

[overlapping voices]

**Speaker**
If we were having this conversation two or three years ago, I think it would be a lot more theoretical, pie in the sky. We now have the Infrastructure Bill, the IRA. We have some fairly specific actions from the New England states. And then, just last Friday, this extension to a regional effort. So, it seems like we've crossed a certain threshold where, whether it's motivated by the availability of money, for political reasons, or just a recognition that, if we're going to get to scale, the status quo isn't going to work.

## DOE and Standardization / Interoperability

*Can the DOE play a role in the issue of standardization? While interoperability standardization is still being solved, can states have some flexibility in their procurements?*

**Speaker**
So, we've got a framework from New England. Bob Snook mentioned this morning in his remarks, identifying points of interest. They've got two proposals into the Department of Energy for specific Points of Interconnection (POIs). So, when I think about "what role can the Department of

Energy play?" The one piece that it seems remaining to be solved is the standardization. And, the same issues that the Europeans are grappling with. And I'm interested, you know – just put a pin in one question – if others in the room know how, say, TenneT is looking at the interoperability. But I see two implications: one, you said, their outside of the box thing. If DOE is going to give money to the states for this modular offshore wind approach, maybe the converters should just be procured separately from the transmission lines. And then, yeah, you're stuck with one vendor, but you've got, at least – you're ensuring interoperability for that first round of projects. And the other one would be: if the procurement is going to move ahead before those issues can be solved – some flexibility in the bids. Let's say the states want to pick winning projects next year so that they can get money from DOE's second round before the next presidential election, but interoperability standardization has not been solved yet. I think there needs to be some flexibility. We're starting to see this from the states, flexibility around inflation adjustment, but a recognition – all right, this project makes sense. It's the lowest risk. We might not have figured out exactly how interoperability works or are you going to be able to go all the way up to 2,000 megawatts or when. So, having some flexibility in procurement, I think, and then DOE really pedal to the medal on those standards. Because, it does seem like DOE, or the National Reliability Electricity Council (NERC) – I don't know exactly who that rests with at the end of the day, but it seems like a natural federal role.

## Transmission Offshore Wind Renewable Electricity Credits ("T ORECS")

*A participant proposed the idea of federal transmission offshore wind renewable electricity credits (ORECs). Would this work as a policy driver for building single export cables in a state?*

**Speaker**

Historically, the states – you know, the OREC program: offshore renewable energy credit – years ago there was always talk about our regional benefits. None of the states would have it, because if we're going to build the factory, and I'm a state regulator giving out an OREC, guess where I want that factory to be built? So that has been going on forever. There's still the OREC program from various states. But, couldn't there be a federal transmission OREC program? Where, if a state eventually says, "time out. No more single export cables coming in here." And now New Jersey has said to the developers for the latest Round Three, "you've got to come into that same area." So eventually, there's going to be a permit problem, by the DEP or the DECs, of each state. So, couldn't there be a federal transmission OREC that gives developers a facility like an OREC, to say, "okay, it's going to cost  $500 million to do this. But, from the TOREC – or Transmission OREC

– I get $200 million from the federal government." … 20 years ago, state ORECs didn't exist. If you went in and said the term "OREC," people didn't know what you were talking about. Now, it's become a standard. So, it can't happen now. But that could be a policy driver for, probably, the federal government to say, "okay, we will back developers, like the state governments back offshore wind generators for delivering offshore energy to meet the state's environmental goals. Well, eventually, a state is going to say, "no more single export cables coming in."

**Speaker**
I think this is a really interesting carrot, right? The federal government?

## DOE Encouraging Cooperation Regarding the Transmission Backbone

*Participants discussed how the federal government might act as a backstop threat for encouraging cooperation, similarly to how the EPA addressed air pollution. The transmission backbone may be a good place to start, as it is hard for individual states or individual ISOs to create it. "TORECs," discussed above, could also be useful here. States are currently driving the offshore wind process. Is there a way for the federal government to help bring states and RTOs together to help match the urgency needed?*

**Speaker**
The comment that struck me, when we going around, … was "the specter of the federal hand." [Another speaker] made it sound quite ominous. Because I love the carrot approach. I'm actually going to write a legal article on this. … Like, what role could the federal government play, as a backstop threat for encouraging cooperation? Right? We've seen it with air pollution and EPA. We've seen it in other venues. In this sector, how could the federal government's threat of taking over also be the stick that could encourage some type of reaction? And I'd just love any perspectives any of you have here, because we've talked about the nice guy approach. But what's the bad guy approach that could also help to encourage more coordination?

**Speaker**
Well, one of the obvious places is the transmission backbone concept, where it's very hard for individual states, individual ISOs to make that happen, and even to plan it out in a meaningful way. What I love about the federal TOREC idea is, you know – in our system, states are the policy incubators. So, we have a number of states who have developed ORECs for offshore wind – from what I can tell, very successfully so far. So that's an interesting – of course, that's an Act of Congress to both authorize and appropriate something like that. But to my mind, where that would make most sense, again, is that backbone. As we all appreciate, in terms of offshore wind transmission: we have the wet side, and then the dry side. The wet side has

always been so intriguing we have a blank canvas. And it seems, at least in theory, cleaner to design that. The terrestrial side is far more muddled and complicated. And, of course, over the years, the way the system has evolved, DOE has no regulatory authority on the terrestrial [unclear]. It can bring suasion instead, as FERC, obviously, does. I do accept the prospect that the federal hand could be heavy-handed.

[overlapping voices]

**Speaker**
But, as has been noted, the states are driving this train, for the moment. The states were the first ones out with the offshore wind procurements. The states were the first ones out working with the European offshore wind developers to approve these direct generation lead line concept and all of that. … Organizational reform is very hard, and it's a tough place to put your political capital. And maybe that's the model that ultimately drives it through. We take that as far as we can. It feels like the urgency that we have, we need something more. I don't know exactly what it looks like, but some strengthening of the federal role to help bring the states together – and RTOs and the ISOs – to do some of the bigger lifts.

## Concern Regarding Regime Change

*Participants discussed the need to ensure the offshore wind process is not dependent on regime changes.*

**Speaker**
Can I add to that: it needs to not ebb and flow with the political winds.

[overlapping agreement]

**Speaker**
Because the gestation period's too long. I mean, even in Massachusetts, where we have a change in regime … environmental policy didn't change that much, right? We had, like, a four-month, five-month hiatus on negotiations in the state, because, as the old administration was leaving, nobody wanted to decide. And then there was nobody in place to make a decision, after the election. So, you know, and at the federal level, I can only imagine it's five times as [unclear].

**Speaker**
A point that [another speaker] made, quietly, to me earlier is that a potential change of regime at the federal level on a lot of this is very concerning. Because, we're going to lose a huge amount of time, should that happen. I guess that's out of our control, at this moment. Whatever that is, that is. So, what is it that we could put in place today, that has momentum? And then, I guess, we deal with the problem that we're going to face, at the point we're going to face it.

## Developing an Offshore Grid

*Participants discussed long-term questions regarding the development of an offshore grid. Regarding DOE funding, it is unclear what will or will not clear the supply chain security vetting process. The results of this vetting will likely influence the market, based on how DOE funding is distributed. Participants also discussed the benefits of a proof-of-concept pilot.*

**Speaker**
Is that the ultimate plan? We're in a situation, now, where we've established a set of regimes that must go forward – because we can't change them right now – and a whole series of investments and assumptions are made on those regimes. How are we going to transition over the years? What mechanisms do we need to put in place once we build that offshore grid? Where we are today – how do we think about that transition, both from a technology, but also from a political process perspective? Do we continue business as usual and create a future and then deal with it then? I'm interested in some long-term questions that we need to think about as we go forward, assuming we are going to be successful in developing an offshore wind industry.

**Speaker**
There's some smart folks at Tufts [unclear] identified and looking ahead, initiate full-scale multi-vendor multi-purpose multi-terminal HVDC network pilot. That sounds a lot like what the states are trying to do. So, I think I appreciate the lofty view and how do you bridge what we do with that?

**Speaker**
Right. It's a lofty view, though.

**Speaker**
It sounds like everyone's agreed that there's some risk that comes in next year with change of regime. A limited amount of funding for now. But, it really sounds like what is needed – and what's on the table – is proof-of-concept. … And so, if we've got the ability to do that –and to support that – that would seem to be pretty clear [unclear]. Now, does that solve the question of the 76-gigawatt grid? Not quite. But it's a way to kind of wrap our arms around it, show if the concept works.

## Stranded Assets and Risk

*Participants discussed the challenges of stranded assets. To move at the speed needed to address climate change, there will likely be some stranded assets or failed pilots. One of the important lessons from the federal highway system is that energy justice, fairness, and cost all need to be considered in this process.*

**Speaker**

You know, if there are real challenges – which, personally, I'm convinced that, seeing the industry move in this direction, status quo is not going to work. … I was chatting this morning, that people are often worried about stranded assets, and that's a form of risk. But the scale of the challenge of climate change and of reaching these massive goals in a way suggests that, if there's not a stranded asset or two, we're not moving fast enough.

**Speaker**
Right. I think that's really important –

**Speaker**
The Federal highway system. For the locals here, has anyone driven 290, which cuts down from Lowell to Worcester? It's not used very often. There's not a lot of traffic. But does that mean the federal highway system is a failure? No. It's just, at some point, the lines they drew on the map back in 1930 are not reflecting where we are 100 years later. But is that a stranded asset? I would say: not necessarily. So, I think – you know, when you look big picture, it's, "yeah, we're going to need all this big stuff." But in the near term, we've got a pilot that's kind of taking shape. And so, how can everything be oriented to [unclear]?

**Speaker**
I think that brings up two very interesting questions. One is this whole notion of innovation and risk. And thinking about pilots – just in my own mind, I've never really been a fan of pilots. But I think, in this situation, we probably do need to create some pilots and understand that either, they're going to be a failure, that we're not going to see the success that we interpreted. But I think that this becomes a really very important concept, and somebody is going to have to eat the cost of a failed pilot. That will add cost. But I think that that's something that really needs to happen. But when we talked about the federal highway system, what the federal highway system destroyed was neighborhoods. So, can we, as we also think broadly, say: what about energy justice in this model? Because, as we know, the highway system just destroyed whole neighborhoods. And we're still recovering – Boston just recovered from a neighborhood destruction with the southeast expressway. So, could we think a little bit more on where this whole notion of energy justice, fairness, and cost?

## Who's Going to Bear the Cost?

*Participants discussed who will bear the cost, how it will be split between developers, the public, and the utilities. Communities need more clarity about where investments in economic development are actually going. PPAs require a certain amount of local content, but this requirement may drive the cost of the PPA up. Depending on the situation, it may make more sense to have a rate-based approach, rather than a PPA.*

**Speaker**
I think that there will be no transition on transmission without understanding some of those tradeoffs: who's going to bear the cost? How do we split those issues between the developers, the public, the utilities. I mean, these issues are going to loom large. And I think projects will be stopped unless we see some of these considerations built in as well. So, who pays? How much? Again, any thoughts on that?

[Overlapping voices, unclear]

**Speaker**
Having some more details to explain to communities what the $15 billion meant, illustrating that. People would desperately need some more belief that these are real. … [unclear] was talking about the labor agreements, and that it drove $15 billion in investments in low-income communities. And it might have been just the job creation. I don't know.

**Speaker**
It could be job creations. It could be manufactured creations. It could be two-fold of research, research development, future to be teaming up with – it's economic benefits from the construction, right? So, on one hand, you have the coal industry dropping, right? Losing. On the other hand, you could take some of that labor force and move it into the offshore wind. It really depends on who created that statement and what goes into it, to get you the actual information about the economic development that has been put out there.

**Speaker**
And how integrated is this in the thinking? Have you come across any creative perspectives as you delve into these issues?

**Speaker**
There's all kinds. But some of it's just prescribed from the PPA, that they require a certain amount of local content. And this is what you're going to do. So, on one hand, you're driving the need for local content. But, on the other hand, you could look at it – you're almost hurting yourself on one hand, too, because you're driving the cost of that PPA up, because you're forcing an entity into there that isn't really like-for-like, right? This is what they paid for power. But you go look at offshore wind. The PPA is lumped in with a whole bunch of different issues, right? Because it's just not what it costs to make the power. It's power, plus any of the other items that are put in.

**Speaker**
So, from that perspective, then, the social costs that are being part of these…

**Speaker**
Could drive it up. There's also the question of: is the PPA the right way to go, versus a rate-based? Rate-based is going to be a flat: you know what you're paying, here's your ROE. Here's what you pay. But a PPA is per megawatt. So, if they work more, are paying

more for an infrastructure that could be covered? It'd be cheaper if rate-based.

**Speaker**
So, I guess this is my question: as part of the rethinking of the future, if we were in a situation where we could say, “we should be going a rate-based versus a PPA approach.” Is that something that makes sense in any way?

**Speaker**
You could. It depends.

**Speaker**
So, I’ve long advocated that it's right to have generators pay for their interconnection costs. But that breaks down, I think, when you get to the scale that we're talking about, where interconnection of a new generator is going to really be upgrading half the grid. That just doesn't work. And either that or you just have to accept that you're going to have RFPs that cover the wind and half the AC upgrades, which is – I don’t know, probably better just to do it on our own. But, that's a great example of a good use of the DOE money to leverage some activity that's of common benefit. … This is an area where it's not clear you're going to make a return by investing in this public good.

## Points of Interconnection (POIs) Interconnecting the Wet and Dry

*Participants discussed POI selection. The conference brochure includes a map with POIs, which are chosen based on the best plan for power flow. Participants discussed the difficulty of siting or permitting these POIs, as the focus on power flow may not factor in siting restrictions. Is there a way to bring power flow, permitting, route, and generation experts together in the same room for planning purposes?*

**Speaker**
In the other session, there's a discussion about POIs and the need to understand and identify POIs as public assets and what their capacity is. And the idea that the land-side work, which is what this project is, which is the complement to the Atlantic Offshore Wind Transmission Study. So, is there a way to think about POIs on the land side? We have lease areas that are defined by the Federal government on the wet side. We have POIs. Why can't we make these POIs public assets, in the same way that the wet side are also public assets? And then, the question of matching, and how do these things plug into each other? And it feels like we're missing the points on the land side to be able to effectively do that. And is there a way to transform the way we think about POIs to the states’ and RTOs’ satisfaction? But the idea that these are public assets and long-term decision-making is being made about them.

**Speaker**

One of the DOE proposals from New England is to, essentially, reinforce a POI. It's all about the AC side upgrades on a specific POI that's been identified as … helpful for offshore wind. I'm not sure what's public and what's not public, so I'm being very … overly cautious. So, the DOE money is driving exactly what you're suggesting. And I agree.

**Speaker**
So, to follow up on that – and it's good to hear you say all that. It makes a lot of sense to me. And I think, if you look at that map on page three of the conference brochure, and you look at those numbers – this was a piece of work that was done, sort of, independently of what any individual local stakeholder thinks about this or that, that says, "okay, from a power flow point of view, this is where you get the most bang for your buck, and this is how full you can make these POIs before you run into trouble. And you get into these numbers. And as you said, the numbers are actually quite low, in some ways. And I think our point as engineers would be: one of the reasons they're low is because it looks at the whole system and thinks about it in the way the system wants to be treated: the power flow system. So, is it possible to say, for New England, that there are five POIs at four gigawatts each? Now, New England – the states, ISO New England – please come back to us and say, "No, no, no, we don't like those five. We like these five." And then, what we could do with our tools is we could run an analysis on the five that are chosen, in a couple of scenarios, and you could compare these apples to apples and talk about them.

**Speaker**
But the flaw of that map – and it's amazing, from the power flow side – [is that it] always works. Planning always comes back with the greatest one for the power flow. The minute I go try to put a line in there, from a siting/permitting perspective, it is usually in the worst spot that I can never get to, because it's through neighborhoods, it's through an urban development. You can't get the transmission line there. So, there's –

**Speaker**
But I think that is the nature of building.

**Speaker**
It's the nature. I don't disagree.

**Speaker**
You've got to find these connections between the two.

**Speaker**
Yeah. The back and forth almost takes too long. You need to be in the room going, "hey, from the power flow, this is great." And then someone goes, "no, this doesn't work, this works." Because other than that, it's – you just continue. It's a circle.

**Speaker**
And I think that's the point. I think the point is to have a tool that can make assessments

quickly about power flows. You've got the power flows, you've got the permitting, you've got the routes, and then you've got the generation. And these things live in three separate worlds right now, and they meet each other inside of this very lengthy process. And if there's a way to bring them into the room at the same time to talk to each other, then I think that that – which is what happens on a good project. But these projects are saddled with literally traveling between different worlds. And I think that's the question, is how those conversations – could we prototype a conversation that's unconflicted, that's not inside of a competitive process? Just as sort of an experiment to see what this looks like when you do it.

**Speaker**
And I have a question. The proprietary piece of this: how does that fit in to this decision making? So, we can be theoretical. But then there is a proprietary piece. How does that fit into your thinking, as we –

**Speaker**
What do you mean? What piece would be proprietary?

**Speaker**
I don't know. You tell me.

**Speaker**
Siting's a public process – pretty much directed by the PUC and the siting entities. You can go this way. You can go that way. It's got to be the least impact, right? Permitting lays out the rules. Here's the rules. Here's where you've got to file.

**Speaker**
[Developers look at a number of different criteria] and score it out of a scale from zero to five. Or, is it an economic justice area? Not to diminish the power systems piece of it, but there are all these other criteria, that are, a little bit, qualitative, not quantitative. But [the developer's job] is to try to quantify those.

**Speaker**
So, there's whole many things. And when you score them, you score them, and then it comes down to "hey, which is the best route? Which am I actually going to be able to construct? Where are my permits? How many am I going to have?" Right? I can't go through Gettysburg, right? I can't go through the battlefield – or maybe I have to, because that's the only one – but then you have to score it and figure it out, and that takes time, so. I love the engineers. I appreciate them and the planning. But they always pick the one that I can never get to. Ever. But it was always the right one from an electrical standpoint. And you have to negotiate out on how you're going to do it, and then assess the risks. Would this go through? Where? And then – whether you want to hear or not – it goes, "where's my litigation? How much am I going to spend? And can I hold up?" And it's sad that we make decisions… that's the factor.

**Speaker**
So, I'd like to distinguish a couple things. … It's tough that that's how people see engineering. Because, if you're an engineer, there's never one solution. There's always five. And the problem is: we're not actually putting them on the table and thinking about them creatively next to these other criteria. And I think the other thing is: we're mixing up scales. So, the power flow will become the deciding factor when you get up to 76 and beyond gigawatts. Like, the grid is going to drive this. At one gigawatt, at project scale? None of that stuff matters right now. The power flow is not the important thing. And so, it's important to see that all of this is relevant and important at the same time, and it takes different prominence at different scales. I think a difficulty in the conversation is that one sometimes seems to negate another. But I think if we understand what scale we're talking about at what moment, then, I think these things start to become more synchronous with one another. But there's never one solution to a problem. And so, I think that's the object here is to get multiple answers on the table from each of these different scoring criteria.

**Speaker**
Right. But at the end of the day, we have to pick a solution. We have to pick a solution for our path. We have to pick a solution for our PPA. Right? I want multiple solutions. But at the end of the day, the developer has to pick one. Maybe they pick two. But then that's more costly, because then you're supporting two potentialities.

**Speaker**
And if I'm trying to create a project, that's what I'm going to do: I'm going to make it work for my project. But I think that in this conversation, each project is simply a very, very small piece of a much larger puzzle. And that doesn't negate the importance or the difficulty of accomplishing an individual project. But it's just important to keep track of the two separate conversations, simultaneously.

**Speaker**
I see what you're saying.

**Speaker**
To a degree, yeah, I think it's all parallel, though: each one plays a factor to make up a decision. One, even though you say the grid outflows it: technology is really cool, and it's going to do what we say it wants to at the end, whether it's the most cost efficient or not.… But all these factors are going at the same time. And you must consider them … One doesn't outweigh the other.

**Speaker**
Let's be honest. We're still early days here, right? Let's have this conversation when we've got 15 gigawatts in, like the U.K. And we'll be having a completely different conversation, to your point. And so, we're still in the proof-of-concept phase here, with all of our regulatory institutions, with

training up our institutions to play this game. And that's the piece that we're all learning as rapidly as we can, despite all of the barriers there. But I do think in 10 gigawatts, we’re going to be having a very different conversation. And we'll have experience, and we'll actually know what we're talking about.

# 6 Breakout Session: Power Systems

*During this two-hour breakout session, participants continued discussions from the morning sessions, focusing on the power systems aspects. The session also involved discussion and feedback regarding the 85 GW study. In order to protect the anonymity of the speakers, some sections have been removed or summarized.*

## Overview of Session Themes

The session themes are identified and described below. For ease of reading, the transcript contains subsection titles each time a new theme is introduced into the conversation.

### Modeling methodology

*Discussion of the 76 GW study and the modeling methodology used. What kind of optimization was it? How were POIs chosen? Ho was optimization done?*

### POI siting considerations / difficulties

*Where do you site your POIs / substations / converters? Where are existing substations? What costs must be considered when siting POIs? How should you POIs be picked?*

### Sizes of electrolyzers / projects / etc – ties into POI siting theme

*Discussion of electrolyzers, converters, and infrastructure. How big is it? How does the size impact POI siting?*

### Nuclear

*What is happening with nuclear power plants? How does this relate to the current discussion of POIs?*

### Contingency & reserves

*How do you solve the single source contingency problem? How do dynamic reserves impact this? What is happening in Europe to address this problem? How can that be applied (or not be applied) in the US?*

### Demonstration project

*What kind of demonstration study needs to be done? What data do policymakers and developers need? How can they get that data? Includes conversation on contingency and reserves.*

### 200 GW Offshore Study

*Would it be helpful to do a 200 GW study? What would attendees want to learn from the study?*

### How to plan for the future?

*How can policymakers plan for the future? What are the intermediate steps from now to a new grid?*

### Future-ready

*What are regions doing to make their procurements future-ready / able to be integrated with whatever standards are developed later on?*

### Contract re-negotiations

*Brief discussion on the current renegotiation of contracts*

### Land acquisition

*What are the current difficulties with land acquisition for POIs or demonstrations?*

### Compact projects / compressed gas as insulation

*How are companies trying to make stations more compact? How does compressed gas compare to air as an insulator?*

### HVDC Research labs

*Where are there currently HVDC research labs? Why are the needed? Why don't we have any in the US?*

### Energy Islands

*What are the advantages of energy islands? How can these concepts include hydrogen generation?*

## Introduction

**Moderator**

The way we thought we'd do this: we have, not quite, two hours now. I'm going to trying to focus us a little bit on the power system part, extending beyond what we discussed this morning – or earlier today. And then Johan will take it over, probably in 45, 50 minutes. Something like that. And go towards that converter station HVDC power electronics orientation.

I thought that I would just start by posing these questions. And the first one is about cost data, but the second one is really, what are your questions in the context of the grid, and of the power system part. What are the issues that we really need to solve, or we really need to address? And then, there are more questions about some issues that I would like to know about, that I feel the need to explore in more detail. And some of you may have some really good answers to those questions that I've posed. Over the next 10 to 15 minutes, run your mind through these questions, and any others that you might want to consider. And then, at the end of my short presentation here, we can just open it up. Because it is a workshop, and I think the people that are here can share that knowledge with each other and share the perspectives. I thought I would try to show more details related to what I was talking about this morning: just as a summary of the communication of this morning. Give me 10 minutes or so, and then we'll open it up. And again, maybe in 45 minutes after our discussion, we'll lead into to the HVDC part.

## Modeling Methodology

**Moderator**
With respect to this problem that I described this morning: this is what we're solving. This is what we think we should solve. So, there's no mathematics here. But you can see the context. It's an optimization problem. And it's a hard one. It's a really hard one. You're choosing capacities and points of interconnection (POIs). So, it's an integer optimization problem. You can pose it as an LP (linear programming), but it is a hard one to solve as an LP, and it's a competitional nightmare to solve as an integer problem. The redispatch of onshore power delivery buses – of course, you inject six gigawatts into this node, then something's got to compensate for that in the grid. Either more load or less generation, right? And I'm assuming it's less generation in everything I'm doing in the network expansions and the POI reach circuit link – again, that reach circuit is from landfall to the point of interconnection. And we typically think of that as a mile or 20, depending on where it is. And we also think of it as part of a high voltage direct current (HVDC) system. Typically, we're going to use DC in that as part of the MTDC (multiterminal direct current).

**Speaker**
So, I want to challenge people there to think beyond 20 miles. If you're DC already, you can just keep going. And then, that really depends on: what does that mean for where do you build your substations, your converters? And what impact does that have on the grid? Especially that. And that depends mostly on: where's the load? And what are the constraints in the AC grid in between? And, maybe more importantly these days, is: where can you build something?

**Moderator**
So, where can you build the converter station? And how hard is it to build a transmission to get there?

**Speaker**
And can you expand the interconnecting substation?

**Moderator**
Right. Go ahead.

**Speaker**
Yeah. I'd like to repeat the comment just made by [another speaker], because we're finding, in the New England region: on the

one hand, we have a fair number of 345 kV substations near the water. Because that’s where the power plants were. But the phrase we've been coming up with is “don't stop at the beach.” Because, just because some stations may have capacity, headroom – slang we use – to take the HVDC and put it there and then inject it into the system. We found that even small movements inland have huge benefits. Yes, the ISO’s 2050 study shows that hundreds of miles of onshore AC line upgrades can be avoided by just minor differences where you put the DC converters. And the converters – it's going to cost the same, no matter where you put it. So, there is a temptation, we've noticed, with developers – this is not a criticism of developers – but they went from the leasehold to the closest 345 kV substation. We’ve found that even small movements have a huge benefit if we avoid some of those.

**Moderator**
In terms of reinforcement costs on the AC grid?

[overlapping voices]

**Speaker**
Reinforcement costs. There are also other issues, which were not part of this particular equation, involving places where I know that, either because of physical constraints, some of the urbanized areas could be virtually impossible to get enough room. These converter stations require acres and acres of land. The other thing is: there's some environmental justice issues. There’s one place in Connecticut. It is electrically a very good place to connect, but the local community and the city fathers there won’t do it. And the state won't make them. Because they've been overburdened in underserved communities for many years.

**Moderator**
I get your point. And that's an excellent point. I guess, I want to keep those POIs onboard, even the ones that you can’t –

**Speaker**
Oh yeah, for planning purposes.

**Moderator**
– and just assign them a very high cost. Because what you might see is – even under that very high cost, because of some other cost, there might be some trade-offs at least worth thinking about. And to be able to see those as you do your analysis was the orientation I was taking, here. Recognizing that you just may not be able to get to Cardiff. But, well, what if you tripled the DC line cost of getting there? Maybe then, it’s worth –

**Speaker**
If I understood correctly from your presentation this morning. You ran this for a simplified network, right? 670 buses?

**Moderator**

No. This is 93,000-bus Eastern Interconnection power flow model.

**Speaker**
Oh. The optimization model was run for that one?

**Moderator**
I call it a heuristic optimization model. Yes.

**Speaker**
Okay. Now, because I wonder what did you do with the other one?

**Moderator**
Yes. So that's a formal optimizer using –

**Speaker**
But in the other one, how do you capture all those different causes of – implications of the AC line? If you're able to capture that – if you move, a little bit, the POI, – you have differences in the AC reinforcement that you need to make.

**Moderator**
Right. So, the integer decisions are difficult there, with the second model, because we're using an LP. But what you can do is look at the magnitude of the flows into each POI and use that as, kind of, a directive towards what might look good and what might not. So, there's some trade-offs between the different models. The first model is a heuristic optimizer with a human very much in the loop, where you're looking at this stuff. And you're able to take into account all of these things. And the second model is an efficient linear program, but it has very few buses, it's small. And you can't do integers – I mean, you can, but then you triple your compute time, or quadruple or something.

**Speaker**
One way of going about this is choosing the kind of characteristics that you want to see in a POI, using the expendable, not environmentally sensitive area. Preferably located close to the coast, but it doesn't have to be. And create a few different sets like that, based on different weightings of these characteristics. And then associate difference injection scenarios with these different sets of POIs, which you then run in a power flow model. See what are the associated grid reinforcement costs for these different sets of POIs? That could be one way of choosing between different scenarios. Another one that I'd like to, somehow, at least bring into the discussion is: it makes sense to dump the offshore wind power there, where there is a lot of load. So, industrial loads where, in the future, you can forsee a lot of consumption. The electrolyzers that you were talking about, or maybe a large battery system or data centers or the electrification of rail.

**Speaker**
The big question is, where are all our electric commuter rails going to charge?

**Moderator**

So, the nature of the load that's surrounding that POI might make a difference in terms of how you feel about its attractability.

**Speaker**
Yeah. In Holland, most of the offshore wind is going directly to the industrial centers. POIs close to the grids.

**Speaker**
Yeah. In Connecticut, there are some areas along the coast. There is Metro North, an electrified train system with the biggest ridership in the country. And it moves millions of people into New York. There is also electrification of the rail from New Haven up to Springfield, Massachusetts in the near-term. And so, there's a hub there, between those two electric train systems. And there's been some discussion of hydrogen production, as well. And Bridgeport is Connecticut's biggest city. And so, it's a logical place to – because there is the load there, and we know it's going to remain. Also, as we shut down the major fossil Bridgeport power station, we're going to lose the spinning reserves and we're going to have issues of short circuit ratios. And so, having the grid-forming capabilities from the converters might be very useful. Those are other benefits. Say one POI is very expensive. But there may be a lot of benefits to using it, anyway.

**Moderator**
So, moving POIs to loads is a good idea. What about moving loads to POIs?

**Speaker**
Yeah, that's sort of, if you have a part, maybe, as a question – you know, hydrogen. All our modeling up to now didn't include any hydrogen modeling, right? So, hydrogen is this big uncertainty, right now. How do we, actually – we can build electrolyzers at POIs, right? Where it's cheap to connect. And we build a big load there, which is the electrolyzer, which we can use for storage and other applications, right? So, I think there's a lot to be said about: how's the grid 30 years from now going to change? New loads. Electric vehicles. Electric transportation. Electrolyzers. All that stuff is going to change the load profiles, big time. I think, personally, right? A lot of these POIs may be in an area where there's not a lot of load. But we can put load there. Right? Or we can assume load will come.

## Size of Electrolyzers, Projects, etc.

**Speaker**
Sorry, I came in a little bit late. How space or area intensive is a, say, 100 megawatt electrolyzer? Is it comparable to a converter station, or?

**Speaker**
It's probably sizeable, similar. I mean, a lot of power electronics, a lot of equipment there.

**Speaker**
7-10 acre range.

**Speaker**

Yeah. It's this one little project which we work on, which is about 13 megawatts, and it's, sort of, 10 parking spots. So, it's not that big. So, it's maybe three times this building, this floor space. But that's only for 15 or so.

**Speaker**
Plus, the safety exclusion zone around it.

[overlapping voices]

**Speaker**
What about the size of a two-gigavolt voltage source converter (VSC)? What is the size today? You said acres. But I'm thinking, I've seen them in buildings too, which means that, when I think about that I'm thinking: they can be in many different places. And even these environmental communities. There's a lot of good opportunities for jobs here. And they're not going to be – if it's promoted the right way, I think that could be a lot of benefits, because it's not, like, polluting anything. It's just the cable coming in, the block building like any box store. But how large is that box?

**Speaker**
As large as these offshore platforms. You showed a picture of that. You can have either – there's different ways of arranging converter stations. Offshore, you stack the decks on top of each other. That's the smallest footprint you can possibly squeeze it into, but then it would be a bit taller. And then onshore, you can either have it has a long building – which is the picture that Johan showed in his slide deck – or you can arrange two holes next to each other in a U-shape. The footprint doesn't change. It just changed the shape.

**Speaker**
How many square meters do you have?

**Speaker**
But you're talking about, like, maybe 200 by 200 meters.

**Speaker**
I think – I've got the exact number, but it's in my slides. It's, I think, 60 meters by 40 meters by 80 meters high, right? So, this is a big structure. But, 50 by 50 offshore, let's say.

**Speaker**
Still it's not, I think, a big building, if you think about it in the big context. I mean, take away a large generator plant. Replace it with something which is clean. Looks nice.

**Speaker**
There's no comparison.

**Speaker**
If you compare it to the two-gigawatt coal power plants, it's actually very, very compact.

[overlapping voices]

**Speaker**

The coal ash pond is bigger than what you're talking about.

**Speaker**
But there's very limited places where that exists. I mean, there's two places in Massachusetts. One in Connecticut. Alright. Are three points of interconnection going to be good enough for New England? It's going to be hard to cite a box. Just to…

## Nuclear

**Speaker**
So, what about nuclear plants?

**Speaker**
Electrically, [Millstone] is probably the best in Connecticut. But, it would be a tough site for a number of reasons, although there is plenty of room. It might be preferable to use to the next substation that's electrically connected to Millstone. But it's over a little bit to the east, because Millstone, since it's under the jurisdiction of the Nuclear Regulatory Commission (NRC) – all the safety and all the regulations on – any construction adjacent to the site is under NRC jurisdiction. And that means lots of security, in addition. It's very difficult to do any work there [and] it's governed by security rules that are very different. So, I would use an electrically connected substation, but I'd use the next one over. In addition, under Connecticut law, any small nuclear reactors would have to be co-located at an existing or former nuclear facility, because of the security and training. If there's headroom at Millstone, it's probably going to be reserved for SMRs (small modular reactors).

**Comment**
(Another comment – sort of a non-sequitur here – relates to storage. Three years ago, we had 20 MW of battery storage clear our capacity market. Two years ago, it was 490 MW. One year ago, it was about 3,000 MW. And now, there is 11,000 MW of battery storage in the queue. A lot of these, particularly the bigger ones, are all being designed – and this is not the states' doing. This is developers, they're locating these where the POIs of contracted offshore wind is coming in or anticipated. These are pretty good size facilities, for a 250 MW battery operation. But, there seems to be a trend that these POIs for offshore wind will have – they need a lot of space. Because people are doing other things with them, including batteries.)

**Moderator**
So nuclear, will be retired or not…?

**Speaker**
They're going for another 20 years.

**Speaker**
I mean, there's Maine Yankee site, but you can't get the power out of Maine. You can get it into Maine, but you can't get the power out of Maine.

**Speaker**

Connecticut Yankee site, and I don't know about Pilgrim.

[overlapping voices]

**Speaker**
I think that would be difficult to site.

**Moderator**
But, you're saying the difficulty there is going to remain because of the presence of the spent fuel –

[overlapping agreement]

**Speaker**
Well, and those are, as you said, they're already approved NRC sites. So, any upgrades to future nuclear will happen there. So, I'm sure it doesn't make sense to put in a converter station there.

## How to Pick POIs

**Speaker**
Yeah, I do agree. I think building it more in-land – the interconnection points – would definitely be making sense. For several reasons.

**Speaker**
Well, it almost seems like siting the POIs what we really just touched on, is a very complex decision. And, you know, when we're working on the procurements, the question always comes to the states—why don't the state just pick the points of interconnection for the procurements? And we just say, "everybody bid to this one location." And picking points of interconnection is challenging. You're really talking about overlaying – what you just had up with your design questions is, like, the electrical map versus the siting map. Where is there space? Versus, what are the future plans for the Commonwealth, or for Connecticut, about where you want load to grow? It ends up being this very complex question that intersects almost every aspect of the state government. But there is a benefit of, maybe, just doing a purely electrical exercise. And then giving the decision-making on the siting portion and the load portion over to the state agencies because it's probably hard. But, I think, sometimes we get so dragged into, "what is the absolute best location?" Where maybe we should just say, "well what's best electrically?" And then we'll talk about what's best size-wise and then we'll talk about – and then we'll decide later. And put a big caveat on the conversation we're having today.

[overlapping voices]

**Speaker**
I don't want to pick points of interconnection. You guys can do it. Tell me which one.

**Speaker**
So then, does that change the conversation around cost at all? If the goal is to focus more on the electrical side of things than the

distance traveled, I guess, will still affect the cost of the system overall. But are we achieving the most efficient system to pair with the onshore grid? If we're concerned with the cost of both the onshore and the offshore grid. Am I understanding the cost calculation right, or…?

**Moderator**
Yeah. Well, it's the, I'm going to call it – I like your term, "the electrical problem." Solve that one as a **least cost optimization**, where you do try to find the POIs that minimize the cost of this converter station, given the space that's available there. Minimize the cost of the reinforcements and the electrical grid. And minimize the cost of getting there from wherever it is. And it may be that, you know, 100 miles inland works.

**Moderator**
But let that trade-off be made, you know, in the context of the electrical assessment, so to speak.

**Moderator**
piece of information to the decision-making process. Makes sense.

## Contingency and Reserves

**Speaker**
How do you solve the single source contingency issue? That's a recurrent question, when you talk about large HVDC projects, as well. Some people say, "should we change the definition of n minus one or whatever?" I think a bigger – there's going to be a lot of pushback from the ISO, when we talk about implementing a special protection scheme to solve this. Because nobody likes that, even though they're used a lot, especially in the wet. But, they have very strict requirements and create some complexity. So, how do we go around that?

**Moderator**
I think the remedial action scheme concept has got to be a part of that equation, if you want to get to four or five or six gigawatts.

**Speaker**
In regards to Denmark, in the presentation in the morning. The speaker talked about energy islands, which of course have multiple links at the end to store it. But they lose more power than, I think, we are used to here. And they're discussing, sort of, disconnect load and that's, of course, a Remedial Action Scheme we're talking about here. But there are – allowing it elsewhere, can we think in those terms? And, can we reroute some? Can be drop some? And make that workable. And some redundancy, of course, too. As mentioned in the discussion on the macrogrid, not talking about one single line or even three phase to – one HVDC circuit, it's really some redundancy. Power of three.

[overlapping voices]

**Speaker**
– I mean, that's a way that – because, how often is the line going to be fully loaded?

Because that, really, is going to be the ISO question, is: who bears the cost for the increased reserves for the higher single contingency? That's where the trouble will happen at the ISO. Beyond the operational challenges, it'll be who pays for those increased reserves.

**Moderator**
You don't necessarily have to increase the reserves. In other words, if you are actually going to have to withstand this, a 6 GW loss, without doing anything else. Maybe you have to have a lot more reserves to handle that. But what if, on detection of that 6 GW loss, you trip, you know, a gigawatt of load, and you ramp, do a fast ramp down of the wind. And your HVDC controls enable you to, you know, within 30 cycles or less.

**Speaker**
That's not an incremental change, that's a change far out.

**Moderator**
It may be a far out change for this area.

**Speaker**
It would be, with the RTOs.

**Speaker**
But, not in the overall community of power systems people. It's standard fare in a lot of other areas.

[overlapping voices]

**Speaker**
I really like your use of the term "incremental change." And that's actually something that I've been thinking of, because, as not a power systems engineer, I don't know what is the incremental change. I know that the single point contingency limit is a large restriction on our ability, as state authorities, to – we can't put out a procurement that violates, you know, the operational parameters of our ISO. We have to limit any kind of interconnection to the single source contingency limit. Is there a demonstration project on incremental change? Can we demonstrate something to ISO New England? Is there a project that we sponsor? I'm seeking guidance on here, what is – instead of changing the reserve margin before procurement.

**Speaker**
Two things on that one. First of all, the single source loss would take out 1,200 MW, most likely 1,400 MW+. And that is an hourly by hourly calculation done in ISO New England. The implementation is not in New England. It is in the other systems. There has been discussions. And the reason that ISO New England has reached out to try to make that 2,000 MW – because those limitations are not technically too difficult to handle. But they could cause a cost in a different region. And now we get into a different debate. It's more an administrative problem than a technical program.

**Speaker**

Just continuing in this line. I agree with [another speaker]. States can't put an RFP on the street that violates – 1,200 MW is actually in the tariff, in the text. So, the East Central issue in New York – the construction right now, the East Central interfaces where the 1,200 MW poses a potential threat. It's in New York ISO. But, the trucks are out there for a different, New York. They have to fix that, too, if they're bringing in lots of offshore wind. So, they are correcting their system. NYISO, on March 27$^{th}$, sent a letter to the Joint Interregional Planning Committee, or JIPC, to potentially study going up to 2,000 MW. It's going to take them a while to do that. The issue they're actually concerned about is no longer in New York, because that's being fixed. It's actually a potential in PJM, at a much higher – maybe 1,800 MW or something. And the question becomes: who's going to pay for that? And Connecticut isn't and Massachusetts have never hesitated in their concept papers. They talk about the 2,000 MW/525 kV. That is part of transparent government. States want developers. They want engineers. They want the ISO. States want everybody to know where they're going. In terms of reliability, the areas the states are looking at would be, you know, with a full bipole system, with a dedicated metallic return. Do we think we can get the ISOs and the RTOs to look at – or NERC – the idea of: what is the probability of the full loss of both? And I am cautiously optimistic, because Connecticut runs the phase one, phase two HVDC system – that's a line-commutated converter (LCC) system – over 1,200 MW every day. It's set for 2,000 MW. 1,000 MW each. And that's what states would be doing with the multiterminal. But in a much more controlled system. I don't particularly have a problem with increasing reserves, because, as we do a multi-terminal system, if it's interregional, we'll have access to a lot of reserves. I think there's a way around this. And on the engineering side –

**Speaker**
That really brings a backbone back in discussion, right? You can move power up and down there. If one connection is going down, you can move that power to the other place.

**Speaker**
The chart, the little diagram – the DC to DC, there's more than one. It would be a very robust system.

**Speaker**
It's very robust. And it's controllable, by the way. You can tune it. If you don't like six gigawatts, you can tune it to four. And you can move power can go from one to the other, right? It's controllable. AC is not controllable. You have to look at the least powerful resistance, right? This is a real controllable grid, which really is a powerful concept.

## Demonstration Projects

**Moderator**

The demonstration project idea is great.

**Speaker**
It is very important, I think.

**Moderator**
Let's start with a demonstration study. Right? The computer models can do these things very efficiently, and show what kind of protection, what kind of remedial action is necessary in order to stabilize these kinds of losses. That's the first step. And then, if you can get buy-in on people, you know, engineering, the technical folks that say, "oh _ "

**Speaker**
Looks like it's going to work.

**Moderator**
Yeah, that's possible. Then you can start to think about taking the next step.

**Speaker**
You need failure data too, though. How often do they fail? And when do they…? How often do they both fail?

**Speaker**
And do we have that data or do we need to build a demonstration project to collect?

**Speaker**
We would need that data. I mean, RTOs would want that data to change their tariff.

**Speaker**
The experience is there. More will come. Bipoles do exist, also at ±525 kV. And it's not so much about failures of the technology, when you're talking about bipole failures. It's usually external reasons. And there's a lot of experience with that.

**Speaker**
The last one we had. Last spring, there was a lightning strike. The phase one phase two from Canada actually is multi-terminal, but it's fully bipole. We had a lightning strike that took out one and the other 1,000 cable operated perfectly, without a hiccup.

**Speaker**
I think it's also worth mentioning that the individual parts of the European countries, they don't have two gigawatts of reserves. So, in Netherlands, they have just over one gigawatt, for example. Which is okay to capture the loss, something that you would expect to happen on a more regular basis. And then, just in case the two GW thing does happen, there is enough connectivity with neighboring countries to share their reserves. There's a platform for that. Because of where the countries know of each other's reserves. It's the same thing that they did in Denmark, where they connected 1.4 GW to the Viking Link, even though they only had 700 MW of reserves. They built the 700 MW link to Germany, AC, to be able to share reserves with Germany and enable that 1,400 MW. And that will be similar here, too, in the US. If you have the connectivity to neighboring

regions, you can start sharing reserves. And you don't have to increase the amount that is procured overall. And let's be honest. The amount of reserves that are going to be there, it's going to go down all the time. So, that's why I think six-gigawatt loss is not something that we should really be thinking about.

**Moderator**
What do you mean by that? It's not something that we should be thinking about it?

**Speaker**
Spinning reserves will go down. Simply, you will not have as much reserves on the system in the future, because dispatchable generation will disappear. Unless you're going to curtail a lot of wind farms and solar farms to be able to increase their output as needed, which is also a way of procuring reserves. It's going to be more of a mixture between flexible loads. You can ask to stop using power during times of contingencies, either automatically or on demand, probably automatically. Some curtailed renewables that can increase the output, and then storage.

**Moderator**
I want to just make one quick comment to the load issue, though. In some sense, we've had it for years. It's called under frequency load shedding with a high frequency setting. So, you know, the under frequency load shedding relays are typically set for 59.3 or whatever. But if you set them for 59.75, you'll get a lot of what you're saying.

**Speaker**
When you say, "backup storage," I think about two things. I mean, not only electro-chemical battery, but also hydro. I mean, the UK is really building links to Norway for multiple purposes. Of course, it's money. But that's a backup for storage. It's an absolute fast-building reserve sitting there, waiting. We have a country north of us that might have some to deliver.

**Speaker**
Yeah, we do have some decent projects going forward. The real issue there is going to be in 2041, with Maritime Provinces, because they have a large basin the size of the Republic of Ireland. Also, the battery storage is going to be huge. The only one little comment about the spinning reserves that Connecticut is looking at is that, for the POIs for the HVC offshore, for some of the power conditioning equipment on the AC side, we're actually thinking, not of using STATCOM, but taking our old fossil peaker plants. Remove the burners. Just keep the turbines there and use them as synchronous condensers. So, they will still be, actually, spinning mass.

**Speaker**
Yeah, but even now a lot of these converter technology has virtual inertia, right? So, it's just making sure that those technologies work as part of it. We have to design our

grids assuming it's going to be 100% converter-based. Powering the load or the generation side, it's going to be 100% converter-based. So, there's no rotating machines. Except if we build inertia through the converter into the grid. So, it's a matter of designing our grid differently. It's possible. I've seen it in South Africa, now, they have, every day, eight hours of outages. Every day. Rolling blackouts. Whole country, eight hours per day. Four hours on, four hours off, four hours on, four hours off. But it works. The grid works, believe it or not. It's, maybe, not the best example, but it does work. So, these are all microgrids and converter-based generation and there's actually a hydrogen plant they're putting there now. One of the mines. I think it can actually work.

## 200 GW Offshore Wind Study

**Moderator**
So, we we've talked about the locations and the permitting and the restrictions. Then we've talked about the six gigawatt issue. What about, you know, 85 GW offshore? No. What about 200 GW offshore? Do we need to be studying this? Would you be happy to see such a study?

**Speaker**
I think so.

**Speaker**
200 GW from where to where? The entire East Coast?

**Moderator**
Maine to Carolinas, at least.

**Speaker**
Massachusetts' goal is 2027 to 2030. That's just for one tiny little state.

**Speaker**
Maryland just goes to eight. And they wanted to know where they were going to landfall this. Because the Delmarva Peninsula… We don't have problems in New England, compared to that. So, if you start looking at what states are talking about, 200 is not a bad idea.

**Speaker**
It might even still be modest.

[overlapping agreement]

**Speaker**
Holland – tiny, little country – is going for 90 GW.

**Speaker**
Yeah, Massachusetts' 27 to 30 number is a number, which they are not curtailing significantly, and they're maintaining the entire thermal fleet to balance, instead of curtailing and using the balanced grid.

**Moderator**
If you were DOE Secretary, and you have this perspective, coast to coast. Is 200 GW offshore wind a good bet? Is it a good investment? I mean, I'm just –

**Speaker**
It depends on what your alternatives are, right? So, in the US, you also have a lot of space onshore, for solar and wind, which you don't have in Europe. So, your offshore has to happen.

**Speaker**
But you build transmission from offshore wind –

[overlapping voices]

**Speaker**
But those are the choices, then. But what's easier? What's cheaper? What has the least environmental impact? I think those are the questions to ask. Thinking about, what do we actually need in terms of energy consumption? 2030, 40, 50? And what can we realistically realize in the available space? And I say available space, that's after you've talked to the fisheries and the Navy, you know. What then remains? That will give then you a number, I think, to work with.

**Speaker**
Not to make this too complicated, but are we solving the lowest first cost or the lowest life cycle cost? For everything. Because if you're saying life cycle, all your hydrogen… I mean, you need a lot more data to figure that one out.

**Moderator**
My orientation is always the second one of those, right?

**Speaker**
Life cycle?

[overlapping voices]

**Moderator**
Makes the most sense to me.

**Speaker**
I think the assumptions that we have now – it's basically just interconnection cost, right?

**Moderator**
Ultimately, you want to make these kinds of decisions based on life-long – more than life, actually.

**Speaker**
Wasn't there some study from NREL's part of the Atlantic Offshore Wind Transmission Study, where they showed different scenarios, one scenario being that solar energy become significantly cheaper still, and bigger uptake in the US. Which then basically means you need less offshore wind. You do need to look at these different kinds of scenarios.

**Speaker**
I think it will be both, right? This highly distributed solar makes sense. But you can't build everything. So, it has to be a combination. And also, the natural diversity of solar and wind. I don't think we study that

enough. But, I mean, there's absolutely a natural diversity between the two. So, you can use the same infrastructure to interconnect solar and wind at the same place. You don't have to double up the capital investment.

**Moderator**
Yeah, diversification is a great feature.

**Speaker**
Diversification within resources, between the different wind areas, first of all, but also between wind and solar. Very much so, yeah.

**Speaker**
And, you know, in the future, we should not forget other sources of power, e.g. wave energy. At the same locations, if you're offshore. At the same locations, you may actually have wave energy in the future, which is cost effective. So, if you have that backbone bolt, you can actually think about a lot of scenarios where you can diversify generation.

**Speaker**
So, I think taking that together with the idea that, it's one thing to say where you're going and then what are the steps? But I would actually offer them that all of this comes together into a conversation of what happens a year or two years, three years, four years. And that there are people in the room and there are people who could be tasked with coming up with multiple scenarios to evaluate this. But these have to be holistic, because they have to take into account these various possibilities, it has to be possible to look at them and say, "no, that's not going to work." And, "that might be nice, but we have to change this." To have things on the table where people are, you know, playing with that a little bit in parallel with all of the urgent work that's going on to move these things.

**Speaker**
That would be useful. What also it would be useful is a complement to the Atlantic Offshore Transmission Study, which really looks at the wet side but not how it affects the dry. I'm not talking about anything deterministic, I'm talking about something that's directional, because if I can take back to my manager that listen, if we do this build-out the wrong way, we double our land-based costs. Or the power flows go all sideways. Information like that would be very helpful to us.

**Speaker**
Well, and in that regard – this is up to you all, how you want to take this or handle it, but – this study is essentially the dry-side counterpart to the Atlantic Offshore Wind Transmission Study. NREL and PNNL are very well aware that we're having this, we've coordinated with them. And I think a request from someone like yourself to say, "hey, I was at this thing. I was interested in this. And we're interested in what is DOE's sense of this?" I think that the table is set to see it

in that way. And then, I think it also… Well, anyway, I'll just put it there. And I think our intention would be to kick off this conversation now and sustain it until December, in response to questions from folks about "well, what is it that you want to see? And how do we do this? And then how do we get into with the power systems engineers to make this more real?" So, I think that the basis is there. But it's ready to be reworked in such a way that it becomes more useful to you.

**Moderator**
So, what I heard you, earlier, referring to, is it, in some sense, a relief of the pressure that you were describing? I mean, that's kind of what you would use this kind of study for, right? To show that these –

[overlapping voices]

**Speaker**
This study would be useful for as we were describing. I'm in the dry side. Gives us a huge amount of opportunity to discuss with DOE, particularly if we have a joint interregional plan, like the letter suggests. But also, our own state energy officials. Because the governor is not an electrical – I'm not aware that any governor has tremendous background in electrical engineering.

**Moderator**
We need to change that.

**Speaker**
What, really, has been helpful – and the DOE studies were both cited in the letter to Maria Robinson. And because we – this is valuable information to say why we need to do these things. The second thing, though, is that, as [another speaker] was saying, the system that the states have used to date – which relied on the PPAs for energy and RECs, and then, basically, had the developers do everything – that's changing. We're going to probably be doing at least, maybe, one more of these – I think you've got one on the street or will have one on the street. But I'm seriously thinking, and recommending up through my food chain, that we do a transmission-type build, which would relieve a lot of the pressure on the developers. If the developers can, therefore, just connect to an existing or partially existing grid, the first step, to me, is getting the POIs confirmed. I'm taking that. That is one approach. There are several pathways. A study like you're talking about, that shows different options and different pathways – states can do it this way, states can do it that way, this may be better – that would be helpful information, helpful ammunition.

**Speaker**
So, in that regard, I can imagine – what Jim presented today were five POIs in four gigawatts each in New England in this optimized format. But then the next step would be to come to together [with states, RTOs and utilities who could say] "these are the five POIs we want you to look at. Now,

look at these and compare them to the five that the optimizer came up with, and let's talk about the differences, so we can weigh them." That's a step that we would like to take sooner than later, honestly.

## How to Plan for the Future / What to Do Next

**Speaker**
The states do a lot of planning out until 2050, which is the ultimate target to hit our emission goals. Modeling is always wrong. I guarantee you, in 2050, the grid will be completely different than all of us contemplate in this room. My big question is: what do we do next? It's very helpful to say, "okay, let's model 200 GW." But what is the finding that comes from that study that helps do something this year? And I think that's a challenge, right?

**Speaker**
So, let me turn it around. What do you think we should? What would you like to see? What will help you?

**Speaker**
I think we need to think about small, bite-size things, right? Because I think, very often, states get proposed with, "let's build this huge grid." And it feels to state policy makers, it feels to local communities, as something that is just too much. It's too much to contemplate: what is it administrative step to make that happen? What is the barrier, right now, to picking POIs? Because states often leave this decision up to the developer. They say, "we want offshore wind. It's your responsibility to figure out how to get it here. And then we'll evaluate the way that you made the plan. And we'll pick your project." But what is the barrier for states feeling comfortable picking the POIs? Or is it the size of the POI? Is it this single source contingency? Is it something operational? Is there a project to build? What are states procuring?

**Speaker**
First, that's probably the right question to ask right now. But if you have had a vision, what the system will look like 2050 plus and how do you want this redundancy built in? Do you want to build some structure to allow more redundancy, allow larger failures, the macrogrid on top of it. How do we get that? Is the step I'm taking today the path to that route? Or is it the path against that route? And if it's against it, I think we need to think twice. If it's on the road, I think we just need to – and you're not going to get your 2050 plan. But you're going to get somewhere in the neighborhood.

[overlapping voices]

**Speaker**
I guess what I'm saying is, I don't know the path. I've been shown the end a lot, but I don't know if I'm on the path. That's my challenge.

[overlapping voices]

**Moderator**
Create the path. It’s not simply the end. It's not now or 2050, but it's 2024, it’s 2025, it’s 2026, dot dot dot dot.

**Speaker**
So, which aspect of this grid would you build first?

**Speaker**
Well, I would make sure that whatever you build – you know, these existing projects with just a single point of point connection, AC, is absolutely a wrong way to do any of this stuff. So that's wrong, right? Just to be straightforward. So, at least build something, which you know is adaptable to future. Be future-rated or try to be future-rated. What I like about that presentation this morning: every single project we look at has to be future-ready, right? It has to be multi-terminal ready.

[overlapping voices]

**Speaker**
As a non-power systems person, everyone was like, “oh New York’s doing this great thing.” And then I hear, “no, New York did a bad thing.” And I’m like, I don't know what New York did.

[overlapping voices]

**Speaker**
But they stopped short. That's my understanding. They stopped short of really doing the right thing.

## Future-Ready

*(The following is a synopsis of the discussion provided to avoid sharing comments that may be seen as too identifying.)*

*This discussion included the status of existing procurements as well as the future-ready grid. New England has hesitated to approach the multi-terminal DC grid design as a meshed grid. Nevertheless, New England states prefer not to prevent the possibility of future multi-terminal AC capabilities through the RFP process. In addition to New England, parts of the East Coast are also backing the multi-terminal DC system, such as the Canadian maritime provinces. New England states are doing procurements as collaboratively as possible. But the states all have different laws to consider, so they are putting out their procurements at different times with different authorities. The circuit breakers and interoperability needed to achieve this are not currently commercially available. Many states would find it helpful for DOE, NREL, NERC, or an equivalent organization to create a standard voltage level. This would allow for intercommunication and controllability. States do not need to wait for NERC or DOE, however – as an example, NYSERDA made the decision to use a 230 kV AC link. This could be an opportunity for DOE funding, as DOE is interested in funding innovative projects. States could* *put together a demonstration project to convince DOE to claim there should be a common voltage. The TenneT 2000 spec sheet is a useful point of reference for technical specifications for HVDC grid systems.*

## CONTRACT RE-NEGOTIATIONS

*(The following is a synopsis of the discussion provided to avoid sharing comments that may be seen as too identifying.)*

*In this session, there was also discussion about the status of contract re-negotiations and the future grid. Information about which projects are threatened with possible cancellation is public. Next steps depend, to a degree, on how much flexibility there is in each project's development plans. There is strong pressure on the states and the environmental community to build wind farms as fast as humanly possible, in order to hit the emission goal limits that are set for 2030. The most recent RFPs have included requirements for projects to be online by a certain date. This timing may be impacted by contract re-negotiations. Policymakers are looking not only at the lowest cost projects, but also the fastest projects, in order to stay on schedule for emission reductions. It is important to keep in mind that the wind farm projects are PPAs (power purchase agreements) for energy RECs, not IRPs (integrated resource plans) or electrical engineering plans. The contract flexibility currently being sought after is beyond the scope of the existing procurement process.*

### Land Acquisition

**Speaker**

The study is – I agree with [a previous speaker], the most important thing for us on the state side would be picking the POI. Because, no matter what, if we are going to be doing a demonstration of something, we have to do it somewhere, right? We're going to have to take the first step and pick where to do this. I think the study would be really helpful on – we've often talked about "no-regret" scenarios. What is the no-regret? Let's do that. What's the next step, that absolutely, that makes sense to everybody. Let's take it. The study would be really helpful in figuring that out.

**Moderator**

We can do that study – we can do a part of that study, anyway. It really benefits from having a very close relationship and cooperation and coordination with people that know, you know, "this substation, you're just, you can't get there." All of that information is not easy to gather. It's possible to gather. If you spend the next five years, 24/7, you can get it. But you can't get it efficiently. And I'm thinking that there's people that have it in the room.

**Speaker**

I think that's very important. But some substations, you just can't – there's no space in there or…

*[Discussion ensued on non-technical factors that can impact the siting of substations and the needs of developers to be aware of these sensitivities.]*

**Speaker**
But there are certain things that, just – the facts are that some stations may be electrically fine, they may look developable, but simply are not. For reasons that the people who live there know.

**Speaker**
Well, actually, that's a good point, right? Because a lot of what we rely on – the technical knowledge – does live with developers.

[overlapping voices]

**Speaker**
Good credit to Jim here and his team, because they have parameters saying cost of the substation development. So, we get the right result out. But that information is not residing with academia today.

**Speaker**
And it's not residing with the state government, either. And that's a problem.

**Speaker**
Because there's no one who has all that knowledge. That's hyper valuable knowledge. If you want to do it for the whole coast, you're going to have to work with 20 different organizations to get all that information.

**Speaker**
I would say yes. And, I would also say, I think it's possible. Because, when you look at the East Coast, if all you do is say, "in our maps, the 500 kV lines are blue and the 345s are purple," you can pretty much get most of the way up the East Coast, and see exactly where you need to interconnect, because you just go to the blue line. And so, I think, then, you get into a region where you choose, you know, 50 POIs. All of Jim's little teardrops that he showed. And then, you find the ones that, really, make the most sense and then you find that there are a couple of spurs where you reverse the power flow. And so, Jim's model almost perfectly recreated the results of the New Jersey SAA. Because everything goes into Laramie, Smithberg, and Deans. And it's all right there and you don't need an offshore grid. And very similarly in terms of, where was it, Canal and Barnstable? Okay, is the POI here or here or here? But it's all in the same spur. So, I think this idea that we can analyze the main power flows and where the reversals are and then you can use that to hone in. So, I don't think the system is quite as complicated as it looks at first blush, once we start to dig in a little bit to the specifics.

**Speaker**
Exactly. This is the same thing on the ports. New Bedford is a good example. There were 21 acres in New Bedford. Developers tore down an entire radio tower to create three more acres. And there was a 50-foot easement that the developer actually couldn't get, to another four acre parcel, because of an owner. And so, when it comes to the East Coast, land is the thing that drives all of them.

[overlapping voices]

**Speaker**
And it's the limiting factor. In this whole European way of thinking, everyone's saying, "plan for worst." Make sure that you're trying to get that land. And then build what you need. Which is seven years later, when you know how much you actually need.

**Speaker**
I think that's right. I think this all begins with land acquisition. Which is kind of interesting, because then it becomes, "okay, what are my spatial requirements? How many square meters do I need?" And then you can actually do some pretty simple, straightforward studies. Boom-boom-boom, boxes on the map. Then you start to play with this.

[overlapping maps]

**Moderator**
This is what I did for this. I went through all of those 80+ POIs. Mapcarta, anybody every use Mapcarta? I just looked at them and said, "is there any space here?" And if there's no space, they got one number. If there's a lot of space, they got another number. That's what I could do. But, I'm guessing that there's more than that. I know there's more.

**Speaker**
We need the right people. We don't need authority, but we need whoever has the authority to understand and to support this notion of aggregating some of this from a strategic point of view. And that's then a question to the states: where does the information reside? Where does the authority reside? How do you do this within protocol? And then, how do you get it into hands where you're not giving away private information? This publicly available data is a symbol in a way that's helpful.

[overlapping voices]

**Speaker**
Also, wetlands could be an issue.

[overlapping voices]

**Speaker**
All the information is hiding in plain sight, but it's about aggregating it in a way that the different stakeholders bless it, right?

**Speaker**

We need to do a suitability analysis using the protected areas database.

**Speaker**
What were you going to say?

**Speaker**
So, for your model for the network upgrades, after you add the offshore, did you consider phase shifters, so they could help move power about?

**Moderator**
I didn't consider any new phase shifters. No.

**Speaker**
It could help a lot, rather than building new lines.

**Moderator**
Good point.

**Speaker**
Convert them all to DC.

## More Compact / Compressed Air as Insulation

**Speaker**
I think there's a lot of good discussion there. I do have some ideas about your show and tell questions. So at least, what I put together and maybe getting your feedback would be –

[overlapping voices]

**Speaker**
So, I don't want to do the presentation again. But I do want to get your inputs. What we spoke about is a two gigawatt HVDC link, right? And the discussions around protection. So, those are the two big questions. If we have a six gigawatt interconnection, do we need three parallel stations? So that's what we're talking about. Or in the future, are we thinking about – by future I mean, maybe not the first round, but 10, 15 years from now? Looking at a station, which may be so compact that we can build it up to six gigawatts, rather than two or three. What I've heard happening with the vendors, ABB and Siemens – is that that is where we're looking at, is to really try to compact things. On the DC side, a lot of gas insulation, rather than air insulation. Compressed gas. If you open up a station – I put a picture in there from the DolWin-3 station. That's a converter station and that is actually offshore, right? So that's basically mostly air. What you see, if you really zoom in to that picture, you see some installation there and you see a little bit of a DC-link capacitors. And then you see the silicon carbide devices backed into a very small space, but the rest of this air. So, why do we need so much space? If we can get better insulation materials or better integration of these technologies, we can build these offshore platforms. And onshore, it's going to be same for onshore – much more compact. And hopefully much less costly. So that's what I've seen from a research community. But the big focus is, of course,

on making these stations much more compact, by using gas.

**Speaker**
What kind of alternatives are there for air as insulation?

**Speaker**
So basically, first of all, compressor – use compressed air.

**Speaker**
In the converter station?

**Speaker**
So, just keep it pressurized. You can get much more dielectric capability. The other piece is, just, take the air out and put another gas in. Which is sort of what we do with GIS (gas-insulated switchgear) circuit-breakers.

**Speaker**
But that’s not for valve hall, right?

**Speaker**
No, that's for the whole enclosure. If you look at the picture upstairs, that's a Siemens GIS breaker. That's a 550 kV. It's only 5kA. It doesn't sound like a lot, but it’s a big compact, making that whole breaker much more compact.

**Speaker**
No, definitely. And for a disconnector, because it's not a breaker –

[overlapping voices]

**Speaker**
So, what you see here is a cable transition station. So, you have a few disconnects in there. Maybe some instrumentation to measure things and in-rush current perhaps. Plus, what it's really meant for is being able to test different sections of DC cable. And that technology is being qualified. You can buy that today. A converter hall, I think, is much more challenging. So, if you were going to do that – I think compressed air, that’ll be the most straightforward way? I think it's impractical to fill an entire converter with gas. You still need the space between the modules to be able to exchange them, because they failed. I don't know if you’ve ever been in one of those, but putting something under pressure there, it’ll be a much heavier thing. The question is, what do you gain with that, right? It is the main challenge, I agree, with trying to make things more compact on the HVDC side.

[overlapping voices]

## HVDC Research Labs

**Speaker**
I did have, in one of the other pictures, a size. It's a large investment. But anyway, at least from the future, where we look at, there's going to be a lot more focus on the DC protection and trying to make these stations more compact. There’s the size, actually, on the slide. That’s actually the DolWin-3, including AC side, the station.

It’s 85 meters high. A big part of it's underwater. And 54 meters by 90 meters wide. So, coming back to that DC connect, one option is to look at the cable, itself. Can you integrate that GIS idea in the cable underwater? Do you really need to do everything above ground? Maybe future things. But, coming back to the research and demonstration platforms. First of all, from a research and development lab facilities point of view. We don't have an HVDC research lab in the US. I’m talking about real scale, HVDC-scale lab. I think that is needed, personally, to demonstrate these technologies, to make them ready. I remember, years ago, when the Chinese just got into the short-circuit and high-voltage projects. We had to go and help them to build labs. They have, now, the larger labs in China than in the Netherlands. So, that's what we have to do. If we build a project, or we contract a project with a vendor, we have to make sure that that technology – that lab capability – stays in the US or comes to the US. I know that's not the culture here. But that is absolutely crucial, that we actually have capabilities in this country to actually evaluate and study us.

[overlapping voices]

**Speaker**
Where’s your proposal? There is not the lab, like the RTE has, with the replica –

[overlapping voices]

**Speaker**
Well, this is actually just this private lab, which we are trying to work at Clemson, is to actually upgrade a lab, which can do at least hybrid simulations for grid interfaces. You can't build a 500 kV, three gigawatt lab. So, you do have to think about, at least from a collector point of view, to actually build it. This is just our ideas from it. But I think, in general, there have to be more labs and capability of demonstrating these things.

**Speaker**
Massachusetts.

**Speaker**
Massachusetts, right? I don't know if there is some HVDC work which you guys are going to have there.

**Speaker**
No.

**Speaker**
But, I mean, that is the problem. Right now, we don't have lab capabilities in the US to really show and tell what has happened. The other piece of it is the system level discussions, which we have, right? Where you have these large-scale simulations, which Jim mentioned, where you basically can study not just the AC and DC grids and the point of interconnections, but how this would evolve, eventually, in a hydrogen network, as well. Having that multi-energy simulation platforms to study these impacts is crucial. That's more of a system level.

EMTP (electromagnetic transient program), electromagnetic studies are used for studying protection transients. You know, things we mentioned. There's so much more I can put on this list to make us a little bit more sure that the technology is ready and de-risk ourselves. We're going to invest billions and billions of dollars in this offshore, and probably onshore, grid. So, we have to have some form of de-risking ourselves.

**Moderator**
Would you say this is as compact as an HVDC converter design, as you can get?

**Speaker**
Right now, that is what we have. The latest platform was built in Europe.

**Speaker**
In my mind, I'm thinking of this substation in New York City. Farragut? And I think it's, on one side, surrounded by water. On the other side, nothing but buildings and streets. And electrically, to your point earlier, it's pretty good. But as I look at it on the satellite Mapcarta, there's nowhere to build anything at that place. You might do this. But would you do this?

**Speaker**
It gets more compact, still. So, this isn't a German platform, which means there's a lot of requirements for additional things. So, there needs to be quarters for people that can stay on the platform. It's the gold-plated version. If you look at the platforms being built in the UK now, they are much leaner in the design. And I would say that would be a good indicator for how small you can get, without resorting to all kinds of new insulation materials around.

**Speaker**
Do you have links to those designs, right now?

**Speaker**
Some of it. So, if you look at the Sofia project, for example, I think you can probably find, if you Google around, what the dimensions are for that one. And the other ones are Dogger Bank projects. They're both 1,200-1,300 MW something. What kind of labs are you talking about, here? Are these mostly real-time simulation labs? Or, also, high-voltage power testing?

**Speaker**
It's both. So, I think we do need to look at real high-voltage labs, where you can demonstrate the dielectrics, the new technology. Bringing manufacturing back to the US to actually get manufacturing done here under our conditions. This is long-term. It's not going to solve your short-term problems right now.

**Speaker**
It's partly happening, already. So, the cable factories that are being built in the US now?

[overlapping voices]

**Moderator**
Mississippi State has a high-voltage lab. But I'm not aware that they do anything DC. Georgia Tech, or Georgia Power, has something.

**Speaker**
There are high voltage labs but they got out of fashion. Universities don't want to use them, because they're expensive and a lot of real estate. But I think a lot has to come back and get upgraded.

**Speaker**
I think the question is, what kind of lab are you looking for? So that – you have production labs, which … Maybe something for research?

**Speaker**
I think somebody mentioned the digital twin type of labs, where you basically don't build the full capability of a HVDC terminal.

**Speaker**
But that's what they have, the RTE in France, for example. They use that for real-time simulation.

[overlapping voices]

**Speaker**
I think do you do need to do both. You need the controls, hardware in the loop, and control platforms. But you also need the power side. Now, the power side, again, what do you need? And it depends, right? Do you need the full high-voltage capability? Do you just need one single phase on, where you can actually evaluate the internal controls of the converters? Or you need the system-level control? You definitely need the system-level control, that I'm 100% sure on. You need to have Western Interconnect on a real-time simulator. And you have to have a real control system for those converter stations in that simulation. But it must be real-time. It can't be offline. You have to, basically, look at a contingency, see at the control inputs. Is that going to be responsive? So, there's a lot in the labs, which we need to upgrade.

**Speaker**
What would be the role, if any, of the original equipment manufacturers (OEMs), of these labs?

**Speaker**
Well, they have to provide their controllers as part of the labs, right? So, we have to use – if there's a new project coming in, they have to give that same controller to that lab. And it may be at every lab, it may be at every other lab. But it has to be in that lab. And if you want to check contingency, you have to run it first in the lab, and then say, "okay, that seems to work," before you set it up in your control. That size, I think it's a DOE facility. That's what I anticipate this would need to be. I actually have a picture of those European labs, a few of them.

[changing slides]

**Speaker**
So, these slides are, basically, what – France has the, I think they call it the "super grid," the UK has the National HVDC Center. And then the industry, of course, have their own labs you mentioned, next to them. That national lab on HVDC is missing in our example. So, that's, I think, what we need. It may be a DOE lab, it may be a national lab extension but it's definitely –

**Moderator**
What is it that you need in Charleston, to do this?

**Speaker**
It's not going to be in Charleston, right? We don't have that sort of power level. It would probably be at NREL. It won't be a specific university. It may be a center consortium of universities. Can't be just a single university, I don't think so.

**Speaker**
How long do these labs take to set up?

[overlapping voices]

**Speaker**
It can be pretty quick.

**Speaker**
Most of the equipment that you see is – I would almost say off the shelf. You need to order it, of course. Take some time. You need to build the building. I would say it wouldn't have to take much more than a few years to put it together. It depends a little bit on what kind of lab you want. So, if you want to build a DC high-voltage laboratory, that is relatively easy. If you say, "I want a short circuit testing laboratory," that's different. That will take significantly longer, I think. And then the other one. So, those two are testing physical aspects. The testing functional aspects unit is real-time simulation lab.

[overlapping voices]

**Speaker**
I believe there is currently a wind consortium center proposal from DOE. Tufts is submitting a proposal. But some of those centers are really what we're talking about, having that capability around a larger lab. Not just a physical lab, but also a simulation lab.

**Speaker**
Maybe most importantly for training purposes. Even if you're not doing your own research, you have people setting up and running tests, and getting the skills, and handling HVDC, of understanding how these controllers work. That's something that is missing here.

**Moderator**
To me, this sounds like an NSF ERC. I'm not in the business of wanting to lead an ERC, I'm 64, so I'm going to do something different here. ERCs are 10 years, but this is a 10-year plus issue. If you wrote a proposal

today and it was funded in two years or three years, it'd be very well-timed.

**Speaker**
This is another example, again, from Europe, where the availability of such a lab wasn't something that came out of the market. The 500 kV DC lab that CESI built in Mannheim. That was essentially paid for by TenneT, because TenneT wanted to make 500 kV cables possible. They needed a lab to show that that was possible. They did work together with the industry to see who'd be willing to do that with them. But it would not have happened by itself. It needs a push. And the question here is, in the absence of the US TenneT, who can give that push here?

**Speaker**
I only think DOE or NSF or some agency like that.

**Speaker**
Anyway, I think we want to keep this as a discussion. But that is really – to do this show and tell, get the regulators, get the ISO leaders to come and show that, yeah, this does actually work, right? We can study scenarios. We can do these single-contingency analysis and figure out, is this realistic or not? Right now, we guess. I mean, we think –

**Speaker**
But the states also have something to do in that area: DOE, certainly, but also the states, for example, New York/NYSERDA or New Jersey/EDA.

**Speaker**
I'd heard it discussed. I didn't know how serious it is. People have been talking about the idea of having an actual test center.

[overlapping voices]

**Speaker**
And so, people know this has to be done. The benefits are obvious. If the ISO and state energy officials can down and actually see the project, have it explained to them, and be assured it runs, that's going to be huge. Because, as [another speaker] said earlier, in the state world, everything is a prudency review. And is it ever prudent to do something that's never been tested?

**Speaker**
If you change scenarios, you have a place to test it out first, before you turn the switch.

**Speaker**
Exactly. And also, how are we going to get the workforce to run our HVDC grid if we don't have a place to try and test it.

**Speaker**
Well, that's what all of those things are for.

**Speaker**
So that's why it's very important to link it with several universities in a consortium. Jim worked on a training proposal for DOE.

And that’s what you need. You really need a new curriculum, you need new courses. This is great. This is the future. And we need to do this, right?

**Speaker**
Or paired with a larger project, right? There's always the opportunity, with funding something very large, to require or request things to be funded. Millions and millions of dollars these developers put towards other things. It's always easier to have those things exist first and then get the funding for them, because it's your innovation, it's your creativity from the academic side. And we want developers, maybe, to contribute to it. But maybe they're not the best ones to develop. They don’t want to set up labs. They want to fund labs so that it gets considered by state governments and their economic and workforce development.

**Speaker**
That's why they do it.

## Energy Islands

**Speaker**
So, I have a question. You said in your presentation this morning they were showing that concept of energy islands, or even artificial islands. So, I was thinking that if we have, for example, the lease or call areas 16 GW, which means that will be having eight, two GW platforms. So, is there a number, which shows that, beyond this power level, the artificial islands are more economical as compared to building separate ones. Or, what is the advantage of building artificial islands compared to platforms?

[overlapping voices]

**Speaker**
It's a good question. I mean, eventually, if it's an island, I think it is considered as one platform, maybe several stations inside. But it's one big platform, right? Or artificial island., Can we actually integrate those existing ones smaller? I would like to see them smaller, more compact, personally. Because then the cost will go down, as well. The installation costs, the marine, the ships. You have to carry the materials out there in the ocean. So, there's a lot attached to the supply chain of this work as well.

**Speaker**
I think several of those island concepts should also consider the hydrogen.

**Speaker**
Yeah, that's exactly the case. Because they generate the hydrogen on the platforms and then ship it, the gas lines out.

**Speaker**
If you visit the website, the North Sea Wind Power Hub, they have a lot of documents on that to give you an answer to that question. The basic number that they put out there is 450 MV with today’s converter technology. After that, it starts making sense to start looking at islands compared to separate

jackets, basically. And the other thing that was interesting about the presentation this morning is that they showed that the island, itself, doesn't have that many converters on it. So, it acts as a DC hub. And the converters are placed outside on platforms, closer to the wind farms.

**Speaker**
Which is a fundamentally different way of thinking.

**Speaker**
And that's basically how it is in AC, right? AC switching stations?

*NOTE: from this point on, there are multiple conversations happening throughout the room.*

# Appendix A: Keynote Address Slides

ENERGINET

# ENERGY ISLANDS

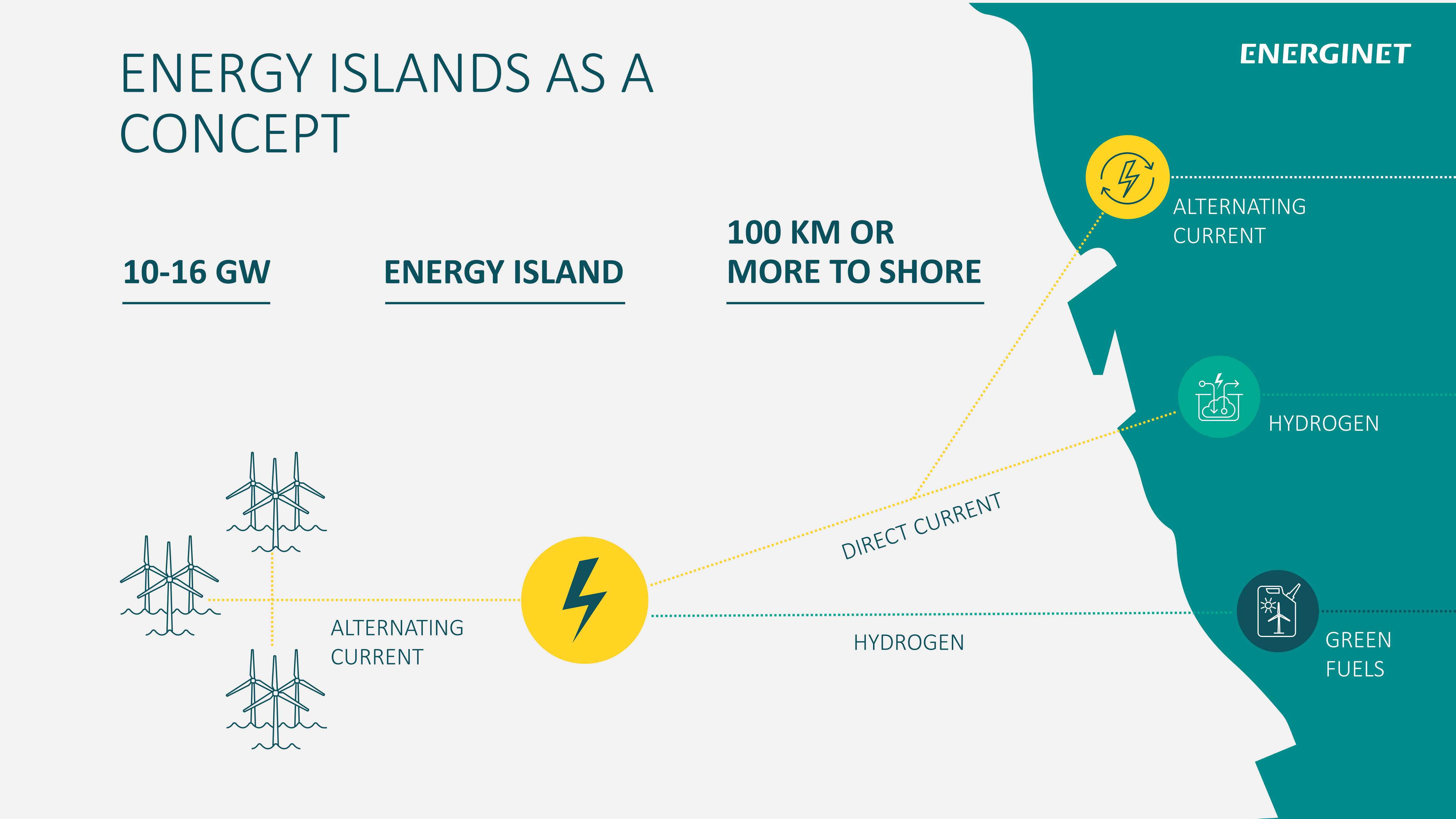
## Turfts Offshore Wind Transmission Workshop

*Peter Godt-Larsen*

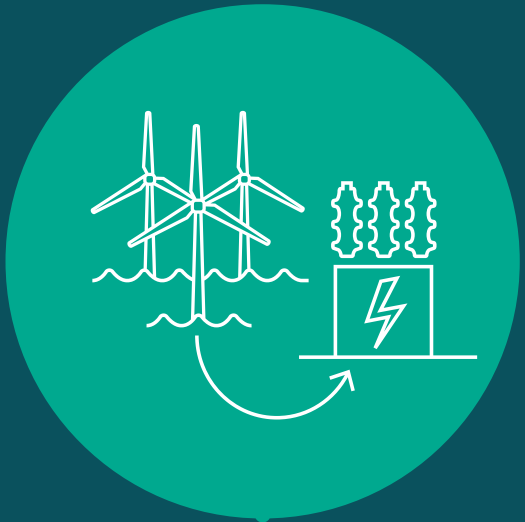
# ENERGY ISLANDS IN DENMARK

**The North Sea**
3 GW offshore wind, later 10 GW – enough for **10 million households**

**The Baltic Sea**
3 GW offshore wind – enough for **3 million households**


ENERGY ISLANDS AS A CONCEPT
ENERGINET
10-16 GW
ENERGY ISLAND
100 KM OR MORE TO SHORE
ALTERNATING CURRENT
DIRECT CURRENT
HYDROGEN
ALTERNATING CURRENT
HYDROGEN
GREEN FUELS

# A NEW WAY OF WORKING



The energy islands are nothing like business as usual. The dual functionality of the islands raises complexity.

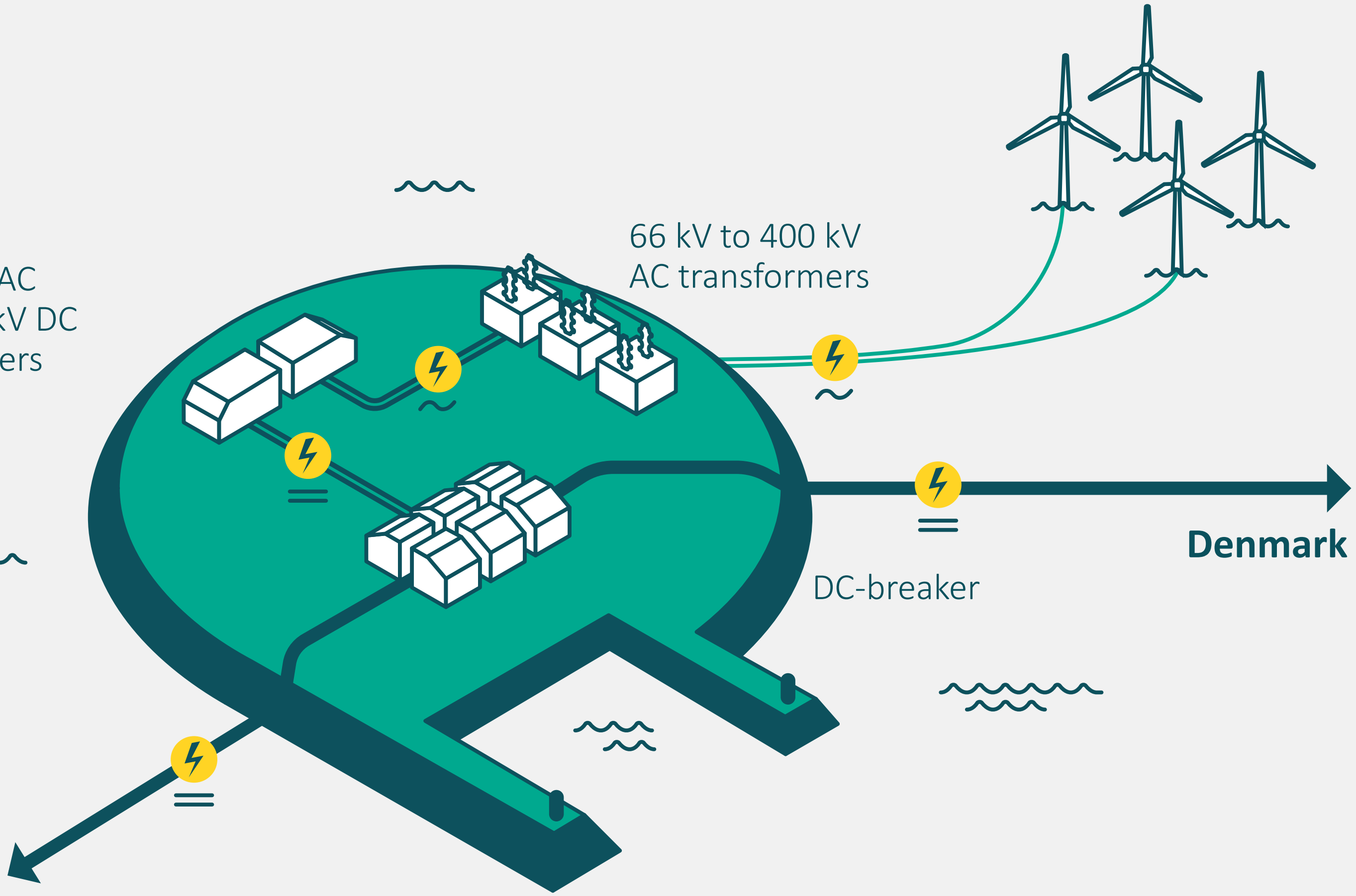
The states are first movers in establishing international connections to the islands. The TSO’s follow up on the work.

The Offshore wind farm developers play a central role.

ENERGINET

# NORTH SEA ENERGY ISLAND 2033

## Converters and DC-breaker on the island



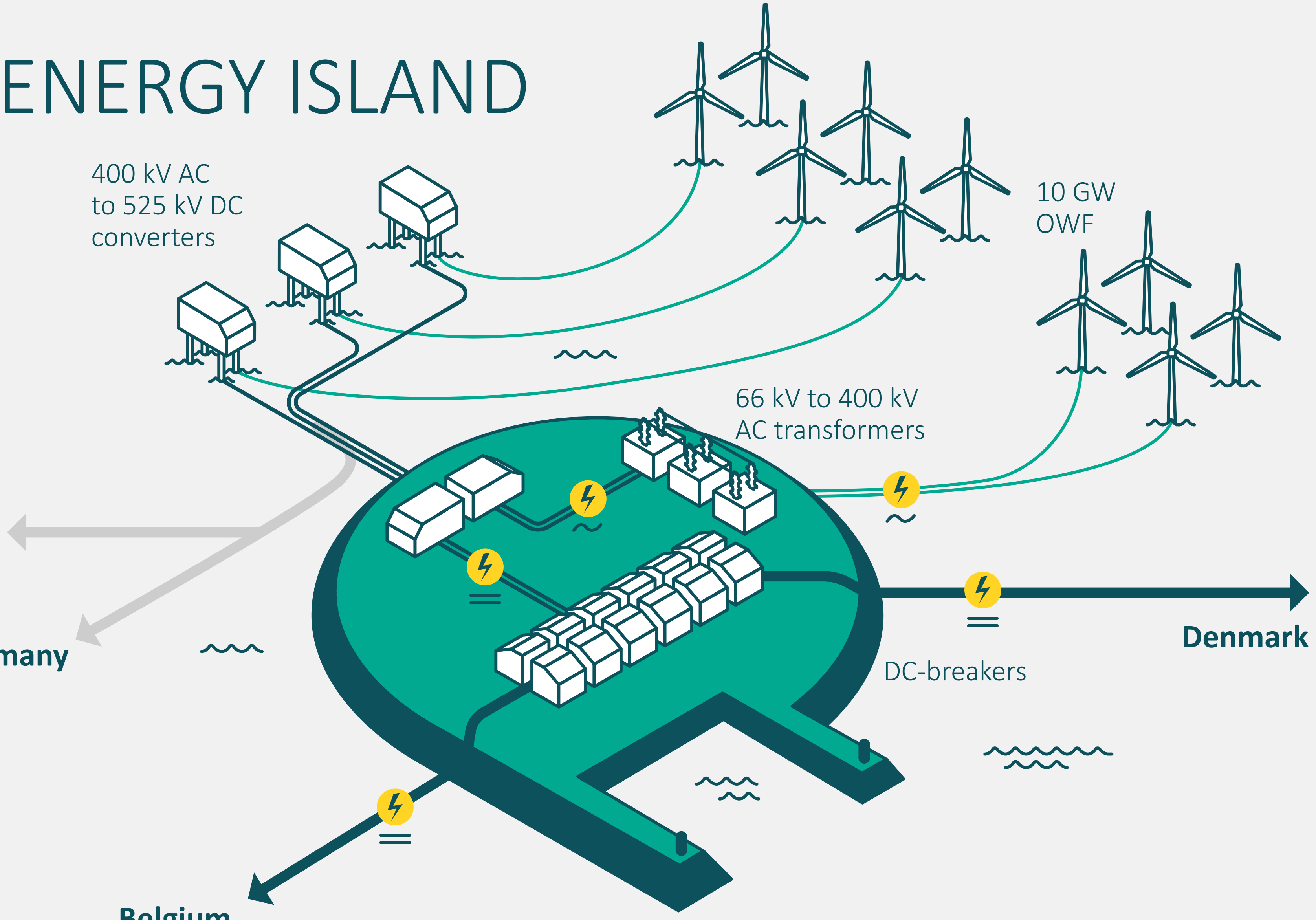

~ Alternating current

═ Direct current

ENERGINET

# NORTH SEA ENERGY ISLAND 2030'IES

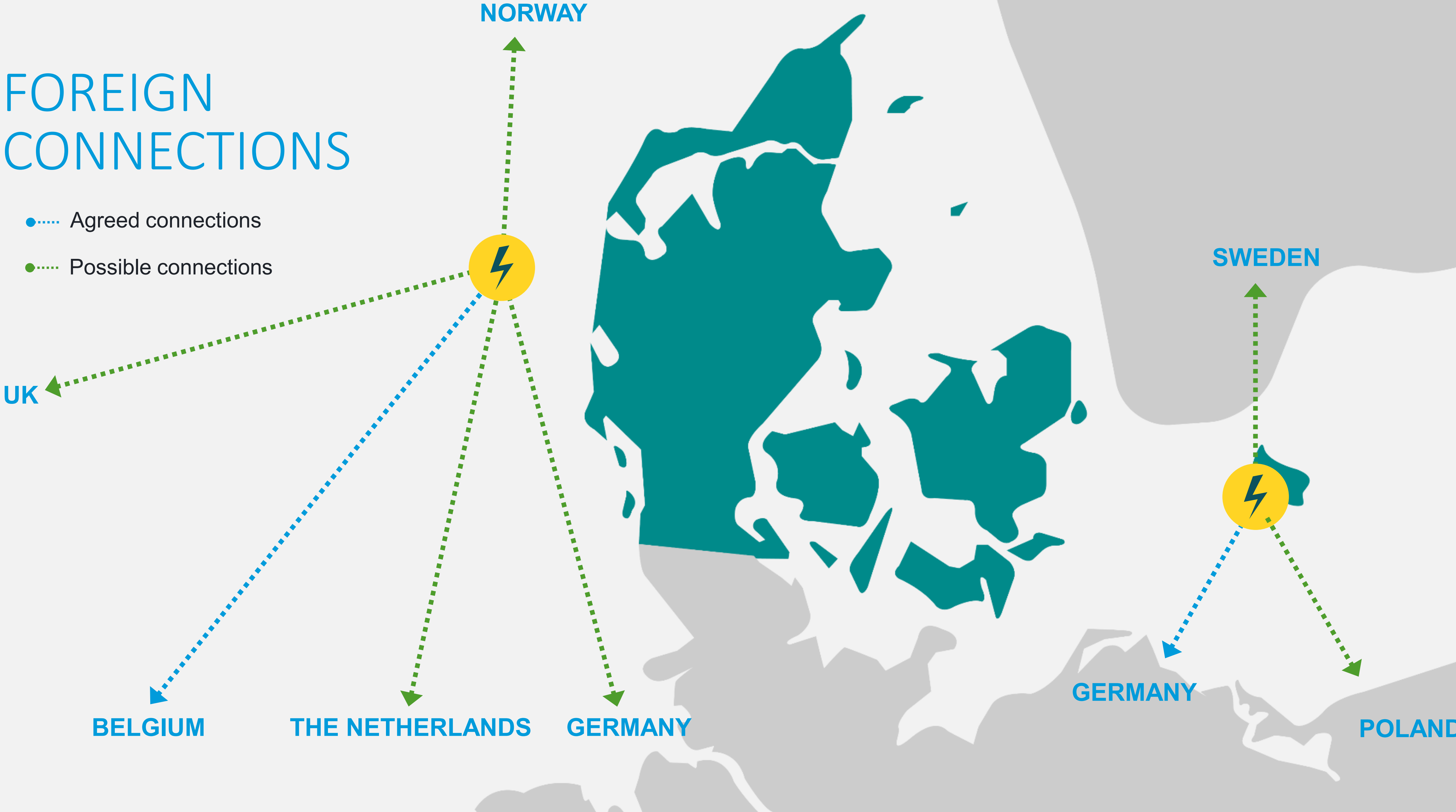
More DC-breakers on the island and additional converters on platforms



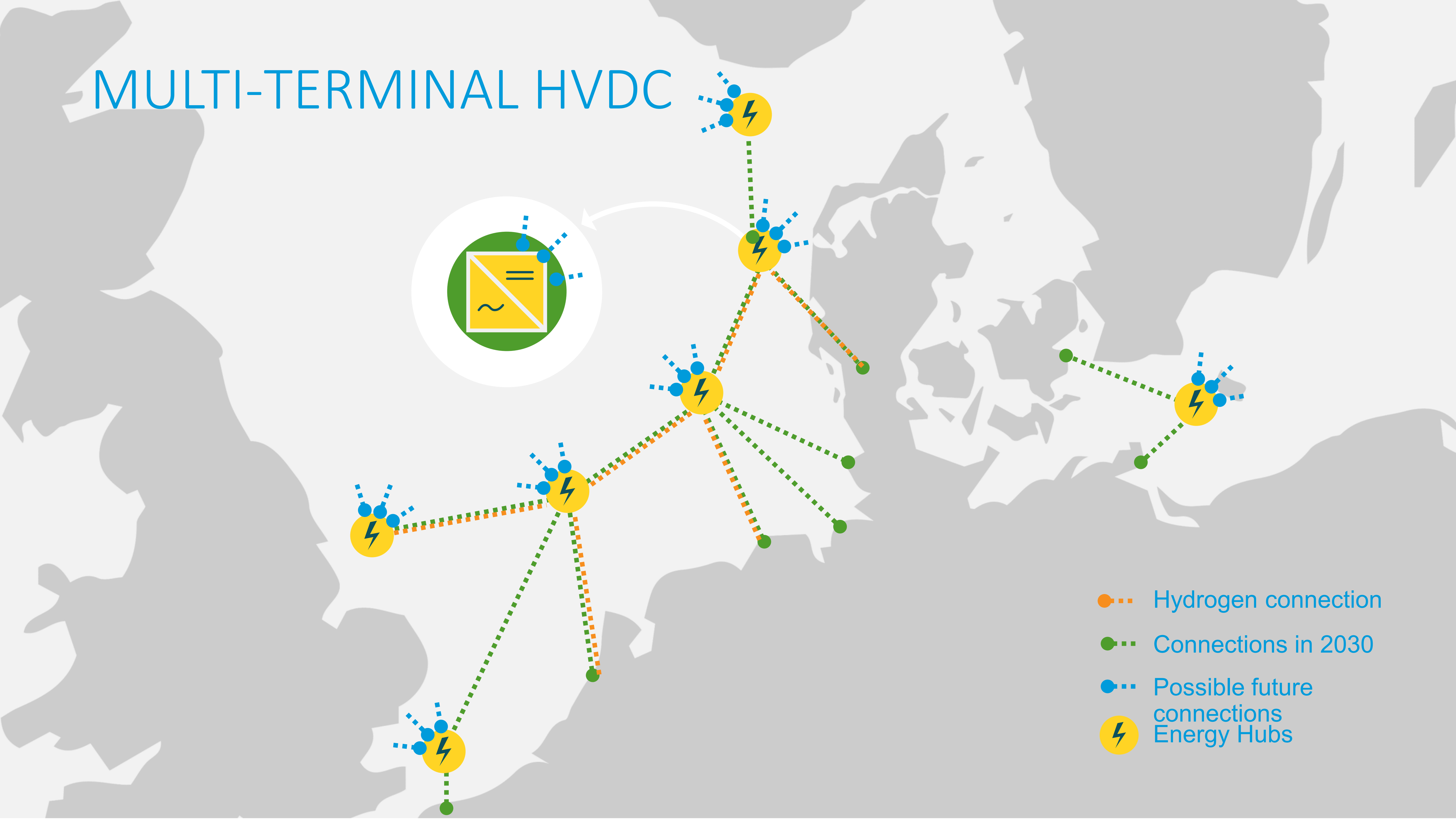

~ Alternating current

= Direct current

# FOREIGN CONNECTIONS



# MULTI-TERMINAL HVDC




ENERGINET

# FOLLOW OUR WORK

**Energinet:**
https://en.energinet.dk/infrastructure-projects/energy-islands/

**Danish Energy Agency:**

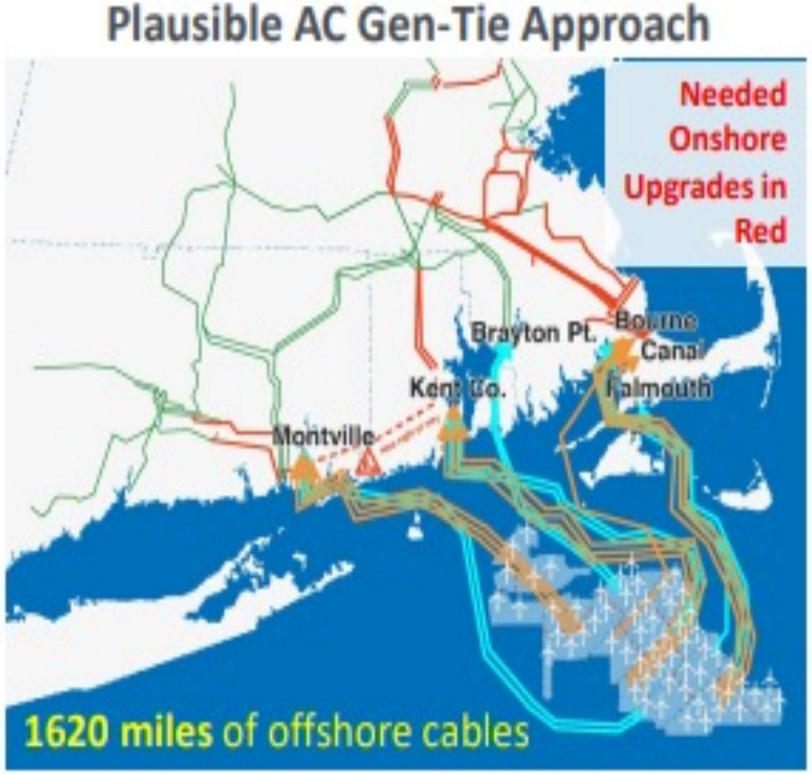
https://ens.dk/en/our-responsibilities/wind-power/energy-islands

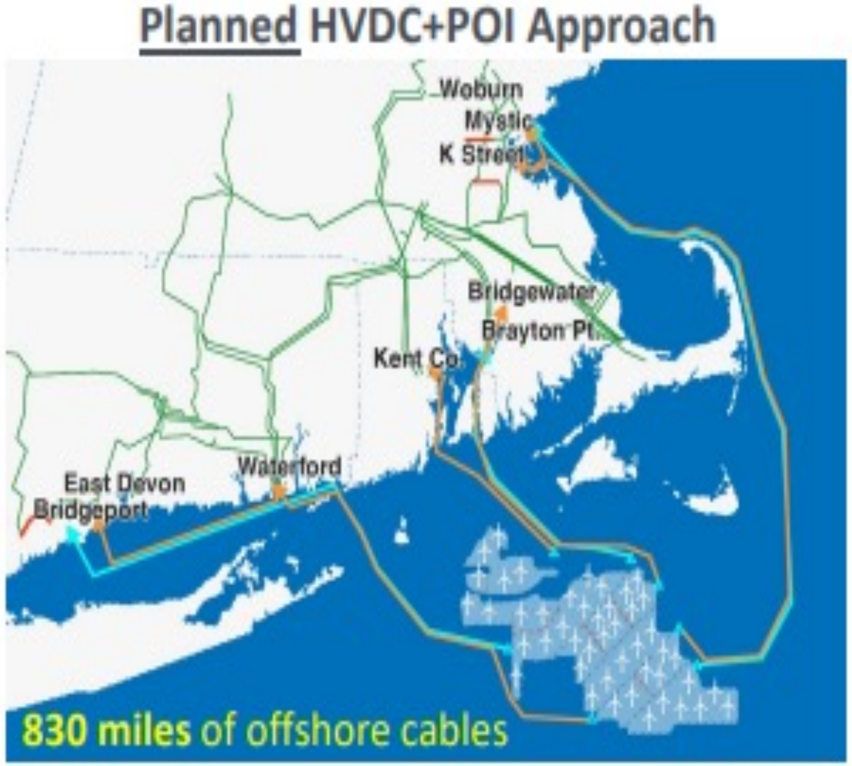
**The international consortium developing the concept:**

https://northseawindpowerhub.eu/

# Appendix B: Policy Panel Slides

FIGURE ES-3: UNPLANNED VS. PLANNED TRANSMISSION FOR NEW ENGLAND OSW




Source: J. Pfeifenberger, S. Newell, W. Graf, The Brattle Group, *Offshore Transmission in New England: The Benefits of a Better-Planned Grid*, May 2020.

# Main Points

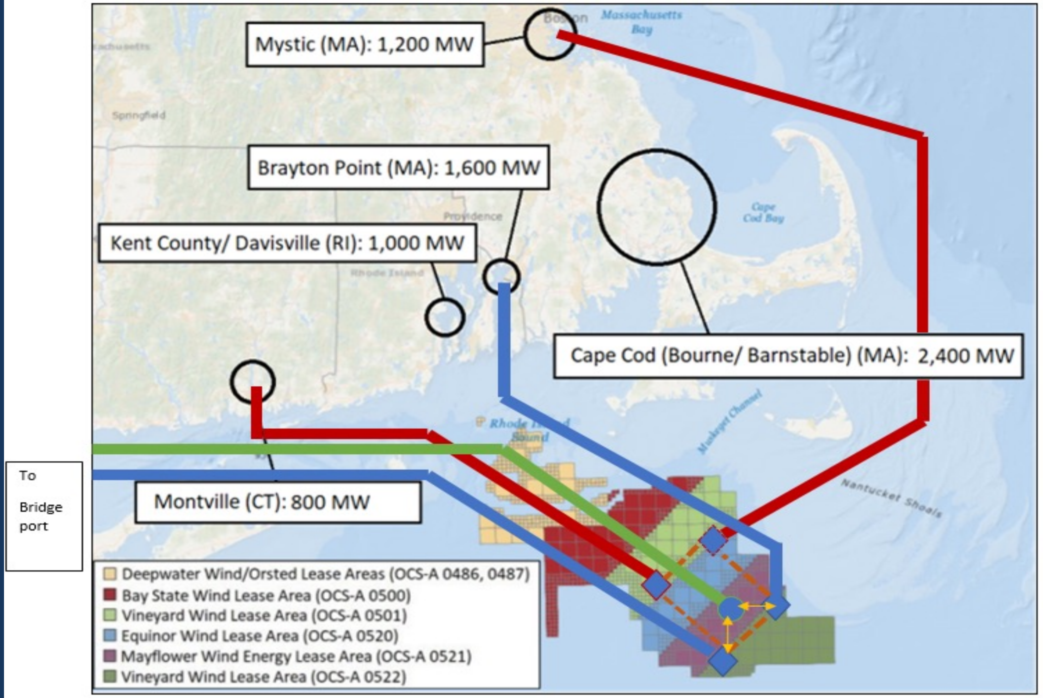
- Modular – build out 2000 MW at a time
- Plan provide states with an off-ramp
- Designed to access DOE funding
- States select landfall points
- Equity a central issue in siting landfall points
- Minimizes marine impacts
- Designed to co-optimize with land-based grid
- Designed to permit future “meshed” grid

Phased Offshore Wind Transmission Concept Plan

Phase I two 1200 MW HVDC lines in Blue one each for MA and CT

Phase II Future 1200 MW HVDC lines in Red

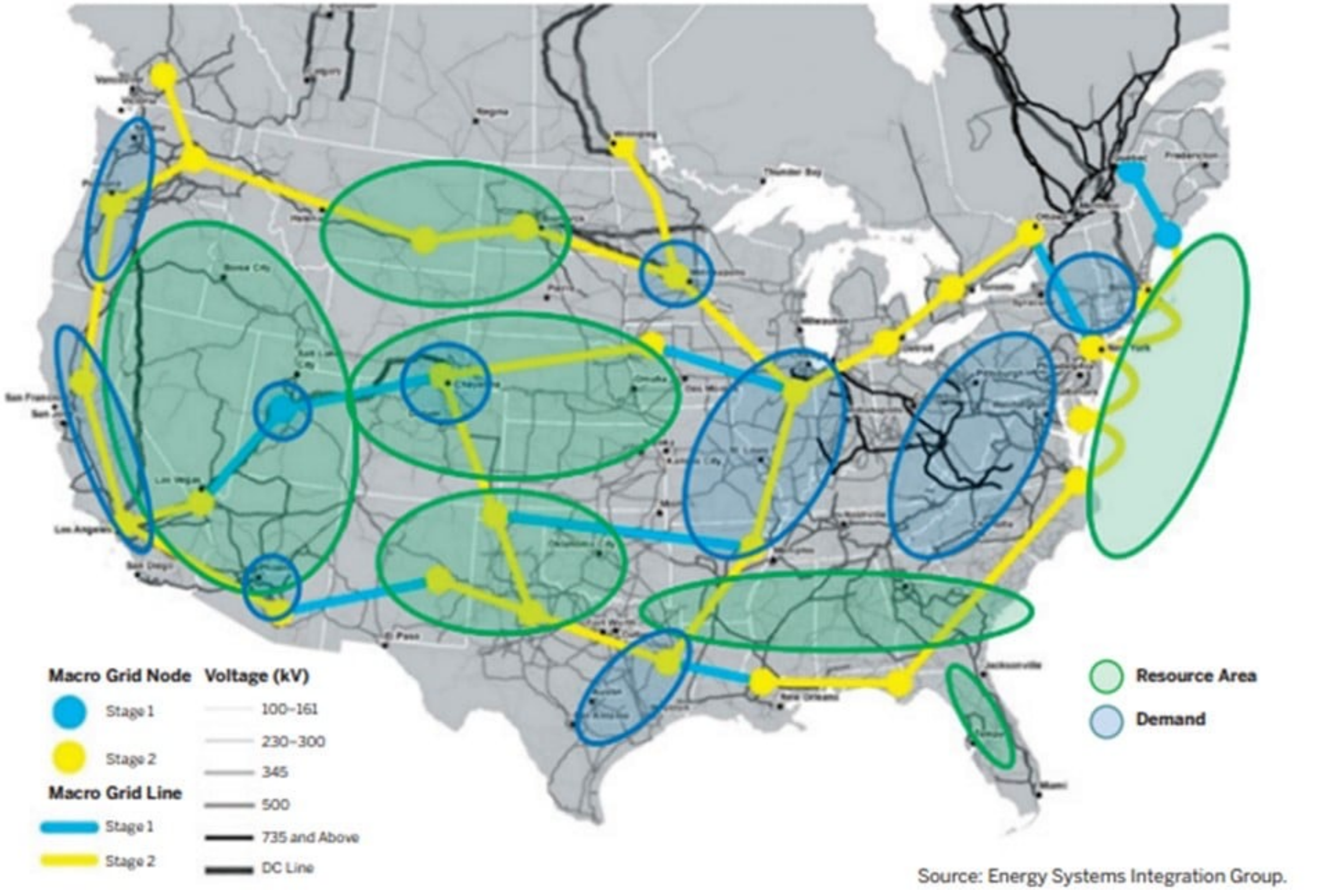
NYSERDA Beacon 1230 MW HVDC line in Green (to Astoria, Queens)




Dashed lines represent future potential interconnections between converters to increase offshore grid flexibility

Double Arrow lines represent future potential interconnections between converters of projects in different ISOs to permit controlled interregional transfers of offshore wind power

## Macrogrid Concept with Overlaid Clean Energy Resource Areas and Locations of Major Electricity Demand




Source: Energy Systems Integration Group.

- https://newenglandenergyvision.com/new-england-states-transmission-initiative/
- Robert.Snook@ct.gov

VINEYARD OFFSHORE

# Tufts Offshore Wind Transmission Workshop

Carrie Cullen Hitt

Senior Director, Grid Policy

# Who We Are

- Vineyard Offshore launched in April 2021 by the same team behind Vineyard Wind
- Leading the development of 3 lease areas owned by Copenhagen Infrastructure Partners (CIP) - OCS-A 0522 (MA WEA), OCS-A 0544 (NY Bight), and provisionally OCS-P 0562 (California)
    - CIP is world's largest dedicated fund management company in greenfield renewable energy investments with $19 billion of assets under management
    - CIP committed to deploying $100 billion in green energy investments by 2030
- Combined with Vineyard Wind 1, Vineyard Offshore has more than 6 GW of capacity on the East and West Coasts

# Our East Coast Projects and Lease Areas

# Our Team

## Experience and Success

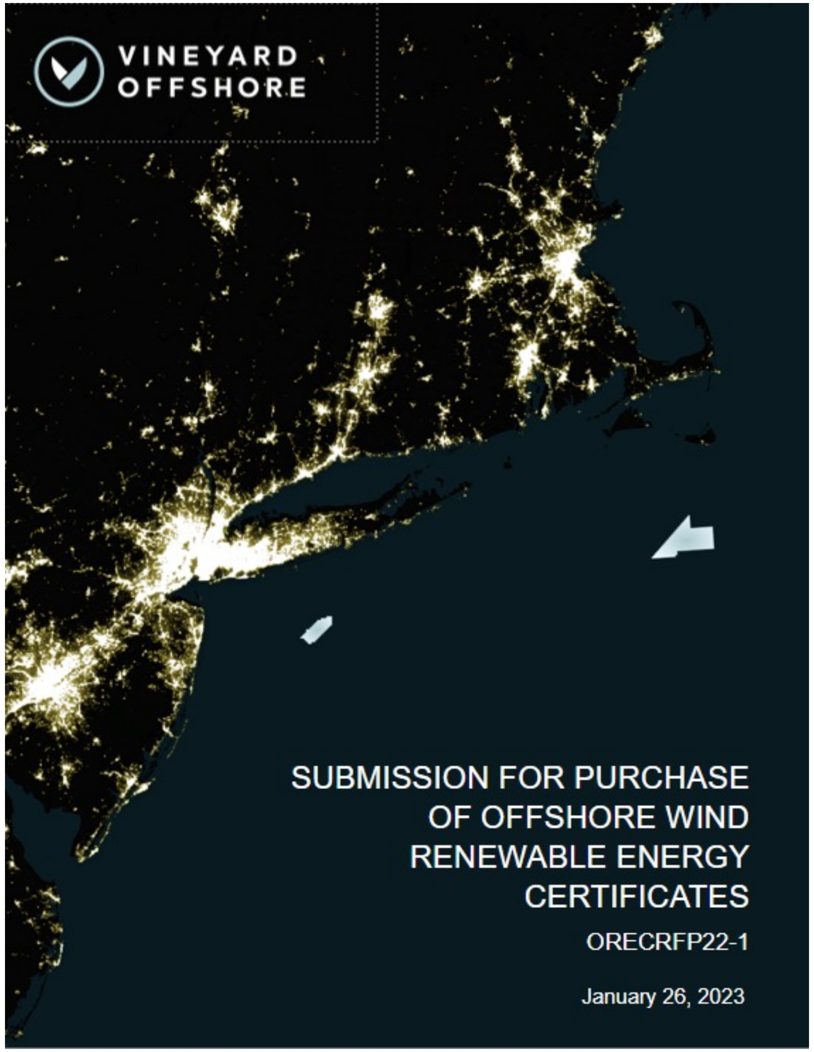
- Developed and financed Vineyard Wind 1, the first commercial-scale offshore wind project in the US; COD anticipated in 2024
- Negotiated and executed the first offshore wind Project Labor Agreement (PLA) in the US
- Actively engaging with unions, workforce, and businesses to build a local offshore wind workforce and supply chain
- Developed and secured offtake agreements for almost 3 GW of offshore wind capacity between 2017 – 2021

Vineyard Wind 1 PLA signing event

# ORECRFP22-1 Submission Summary

## Proposal Overview

- Excelsior Wind and Liberty Wind with up to 2.6 GW of offshore wind capacity
- $15 billion in direct economic benefits of which at least 35% will be realized in disadvantaged communities (DACs)
- 25,000 good paying full-time equivalent job years
- $1.3 billion in wind turbine, nacelle, and cable manufacturing SCIP facility investments
- Up to 700 MW of battery energy storage in NYC and Long Island
- Up to $116 million in direct funding for workforce, manufacturing, innovation, supply chain, environmental, community, and fisheries initiatives



# Community Engagement and Environmental Justice

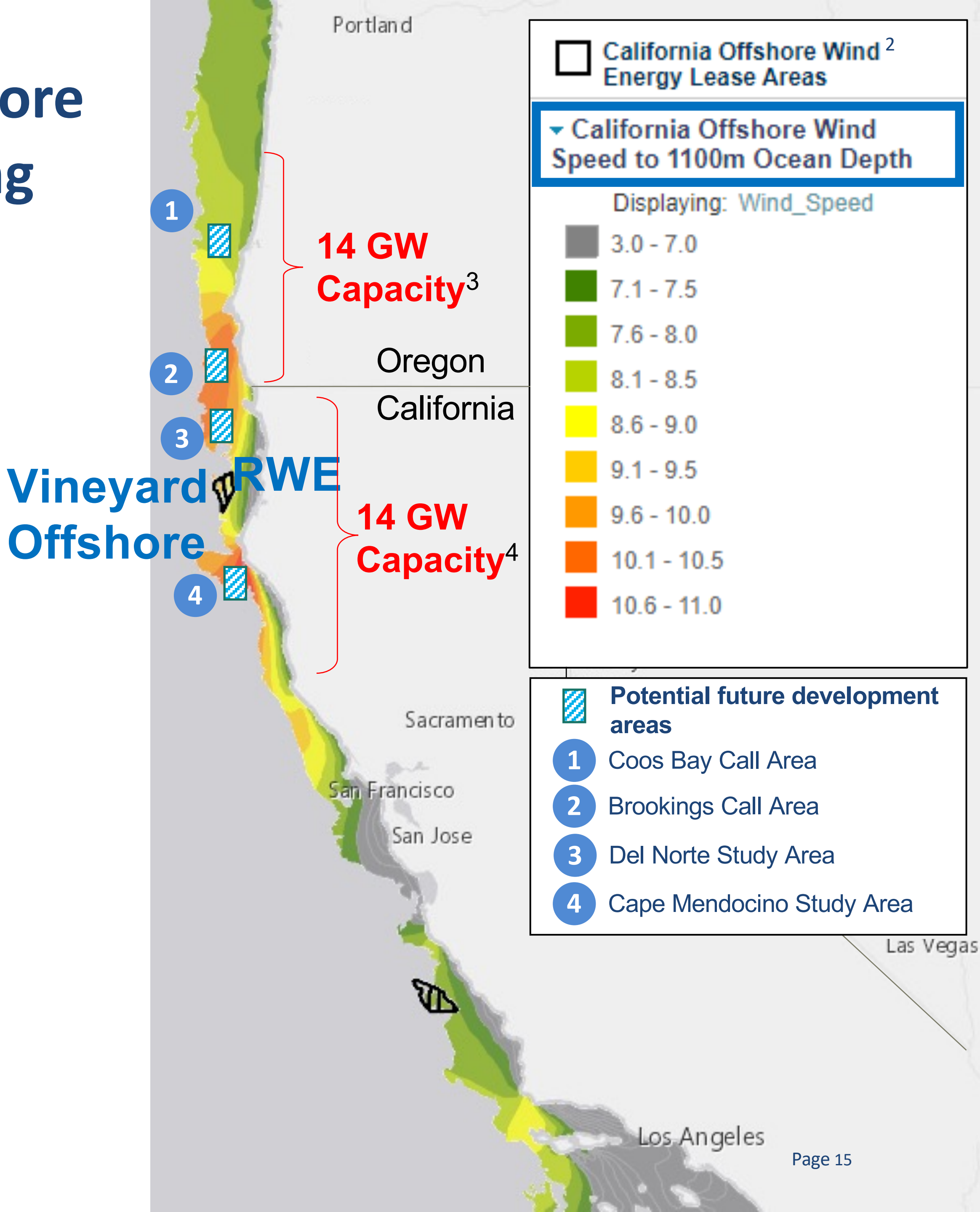
## Philosophy and Core Values

- Identify a **diverse** and **representative** set of stakeholders and opportunities for collaboration
- Communicate and engage **early**, **often**, and **transparently**
- Ensure project information is **accessible** and **well understood**
- Forge constructive stakeholder relationships built on **trust** and **transparency**
- Develop a **shared understanding** of opportunities to avoid, minimize, and mitigate impacts
- Deliver **tangible**, **direct**, and **sustained** economic benefits to host communities and DACs
- Hire from the **local communities** where our projects are located

***Centering on EJ in New York: Commitment to deliver at least 35% of New York spend in DACs and prioritize hiring in host communities and DACs***

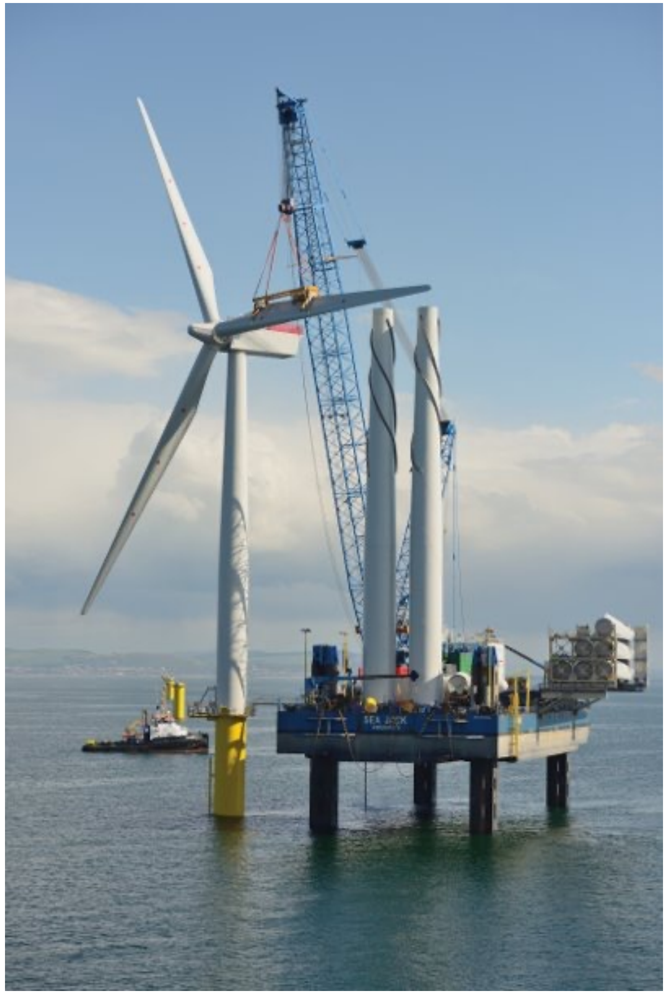

# Northern CA & southern OR will form the core of offshore wind development due to strong wind resources

| | Vineyard Offshore | RWE |
|---|---|---|
| Lease Name (Number)[1] | Humboldt SW (OCS-P 0562) | Humboldt NE (OCS-P 0561) |
| Water Depth[1] | 614-1,137m | 537-1,017m |
| Generation Capacity | 1.0-1.6 GW | 1.2-1.6 GW |
| Distance to Shore[1] | 20 miles | 20 miles |
| **Avg Wind Speed (m/s)[2]** | **8.6 to 9.5** | **8.5 to 9.5** |




Sources:
1 "California Final Sale Notice" by United States Department of the Interior (Bureau of Ocean Energy Management)
2 "California Offshore Wind Energy Lease Areas" by Conservation Biology Institute is licensed under CC BY 4.0 / Modified Legend, Labels, etc.
3. "West Coast Offshore Wind Transmission Literature Review and Gaps Analysis" by US DOE (Brookings and Coos Bay Call Areas)
4. "CAISO Transmission Planning Process" by CAISO

VINEYARD OFFSHORE




**Carrie Cullen Hitt**
**Senior Director**
**617 688 9417**
**chitt@vineyardoffshore.com**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/VineyardOffshore

/Vineyard-Offshore

VINEYARDOFFSHORE.COM

# Siting and Interconnecting Offshore Wind

## Navigating New England Regulatory Processes

Kelly Smith
June 22, 2023

OCEAN WINDS

# Requirements to De-Risk and Move Projects Forward

## Grid Interconnection

- Queue position with acceptable cost and schedule for grid upgrades
- Viable route from lease area to onshore point of interconnection (POI)

## Permitting & Site Control*

- **Federal** > BOEM, USACE, DoD, EPA, NOAA, USCG, USFWS
- **MA State** > EFSB, MEPA, CZM, DEP, BUAR, MHC, MassWildlife, DMF
- **Local** > Town government, host/tax agreement, private landowners

## Route to Market

- In the U.S., state power purchase agreements (PPAs) are dominant

## Supply Chain

- Early commitments to secure commercial operation date (COD)
- Engineering, procurement, and construction (EPC) contracts negotiated

Contracts should be mature to undertake Final Investment Decision (FID) and begin manufacturing & construction.

* As an example, SouthCoast Wind's lease area development is expected to require ~60 permits with ~30 agencies.

# Review of the ISO-NE Interconnection Process

- Queue positions (QPs) are studied in the order in which they are filed. If there are many QPs in the same geographic area, ISO-NE may choose to undertake a cluster study.
- Queue reform proposed under FERC that would transition to “first ready” + cluster study approach is ~1 year out.

| ISO Milestone | Approx. Timing (months) | | Commitments | Developer Risks |
|---|---|---|---|---|
| File QP | | 0 | $50,000 | OSW generators must have a lease area |
| Scoping meeting | | 1 | | |
| Feasibility Study (FS) | Start<br>End | 1<br>1.5 | ~$175,000 | Wait time for FS to start is variable (1 mo – 1 yr). Developer must have data ready (PSSE model & ASPEN model). |
| System Impact Study (SIS) | Start<br>End | 12-24<br>9 | ~$500,000 + site control | Wait time for SIS to start is highly variable (a few mo – 7 yrs). Must demonstrate substation site control & have additional modeling ready. |
| Facility study *[optional]* | Start<br>End | 1<br>2 - 6 | ~$250,000 - $1,000,000 | Wait time minimal. This step often bypassed to accelerate IA. |
| Interconnection agreement (IA) | End | 6 - 14 | Upgrade costs (phased) | Depending on prj size & POI strength, costs can be hundreds of millions, and time to grid availability can be 4-10 years. Costs are phased based on schedule. |
| | **TOTAL** | **33 - 57** | **(2.8 - 4.8 YEARS)** | |

# Progress vs. 2019

**Vineyard Wind (VW)**

800 MW

- QP – Nov. 2016
- IA – Jul. 2020 (3.7 yrs)

**Park City Wind (PCW)**

791 MW

- QP – Dec. 2017
- IA – Sep. 2022 (4.8 yrs)

**Revolution Wind (RW)**

704 MW

- QP – Sep. 2018
- IA – Jul. 2021 (2.9 yrs)

**SouthCoast Wind (SCW)**

1,200 MW

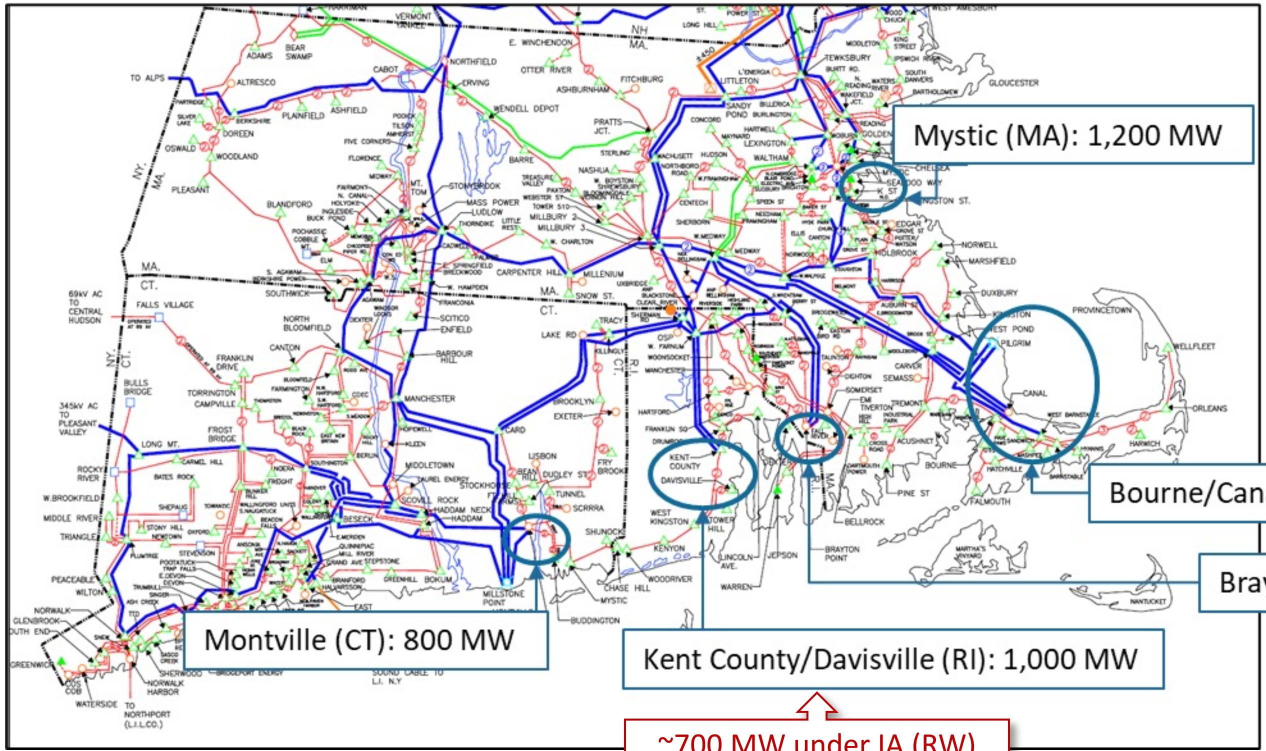
- QP – Feb. 2019
- IA – Aug. 2022 (3.5 yrs)

ISO new england

## 2019 Economic Studies

*Detailed Assumptions*

- Based on the currently expected transmission system for 2030, the ISO anticipates that the following levels of off-shore wind additions (approximately 7,000 MW) have the potential to avoid major additional 345 kV reinforcements*
  - This assumes FCA 13 retirements have occurred, including the retirement of Mystic 8 & 9




*Some 345 kV reinforcement/expansion may still be needed for this scenario. This anticipation is preliminary (system impact studies have not been completed for all of these MW). This anticipates minimal interconnection at nameplate levels and capacity interconnection at intermittent capacity values – does not anticipate all of the MW being able to run simultaneously at nameplate levels at all times on the system.

~1,600 MW under IA (VW & PCW)

1,200 MW under IA (SCW)

~700 MW under IA (RW)

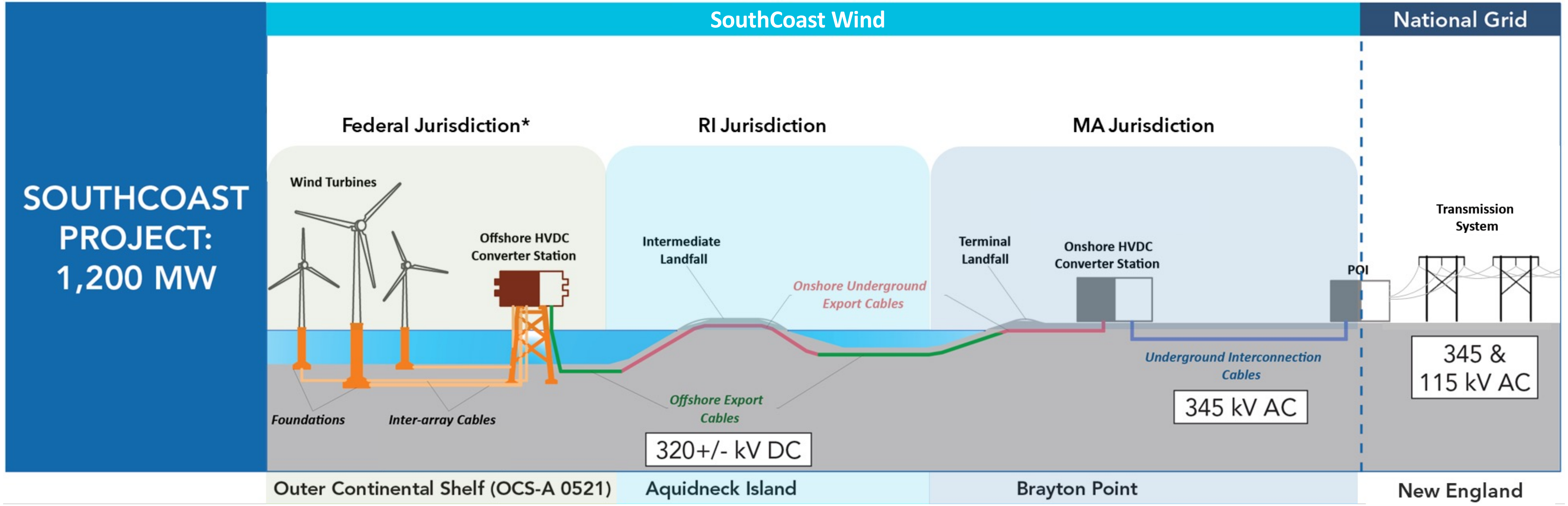
ISO-NE PUBLIC

5

Source:

Planning Advisory Committee. 2019 Economic Studies Detailed Assumptions. Presented by Peter Wong and Patrick Boughan, ISO New England. August 8, 2019. *https://www.iso-ne.com/static-assets/documents/2019/08/a8_2019_economic_studies_detailed_assumptions.pptx*

# Project Siting – SouthCoast Wind 1 Components



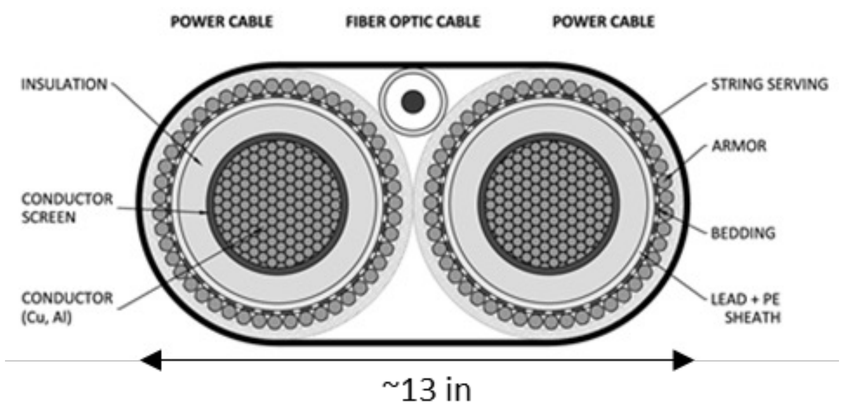

* BOEM review covers entire project

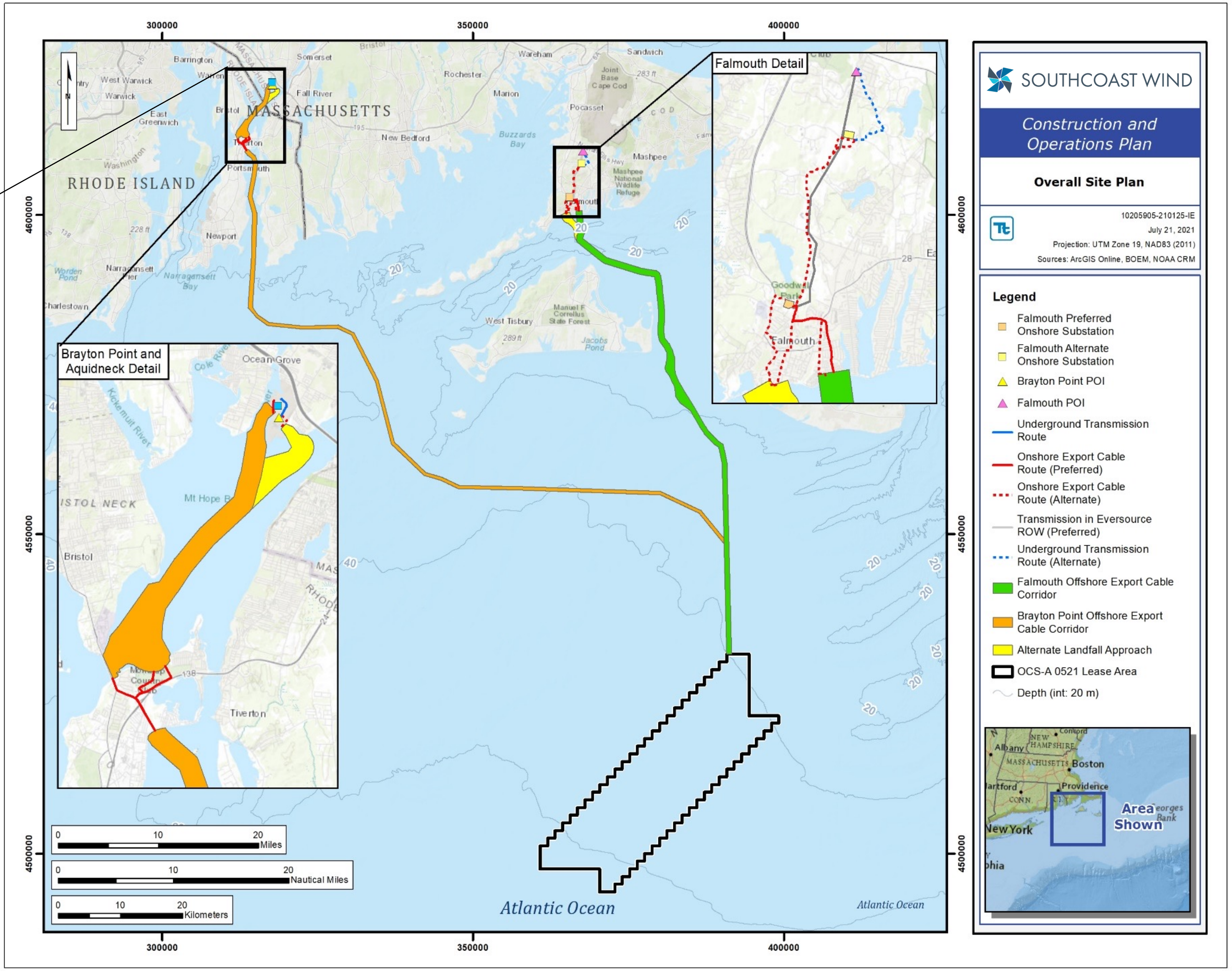
## Key

**AC:** Alternating current
**DC:** Direct current
**kV:** Kilovolt (measures voltage)
**MW:** Megawatt (measures bulk power)
**POI:** Point of interconnection to the regional grid

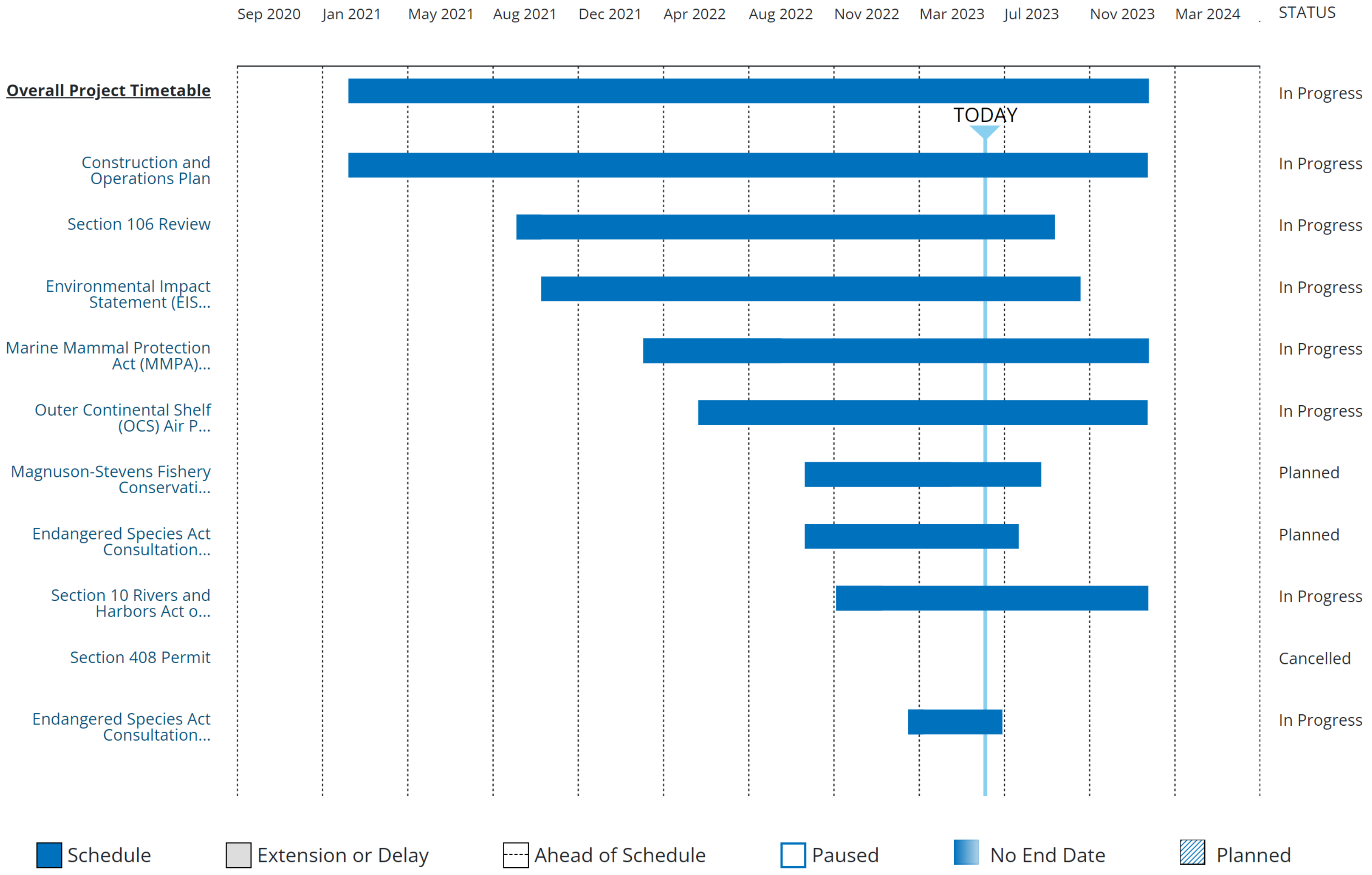
# Project Siting – SouthCoast Wind 1 Export Cable Route

- **Lease Area**
  - 127,000 acres, 149 positions
  - 2,400 MW+ generation potential
- **Route to Brayton Point, Somerset, MA**
  - 90 mi (145 km) in federal waters
  - 20 mi (33 km) in RI state waters
  - 2 mi (3 km) in MA state waters
- **HVDC Cable Bundle (1,200 MW)**



# SouthCoast Wind 1 Timeline of Federal Permitting Activities




- **BOEM federal review of the COP is the longest process**
  - Expected to take ~3 years from initial COP submittal to approval
  - Follows an envelope approach. Export cable routes must be identified in initial submittal.
- **Energy Facilities Siting Board (EFSB) state review**
  - Expected to take ~2 years to receive approval to construct
  - Require greater engineering detail in state jurisdiction
  - Adjudicatory process
- **Risky for projects to take Final Investment Decision (FID) until major permits are in hand**

## Appendix C: Technical Panel Slides

# Transmission Expansion Planning Models for Offshore Wind Energy

James McCalley

## Project team


- Eric Hines, Per-Anders Lof, Barbara Kates-Garnick, Rebecca Wolf, Julie Harris, Emma Hibbard, Tufts University
- Johan Enslin, Moaazam Nazir, Clemson University
- James McCalley, Ali Jahanbani, Abhinav Venkatraman, Iowa State University


**Presented at the**

**Offshore wind transmission workshop: Visualizing the technology & policy interface**

June 22, 2023

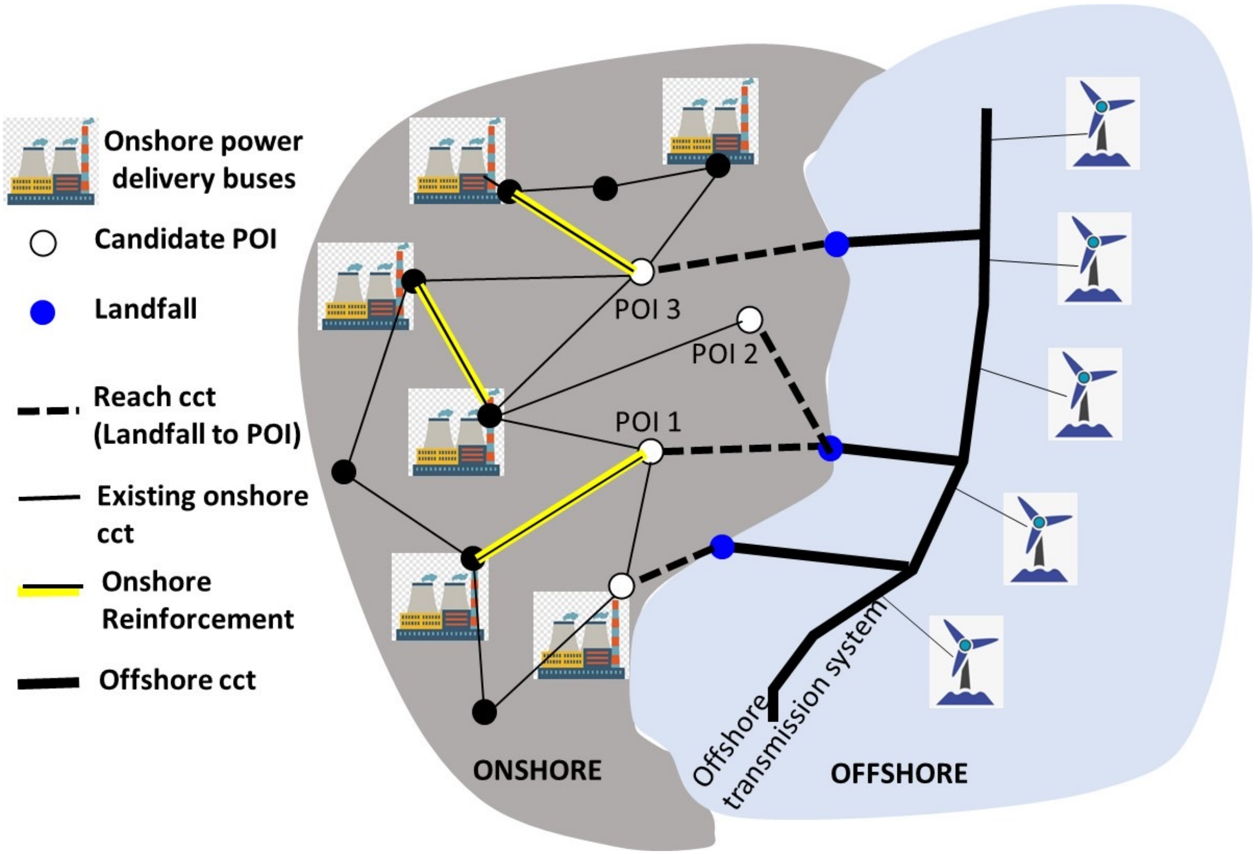
Overview:

1. Underlying assumptions
2. Introduction of 3 transmission models
3. Results and takeaways

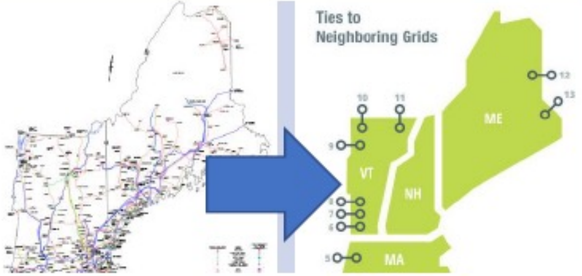
IOWA STATE UNIVERSITY
CLEMSON CHARLESTON
Tufts UNIVERSITY

# Underlying Assumptions

- **Onshore power system** is the focus
- **High OSW capacity** in each region
- **“Backbone” offshore** transmission
- **Maine to Carolinas** is area of interest, 1 region at a time
- **Least-cost design** for given OSW capacity is the goal
- **Max POI capacity=6 GW**



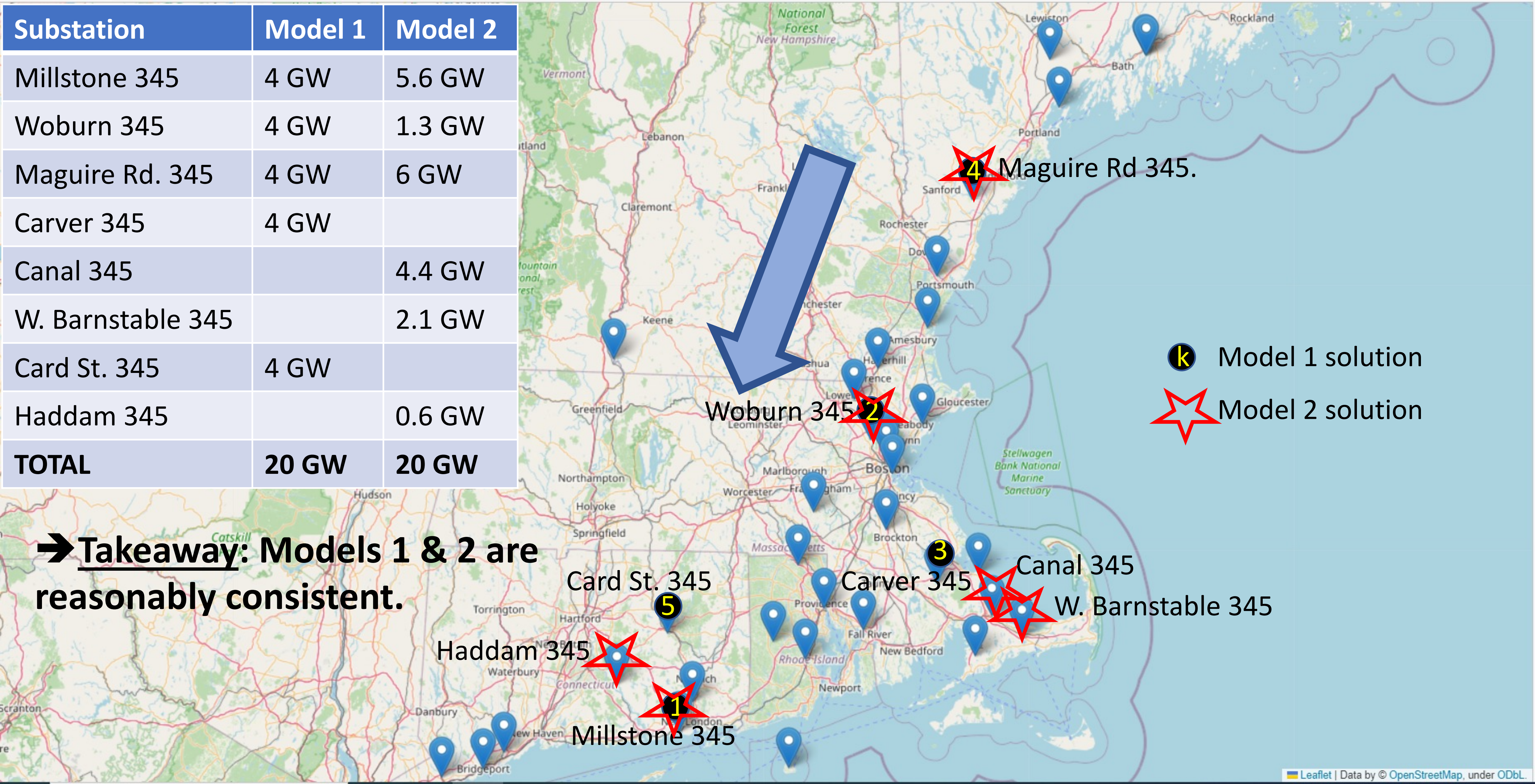
# Introduction of Three Models

| ATTRIBUTE | MODEL 1 | MODEL 2 | MODEL 3 |
|---|---|---|---|
| **Model size** |  93,520 buses |   722 buses |  176 buses |
| **Area represented** | Eastern Interconn. | One region | EI & WECC |
| **Conditions modeled** | One: Sum pk, 2031 | 255: 17/y, 2031-'46 | 513: 19/y, 2024-'50 |
| **Contingencies?** | Yes, N-1 | No | Only at MG level |
| **Method** | Heuristic optmzatn w/AC+DC pwr flow | CEP LP-optmzatn w/DC pwr flow | CEP LP-optmzatn w/DC pwr flow |
| **What it tells us** | POI identification | POI identification; offshore Tx design | Relation of OSW & national grid needs |

# Results and takeaways

# Comparison of Model 1 and 2 Solutions for ISO-NE

| Substation | Model 1 | Model 2 |
|---|---|---|
| Millstone 345 | 4 GW | 5.6 GW |
| Woburn 345 | 4 GW | 1.3 GW |
| Maguire Rd. 345 | 4 GW | 6 GW |
| Carver 345 | 4 GW | |
| Canal 345 | | 4.4 GW |
| W. Barnstable 345 | | 2.1 GW |
| Card St. 345 | 4 GW | |
| Haddam 345 | | 0.6 GW |
| **TOTAL** | **20 GW** | **20 GW** |




➔**Takeaway**: **Models 1 & 2 are reasonably consistent.**

Type here to search 82°F Sunny 3:38 PM 6/13/2023

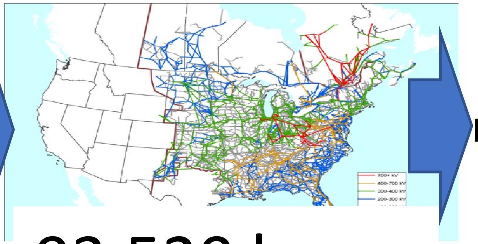
# Model 1: Heuristic Optimization for Selecting POIs & Capacities

Given regional OSW level, select POIs and capacities to minimize cost of reach circuit + DC converter station + AC substation expansion + onshore transmission expansion

Subject to each POI Capacity <= 6 GW and power flow constraints, normal/contingency conditions

**Regional Allocation**

| Region | Desired capacity |
|---|---|
| NYISO | 20 GW |



93,520 buses

**Candidate POIs**

**Onshore power delivery buses**

**(1a)** Run TARA

**(1b)** RUN POIA

**POIs, capacities & costs**

**(2)** Identify POI k & capacity

**(3)** Expand Tx for POI k k=k+1

| Solution | |
|---|---|
| Millwood 345 | 4 GW |
| Farragut W. | 4 GW |
| Millwood 345 | 2 GW |
| Shore Rd. 345 | 4 GW |
| Holbrook 138 | 2 GW |
| Farragut E. 345 | 4 GW |

# A 76 GW East Coast POI Design (based on Model 1)

| Region | Target capacity |
|---|---|
| ISO-NE | 20 GW |
| NYISO | 20 GW |
| PJM | 30 GW |
| South | 6 GW |

➔**Takeaway**:
**This 76 GW EC design, w/ 19 POIs, has a $50B interconnection cost ($0.66M/MW), excluding offshore Tx.**

| Iteration | Solution | | Avg. Cost |
|---|---|---|---|
| 1 | Millstone 345 | 4 GW | $0.479M/MW |
| 2 | Woburn 345 | 4 GW | $0.469M/MW |
| 3 | Carver 345 | 4 GW | $0.497M/MW |
| 4 | Maguire Rd. 345 | 4 GW | $0.503M/MW |
| 5 | Card St. 345 | 4 GW | $0.572M/MW |
| 1 | Millwood 345 | 4 GW | $0.674M/MW |
| 2 | Farragut W. | 4 GW | $0.766M/MW |
| 3 | Millwood 345 | 2 GW | $0.772M/MW |
| 4 | Shore Rd. 345 | 4 GW | $0.897M/MW |
| 5 | Holbrook 138 | 2 GW | $0.855M/MW |
| 6 | Farragut E. 345 | 4 GW | $0.955M/MW |
| 1 | Smithbrg 500 | 4 GW | $0.441M/MW |
| 2 | Larabee 230 | 4 GW | $0.441M/MW |
| 3 | Landstn 230 | 4 GW | $0.496M/MW |
| 4 | Deans 500 | 4 GW | $0.574M/MW |
| 5 | Fentres 500 | 4 GW | $0.615M/MW |
| 6 | Cardiff 230 | 4 GW | $0.747M/MW |
| 7 | Indian River 230 | 2 GW | $0.593M/MW |
| 8 | Smithbrg 500 | 2 GW | $0.860M/MW |
| 9 | Deans 500 | 2 GW | $0.935M/MW |
| 1 | Winyah 230 | 4 GW | $0.576M/MW |
| 2 | Sutton 230 | 2 GW | $1.198M/MW |

$10.1B; $0.504M/MW

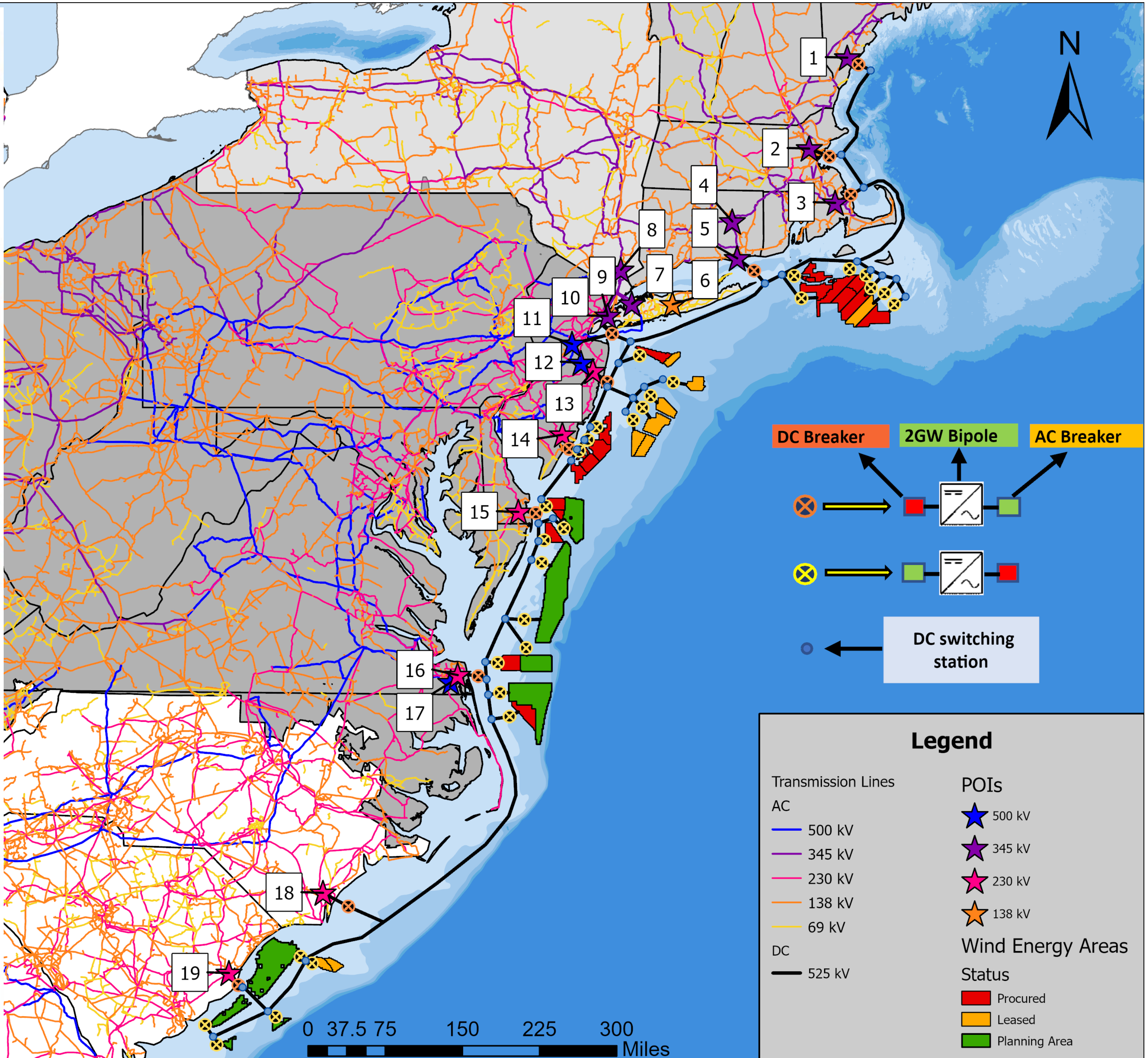
$16.4B; $0.821/MW

$18.0B; $0.601M/MW

$4.7B; $0.783M/MW

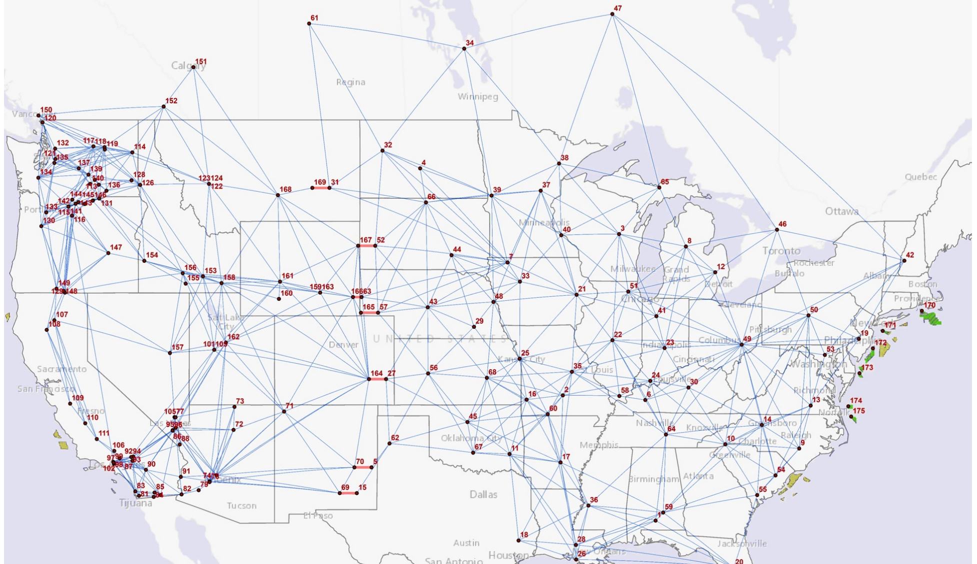
Millstone relieves flows in Iteration #1 and Woburn is cheaper in Iteration #2.
➔Iteration k POI injection may decrease cost of a POI in iteration k+1

| POI | kV | State | Capacity (MW) |
|---|---|---|---|
| **ISO-NE** | | | |
| 1 Maguire Road | 345 | ME | 4000 |
| 2 Woburn | 345 | MA | 4000 |
| 3 Carver | 345 | MA | 4000 |
| 4 Card Street | 345 | CT | 4000 |
| 5 Millstone | 345 | CT | 4000 |
| **Total** | | | **20000** |
| **NYISO** | | | |
| 6 Holbrook | 138 | NY | 2000 |
| 7 Shore Road | 345 | NY | 4000 |
| 8 Millwood | 345 | NY | 6000 |
| 9 Farragut East | 345 | NY | 4000 |
| 10 Farragut West | 345 | NY | 4000 |
| **Total** | | | **20000** |
| **PJM** | | | |
| 11 Deans | 500 | NJ | 6000 |
| 12 Smithburg | 500 | NJ | 6000 |
| 13 Larrabee | 230 | NJ | 4000 |
| 14 Cardiff | 230 | NJ | 4000 |
| 15 Indian River | 230 | DE | 2000 |
| 16 Landstown | 230 | VA | 4000 |
| 17 Fentress | 500 | VA | 4000 |
| **Total** | | | **30000** |
| **South** | | | |
| 18 Sutton | 230 | NC | 2000 |
| 19 Winyah | 230 | SC | 4000 |
| **Total** | | | **6000** |
| **EAST COAST** | | | **76000** |

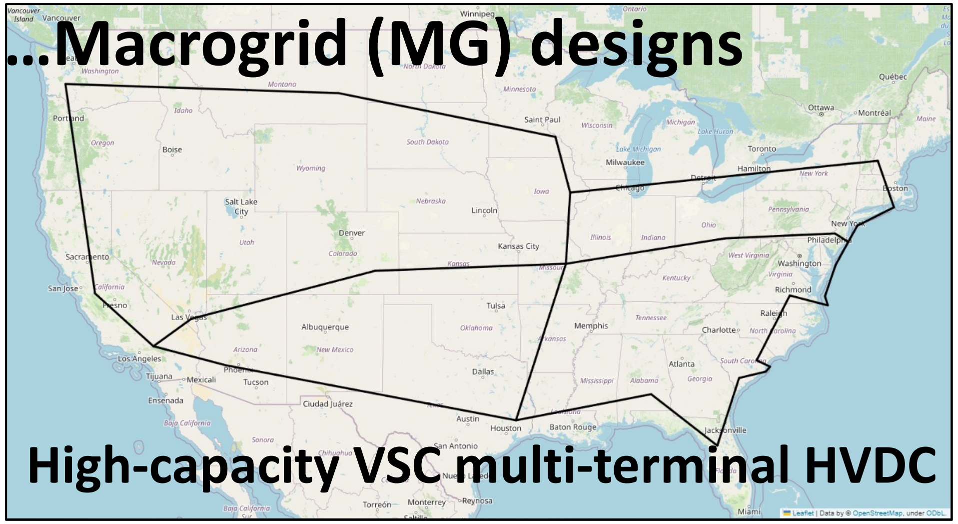


# Model 3 Description

| ATTRIBUTE | MODEL 3 |
|---|---|
| **Model size** | 176 buses |
| **Area represented** | EI and WECC |
| **Conditions modeled** | 513: 19/y, 2024-’50 |
| **Contingencies?** | Only at MG level |
| **Method** | CEP LP-optmzatn w/DC pwr flow |
| **What it tells us** | Relation of OSW & national grid needs |



**Using Model 3 to study**



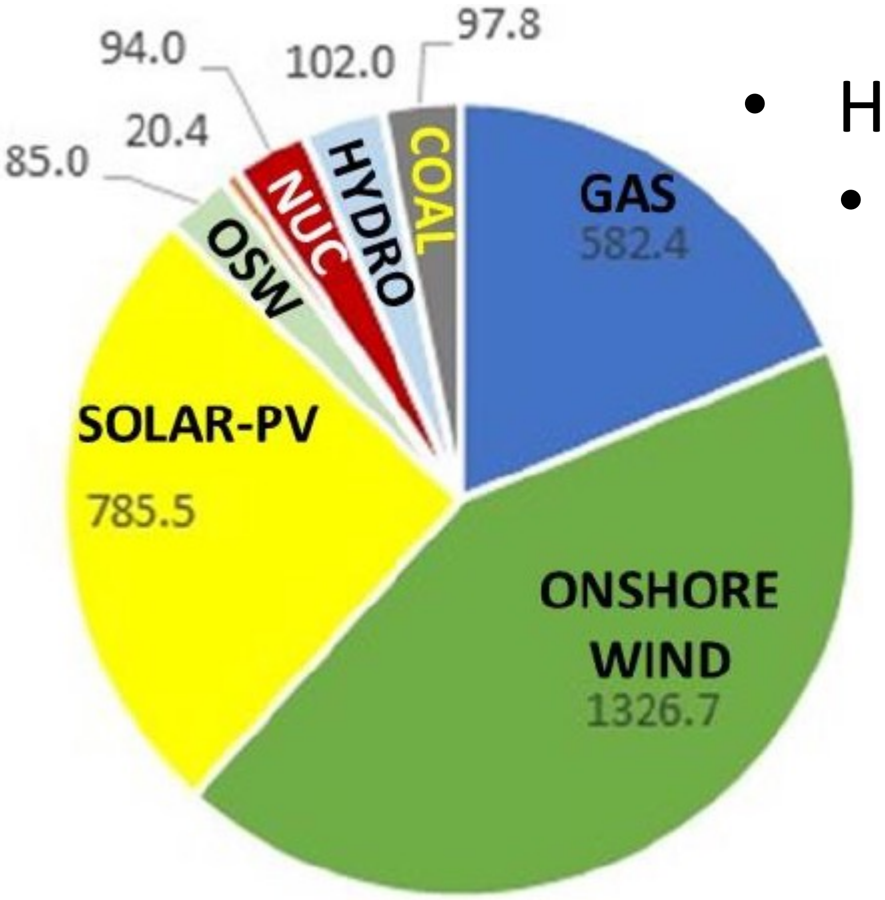
**…Macrogrid (MG) designs**

**High-capacity VSC multi-terminal HVDC**

- Model builds HVDC capacity if economic
- Macrogrid provides two main benefits

(1) multi-regional sharing of energy & services; (2) relieving underlying AC system

# Model 3 Result



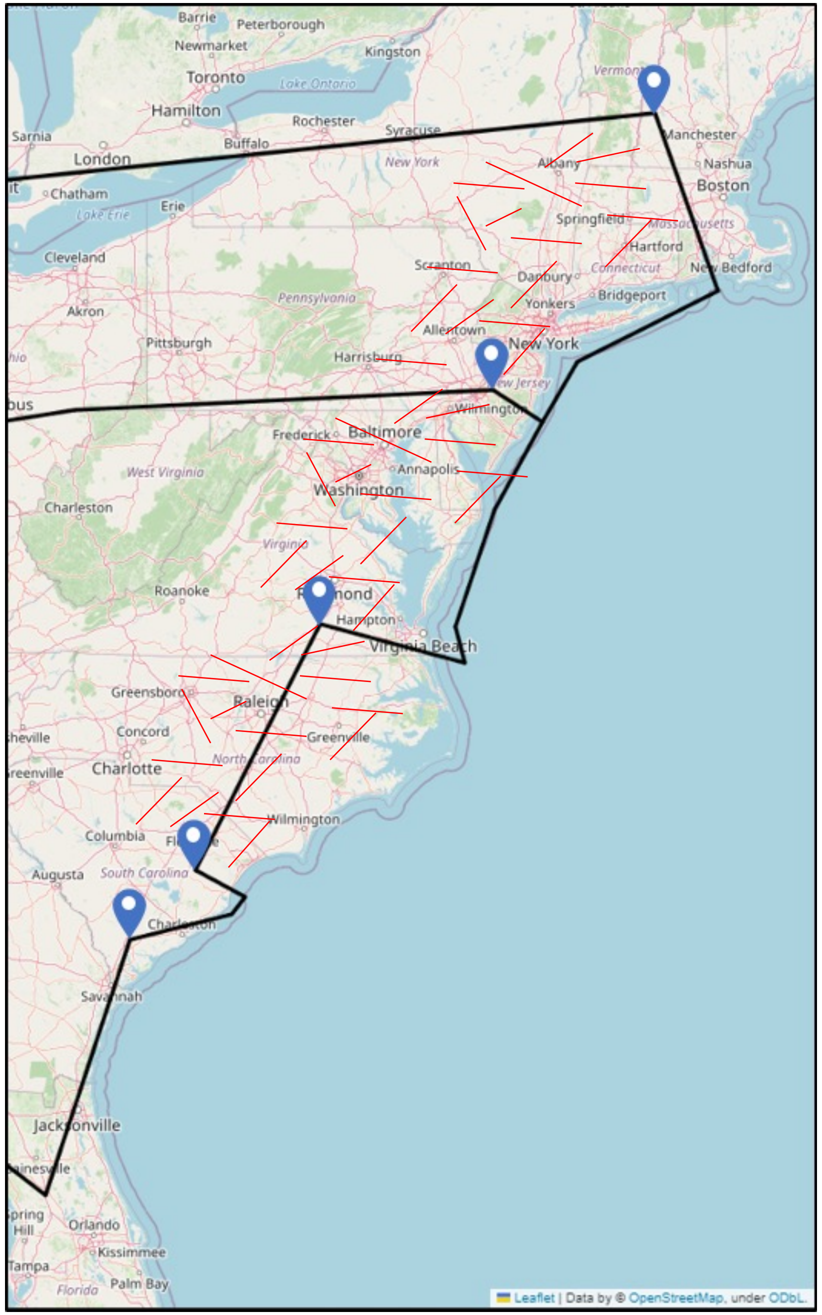

- High load growth/83% clean electricity scenario;
  - US needs 3187 GW of (triples today's level), of which ~900GW may be on East Coast (EC).
    - 85 GW is EC OSW (2.6% US, 9.4% EC)

➔ **Takeaway:**

**East Coast OSW level of 85 GW is locally significant but nationally small.**
**We will consider 200 GW (6.3% US, 22% EC).**

# Model 3 Result

| | OSW + Macrogrid | OSW without Macrogrid |
|---|---|---|
| EI Line Investment Cost (AC only) | $100 B | $146 B |




➔ **Takeaway:**

**The E. Coast Macrogrid segments reduce loading on underlying AC transmission & reduces the expensive/socio-politically-difficult need to build AC reinforcements.**

# Takeaways

**1. Good modeling:** Models 1 & 2 are reasonably consistent.

**2. $50B:** This 76 GW EC design, w/ 19 POIs, has a $50B interconnection cost ($0.66M/MW), excluding offshore Tx.

**3. 200 GW:** East Coast OSW level of 85 GW is locally significant but nationally small. We will consider 200 GW (6.3% US, 22% EC).

**4. Macrogrid reduces OSW transmission work:** The E. Coast Macrogrid segments reduce loading on underlying AC transmission & reduces the expensive/socio-politically-difficult need to build AC reinforcements.

- Expandability
- Compatibility
- Interoperability

# Integrating Large Levels of Offshore Wind and Onshore Solar Power to the Grid using a Macro MTDC Network

2023


Prof Johan Enslin, FIEEE, FSAIEE, PrEng

Duke Energy Endowed Chair in SmartGrid Technology

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https://www.clemson.edu/cecas/departments/charleston/


June 22th, 2023

CLEMSON

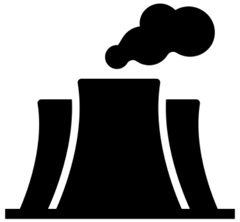
# Outline

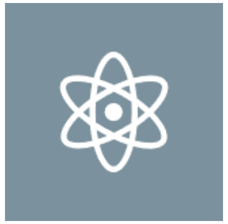
- Why a Macro On- and Offshore MTDC Grid?
- Offshore Wind HVDC Technology Readiness
- Configuration for a MTDC offshore network
- 2 GW HVDC Terminal Standard
- Proposed 76 MW MTDC OSW Network
- Future Research and Capability Goals
- Conclusions

# Why do we need to build MTDC Backbone Grids?

## - Required for 4th Industrial Revolution – End-to-End Electricity -

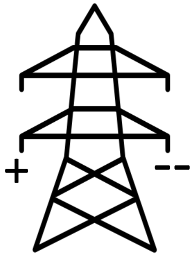
- Aging Infrastructure and Urgency
  - 80 years old centralized T&D infrastructure for fossil and nuclear plants
  - Incompatible able for carbon-neutral non-dispatchable power generation
  - Net-zero carbon goals by 2050 – Urgency for new technology

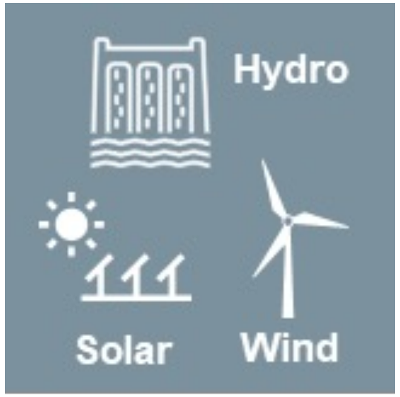




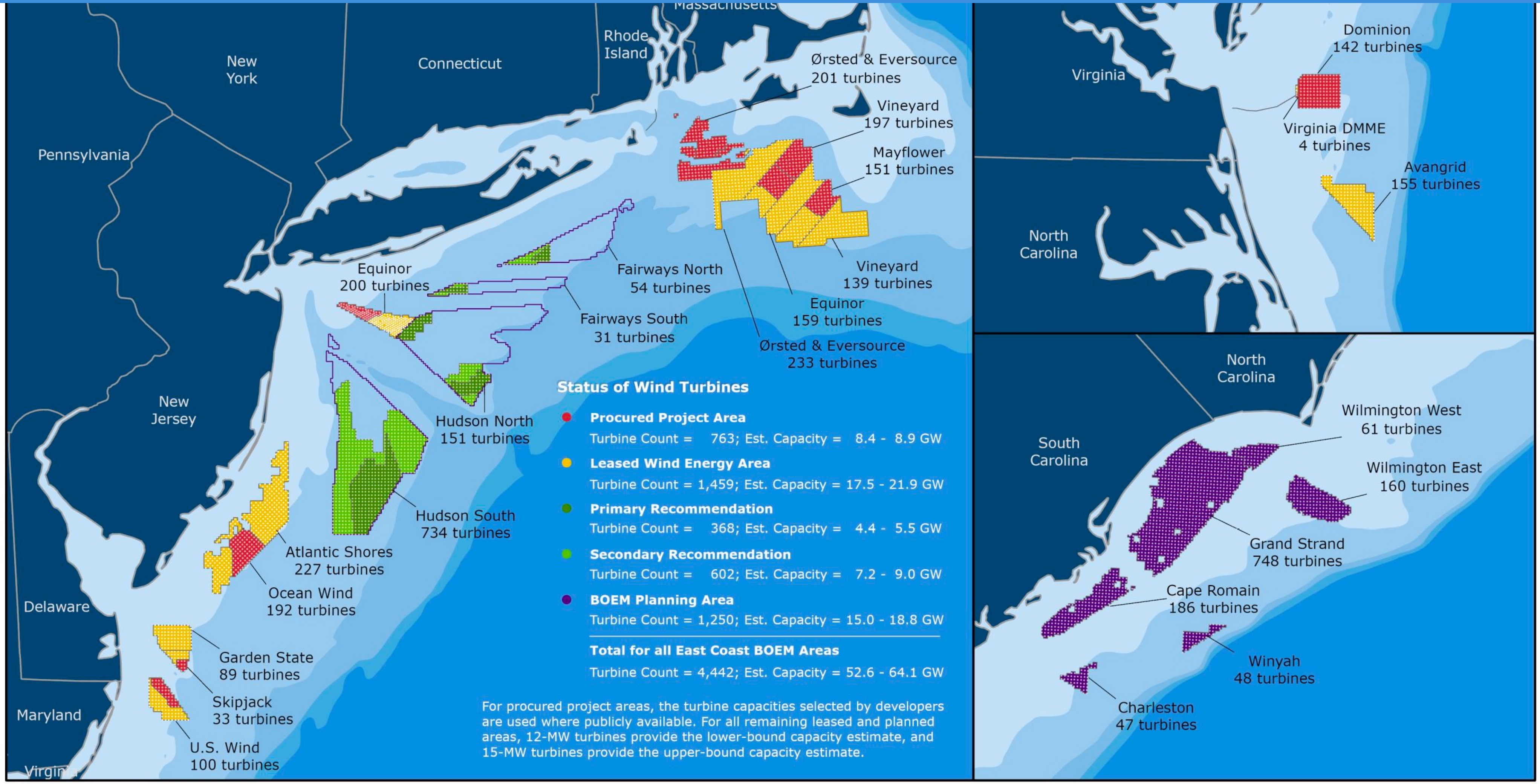
- End-to-End Carbon-Neutral Electrical Energy Transition by 2050
  - Integrate 200 GW of offshore wind, 100 GW Nuclear and 1 TW of Solar
  - Large load-growth due to electrification of transportation
  - Integration technology for bulk hydro, hydrogen and battery storage


- Need a new macro-UHV on- and offshore grid
  - Multi-Terminal DC MacroGrid overlaying existing AC networks
  - Reduce HVDC, Breakers' technology cost and real-estate
  - Improved resiliency and controllability of power grid
  - Energy Diversity-Equity-Inclusion and scalability
  - MTDC macro-grid for controllability and grid stability
  - Utilizing wind and solar natural diversity and Capacity Factor
  - **Lowest Societal Cost to Integrate Large-Scale Wind and Solar**



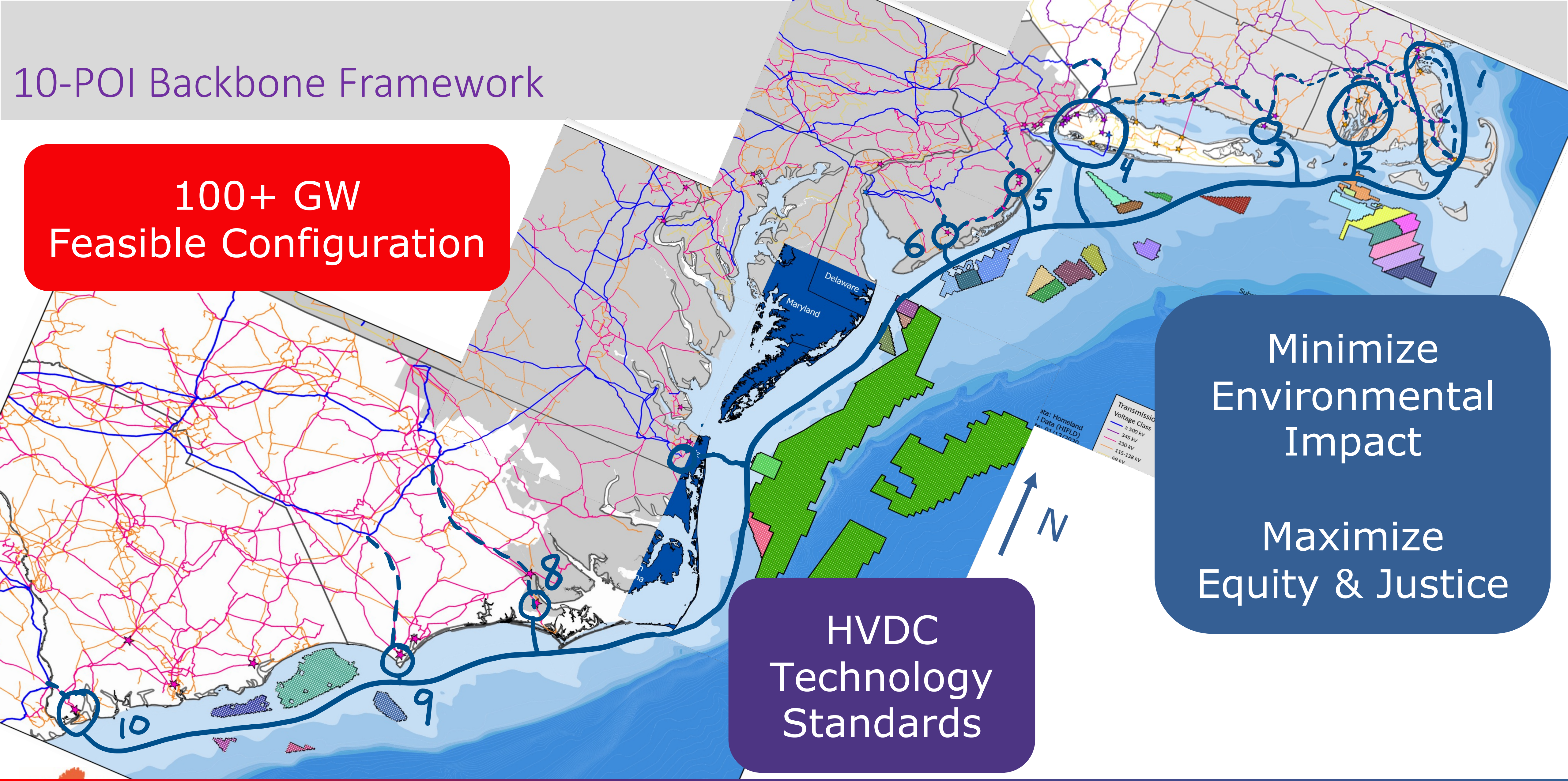



# OSW Projects Planned for Eastern US



# 10-POI Backbone Framework

100+ GW
Feasible Configuration

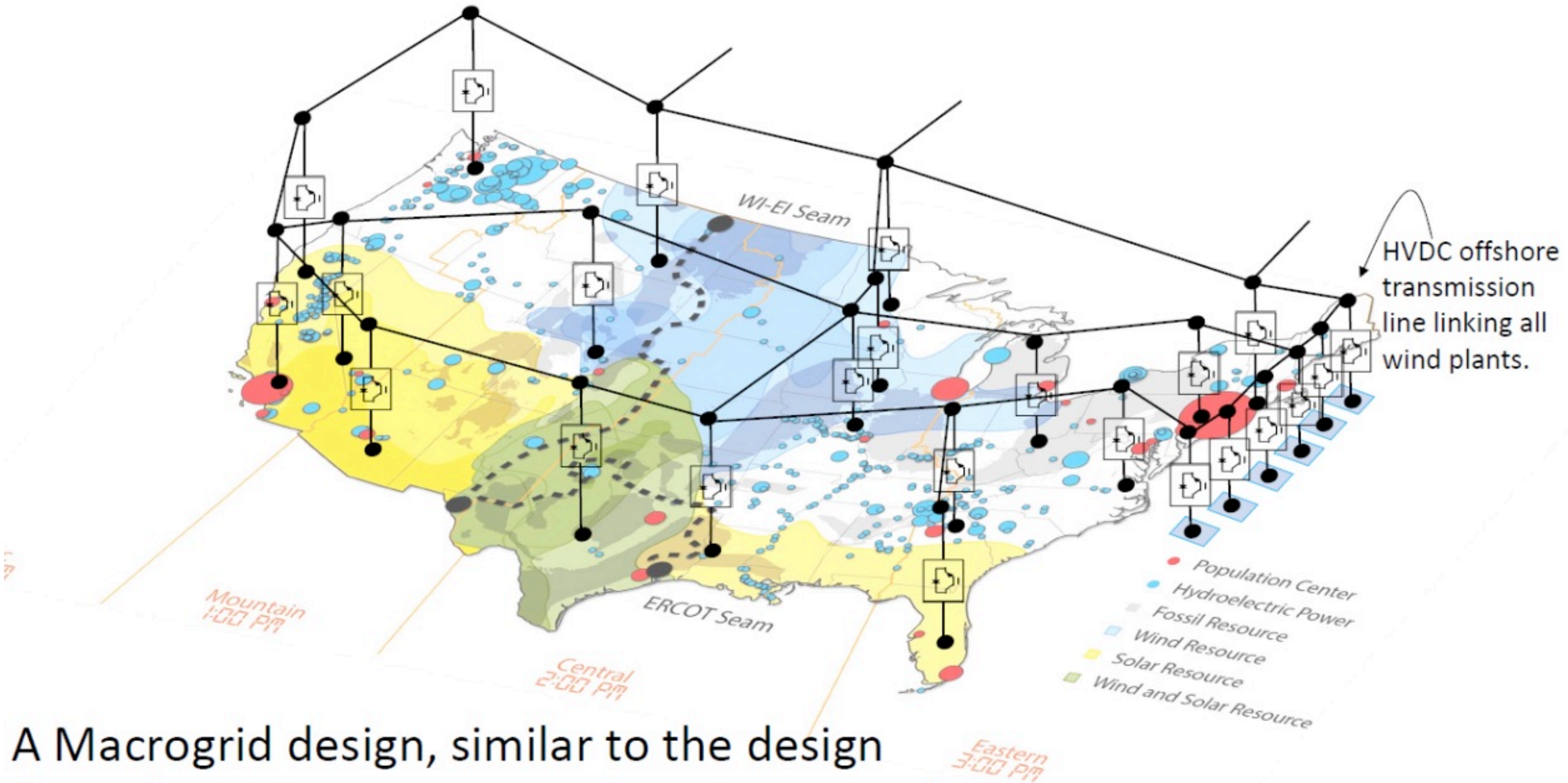



Minimize Environmental Impact

Maximize Equity & Justice

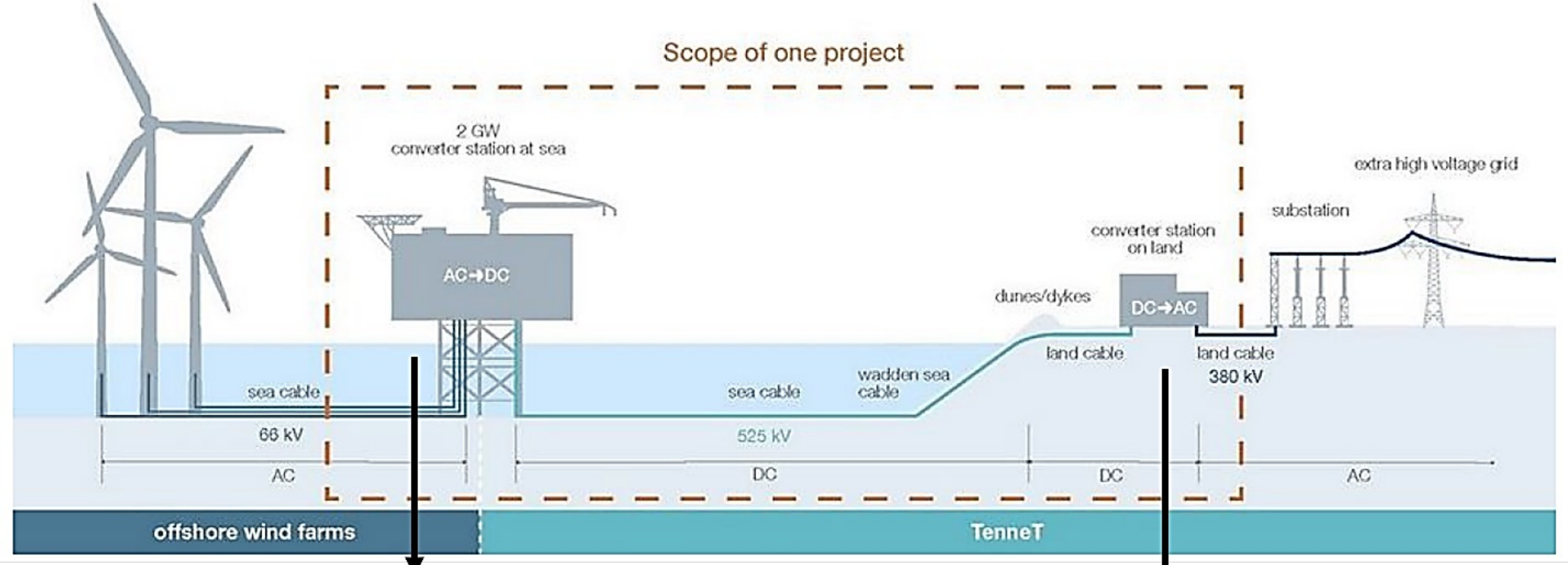
HVDC Technology Standards

# HVDC MTDC Onshore and Offshore MacroGrid



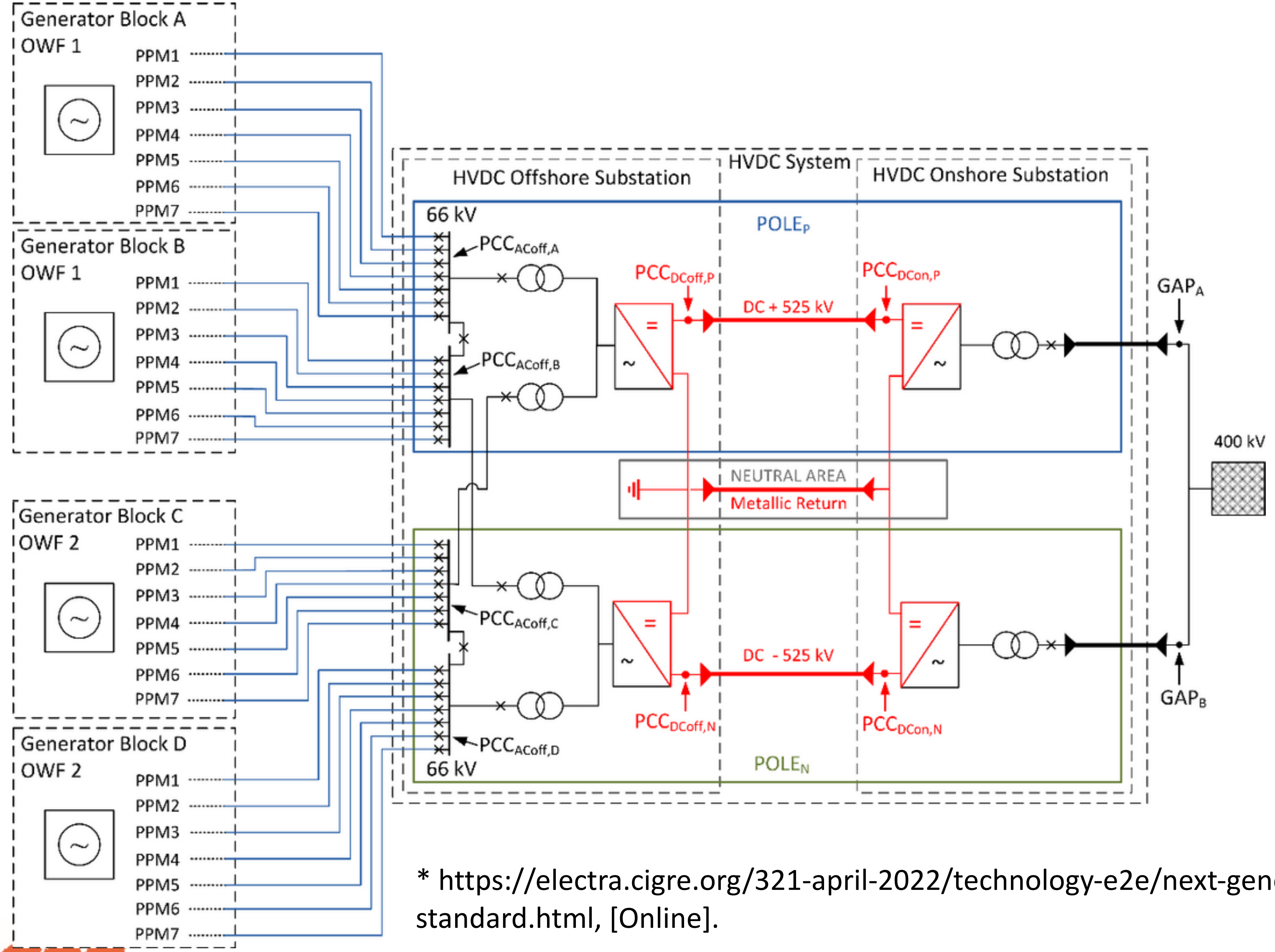

A Macrogrid design, similar to the design from the NREL Interconnections Seam Study. www.nrel.gov/analysis/seams.html

# TenneT 2GW Standard




Next Generation Offshore Grid Connection Systems: TenneT's 2 GW Standard, Accessed on: July 30, 2022. [Online]. Available: [https://electra.cigre.org/321-april-2022/technology-e2e/next-generation-offshore-grid-connection-systems-tennets-2-gw-standard.html#:~:text=With%20the%202%20GW%20standard, Sea%20in%20the%20near%20future](https://electra.cigre.org/321-april-2022/technology-e2e/next-generation-offshore-grid-connection-systems-tennets-2-gw-standard.html#:~:text=With%20the%202%20GW%20standard,%20Sea%20in%20the%20near%20future).

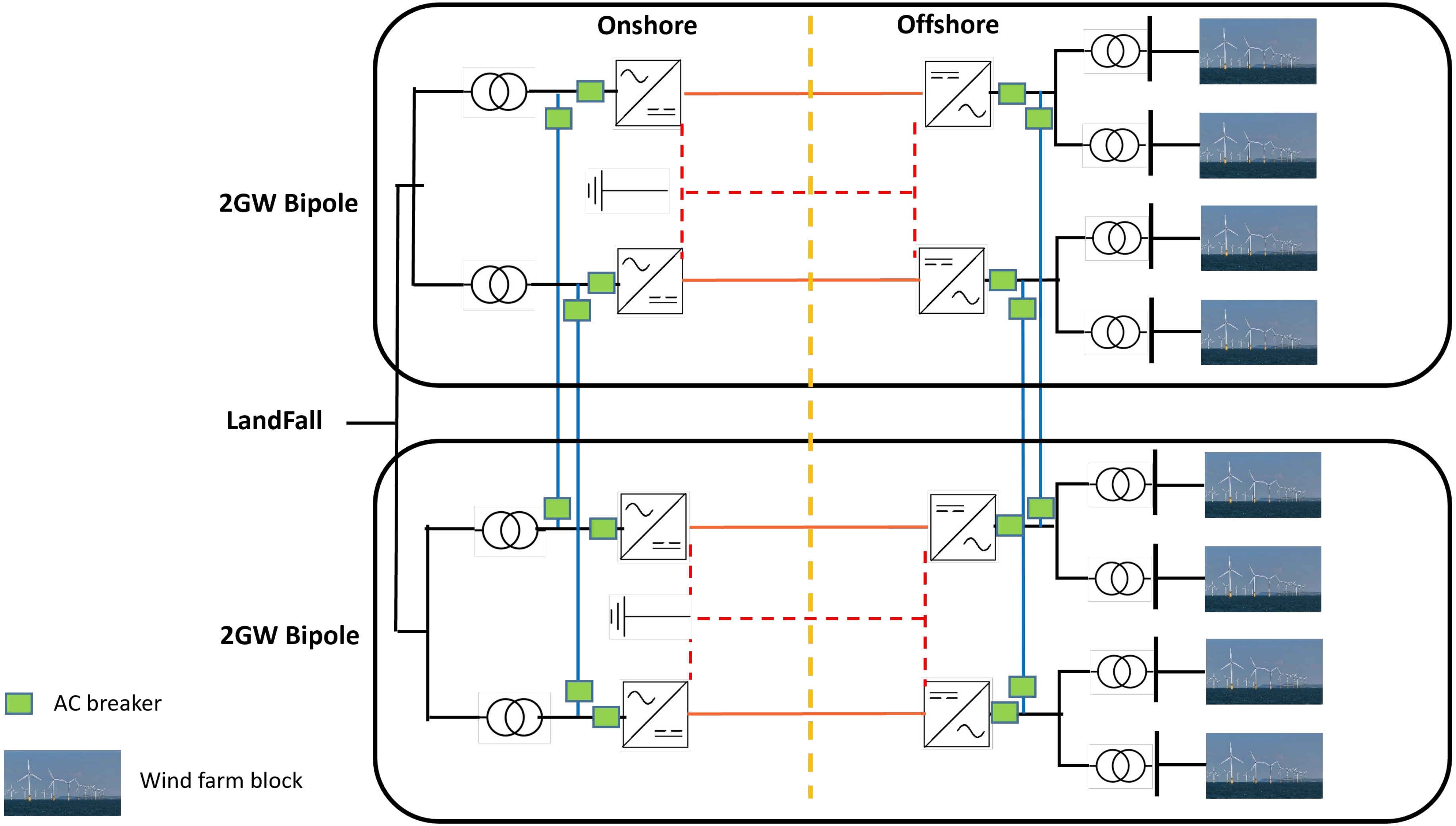
# 2 GW Bi-pole HVDC Terminal




Bi-pole cable with metallic return

* https://electra.cigre.org/321-april-2022/technology-e2e/next-generation-offshore-grid-connection-systems-tennets-2-gw-standard.html, [Online].

# AC vs DC Interconnection

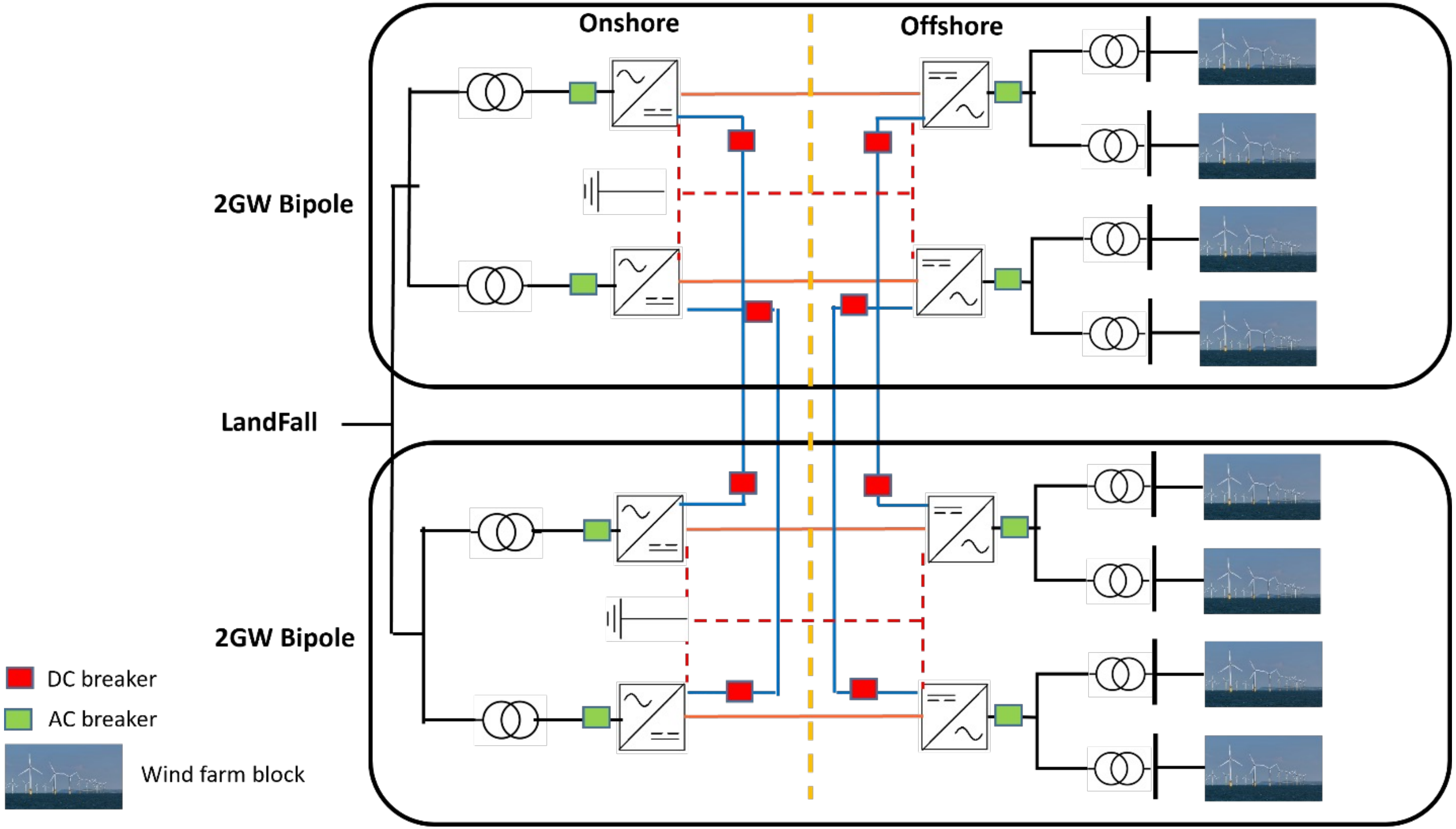



**AC Interconnected MTDC**

+ Resilient Interconnections
+ Reliable AC Protection
+ Onshore Switching Stations
- Unregulated Landfall Power
- Point to Point HVDC DC
- Limit to 1 - 2 GW Landfalls

M. Nazir, J. H. Enslin, E. Hines, J. D. McCalley, P. -A. Lof and B. K. Garnick, "Multi-terminal HVDC Grid Topology for large Scale Integration of Offshore Wind on the U.S Atlantic Coast," 2022 7th IEEE Workshop on the Electronic Grid (eGRID), Auckland, New Zealand, November 2022,

# AC vs DC Interconnection

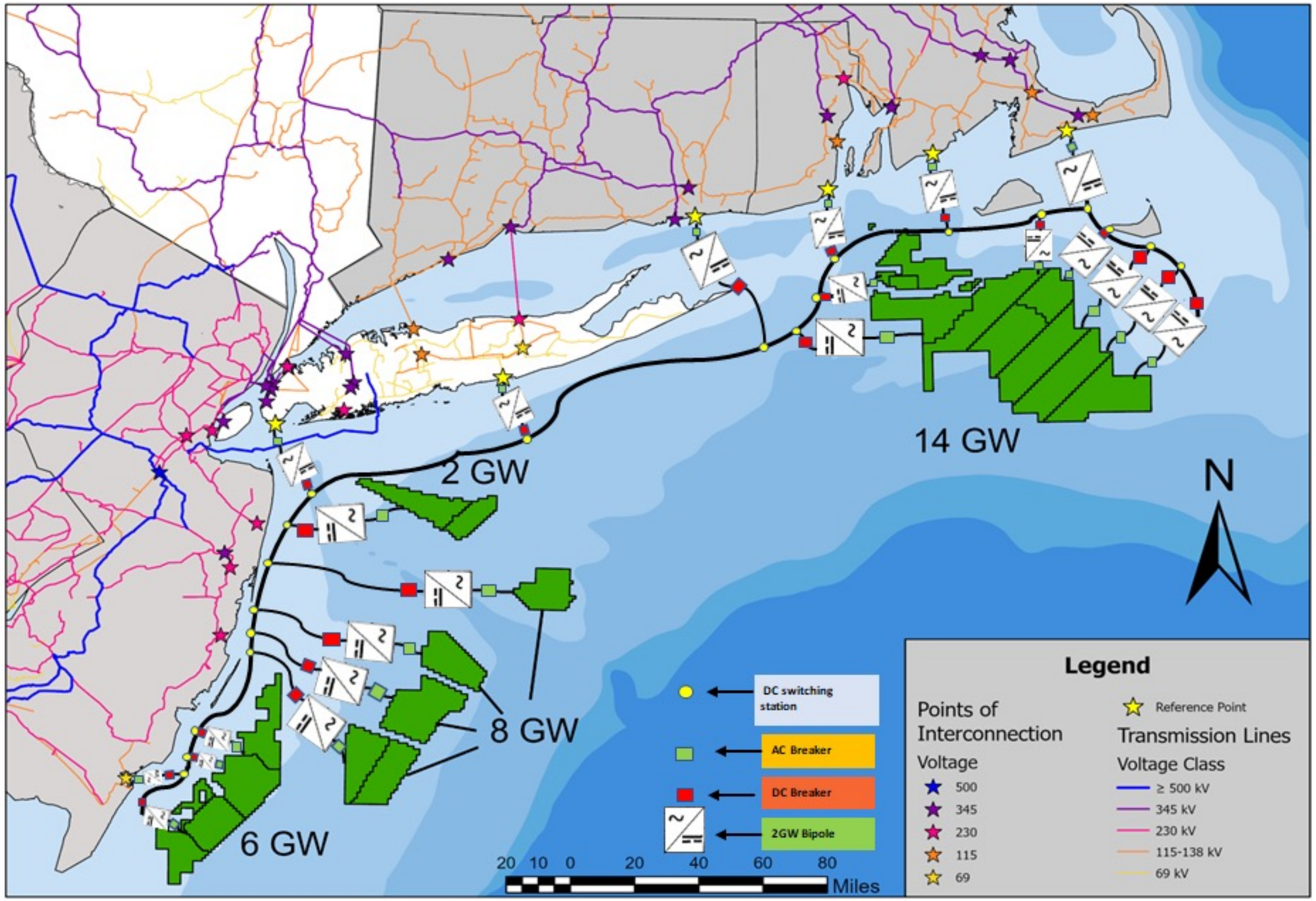



**DC Interconnected MTDC**

+ Resilient Interconnections
+ Regulate Landfall Power
+ Five 2 GW bipole clusters
+ Proposed 10 GW Landfalls
- Reliable DC Protection
- Offshore Switching Stations

M. Nazir, J. H. Enslin, E. Hines, J. D. McCalley, P. -A. Lof and B. K. Garnick, "Multi-terminal HVDC Grid Topology for large Scale Integration of Offshore Wind on the U.S Atlantic Coast," 2022 7th IEEE Workshop on the Electronic Grid (eGRID), Auckland, New Zealand, November 2022,

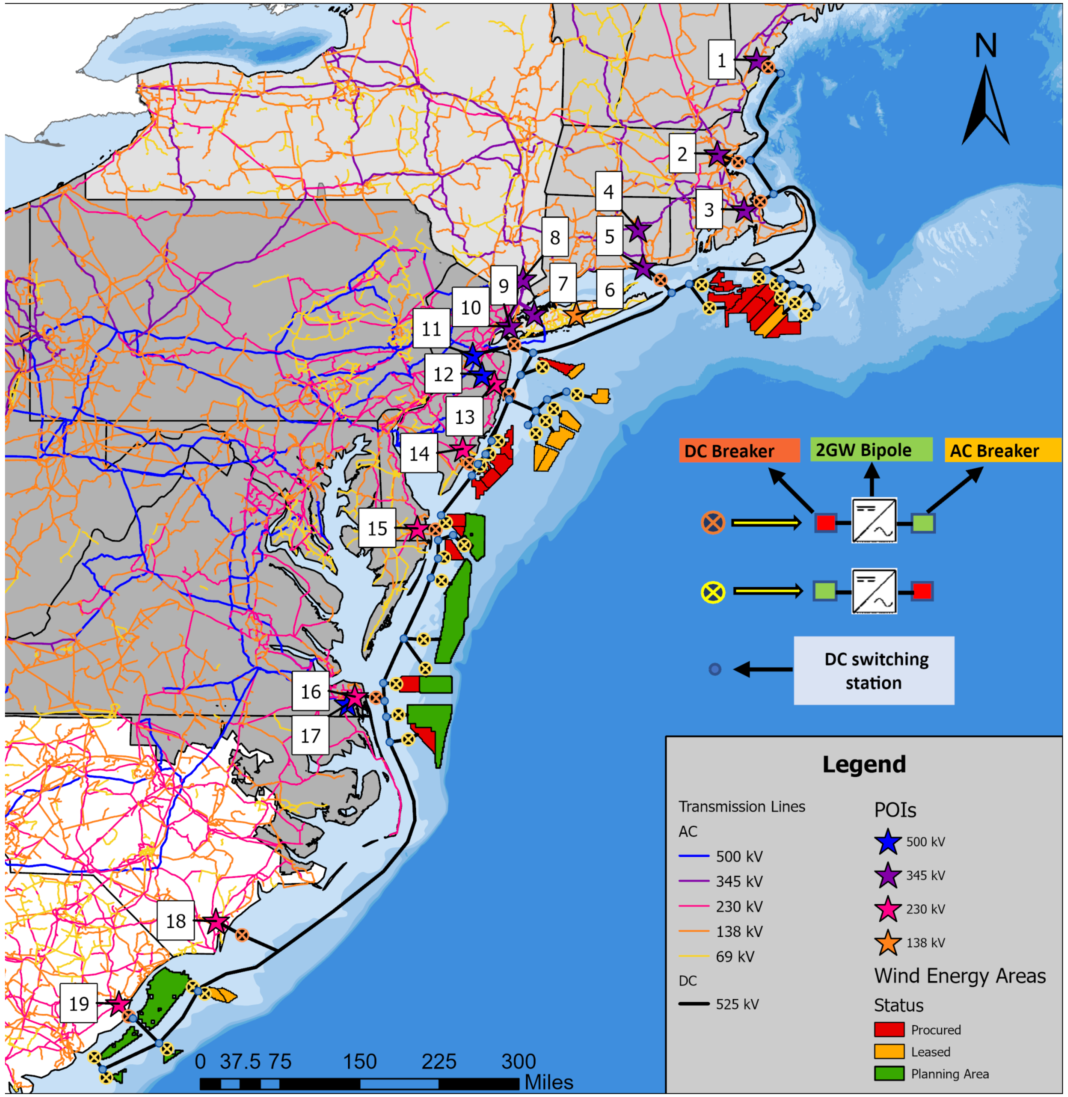
# Proposed 30 MW MTDC OSW Network




| Parameter | Value |
|---|---|
| Converter technology | VSC-HVDC |
| Rated voltage | 525kV |
| Rated Backbone Power | 4-6 GW |
| Offshore/Onshore Converter station power rating | 2GW, Bi-pole HVDC |

| Targeted Price | |
|---|---|
| 2 GW Terminal with DC/AC Protection | $ 1.5 B |

# Preliminary 76 MW MTDC OSW Network




| POI | | kV | State | Capacity (MW) |
|---|---|---|---|---|
| **ISO-NE** | | | | |
| 1 | Maguire Road | 345 | ME | 4000 |
| 2 | Woburn | 345 | MA | 4000 |
| 3 | Carver | 345 | MA | 4000 |
| 4 | Card Street | 345 | CT | 4000 |
| 5 | Millstone | 345 | CT | 4000 |
| | **Total** | | | **20000** |
| **NYISO** | | | | |
| 6 | Holbrook | 138 | NY | 2000 |
| 7 | Shore Road | 345 | NY | 4000 |
| 8 | Millwood | 345 | NY | 6000 |
| 9 | Farragut East | 345 | NY | 4000 |
| 10 | Farragut West | 345 | NY | 4000 |
| | **Total** | | | **20000** |
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| 11 | Deans | 500 | NJ | 6000 |
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| 16 | Landstown | 230 | VA | 4000 |
| 17 | Fentress | 500 | VA | 4000 |
| | **Total** | | | **30000** |
| **South** | | | | |
| 18 | Sutton | 230 | NC | 2000 |
| 19 | Winyah | 230 | SC | 4000 |
| | **Total** | | | **6000** |
| **EAST COAST** | | | | **76000** |

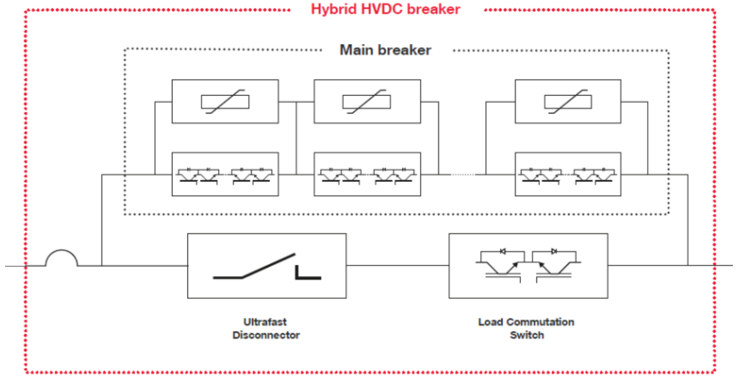
| Estimated 2 GW HVDC Terminals | |
|---|---|
| 40 Onshore | $ 40 B |
| 40 Offshore | $ 80 B |

Wind Probability Density and CF may reduce these with 50%

# Research Focus on HVDC and DC Protection

- **Develop highly integrated and compact technologies for resilient 4-10 GW MTDC grid interconnections.**
- Technology integration – SiC Devices, GIS Insulation, Protection
- Cost reduction 10x for MTDC Terminals and Hybrid DC Protection
- Macro system-wide dynamic and wind probability study
- Control concepts for offshore energy platforms in standardized HVDC Building Blocks to increase resiliency.
- Parallel operation of AC, DC, and Hydrogen networks at 4-10 GW
- Coordinate DC and AC Protection to reduce requirements
- Hybrid AC & DC Substations with Smart Hybrid Transformers

HVDC GIS DC CB 550 kV at 5 kA
Siemens Energy




HVDC Hybrid DC CB 550 kV at 30 kA
Hitachi Energy

GE VSC HVDC MMC (DolWin-3)