U.S. Offshore Wind Transmission:
Holistic Planning and Challenges

PRESENTED BY
Johannes Pfeifenberger

PRESENTED AT
Massachusetts Clean Energy Transmission Working Group

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Brattle

Contents

This presentation is based in part on the report, ***The Benefit and Urgency of Planned Offshore Transmission***, prepared with my colleagues at The Brattle Group, contributions from DNV, and input from an advisory panel of policy and industry experts. American Clean Power Association (ACP), the American Council on Renewable Energy (ACORE), the Clean Air Task Force (CATF), GridLab, and the Natural Resources Defense Council (NRDC) commissioned the analysis.

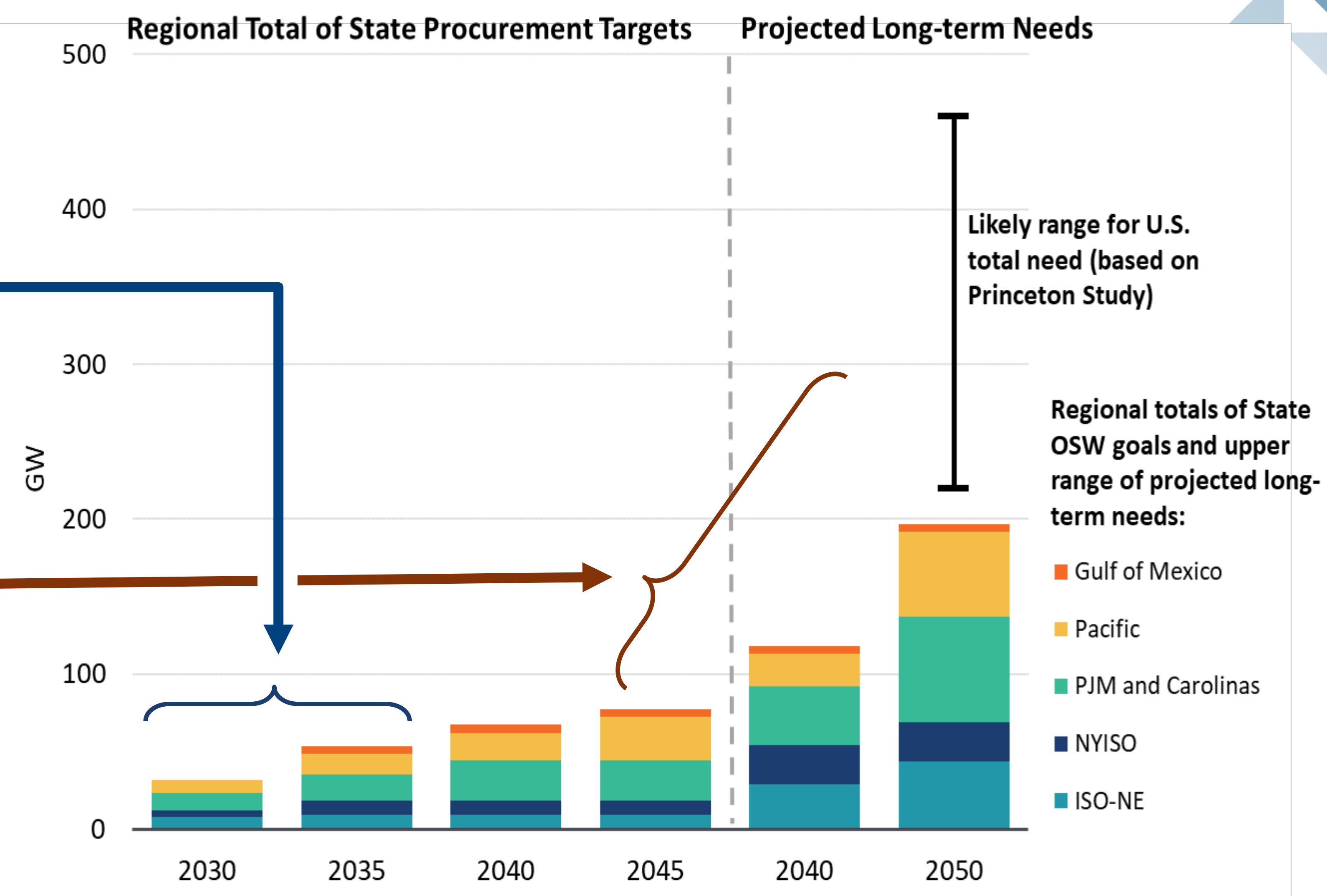
The Urgency of Starting to Plan for OSW Transmission Now

ISO-NE and neighboring regions need to urgently plan transmission

1. Total 30-50 GW of OSW by 2030-35, 9 GW in both ISO-NE and NYISO, 15 GW in PJM

while also considering

2. The much higher longer-term needs of 200-450 GW of U.S. OSW by 2050, with 20-40 GW in each RTO



Note: most U.S. OSW generation will need to be delivered to shore; some may be used to produce hydrogen

What is Transmission Planning for Offshore Wind?

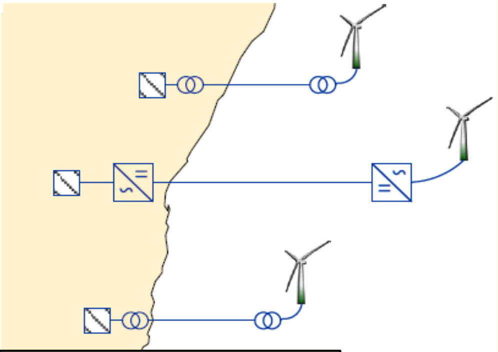
Transmission planning for OSW generation needs to focus holistically on three elements to reduce total OSW costs and its environmental/community impacts:

1. Where are the best points of interconnection (POIs) for OSW generation that reduce the need for expensive new onshore transmission and upgrades to the existing grid? **This requires holistic network planning that considers all future needs, including aging asset replacement, interconnection of onshore resources, load serving needs, etc.**
2. How can marine cable miles and shoreline impacts be reduced (e.g., high-capacity lines and transmission corridors for cables of multiple OSW plants)?
3. Can submarine cables be networked offshore to reduce overall costs and reinforce the existing grid

Offshore transmission concepts:

Radial Tie Lines

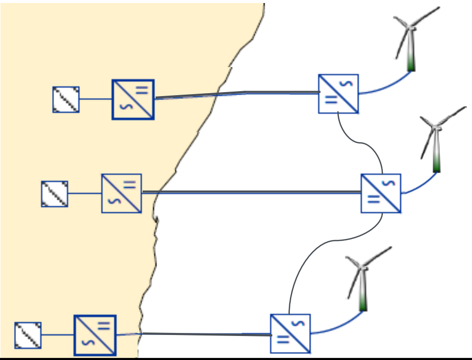
Transmission links bundled with individual OSW plants



Prevailing approach

Meshed Generation Ties

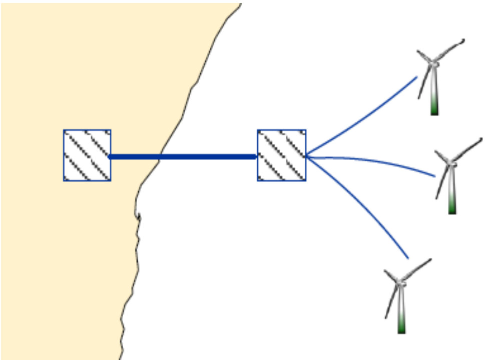
Individual lines to shore linked through offshore transmission



NY/NY “network-ready” req.

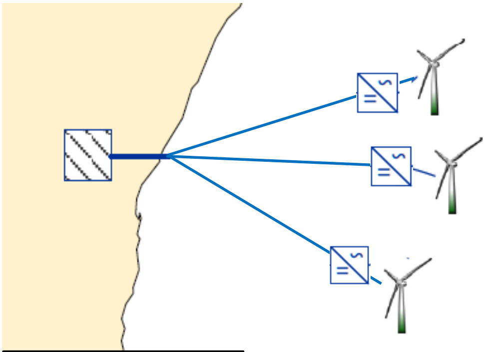
Offshore Collector

Planned tie line for multiple OSW plants



Onshore Collector

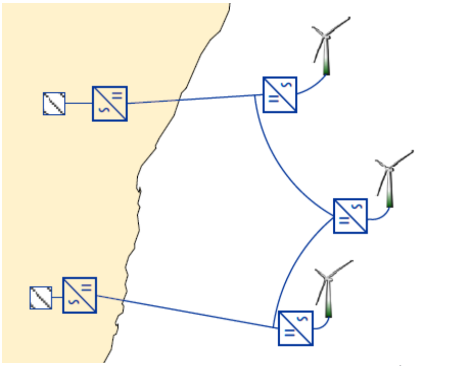
Onshore POI and corridor for multiple OSW plants



NJ SAA result

Backbone Offshore Grid

Planned transmission tie lines for multiple OSW plants



The Benefits of Proactively-Planned OSW Transmission

Numerous studies document the benefits of starting proactive planning now

- Choices of POIs, transmission corridors, technology to address 2030 needs will have long-term repercussions, possibly foreclosing attractive options to address longer-term needs

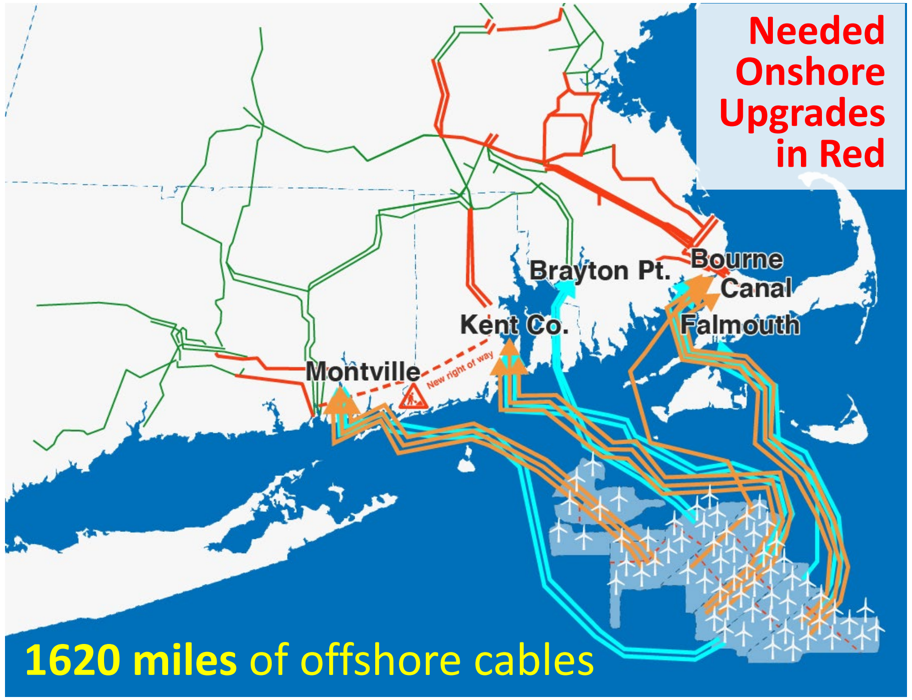
Based on studies and experience (such as in NJ), proactive planning for 100 GW of additional U.S. OSW generation by 2040-50 can:

- Reduce overall transmission costs by at least $20 billion
- Result in 60-70% fewer shore crossings and onshore transmission upgrade costs
- Reduce marine transmission cable installations by 50% or approx. 2,000 miles
- Significantly accelerate achievement of OSW development timelines by:
  - Eliminating interconnection and transmission-related delays
  - Reducing project-development and cost-escalation risks
  - Reducing environmental and community impacts
  - Achieving more competitive procurement outcomes
  - Facilitating investments in the local clean energy economy

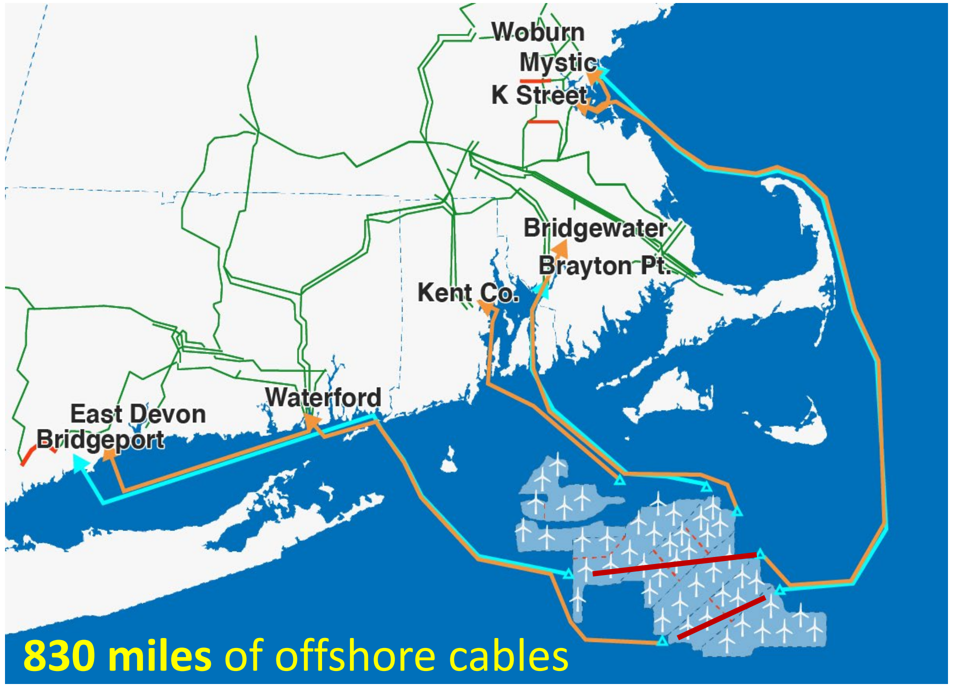
Studies show that delaying the planning effort by just 5 years may reduce these 2050 benefits by half!

Example: Planned Regional Offshore Transmission (for 8,400 MW total OSW in New England)

Plausible AC Gen-Tie Approach



Planned HVDC+POI Approach

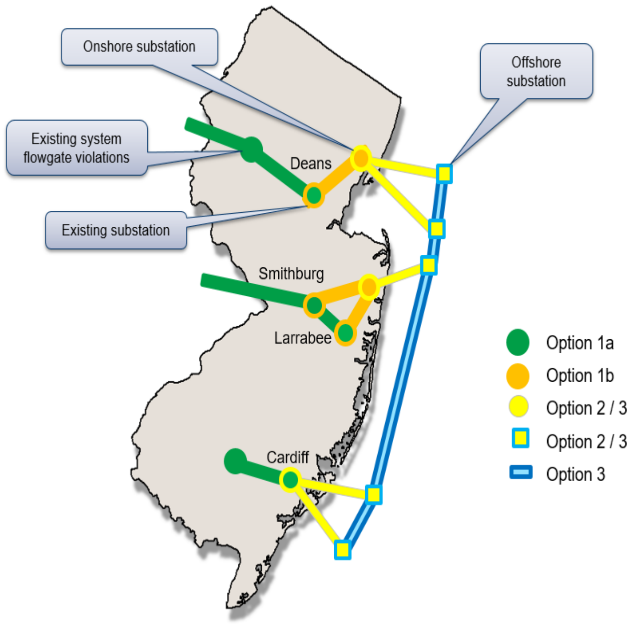


1. Higher-capacity HVDC lines: can reach better POIs and **reduce by 50-70% the impacts on existing ocean uses and marine/coastal environments**

2. Proactively-planned POIs: **reduce onshore upgrades by 60-70%** compared to continued reliance on current, incremental generation interconnection process

3. Opportunities for **linking offshore platforms**: to create networks that increase reliability and reinforce the onshore grid

Example: PJM's SAA for 6,400 MW of NJ OSW Transmission



Options 2-3 were not selected because:

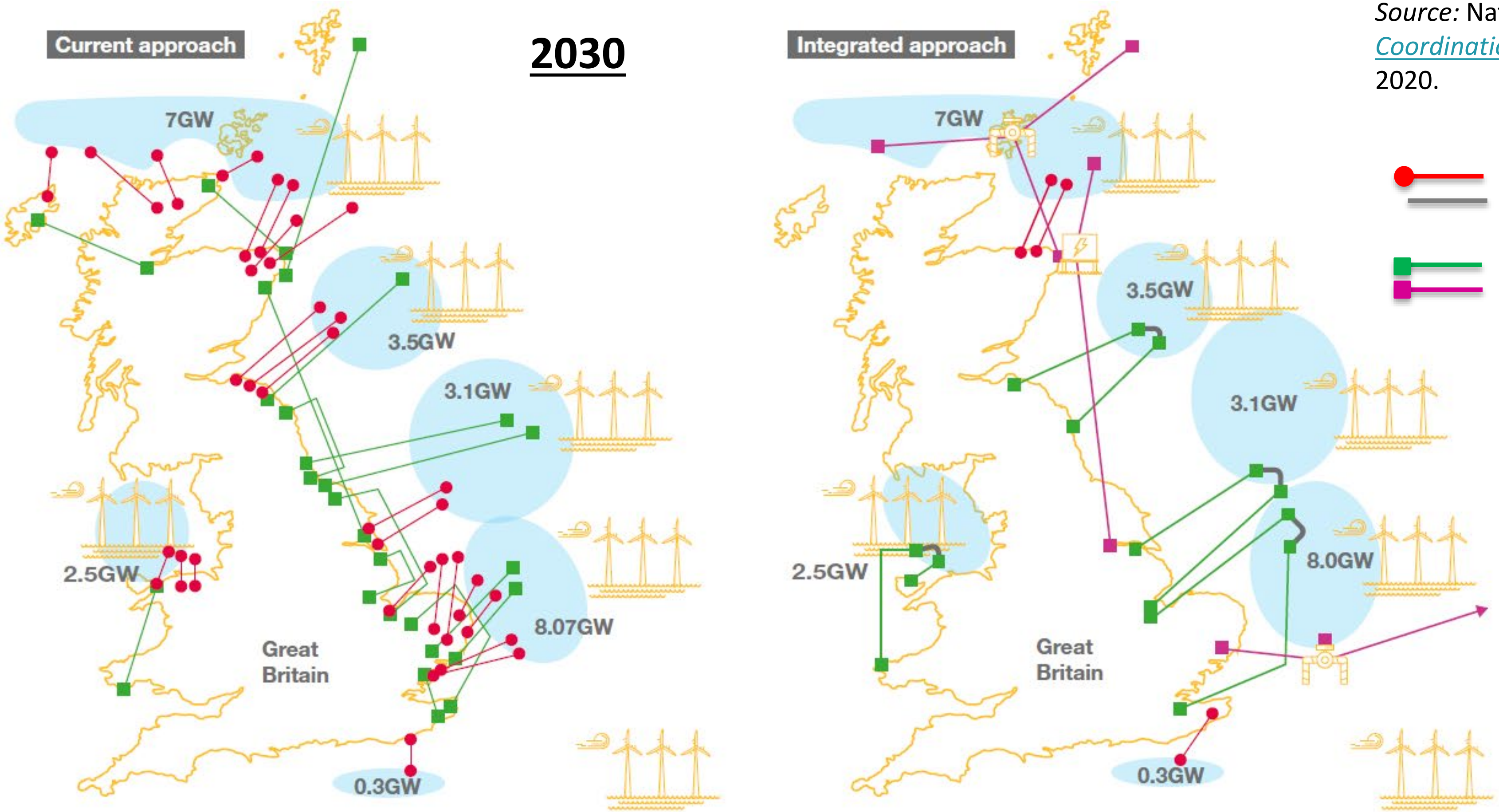
- Uncertain tax credits
- Less cost containment, schedule and operating risk mitigation than offered in OSW PPAs
- Higher permitting complexity
- Risk of duplication, poor locations, less competition
- Insufficient Option 3 value

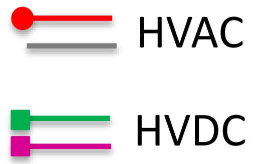
- PJM solicited four types of OSW transmission options for New Jersey
  - **Option 1a** – Onshore upgrades to existing grid (to create needed capacity at POIs)
  - **Option 1b** – New onshore transmission to facilitate connection
  - **Option 2** – Cable connections to offshore substations
  - **Option 3** – Offshore network / links between offshore subtations
  - Bids could address individual elements (options 1a-3 as shown) or complete solutions
- Received 80 innovative proposals from 13 bidders
  - 1a solutions (for upgrades to existing network) **reduced costs by $1 billion** compared to upgrades identified in individual GI studies to date
  - Consistent with even larger savings identified in PJM study for 75 GW of renewables
- BPU selected and further ordered:
  - All 1a upgrades needed to enable POIs for 6,400 MW
  - 1b upgrades for an **onshore "collector station"** for 3742 MW of POI capacity
  - **Prebuild a common cable corridor for four HVDC cables** of up to 1500 MW each (from collector station to shore)
  - **HVDC transmission** (to reduce needed ROW) and **network-ready** offshore substations

Source: https://www.brattle.com/insights-events/publications/new-jersey-state-agreement-approach-for-offshore-wind-transmission-evaluation-report/

UK Study of Current and "Integrated" OSW Transmission Approach for 18-41 GW by 2030-40

Source: National Grid ESO, [Offshore Coordination Phase 1 Report](), December 2020.

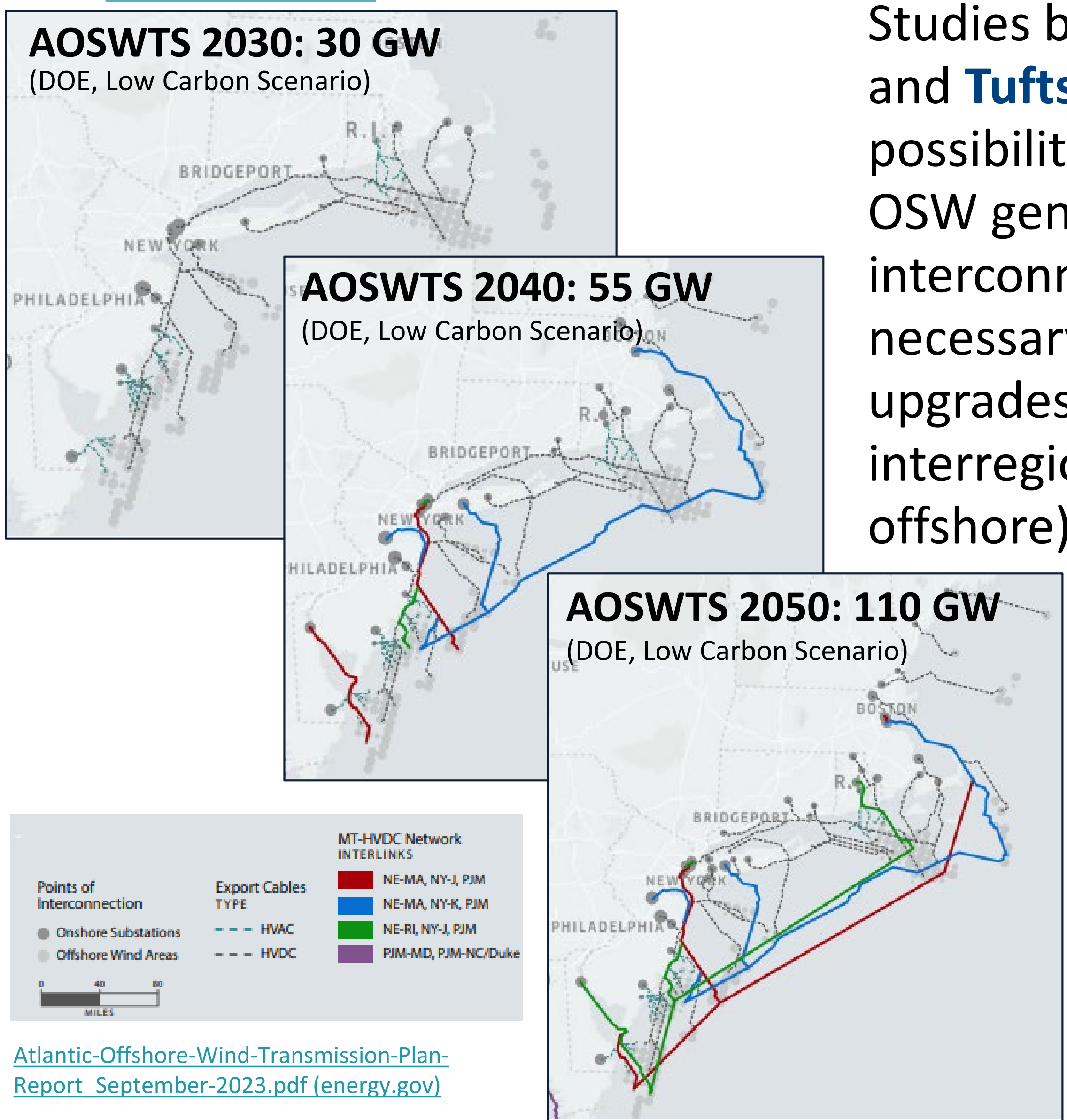




Results: if planning starts now, the **"integrated" solution reduces estimated transmission costs by 19% and the number of landing points by 50-70%**. Delaying planning by only 5 years reduces 2050 benefits by half.

See also: the Holistic Network Design (HND) effort to implement the integrated OSW-related network plan

Regional and Interregional Transmission for OSW generation

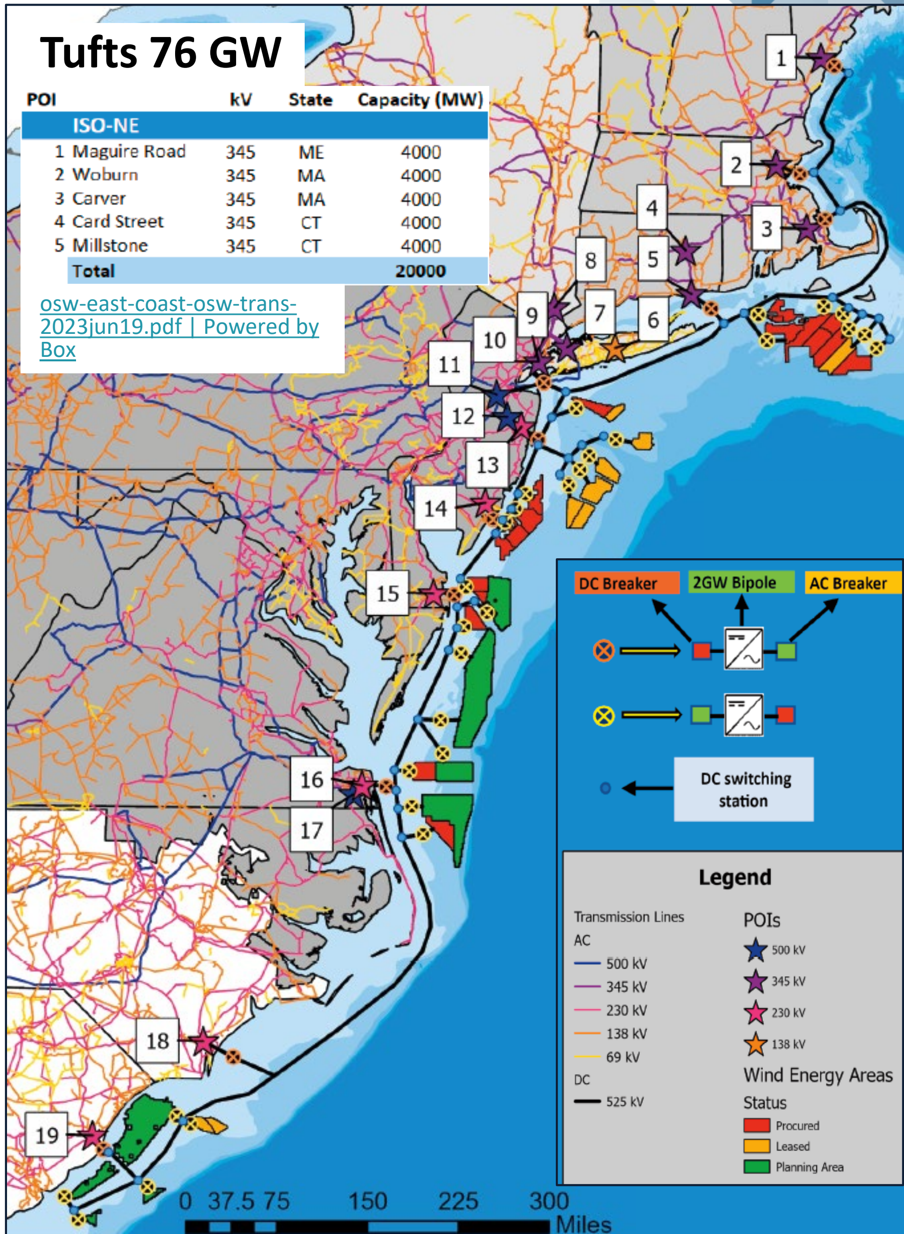


[Atlantic-Offshore-Wind-Transmission-Plan-Report_September-2023.pdf (energy.gov)]

Studies by **DOE (AOSWTS)** and **Tufts** point to the possibility of co-optimizing OSW generation interconnection (and necessary onshore upgrades) with new interregional (mostly offshore) transmission links.

Note: These studies do not currently take into account attractive new interconnections with Canada.

Studies show an additional 4-7 GW of interties would be very cost-effective for New England. Same for NY.



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

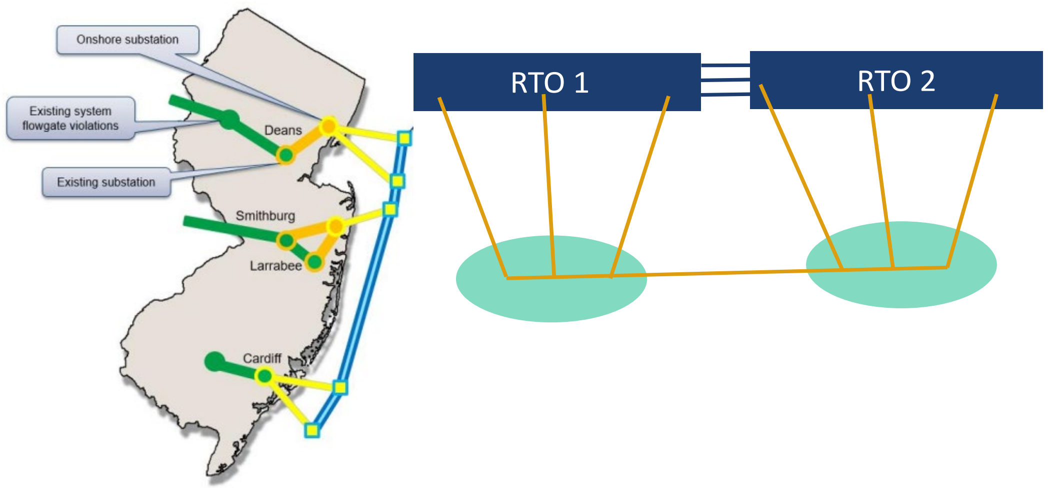
Benefits of Networked Offshore Transmission

Using standardized, modular offshore transmission facilities that can be networked into an offshore transmission system and integrated with the onshore grid offers important additional advantages:

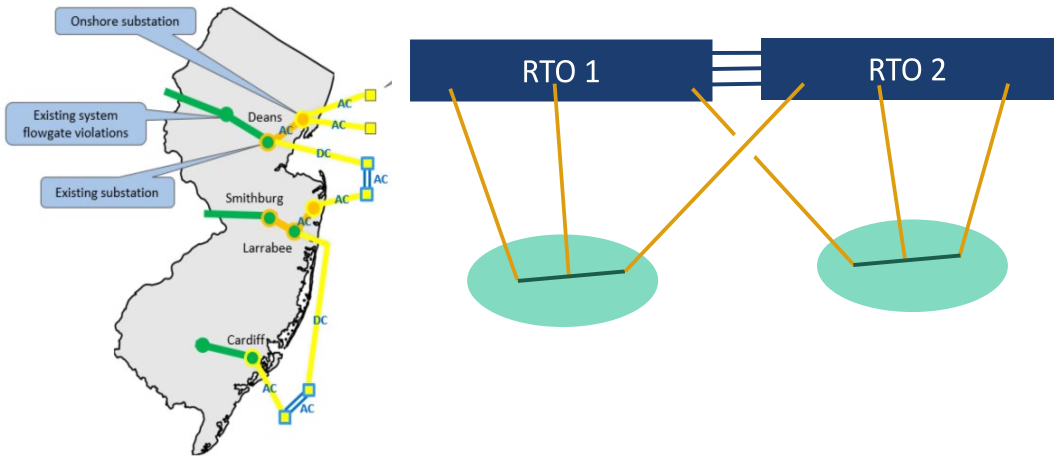
- Improve the reliability and value of OSW generation deliveries
- Allow for the utilization of new, higher-capacity transmission cables (each able to deliver 2–2.6 GW of OSW), which further reduces costs and impacts to communities and the environment
- Improve the utilization and flexibility of the offshore transmission infrastructure
- Reinforce and avoid upgrades of existing onshore grids, which will improve grid-wide reliability and reduce future congestion costs
- Create unique, cost-effective opportunities to add valuable interregional transmission links (e.g., addressing constraints into New York City), that increase grid resilience and reduce system-wide costs

Offshore Grid Designs and Modularity/Compatibility

Conventional Thinking?



More Effective Alternative?



- Many offshore grid designs are possible and will have to be evaluated through proactive, multi-value planning for:
  - Total (not piecemeal) generation interconnection needs
  - Creating cost-effective capability at the POIs in the most attractive grid locations with least environmental impacts
  - Identifying the most beneficial onshore+offshore grid configurations (see illustrations)
  - Effective integration of regional and interregional planning
- Technology standards will need to be developed to ensure modularity, compatibility, and inter-operability
  - Mesh-ready, technology-compatible offshore substation design?
  - New 525kV HVDC technology as "standard" going forward?
  - Vendor compatibility requirements?
  - Advanced technology solutions to address onshore injection limits (based on single-largest-contingency)?

Significant U.S. Policy and Regulatory Challenges

Grid Planning Processes	1. Slow and costly **generator interconnection processes** 2. Siloed **regional grid planning** processes that fail to identify cost-effective solutions for multiple needs 3. The absence of effective planning processes for **interregional transmission**.
Regulations, Contracts, & Operations	4. Uncertain federal **investment tax credits** for offshore wind delivery facilities 5. Undefined **regulatory and contractual frameworks** for the shared and networked offshore transmission 6. **Grid operations** not yet capable to optimize use of HVDC links 7. Unclear **BOEM permitting** for unbundled offshore transmission 8. **Uncoordinated processes** for lease-area auctions, state procurement, and transmission planning
Technology	9. Lack of HVDC **technology standardization** and slow adoption of HVDC in the U.S. 10. The lack of a compelling benefits case for specific **meshed offshore grid designs**

The U.S. Lease and Procurement Process is Particularly Challenging

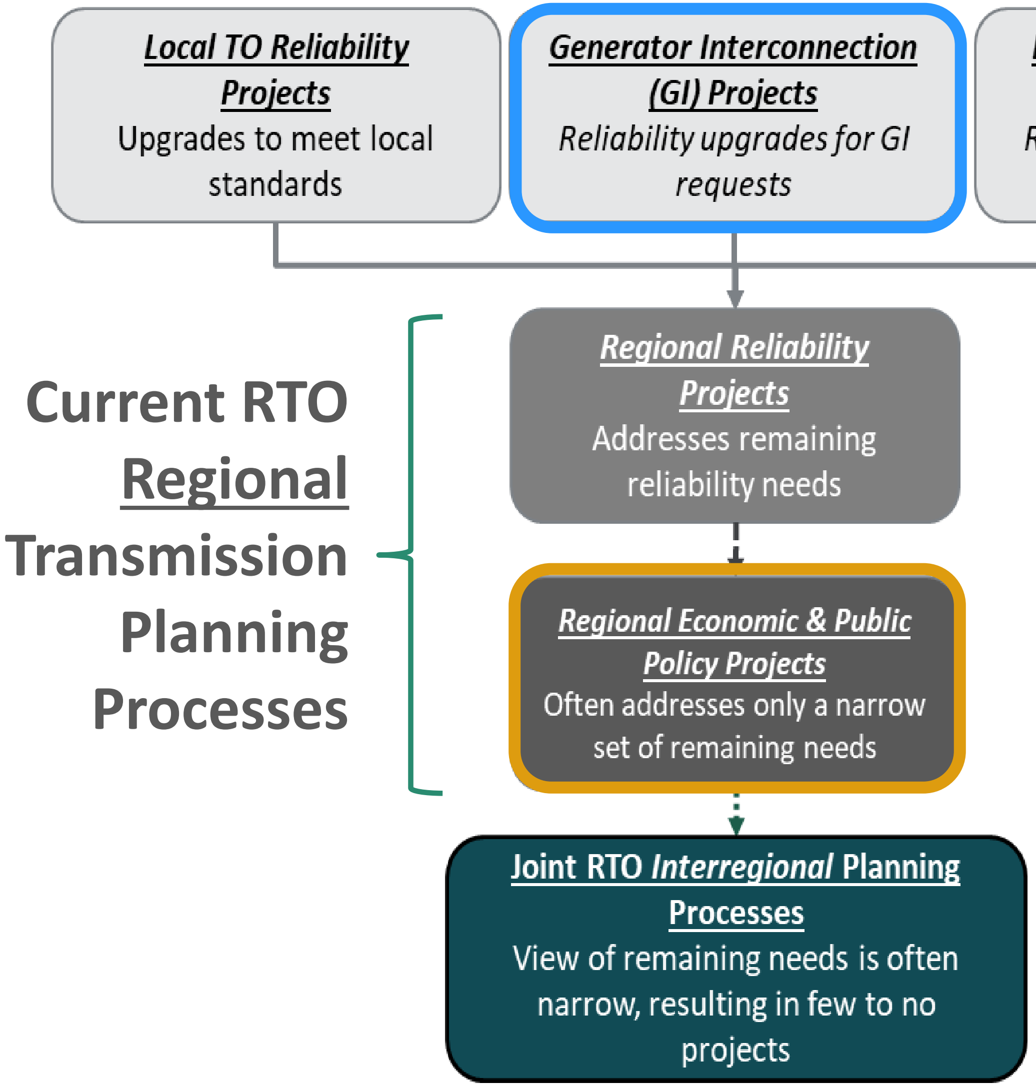
U.S. separation of OSW leasing, procurements, and transmission planning is particularly challenging:

- **Lease area auctions** requires OSW generators to commit before they know which state will procure their generation, which ISO/RTO region to which they will have to deliver, and which transmission upgrades will be necessary to interconnect
- **OSW generator permitting**, including cable routes and applying for grid interconnections, will have to start before they know which state will procure their resources or how expensive interconnection-related upgrades will be
- **State procurements** of OSW generation before they know which generators from which lease areas will make the most attractive offer or how expensive the winner's interconnection costs will be
  - The number of OSW generators able to bid into state procurements is limited to those with nearby lease areas
  - Delivery infrastructure cannot be pre-developed because the location of winning bidders' lease areas will not be known until after the procurement is completed
- **Transmission solutions** can be finalized only after procurement decisions have been made, creating significant uncertainties about the feasibility and cost of onshore transmission upgrades at the selected POI

A better process (increasingly used in Europe, but requires federal legislation) would be:

1. States make commitments on how much OSW generation they would like to procure over what timeframes (2030-2050)
2. BOEM develops specific wind energy areas that, at a minimum, can meet the state commitments
3. States and ISOs/RTOs (in collaboration with BOEM) develop permittable and cost-effective transmission solutions (and costs) for delivering the OSW generation to shore
4. States issue (one-stop) solicitations for the development of OSW generation within the specified wind lease areas (which already have permittable transmission and interconnection solutions)
   - More competitive procurements (because bidders are not limited to those with wind-energy leases)
   - Less risk for developers and states (because delivery routes are pre-permitted and cost-effective interconnection solutions are already specified)
   - Allows for pre-development of the delivery and transmission interconnection infrastructure

U.S. Transmission Planning is Balkanized



These solely reliability-driven processes account for > 90% of all transmission investments

- None involve any assessments of economic benefits (i.e., cost savings offered by the new transmission)

Generation interconnection processes often have become the primary tool (and barrier) to support public policy goals for clean energy

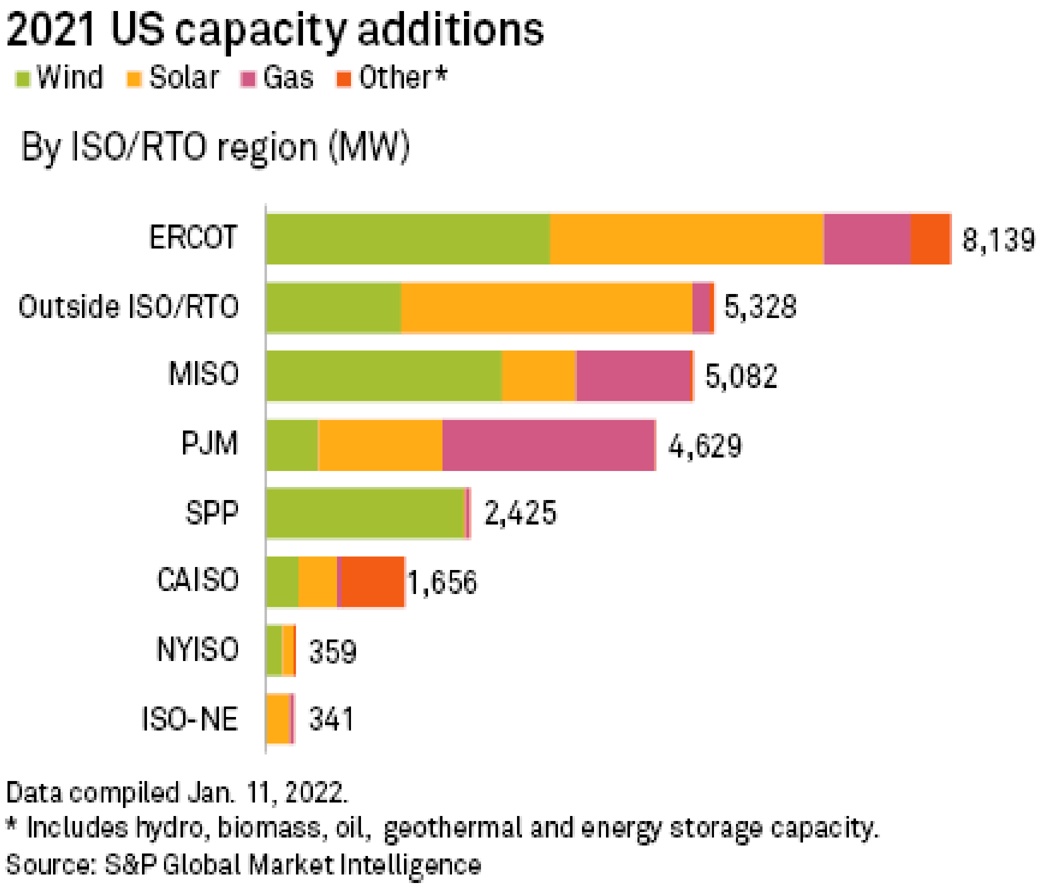
Planning for economic & public-policy projects results in less than 10% of all U.S. transmission investments

Interregional planning processes are large ineffective

- Essentially no major interregional transmission projects have been planned and built in the last decade
- Numerous national studies show that more interregional transmission is needed to reduce total system costs

Generation Interconnection Processes are a Major Bottleneck

Some RTOs are able to interconnect disproportionately more generation, and have been able to do so more quickly.



RTO Size	Capacity in Queue
80 GW	135 GW
200 GW	330 GW
150 GW	155 GW
180 GW	245 GW
95 GW	100 GW
52 GW	160 GW
42 GW	75 GW
32 GW	30 GW

Planning regions with the most ambitious state clean energy standards (i.e., east and west coast states) are lagging behind regions such as Texas and the Midwest:

- ERCOT: added 10% of system capacity in 2021
- NYISO and ISO-NE: only 1%
- All others: 2-4%

Options are available to improve generation interconnection

See also: Generation, Storage, and Hybrid Capacity in Interconnection Queues | Electricity Markets and Policy Group (lbl.gov)

Recommendations for Addressing the Identified Challenges

Immediate Action (this year): to ensure that some challenges can be addressed expeditiously in states' OSW generation and transmission procurements

1. **Increase staffing at state and federal regulatory agencies involved in OSW planning**
   - *Relevant entities: state governors or senior policymakers, federal policymakers*
2. **Create and empower multi-state decision-making entities**
   - *Relevant entities: state governors or senior policymakers and state regulatory agencies with support of grid operators, DOE, FERC, BOEM, industry stakeholders*
3. **Provide IRS guidance regarding applicability of ITC to offshore interconnection facilities**
   - *Relevant entities: IRS*
4. **Identify feasible POIs to cost-effectively accommodate identified OSW needs over time**
   - *Relevant entities: states, multi-state entities, DOE, grid operators, FERC*
5. **Develop network-ready standards for offshore facilities that can be linked to create offshore grid**
   - *Relevant entities: DOE, states, grid operators with input from OSW generation and transmission developers*
6. **Clarify and modify BOEM transmission permitting and lease-process coordination**
   - *Relevant entities: BOEM, DOE, OSW transmission developers*

Recommendations for Addressing the Identified Challenges

Near-Term Actions (1-2 years)

7. **Develop multi-state <u>cost-allocation framework</u>**
   - *Relevant entities: state regulatory agencies, grid operators, FERC*
8. **Develop <u>HVDC-technology</u> and operational standards**
   - *Relevant entities: DOE, grid operators, states*
9. **Improve <u>regional</u> transmission planning processes (ongoing)**
   - *Relevant entities: FERC, grid operators*

Mid-Term Actions (2-3 years)

10. **Create effective <u>interregional</u> transmission planning processes**
    - *Relevant entities: FERC, grid operators, multi-state entities with input from market participants*

Longer-Term Actions (3-5 years)

11. **Develop offshore grid <u>contracts and regulations</u> for shared-use and open-access facilities**
    - *Relevant entities: DOE, FERC, states, multi-state entities, ISOs/RTOs, with input from OSW generation and transmission developers*
12. **Develop grid <u>operations</u> and <u>wholesale market</u> design modifications**
    - *Relevant entities: DOE, FERC, grid operators, transmission owners*

Option for Accelerating Generation Interconnection

In response to FERC Order 2023, a number of options exist to accelerate generation interconnection for clean energy resources. These options have proven effective based on experience in other U.S. regions, Canada, and Europe.

- Allow for sharing and transfers of interconnection rights at existing POIs through fast-track process that bypasses the generation interconnection queue for new POIs (which would be consistent with FERC's new first-ready/first served requirement)
- Provide a streamlined (non-firm) ERIS interconnection option that can later be upgraded to (firm) NRIS
  - Upgrades focused only on local interconnection needs with congestion management for "deep" network constraints
  - Similar to ERCOT; see Enel working-paper.pdf (enelgreenpower.com) [Note: Brattle was not involved]
- Consider the U.K.'s "Connect and Manage" (replaced prior "Invest and Connect")
  - Reduced lead times by 5 years; network constraints addressed with congestion management and T planning https://www.gov.uk/guidance/electricity-network-delivery-and-access#connect-and-manage)

Generation interconnection based on "connect and manage" when combined with proactive transmission planning offers more timely and cost-effective solutions if:

- Near-term needs are quickly addressed through multi-value planning (beyond reliability)
- Long-term needs are proactively addressed through scenario-based long-term planning

Framework for more Proactive Transmission Planning*

FERC NOPR efforts and available experience point to proven planning practices that can reduce total system costs and risks, but are rarely used today:

1. **Proactively and holistically plan for future generation and load** by incorporating realistic projections of all needs: the anticipated generation mix, public policy mandates, load levels, and load profiles over the lifespan of the transmission investments. Avoid siloed, incremental planning processes.
2. **Account for the full range of transmission needs** and **use multi-value planning** to comprehensively identify investments that cost-effectively address all categories of needs and benefits
3. **Address uncertainties and high-stress grid conditions explicitly through scenario-based planning** that takes into account all transmission needs for a broad range of plausible long-term futures as well as real-world system conditions, including challenging and extreme events
4. **Use comprehensive transmission network portfolios** to address system needs and **cost allocation** more efficiently and less contentiously than a project-by-project approach
5. **Jointly plan inter-regionally across neighboring systems** to recognize regional interdependence, increase system resilience, and take full advantage of interregional scale economics and geographic diversification benefits

* Brattle & Grid Strategies Report: Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs, October 2021.

Takeaways for New England

1. Starting proactive, holistic, collaborative planning for offshore wind transmission now is critical for lowering costs, reducing delays, and mitigating community and environmental impacts
   - Identify the **most attractive POIs** for the first 9 GW of OSW in New England, considering both offshore and onshore transmission costs along with community impacts
   - Grid planning for 9 GW at these POIs has to **holistically consider all long term transmission and clean energy needs** (through 2040-50, onshore and offshore, regionally and interregionally), or more cost effective options will be foreclosed
   - Delaying planning effort by five years, may cut in half the planning benefits achievable by 2050
2. Significant coordination, planning, and technology challenges need to be addressed with other states and regions
3. We developed a number recommendations on how to address these challenges
4. Federal funding through IRA and IIJA is available now to support necessary planning efforts and implement recommendations

Thank You!

Comments and Questions?

Additional Slides

About the Speaker

Johannes P. Pfeifenberger

PRINCIPAL
BOSTON

Hannes.pfeifenberger@brattle.com

+1.617.234.5624

Johannes (Hannes) Pfeifenberger, a Principal at The Brattle Group, is an economist with a background in electrical engineering and over twenty-five years of experience in wholesale power market design, renewable energy, electricity storage, and transmission. He also is a Visiting Scholar at MIT's Center for Energy and Environmental Policy Research (CEEPR), a Senior Fellow at Boston University's Institute of Sustainable Energy (BU-ISE), a IEEE Senior Member, and currently serves as an advisor to research initiatives by the U.S. Department of Energy, the National Labs, and the Energy Systems Integration Group (ESIG).

Hannes specializes in wholesale power markets and transmission. He has analyzed transmission needs, transmission benefits and costs, transmission cost allocations, and renewable generation interconnection challenges for independent system operators, transmission companies, generation developers, public power companies, industry groups, and regulatory agencies across North America. He has worked on transmission matters in SPP, MISO, PJM, New York, New England, ERCOT, CAISO, WECC, and Canada and has analyzed offshore-wind transmission challenges in New York, New England, and New Jersey.

He received an M.A. in Economics and Finance from Brandeis University's International Business School and an M.S. and B.S. ("Diplom Ingenieur") in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.

U.S. OSW Generation Commitments and Future Needs

Region/State	Already Procured	State Goals					Projected Long-Term Need (GW)	
	2022	2030	2035	2040	2045	2050	2040	2050
ISO-NE (MW)	**4,841**	**8,042**	**8,642-9,042**	*8,642-9,042*	*8,642-9,042*	*8,642-9,042*	**23-29**	**42-44**
Massachusetts	3,241	5,600	*5,600*	*5,600*	*5,600*	*5,600*	6.7-11	23
Connecticut	1,158	2,000	*2,000*	*2,000*	*2,000*	*2,000*	9.1-11.1	*9.1-11.1*
Rhode Island	430	*430*	1,030-1,430	*1,030-1,430*	*1,030-1,430*	*1,030-1,430*	2.7	5
Maine	12	*12*	*12*	*12*	*12*	*12*	5	5
NYISO (MW)	**4,362**	*4,362*	**9,000**	*9,000*	*9,000*	*9,000*	**9-25**	**14-25**
New York	4,362	*4,362*	9,000	*9,000*	*9,000*	*9,000*	9-25	14-25
PJM (MW)	**8,432**	**8,432**	**14,722**	**18,222**	*18,222*	*18,222*	**13-30**	**33-58**
New Jersey	3,758	*3,758*	7,500	11,000	*11,000*	*11,000*	3.5-13.5	11-26
Maryland	2,022	*2,022*	*2,022*	*2,022*	*2,022*	*2,022*	*2.0*	*2.0*
Virginia	2,652	*2,652*	5,200	*5,200*	*5,200*	*5,200*	8-15	20-30
SERC (MW)		**2,800**	*2,800*	**8,000**	*8,000*	*8,000*	**8**	**7-10**
North Carolina		2,800	*2,800*	8,000	*8,000*	*8,000*	8	7.2-10
South Carolina								
MISO (MW)			**5,000**	*5,000*	*5,000*	*5,000*	**5**	**5**
Louisiana			5,000	*5,000*	*5,000*	*5,000*	5	*5*
CAISO (MW)		**5,000**	*10,000*	*15,000*	**25,000**	*25,000*	**15**	**25**
California		5,000	*10,000*	*15,000*	25,000	*25,000*	*15*	*25*
NWPP (MW)		3,000	*3,000*	*3,000*	*3,000*	*3,000*	**2-6**	**24-30**
Washington							0	4-10
Oregon		3,000	*3,000*	*3,000*	*3,000*	*3,000*	2-6	20
Atlantic Total (GW)	**17.6**	**23.6**	**35.2-35.6**	**43.9-44.3**	**43.9-44.3**	**43.9-44.3**	**54-93**	**96-137**
Gulf of Mexico Total (GW)			**5**	*5*	*5*	*5*	**5**	**5**
Pacific Total (GW)		**8**	**13**	*15*	**28**	*28*	**17-21**	**49-55**
US Total from State and Regional Studies (GW)	**17.6**	**31.6**	**53.2-53.6**	**66.9-67.3**	**76.9-77.3**	**76.9-77.3**	**76-119**	**150-197**
Federal U.S. Total (GW)		**30**				**110**	**40-100**	**224-458**

OSW DEVELOPMENT PIPELINE AS OF DECEMBER 2022

Status	Description	Total (MW)
Operating	The project is fully operational with all wind turbines generating power to the grid.	42
Under Construction	All permitting processes completed. Wind turbines, substructures, and cables are in the process of being installed. Onshore upgrades are underway.	932
Financial Close	All permitting processes completed. Begins when sponsor announces final investment decision and has signed contracts.	0
Approved	BOEM and other federal agencies reviewed and approved a project's COP. The project has received all necessary state and local permits as well as acquiring an interconnection agreement to inject power to the grid.	0
Permitting	The developer has site control of a lease area, has submitted a COP to BOEM, and BOEM has published a Notice of Intent to prepare an Environmental Impact Statement on the project's COP. If project development occurs in state waters, permitting is initiated with relevant state agencies.	18,581
Site Control	The developer has acquired the right to develop a lease area and has begun surveying the lease area.	24,096
Unleased Wind Energy Area	The rights to a lease area have yet to be auctioned to offshore wind energy developers. Capacity is estimated using a 3 MW/km^2 wind turbine density assumption.	8,290
Total U.S. OSW Pipeline:		**51,941**

W. Musial, P. Spitsen, P. Duffy, *et al.*, DOE, Offshore Wind Market Report 2022, August 2022, at 8. Updated with the latest activities of BOEM in the Gulf of Mexico and California.

Sources: see Appendix A of , ***The Benefit and Urgency of Planned Offshore Transmission***

Newly Available Federal Support

Substantial federal support is available now, but should continue to evolve to more fully meet the funding needs of regional & interregional OSW transmission development

1. **Inflation Reduction Act:**
   - ***Section 50153***: *up to $100 million is available for funding for planning, modeling, analysis, and convening stakeholders;*
   - ***Section 50152***: *up to $760 million to facilitate the siting of certain interstate and offshore transmission lines;*
   - ***Section 50151***: *up to $2 billion in facility financing, including loan guarantees, to certain transmission facilities designated by Secretary of Energy to be in the national interest;*
   - ***Section 1706***: *up to $250 billion in energy infrastructure reinvestment loan financing, to retool, repower, or repurpose energy infrastructure, including transmission to avoid or reduce greenhouse gases;*
   - ***Section 13502***: *includes additional tax credits for domestic manufacturing of offshore wind facilities and vessels.*
2. **Infrastructure Investment and Jobs Act:**
   - ***Section 40101***: *up to $5 billion for resilience grants, including $2.5 billion for Grid Resilience utility Grants (40101 (d)) for states, tribes, and territories, and $2.5 billion for Grid Resilience Industry Grants (40101(c)) through competitive grants;*
   - ***Section 40103(b)***: *up to $5 billion for the Grid Innovation Program, funding innovative approaches to transmission, storage, and distribution infrastructure;*
   - ***Section 40107***: *up to $3 billion for Smart Grid Grants, enabling deployment of technologies that enhance grid flexibility;*
   - ***Section 40106***: *up to $2.5 billion on a revolving basis for the Transmission Facilitation Program, which allows DOE to engage in various ways (including capacity contracts) to assist in the design, construction, operation of qualifying facilities.*

Studies: Benefits of Proactively-Planned Offshore Transmission

Cost-Savings, Regional Planning	
Cost-Savings, Regional Planning	• PJM's Offshore Wind Transmission Study for 75 GW of clean energy resources shows a nearly 90% interconnection cost reduction for public policy resources compared with previous cost analyses. • PJM-New Jersey State Agreement Approach shows over $900 million in cost-savings for interconnecting an additional 6,400 MW of OSW, among other benefits. • MISO-SPP's Joint Targeted Interconnection Queue Studies reduce interconnection costs by over 50% while reducing other customer costs by approximately $1 billion. • MISO's Long-Range Transmission Planning effort enables 90 GW of new resource interconnections, offering customer savings with total benefits about 3x total costs. • National Grid's study for the UK found that proactive planning OSW Transmission through 2050 reduces costs by 19%, along with other benefits. A delay of only 5 years, cuts these benefits in half.
Cost-Savings, Inter-regional Planning	• LBNL's recent study found expanding transmission capability between any of the 3 northeastern ISOs by 1,000 MW would have saved $100-300 million per year in wholesale power purchases, expected to grow with time. • LBNL also identified resilience benefits, based on a large amount of interregional transmission value occurring during difficult-to-forecast times of severe system stress. • MIT's recent study of the Northeastern U.S. and Canada found that an additional 4 GW of transmission capacity to Quebec could lower costs of zero-emissions power systems by 17-28%. • A recent national study by MIT found for deeply-decarbonized systems interregional transmission could reduce total generation and transmission costs by up to 20%. • A recent General Electric Study for NRDC showed that expanding interregional transmission capacity by 87 GW between various regions would provide $83 billion in customer benefits.

Studies: Benefits of Proactively-Planned Offshore Transmission

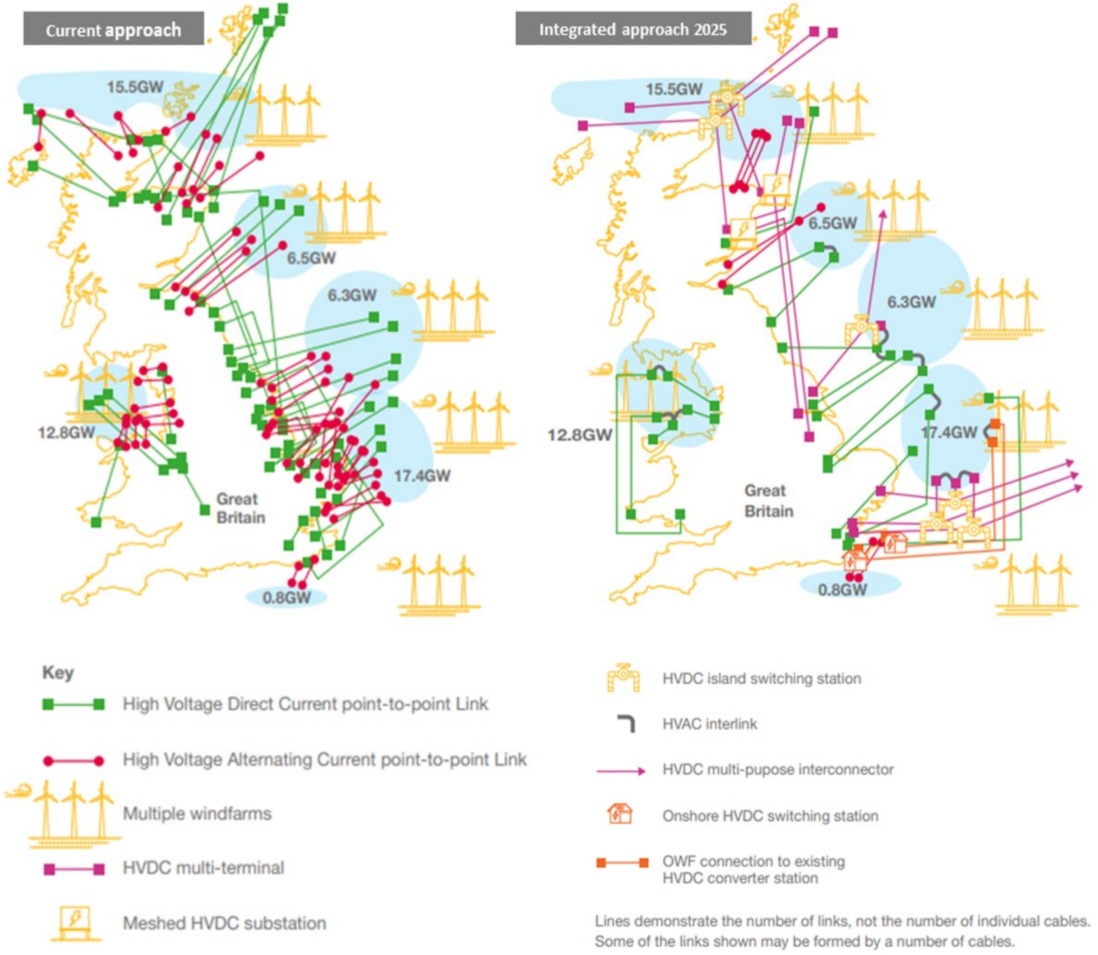
Environmental & Community Benefits

- National Grid found that proactive planning for U.K.'s 2050 OSW goal significantly reduced marine and shoreline impacts, with 70% fewer beach crossings, and 30% lower offshore line-miles. The study similarly found reduced onshore impacts, with proactive planning requiring 60% fewer onshore line miles, and 55% less land.
- Similar benefits have been demonstrated by Brattle and Anbaric for New England and NY
- The magnitude of these benefits is confirmed by New Jersey's experience with the State Agreement Approach, which allowed the consolidation of onshore grid access into a single transmission corridor, reducing onshore environmental and community impacts by two-thirds.

Employment Benefits

- Extrapolating from Clean Energy State Alliance projections, onshoring supply-chains to meet current goals could provide 135,000 jobs.
- The American Wind Energy Association has forecasted 20-30 GW of OSW will support between 45,000-83,000 American jobs by 2030.
- Similar estimates from American Clean Power estimate 23-40 GW OSW will result in 73,000-128,000 direct jobs.

UNPLANNED VS. PLANNED TRANSMISSION FOR U.K. OFFSHORE WIND IN 2050
(Assuming planning efforts start to be effective by 2025)



Source: National Grid ESO, *Offshore Coordination Phase 1 Report*, December 2020.

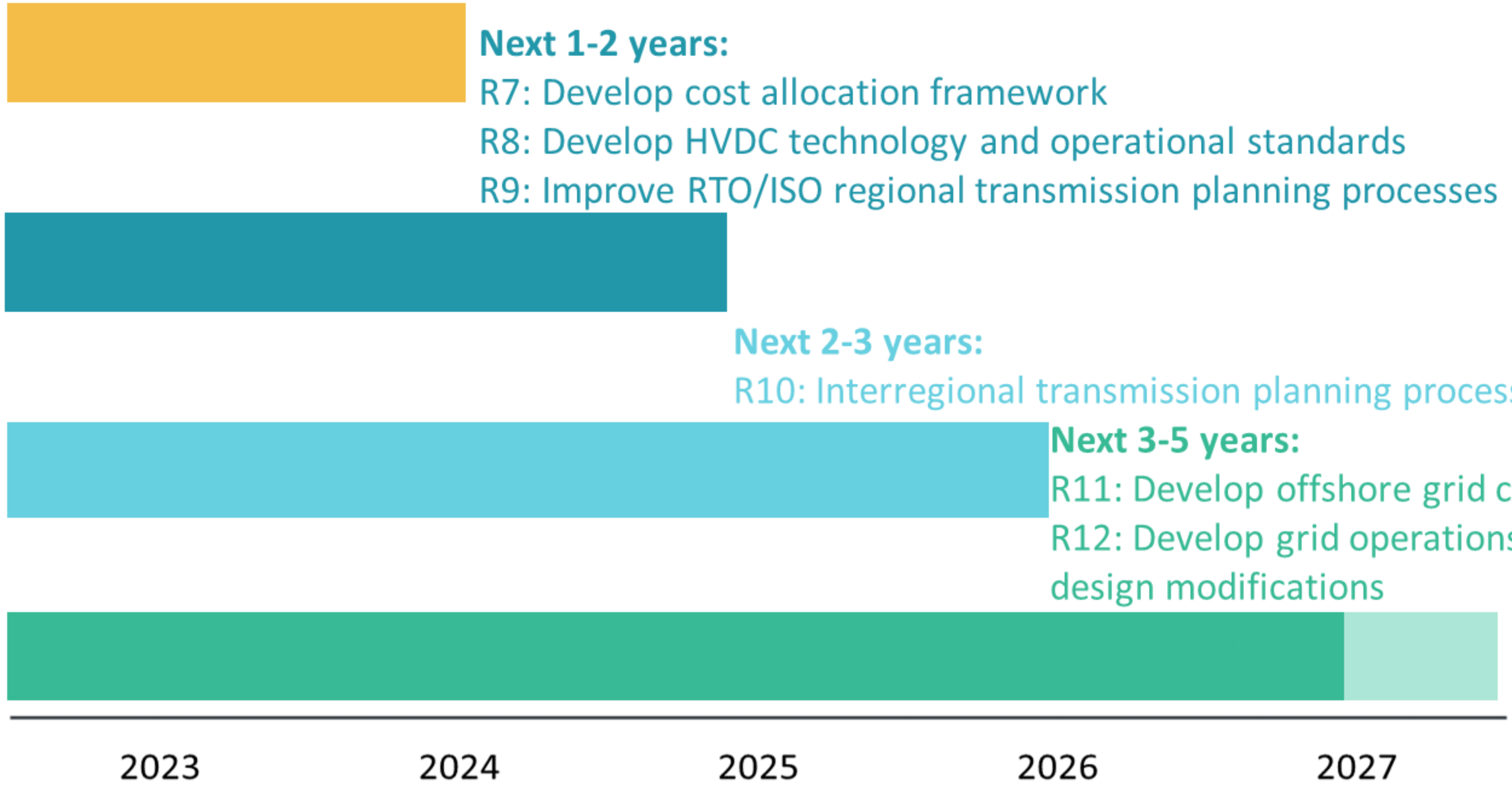
Recommendations to Address the Identified Challenges

Immediate:
R1: Increase agency staffing
R2: Identify and empower multi-state decision-making bodies
R3: Provide IRS guidance regarding applicability of ITC
R4: Identify feasible, cost-effective POIs
R5: Develop network-ready standards
R6: Clarify and modify BOEM permitting requirements

Next 1-2 years:
R7: Develop cost allocation framework
R8: Develop HVDC technology and operational standards
R9: Improve RTO/ISO regional transmission planning processes

Next 2-3 years:
R10: Interregional transmission planning processes

Next 3-5 years:
R11: Develop offshore grid contracts and regulations
R12: Develop grid operations and wholesale market design modifications



Federal funding through IRA and IIJA is available now to support necessary planning efforts and implement recommendations

Challenge: Transmission Cost Allocations

New, less-contentious cost-allocation approaches are needed to achieve efficient OSW transmission solutions. More cost-effective solutions will facilitate cost allocation!

- Reduce generator responsibility for distant network upgrades identified through today's generation interconnection process
  - Focus generator allocations initially on upgrades needed locally for non-firm interconnection rights
- Address network upgrades through transmission planning process, with cost allocation that <u>roughly</u> reflects beneficiaries
  - If network upgrades are mostly driven by states' public policy needs, consider allocating costs to the respective states (in exchange for clean-energy interconnection rights)
  - Without clean-energy interconnection rights, consider allocating costs to benefitting loads and, pro-rata, to interconnecting generators (similar to CAISO's Tehachapi approach and SPP-MISO's JTIQ)
- Implement portfolio-based (not project-specific) cost allocations
  - Less controversial and easier to implement because portfolio-wide benefits tend to be more even distributed and more stable over time

Avoid cost allocations that are strictly based on quantified benefits (which change over time, and across scenario assumptions and benefit metrics)

Five Elements of Generation Interconnection Need to be Addressed

Improving generation interconnection requires addressing all five elements of the GI process. Current discussions focused mostly on Nos. 1 and 5 (NOPR on Nos. 1 and 4)

1. **GI Process and Queue Management:** individual vs. cluster studies, type of studies and contractual agreements, readiness criteria, financial deposits, study and restudy sequences, etc.
2. **GI Scope and "Handoff" to Regional Transmission Planning:** are major ("deep") network upgrades triggered by incremental generation interconnection requests or handled through regional transmission planning?
3. **GI Study Approach and Criteria:** study assumptions, modeling approaches, and specific criteria differ significantly across regions (e.g., ERIS vs. NRIS study differences, injection levels studied, are market-based redispatch opportunities considered?)
4. **Selecting Solutions to Address the Identified Criteria Violations:** most regions select only traditional transmission upgrades to address criteria violations; grid-enhancing technologies, such as power-flow-control devices or dynamic line ratings, are not typically considered or accepted
5. **Cost Allocation:** most regions require the interconnecting generator (or group of generators) to pay for all upgrades identified, even though (a) there may be significant regional benefits to loads and other market participants and (b) more cost effective (multi-value) regional solutions may exist

Option for Improving the Generation Interconnection Process

Reducing the scope of upgrades triggered by generation interconnection processes likely will be necessary to both accelerate and lower the cost of renewable interconnection:

- Attractive: UK "Connect and Manage" (replaced prior "Invest and Connect")
  - Similar to ERCOT; reduced lead times by 5 years; network constraints addressed later (e.g., with congestion management) https://www.gov.uk/guidance/electricity-network-delivery-and-access#connect-and-manage
- ERCOT's generation interconnection process is perhaps most effective in the U.S.
  - Efficient handoff of study roles by ERCOT and Transmission Owners limits restudy needs
  - Projects can be developed and interconnected within 2-3 years; in other regions, the interconnection study process itself may take longer than that
  - Upgrades focused only on local interconnection needs and are recovered through postage stamp
  - Network constraints managed through market dispatch – which imposes high congestion and curtailment risks on interconnecting generators … in part due to ERCOT's insufficiently proactive multi-value grid planning
  - See Enel working-paper.pdf (enelgreenpower.com) [Note: Brattle was not involved]

Generation interconnection based on "connect and manage" when combined with proactive transmission planning offers more timely and cost-effective solutions if:

- Near-term needs are quickly addressed through multi-value planning (beyond reliability)
- Long-term needs are proactively addressed through scenario-based long-term planning

Examples of Brattle Reports on Regional and Interregional Transmission Planning and Benefit-Cost Analyses

Well-Planned Electric Transmission Saves Customer Costs:
Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future

PREPARED FOR
WIRES

Link: Well-Planned Transmission

PREPARED BY
Judy W. Chang
Johannes P. Pfeifenberger

May 2016

THE Brattle GROUP

Toward More Effective Transmission Planning:
Addressing the Costs and Risks of an Insufficiently Flexible Electricity Grid

PREPARED FOR
WIRES

Link: Effective Transmission Planning

PREPARED BY
Johannes P. Pfeifenberger
Judy W. Chang
Akarsh Sheilendranath

April 2015

The Brattle Group

Link: Transmission Benefits

The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments

July 2013

Judy W. Chang
Johannes P. Pfeifenberger
J. Michael Hagerty

Link: Diversity Value

BU
Boston University Institute for Sustainable Energy

The Value of Diversifying Uncertain Renewable Generation through the Transmission System

September • 2020

A Roadmap to Improved Interregional Transmission Planning

Link: Interregional Roadmap

PREPARED BY
Johannes P. Pfeifenberger
Kasparas Spokas
J. Michael Hagerty
John Tsoukalis

November 30, 2021

Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs

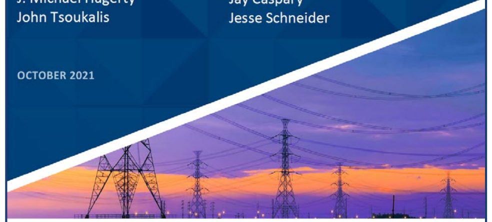
Link: Brattle Grid Strategies

PREPARED BY

The Brattle Group:
Johannes Pfeifenberger
Kasparas Spokas
J. Michael Hagerty
John Tsoukalis

Grid Strategies:
Rob Gramlich
Michael Goggin
Jay Caspary
Jesse Schneider

OCTOBER 2021



Brattle
GRID STRATEGIES LLC

Summarizes proven approaches to quantifying various benefits

Additional Reading on Transmission

Pfeifenberger, Plet, et al., The Operational and Market Benefits of HVDC to System Operators, for GridLab, ACORE, Clean Grid Alliance, Grid United, Pattern Energy, and Allete, September 2023.

Pfeifenberger, DeLosa, et al., The Benefit and Urgency of Planned Offshore Transmission, for ACORE, ACP, CATF, GridLab, and NRDC, January 24, 2023.

Brattle and ICC Staff, Illinois Renewable Energy Access Plan: Enabling an Equitable, Reliable, and Affordable Transition to 100% Clean Electricity for Illinois, December 2022.

Pfeifenberger et al., New Jersey State Agreement Approach for Offshore Wind Transmission: Evaluation Report, October 26, 2022.

Pfeifenberger, DeLosa III, Transmission Planning for a Changing Generation Mix, OPSI 2022 Annual Meeting, October 18, 2022.

Pfeifenberger, Promoting Efficient Investment in Offshore Wind Transmission, DOE-BOEM Atlantic Offshore Wind Transmission Economics & Policy Workshop, August 16, 2022.

Pfeifenberger, Generation Interconnection and Transmission Planning, ESIG Joint Generation Interconnection Workshop, August 9, 2022.

Pfeifenberger and DeLosa, Proactive, Scenario-Based, Multi-Value Transmission Planning, Presented at PJM Long-Term Transmission Planning Workshop, June 7, 2022.

Pfeifenberger, Planning for Generation Interconnection, Presented at ESIG Special Topic Webinar: Interconnection Study Criteria, May 31, 2022.

RENEW Northeast, A Transmission Blueprint for New England, Prepared with Borea and The Brattle Group, May 25, 2022.

Pfeifenberger, New York State and Regional Transmission Planning for Offshore Wind Generation, NYSERDA Offshore Wind Webinar, March 30, 2022.

Pfeifenberger, The Benefits of Interregional Transmission: Grid Planning for the 21st Century, US DOE National Transmission Planning Study Webinar, March 15, 2022.

Pfeifenberger, 21st Century Transmission Planning: Benefits Quantification and Cost Allocation, for NARUC members of the Joint Federal-State Task Force on Electric Transmission, January 19, 2022.

Pfeifenberger, Spokas, Hagerty, Tsoukalis, A Roadmap to Improved Interregional Transmission Planning, November 30, 2021.

Pfeifenberger, Tsoukalis, Newell, "The Benefit and Cost of Preserving the Option to Create a Meshed Offshore Grid for New York," Prepared for NYSERDA with Siemens and Hatch, November 9, 2022.

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Van Horn, Pfeifenberger, Ruiz, "The Value of Diversifying Uncertain Renewable Generation through the Transmission System," BU-ISE, October 14, 2020.

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Pfeifenberger, Newell, and Graf, "Offshore Transmission in New England: The Benefits of a Better-Planned Grid," prepared for Anbaric, May 2020.

Tsuchida and Ruiz, "Innovation in Transmission Operation with Advanced Technologies," T&D World, December 19, 2019.

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Chang, Pfeifenberger, Sheilendranath, Hagerty, Levin, and Jiang, "Cost Savings Offered by Competition in Electric Transmission: Experience to Date and the Potential for Additional Customer Value," April 2019 and "Response to Concentric Energy Advisors' Report on Competitive Transmission," August 2019.

Ruiz, "Transmission Topology Optimization: Application in Operations, Markets, and Planning Decision Making," May 2019.

Chang, Pfeifenberger, "Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future," WIRES&Brattle, June 2016.

Newell et al. "Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades," on behalf of NYISO and DPS Staff, September 15, 2015.

Pfeifenberger, Chang, and Sheilendranath, "Toward More Effective Transmission Planning: Addressing the Costs and Risks of an Insufficiently Flexible Electricity Grid," WIRES and Brattle, April 2015.

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Chang, Pfeifenberger, Newell, Tsuchida, Hagerty, "Recommendations for Enhancing ERCOT's Long-Term Transmission Planning Process," October 2013.

Pfeifenberger and Hou, "Seams Cost Allocation: A Flexible Framework to Support Interregional Transmission Planning," on behalf of SPP, April 2012.

Pfeifenberger, Hou, "Employment and Economic Benefits of Transmission Infrastructure Investment in the U.S. and Canada," on behalf of WIRES, May 2011.

Brattle Group Practices and Industries

ENERGY & UTILITIES

- Competition & Market Manipulation
- Distributed Energy Resources
- Electric Transmission
- Electricity Market Modeling & Resource Planning
- Electrification & Growth Opportunities
- Energy Litigation
- Energy Storage
- Environmental Policy, Planning and Compliance
- Finance and Ratemaking
- Gas/Electric Coordination
- Market Design
- Natural Gas & Petroleum
- Nuclear
- Renewable & Alternative Energy

LITIGATION

- Accounting
- Analysis of Market Manipulation
- Antitrust/Competition
- Bankruptcy & Restructuring
- Big Data & Document Analytics
- Commercial Damages
- Environmental Litigation & Regulation
- Intellectual Property
- International Arbitration
- International Trade
- Labor & Employment
- Mergers & Acquisitions Litigation
- Product Liability
- Securities & Finance
- Tax Controversy & Transfer Pricing
- Valuation
- White Collar Investigations & Litigation

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- Natural Gas & Petroleum
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