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Offshore Wind Transmission: AN ANALYSIS OF OPTIONS FOR NEW YORK

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Project scope and approach

Anbaric retained Brattle to compare the potential costs and benefits of offshore transmission options to contribute to the ongoing studies currently being undertaken in New York State

We qualitatively and quantitatively examined two approaches to developing offshore transmission and associated onshore upgrades to reach New York's offshore wind (OSW) development goals

1. The **“generator lead line” approach** wherein OSW developers compete primarily on cost to develop incremental amounts of offshore generation and associated project-specific generator lead lines (GLLs)
2. An **alternative “planned” approach** wherein transmission is developed independently from generation. Offshore transmission and onshore upgrades are planned to minimize overall risks and costs of achieving the state's offshore wind and clean energy goals

While other transmission configurations are possible, those captured here are representative of plausible outcomes under the two approaches

- The “GLL” approach reflects current trends in how and where OSW developers interconnect to the onshore grid, selecting the least-cost option available for each incremental project
- The alternative “planned” approach reflects a more optimized outcome that is unlikely to occur without an explicit planning process

Rationale and policy goals

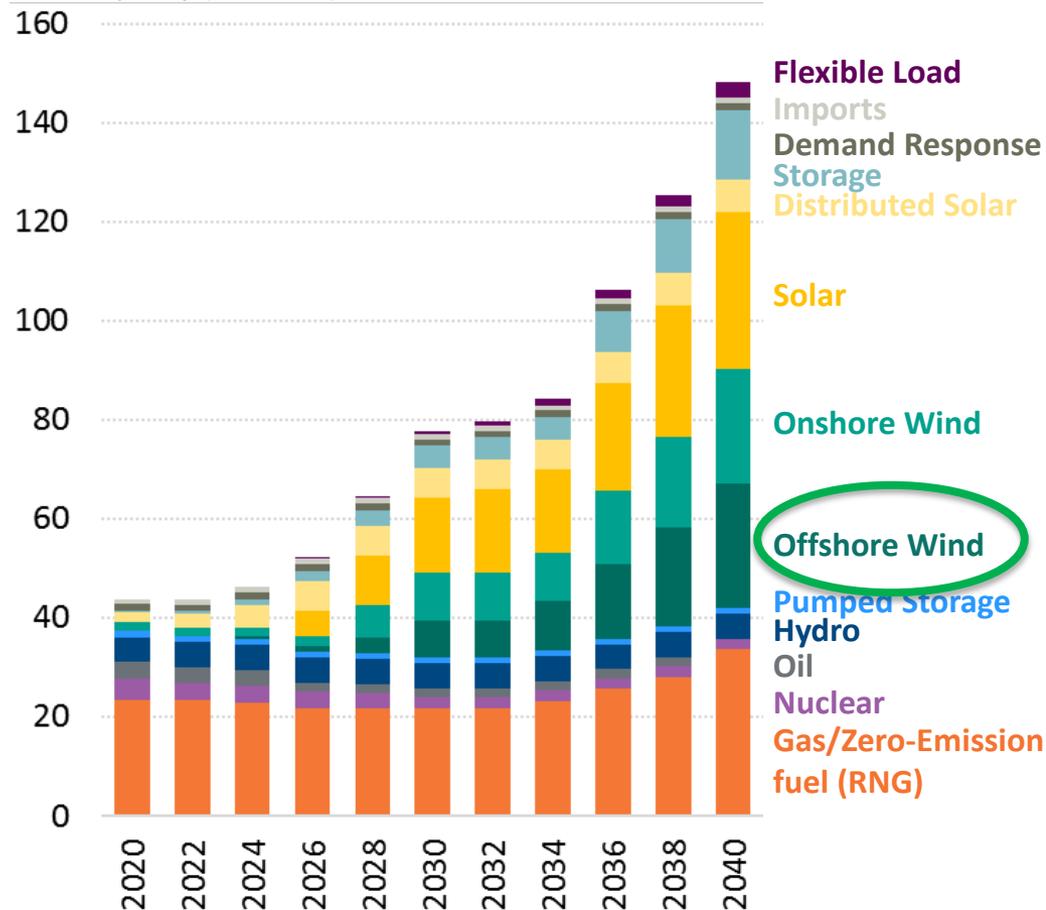
Thousands of MW of new clean resources will need to be built to achieve decarbonization goals in New York – **likely including between 14,000 and 24,000 MW of OSW by 2040**

New York State has already committed to **9,000 MW of OSW**

A key policy challenge is **ensuring a pathway to enable the lowest-cost solutions** for delivering new clean energy from source to population centers

New York “100% by 2040” Decarbonization Goals under a “High Electrification” Scenario

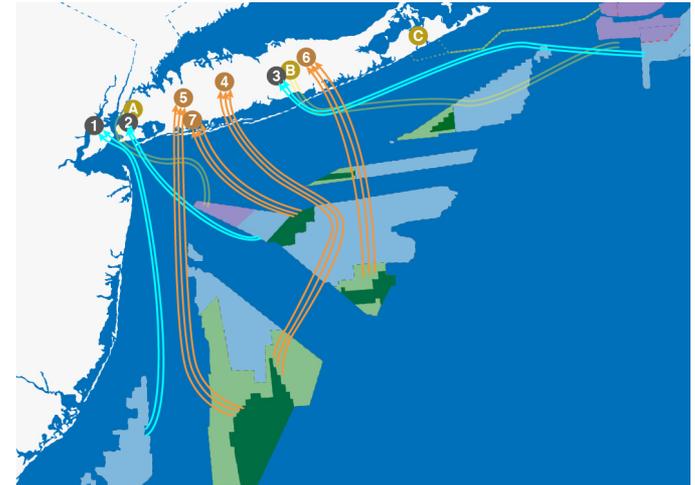
Total Capacity (ICAP GW)



Key takeaways

- 1. Cost Differential Analysis:** Planned approach estimated to reduce total transmission costs by at least \$500 million, not counting additional competitive benefits
- 2. Utilization of Points Of Interconnection (POI):** Planned transmission maximizes OSW integration with efficient utilization of POIs, while the GLL approach risks limiting ability to meet clean energy standards cost-effectively
- 3. Environmental Impact:** Planned transmission significantly reduces the impact on the fishing industry, coastal communities, and marine environments
- 4. Curtailments:** This transmission planning effort identifies curtailment challenges that need to be addressed to reduce developer risk from future projects (though further planning is needed)

GLL Offshore Transmission Scenario



Planned Offshore Transmission Scenario



Comparison of generator lead line vs. planned offshore transmission approach

A planned transmission approach that jointly coordinates onshore and offshore transmission investments to serve New York's offshore wind generation improves outcomes across seven criteria

Elements we examine	Our analysis indicates...	Slides
Total onshore + offshore transmission costs <ul style="list-style-type: none"> Onshore transmission upgrade costs (more risk) Offshore transmission costs (less risk) 	\$500 million (7%) lower under planned approach <ul style="list-style-type: none"> 74% lower under planned approach 19% higher under planned approach 	11-16
Impact to fisheries and environment	59% less marine cable-miles and 54% fewer cables landing on coastline under planned approach	20-21
Offshore wind curtailments	Planning can reduce wind curtailment (and mitigate developer risk from future OSW additions), though further studies are needed	22-26
Effect on generation and transmission competition	Increased competition (with cost savings) under planned approach	15-16
Utilization of constrained landing points	Improved under planned approach	17-19
Utilization of existing lease areas	Improved under planned approach	28
Enabling third-party customers	Improved under planned approach	29

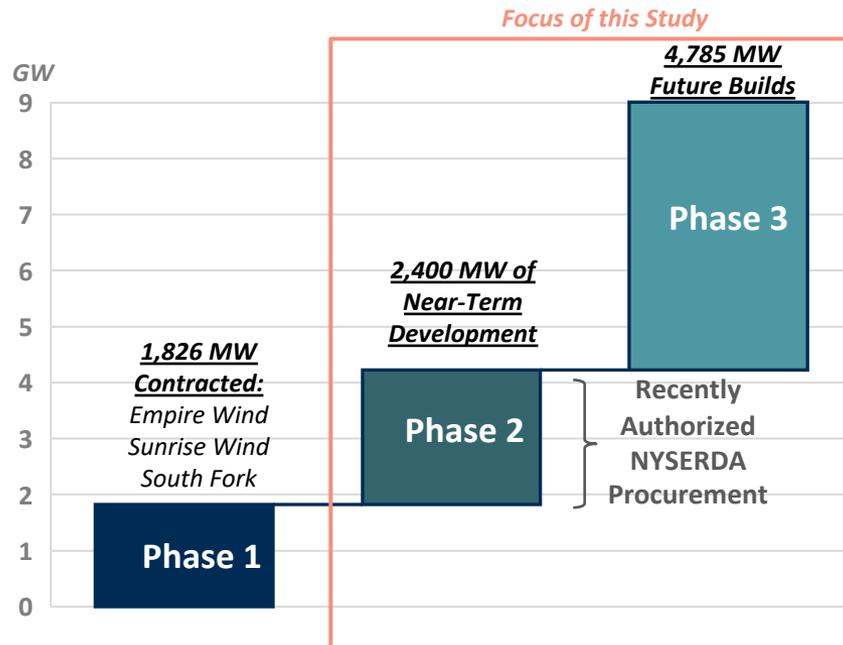
Analytical Approach

We compare transmission approaches to connect 9,000MW of offshore wind to NY

We assume Phase 1 projects already selected proceed as planned with GLLs under both approaches and compare two scenarios for future transmission development.

This analysis applies to **Phase 2 and 3** development. While recent authorization (1-2.5 GW) will proceed with GLL approach, NYSDERDA can incorporate these findings and other analyses underway to inform future procurement strategy.

We assume BOEM finalizes and leases Wind Energy Areas in the New York Bight before Phase 3.



GLL Approach	Planned Offshore-Grid Approach
GLLs – interconnect Empire Wind (to Gowanus), Sunrise Wind (to Holbrook), and South Fork Wind (to East Hampton)	
Continue GLL approach, assuming developers select Points of Interconnection (POI) to minimize incremental project-related (onshore + offshore) costs for <u>each project</u> individually	Planned procurements minimize total (onshore + offshore) costs and risks across <u>all projects</u>
GLL approach uses key cable routes for few projects	Planned routing fully utilizes key cable routes to minimize costs

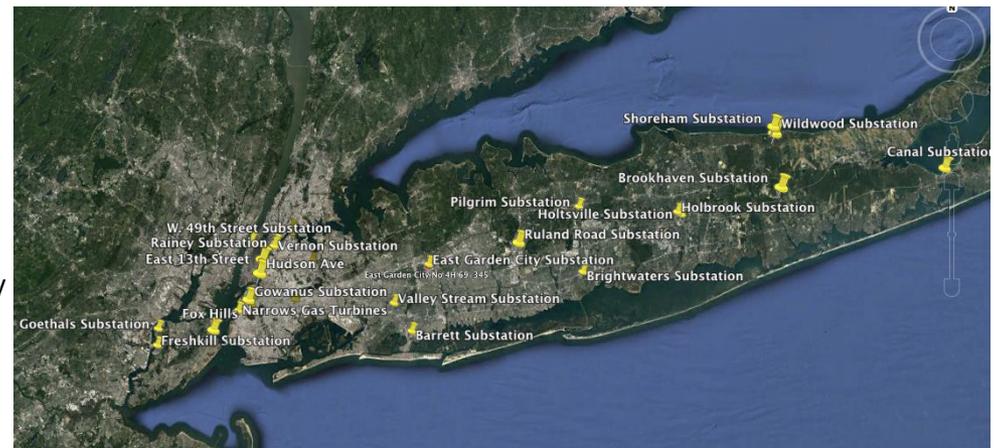
ANALYTICAL APPROACH

We identified GLL and planned transmission scenarios for Phase 2 and 3 developments

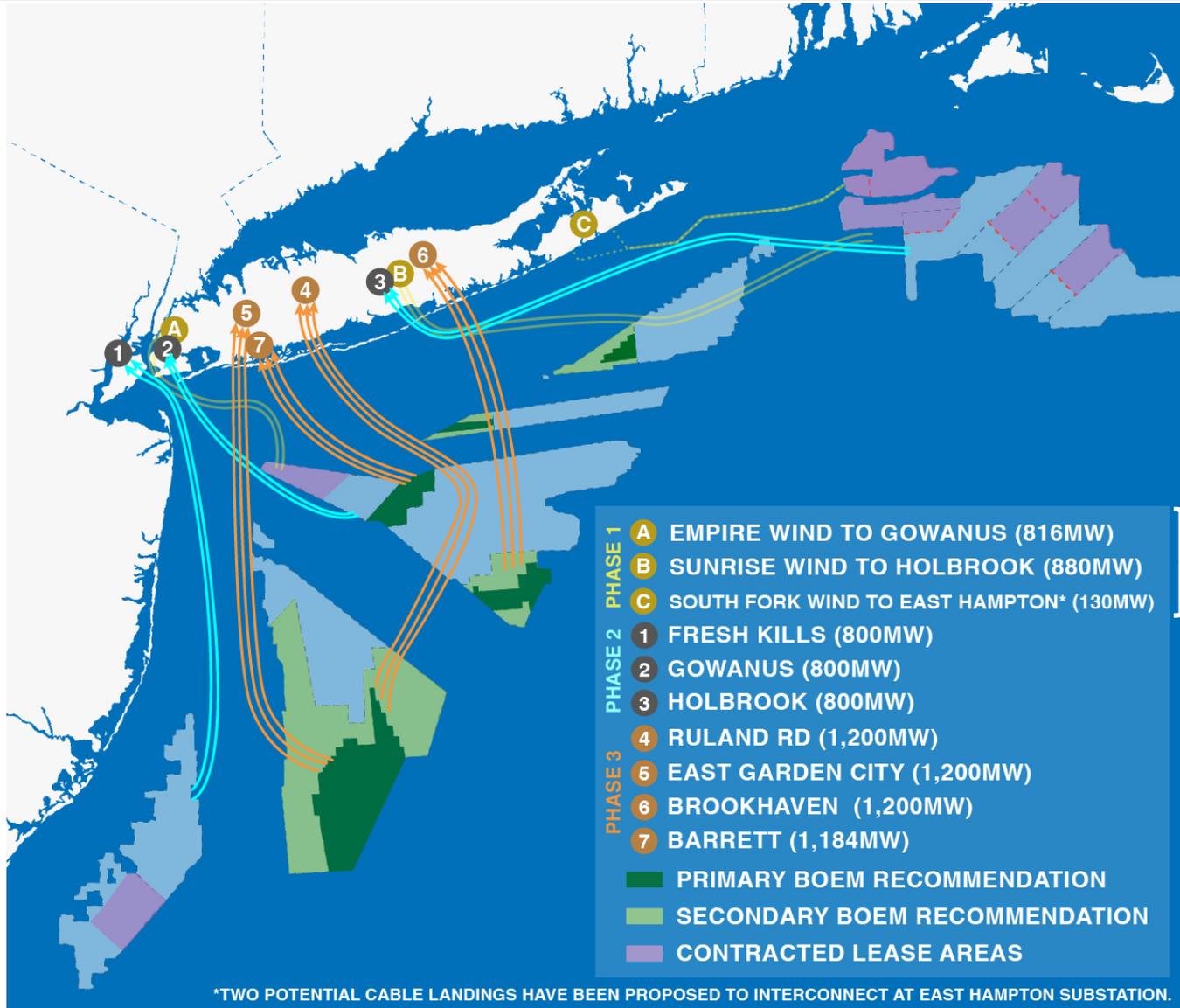
1. Identified **22 substations** at 69kV and above that are accessible for injecting OSW from lease areas
2. Ran **solo injection analysis under summer peak load for each POI** to identify the maximum amount of energy that each POI could accept in isolation
3. Examined sensitivities on solo injections
 - a. For cost-effective system upgrade facility (SUF) to increase injection capability
 - b. Reductions in capacities from combined injections at electrically proximate POIs
 - c. With a new transmission connection between ConEd and Long Island and a new submarine cable between ConEd and Long Island
4. For the set of POIs able to accept 1200MW, **determined upgrades needed to increase injections to 2000MW**
5. Using results and cable routing constraints, we **identified 9 development sequences for further analysis**, consisting of:
 - a. **Energy Resource Interconnection Service (ERIS) Upgrades Analyses:** individual injections were studied for ERIS interconnection requirements. This analysis replicated the thermal loading aspects of the NYISO system reliability impact study (SRIS), in accordance with NYISO Minimum Interconnection Standard (MIS) OATT 25.2.
 - b. **Capacity Resource Interconnection Service (CRIS) Upgrades Analyses:** For each of the development sequences, a deliverability study was conducted to identify transmission upgrades in accordance with OATT 25.3.
6. Identified **two illustrative scenarios** to reflect i) **planned transmission development** to minimize reliability upgrade costs and ii) a potential outcome of the **GLL approach**
7. Conducted **detailed cost estimation** for two scenarios
8. **Evaluated curtailment and optional transmission upgrades** that could reduce curtailment using 8760-hour production simulation

Note: Additional iterative planning analyses will be necessary and beneficial to further reduce curtailments
9. Calculated **detailed cost estimates for optional transmission upgrades**

Substations Considered for POI



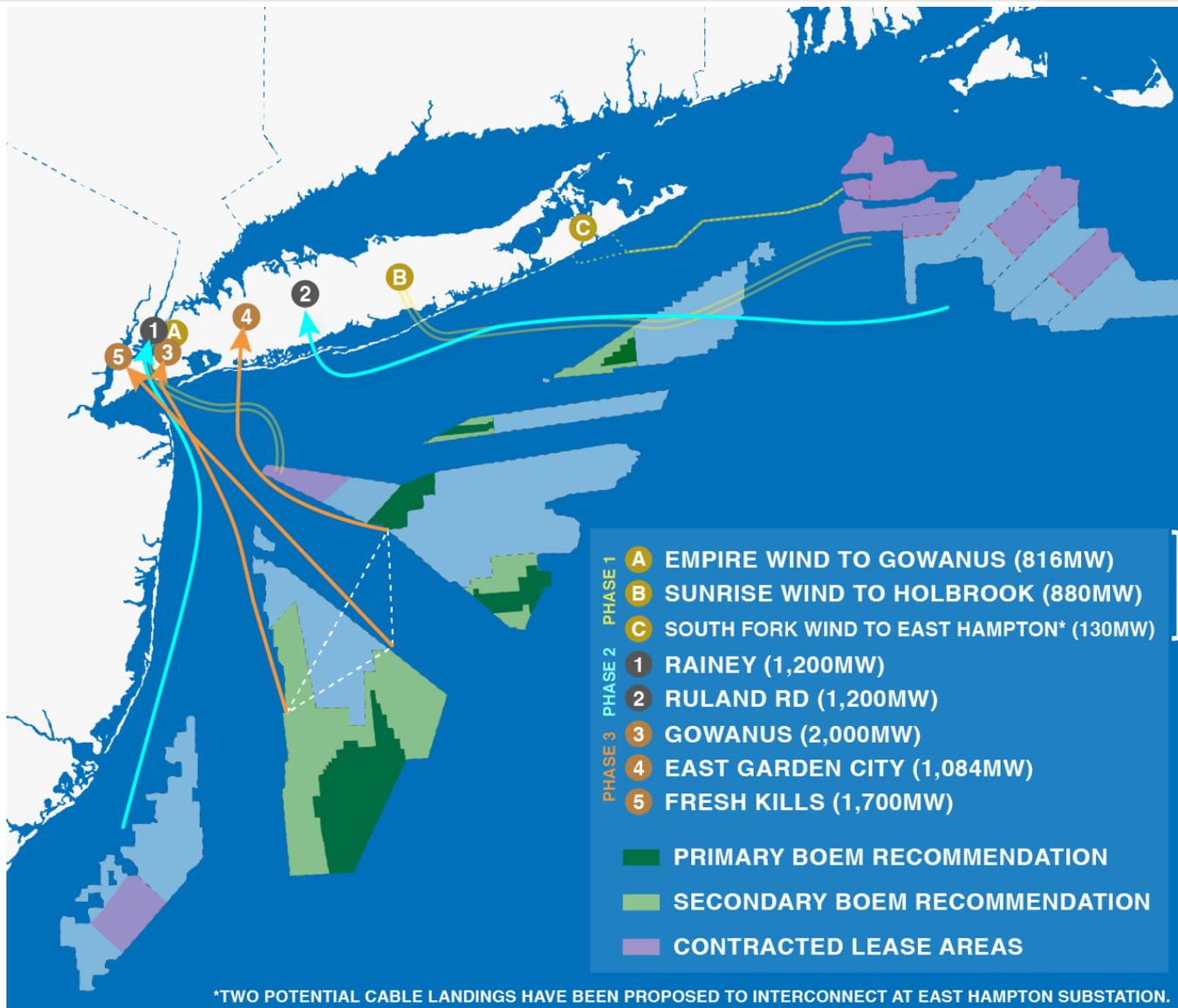
Plausible offshore transmission buildout under generator lead line approach



Phase 1 is already contracted using HVAC cables. In the GLL scenario, projects in Phases 2 and 3 also use HVAC lines.

Already contracted projects

Likely offshore transmission buildout under planned approach



Phase 1 is already contracted using HVAC cables. Planned approach utilizes **HVDC cables** for Phases 2 and 3.

Large injections are utilized at Gowanus (2,000MW) and Fresh Kills (1,700MW) to reduce cabling and costs, and would require modification of current single contingency limit.

Already contracted projects

Cost Differential Analysis

Total costs of transmission are expected to be lower under a planned approach

We estimate total costs of onshore upgrades plus offshore transmission to enable the next ~7,200 MW of OSW would be **\$500 million lower under a planned than the GLL approach**

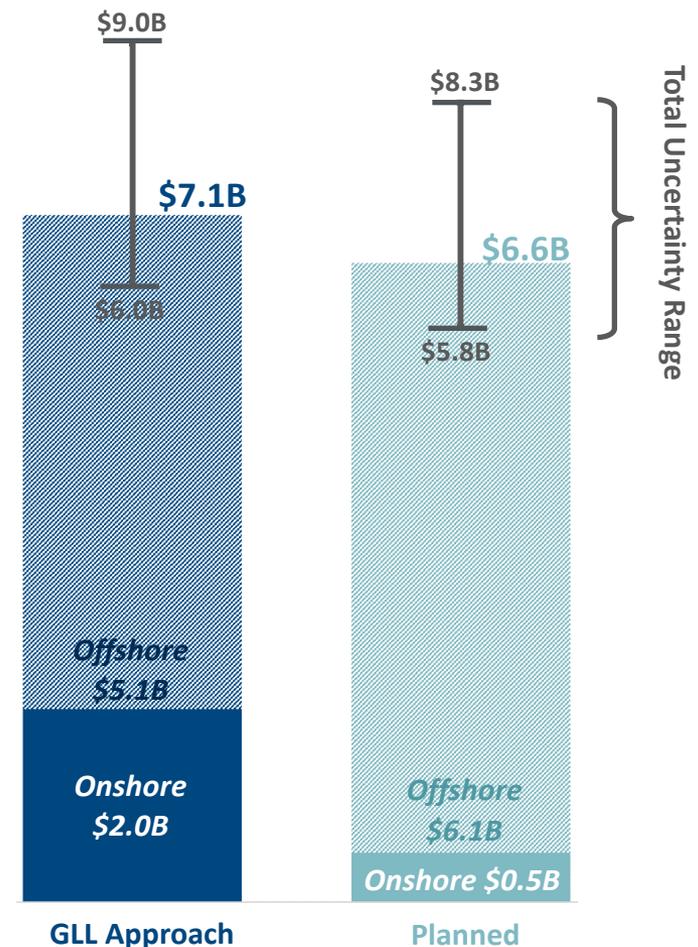
- Onshore upgrade costs of \$0.5B under planned approach vs \$2.0B under GLL approach, a \$1.5 billion savings.
- Offshore transmission equipment in the planned approach would be more costly (\$6.1B vs. \$5.1B), primarily due to the use of HVDC transmission technology in our scenario that yields other important benefits
- Additional cost savings under planned approach of 20-30% may be available from increased competition (see Slide 15)

The planned approach to building offshore transmission can enable significant long-term cost savings and avoid the substantial risks associated with onshore upgrades

- Can also allow developers to anticipate future projects to minimize risks

Source for cost data: Onshore upgrade cost estimates based on Pterra power flow modeling and PSC Consulting analysis of reliability transmission upgrades. See Appendix C for links to additional information. Does not include elective transmission upgrades. Estimate for offshore transmission equipment based on proprietary supplier information provided to Anbaric. We assumed +25%/-10 uncertainty for the offshore cost, plus the uncertainty for the onshore upgrades given by PSC.

Comparison of Total Onshore Plus Offshore Transmission Costs

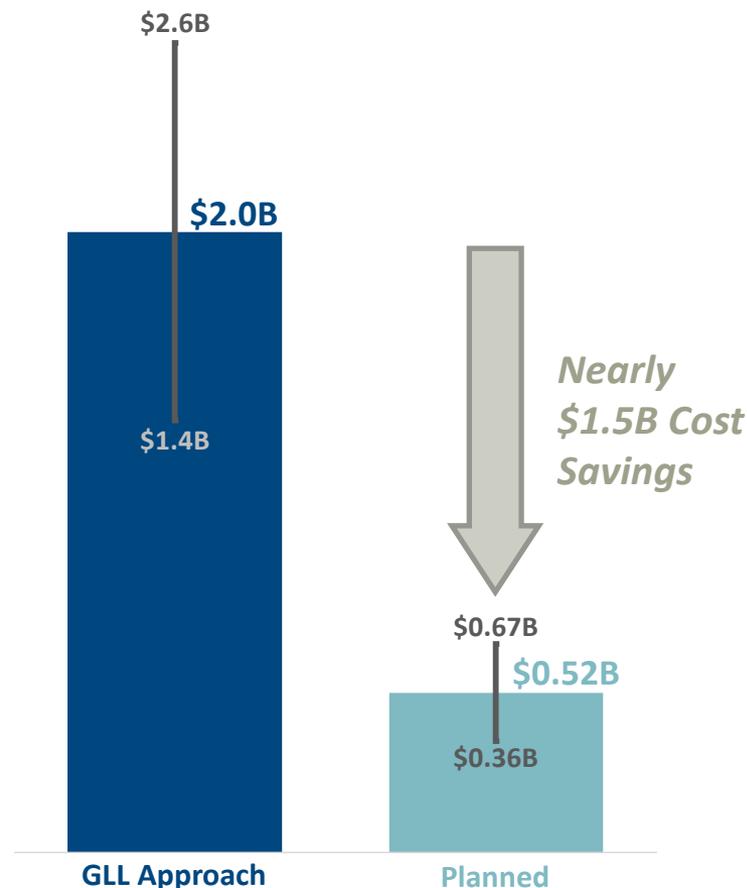


Planning ahead avoids onshore transmission upgrades that otherwise would be needed

Planned transmission can **significantly reduce need, costs, and risks of onshore upgrades** in New York, where multiple factors make upgrades difficult to permit and have led to a history of delays and budget overruns

The fewer onshore upgrades needed under the planned approach imply substantially reduced risks associated with onshore upgrades relative to GLL approach

The Planned Approach Would Reduce Reliability Transmission Upgrade Costs by Three-Quarters Compared to GLL Approach



Planned approach saves \$1.5 B in onshore upgrades compared to GLL approach

GLL Approach

Project	Size (MW)	Upgrades	Estimated Cost (Mil 2020\$ USD)
Fresh Kills	800	345 kV cable circuit	\$185
Gowanus	800	Two 138 kV and 345 kV cable circuits	\$467
Ruland Rd	1200	New 345 kV substation and upgrade line to 345 kV	\$78
Brookhaven	1200	Four 138 kV circuits	\$497
Barrett	1184	Eight 138 kV circuits	\$777

Total: \$2,000 Million

Planned Approach

Project	Size (MW)	Upgrades	Estimated Cost (Mil 2020\$ USD)
Fresh Kills	1700	Two 345 kV cable circuits	\$223
Rainey	1200	Two 138 kV cable circuits	\$117
Ruland Rd	1200	New 345 kV substation and upgrade line to 345 kV	\$78
East Garden City	1100	138 kV circuit	\$97

Total: \$515 Million

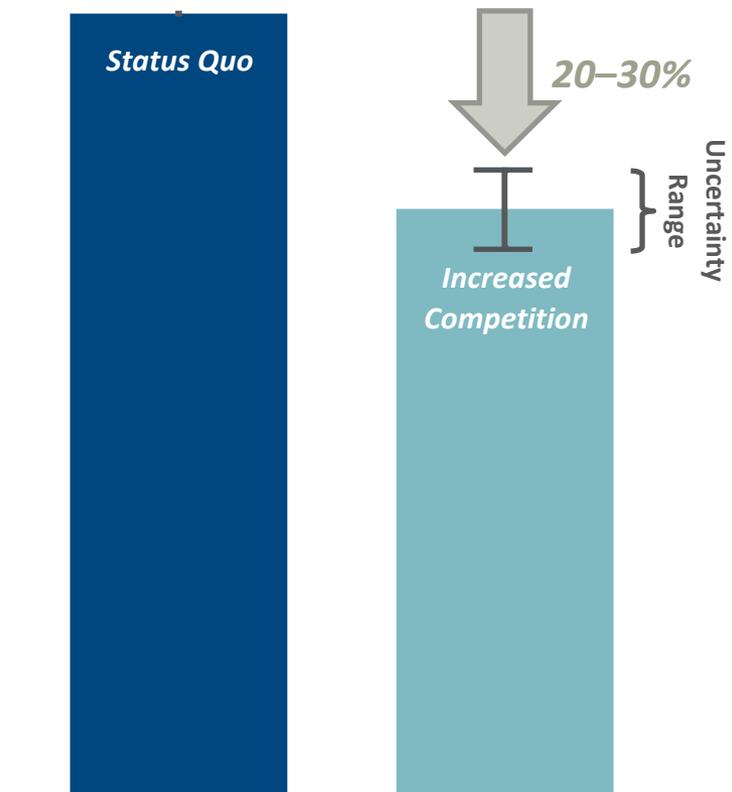
Source: Cost estimates based on analysis of reliability transmission upgrades by PSC Consulting and do not include elective transmission upgrades. See Appendix C for links to additional information.

Planning increased competition among offshore transmission developers

Offshore transmission developers would compete to build planned transmission. This direct competition would put downward pressure on costs to ratepayers (further lowering costs beyond savings described on previous slides)

- Studies of onshore transmission indicate that competitive procurement enables “significant innovation and cost savings of 20–30%” relative to the costs incurred by incumbent transmission companies; the costs of conducting the competitive processes are small compared to the savings*
- Studies of offshore transmission costs in the U.K. similarly indicate that competition across independent offshore transmission owners reduced costs 20–30% compared to generator-owned transmission (driven by lower operating costs and financing costs from improved allocation of risk and reduced risk premium)**

Anticipated Cost Impact of Competition to Develop Offshore Transmission



Sources: * The Brattle Group, “[Cost Savings Offered by Competition in Electric Transmission: Experience to Date and the Potential for Additional Customer Value](#),” April 2019, Produced for LSP Transmission.

** Cambridge Energy Policy Associates, “[Evaluation of OFTO Tender Round 2 and 3 Benefits](#),” March 2016, Produced for Ofgem.

Planning increases competition among OSW generation developers

Competition among developers of OSW generation would be enhanced, yielding a range of potential cost savings



Lower savings

The planned, competitive approach would simplify a major strategic decision for developers

Today, developers must bid before they have accurate information about their transmission upgrade costs and curtailment risk. Removing these risks from the offshore generation procurement should lead to lower bids because of the reduced risk premium alone

Higher potential savings

Ultimately, the planned approach could increase participation and competition in OSW solicitations.

In Europe, planned transmission approaches have enhanced head-to-head competition leading to **zero-subsidy bids** in recent procurements (see case study details in Appendix B)

We anticipate more willing bidders and more competition with increased access to transmission (though overall still limited by number of leaseholders)

Efficient Utilization of Points Of Interconnection

Constrained access routes require efficient offshore transmission to meet goals at low cost

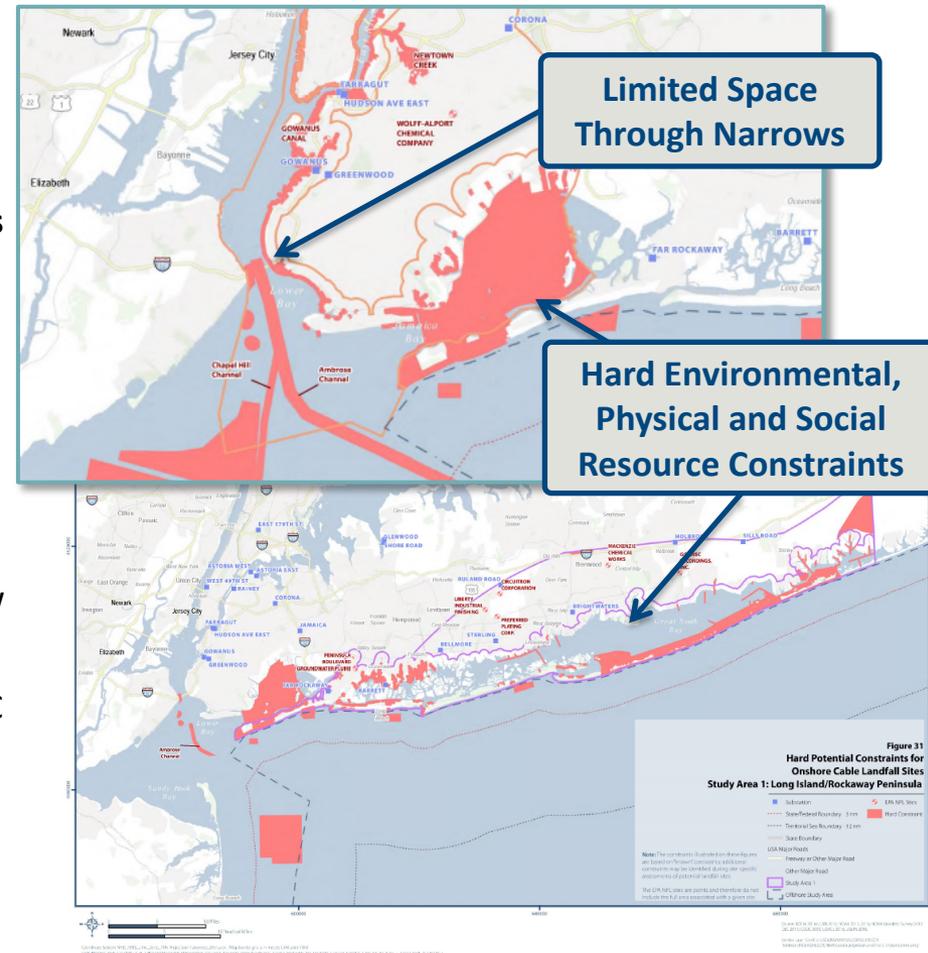
There are a limited number of robust POIs for connecting offshore wind to the onshore grid and limited access routes to these POIs

If each OSW project builds a separate GLL to the onshore transmission system, **viable landing sites and cabling routes will become constrained. A planned transmission approach can make better use of the limited landing sites**

The clearest example of this is the cable approach route through the **Narrows** to reach POIs in New York Harbor:

- Existing Federal shipping channel, anchorages etc. likely leave space for only 4 offshore wind cables
- 2 (HVAC) cables already planned by Empire Wind to Gowanus
- Planned approach uses 2 DC cables totaling 3200 MW to Gowanus and Rainey
- GLL approach may use remaining space for 2 more AC cables for 800 MW to Gowanus; this pushes 2400 more MW to Long Island, requiring more substantial onshore upgrades to existing onshore system

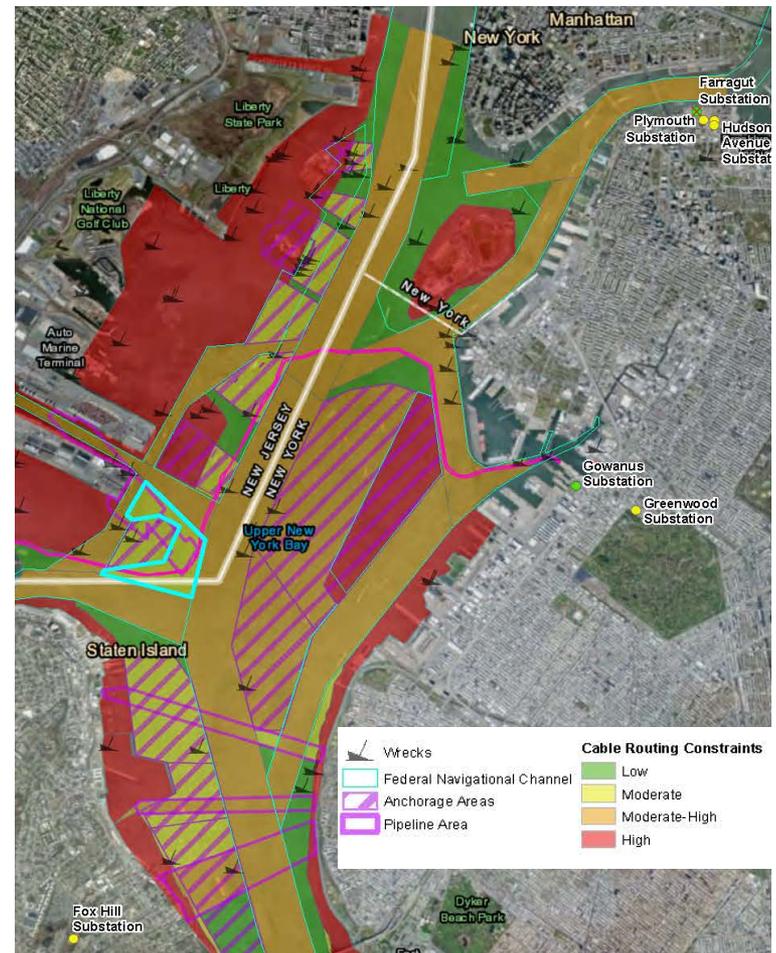
Landing Limitations along NY Coast



Narrows likely has space for only four cables, suggesting maximizing utility of route is key

- **Major constraints to routing through the Narrows and the Upper Bay** are physical width of suitable seabed, federal navigation projects (FNPs) (channels and anchorages), cable spacing requirements, and competing uses
 - All potential routes are heavily constrained by navigational aspects in the Upper Bay: primarily the inner harbor anchorages and federal navigational channels
- In The Narrows and Upper Bay of NYC harbor, **maximal transmission capacity in the available space may be achieved most efficiently by using HVDC technology** to connect clusters of OSW farms to a grid that has been extended offshore
- Given the constraints in the Upper Bay, it is likely **four routes could access NY Harbor**
- Not utilizing Narrows effectively **risks limiting ability to cost-effectively route OSW transmission into New York City** and meet climate goals without large costs

NY Harbor Route Constraints



Source: Analysis of Narrows constraints by Intertec (see Appendix C for details).

Environmental Impact

Reduced impacts to fisheries, coastal communities, and the marine environment

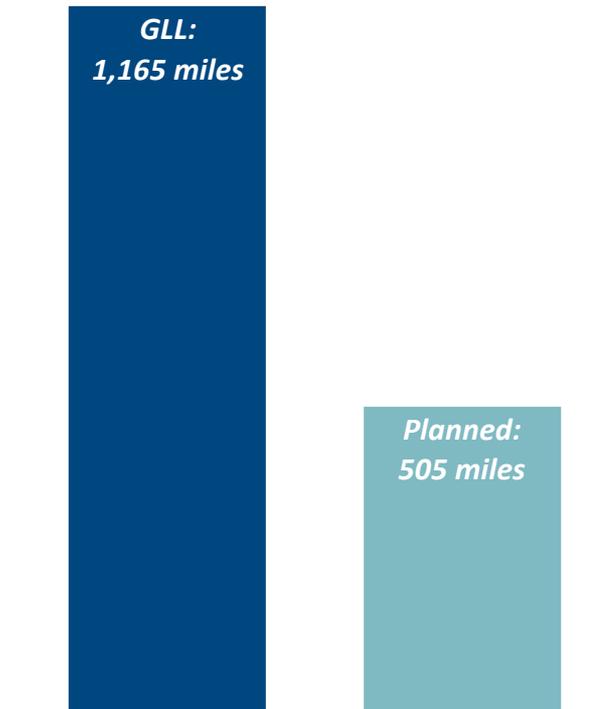
Better planning can **reduce the cumulative effects of offshore transmission on fisheries, coastal communities, and the marine environment**

- Fewer cables results in **less disruption and impacts on the marine and coastal environment**
 - Under a planned off-shore-grid approach **marine trenching can be reduced by almost 60%**
- Offshore cables could further be grouped in transmission corridors to minimize impact; this is not possible to enforce under the GLL (one-off, unplanned) approach

Minimizing the number of offshore platforms, cabling, seabed disturbance, and cables landing at the coast **reduces impacts on existing ocean uses and marine/coastal environments** to the greatest practical extent

Comparison of Total Length of Undersea Transmission Under GLL and Planned Approaches

(Excluding Already-Contracted Projects)



Curtailments

Planned approach provides curtailment benefits but further analysis is required

The initial analysis indicates that the planned approach can yield reductions in offshore wind curtailments

- With 4,200 MW assumed in service, total curtailments under the planned approach are negligible at 0.1% but significant in the GLL approach at 4.2%
- At 9,000 MW in service, however, the total curtailments are 18.0% across two interconnections under the planned approach, and 18.2% across five interconnections under the current approach

These significant curtailments are identified only by the full annual (8760 hour) analyses of future system conditions. They are missed by reliability/deliverability analyses.

- An additional iteration of planning analyses (alternative configurations including storage, deliverability analyses, and full annual analyses) will be necessary to identify planned offshore transmission configurations and onshore upgrades that can more significantly reduce the identified curtailments associated with adding the second half of the planned 9,000 MW to the grid

At 9 GW, curtailments are high in each scenario and require further attention

Both approaches indicate significant amounts of offshore wind generation curtailment that will have to be addressed

- With 9 GW of wind in service in 2035, modeled curtailment levels* are similar for the two approaches, at **18.2% in the GLL approach and 18.0% in the planned approach**, equivalent to lost output from ~1,650 MW of offshore wind.
- These levels of curtailment will undermine project economics of all offshore wind projects
- Elective upgrades evaluated in this study reduce curtailment to 14% in both scenarios, but cost \$550 million more in the unplanned scenario
- Challenges associated with cost allocation under the GLL approach will likely hinder development of elective transmission upgrades, leading to higher curtailment for later projects that imperil project economics

Optional Upgrades to Reduce Curtailment in GLL and Planned Scenarios

Upgrade	Cost (\$ Million)	Avoided Curtailment (%)	Equivalent Capacity (MW)
GLL Approach			
Ruland Rd – Holbrook	\$194 - \$364	4.3%	383 MW
Shore Rd - Dunwoodie	\$315 - \$403		
Total	\$409 - \$768		
Planned Approach			
3 rd Gowanus-Rainey Circuit	\$110 - \$206	3.3%	297 MW

*may be higher due to must-run units

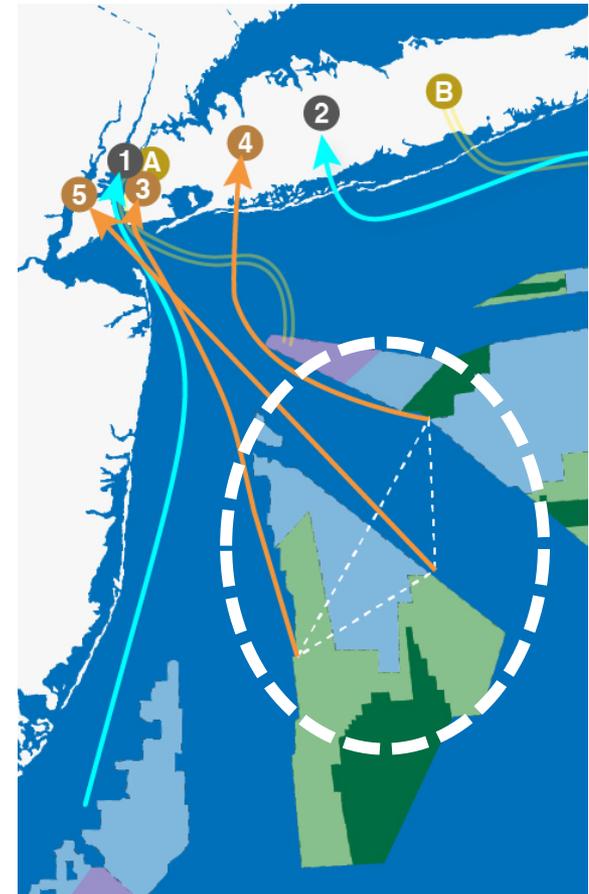
Networking offshore transmission reduces curtailment risk

Designing and building the offshore grid with networking capability preserves the option to create a **meshed offshore configuration to improve reliability and reduce curtailments**. Networking offshore converter stations in the NY bight may be possible and advantageous in the future

- If three HVDC converter stations were networked offshore, power flows can be controlled and diverted from landing points with high curtailments to other landing points
- Moreover, **an outage of one line would still allow flowing full power on other lines** during period when wind farms are operating at less than 100% capacity. Networking could reduce outage-related losses by a factor of 4 or more in comparison to a radial approach.

Further networking of NY and/or NE lease areas into both NY and NE would expand these reliability and curtailment benefits, at additional cost

DC Technology Enables Potential Future Offshore Networking in the NY Bight



Source: Anbaric analysis based on annual generation.

Notes: Several European countries are studying meshed DC configurations for use interconnecting OSW in the North Sea. Reference materials compiled by Curis et al., "[Synthesis of available studies on offshore meshed HVDC grids](#)," 2016.

Planned energy storage to integrate OSW and reduce curtailments

New York has committed to deploying **3,000 MW of storage by 2030**

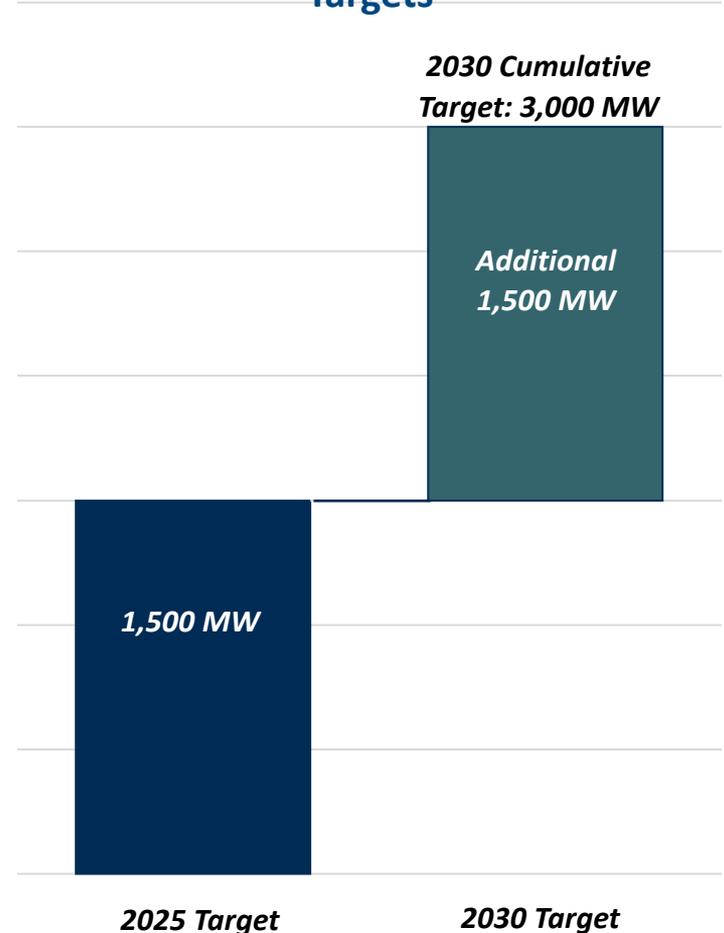
Storage enables retirement of aging and inefficient 'peaking' power plants that would otherwise back up offshore wind.

Planning for deployment of storage jointly with OSW can facilitate integration of OSW and reduce costs and curtailments

- Storage can minimize or **avoid onshore transmission upgrades** that otherwise would be needed to address reliability needs
- In many cases, storage planned jointly with an OSW generation network can **reduce curtailment** more cost effectively than transmission upgrades

In the absence of planning, opportunities may be missed to deploy storage in locations where storage simultaneously facilitates OSW integration

New York State Energy Storage Targets



Additional Takeaways

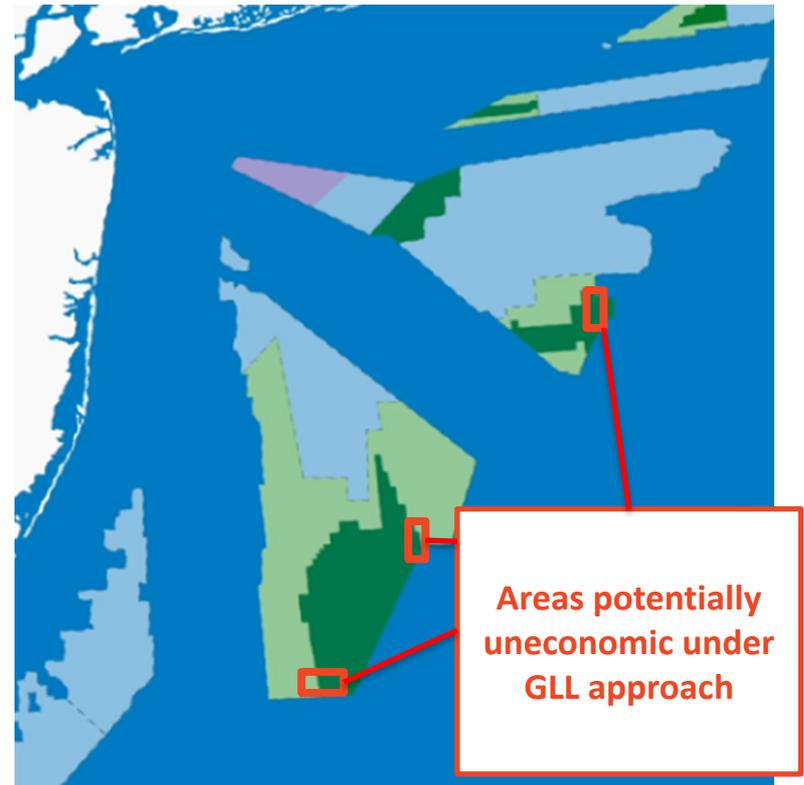
Planning can realize the full potential of existing lease areas

Without a well-planned offshore grid, some of the existing offshore lease sites may not be economic to develop

- After developers interconnect the bulk of their lease sites, it may be cost prohibitive to interconnect the residual areas (of perhaps 50 MW to 250 MW each) using AC generator lead lines sized to carry ~400 MW each
- This increases the risk of inefficient use of lease sites and stranded assets

An offshore grid with well-located offshore collector stations would increase the likelihood that residual lease areas could be developed cost-effectively, and that the full potential of all lease areas can be realized

Developers May Find Residual Areas Uneconomic to Interconnect With Generator Lead Lines



Enabling third-party customers

An independent, open-access offshore grid can create opportunities for additional (non-mandated) OSW resources to be built at lower cost

- As OSW generation costs decrease, third-party customers have expressed interest in purchasing offshore wind, but even large individual customers are unlikely to purchase sufficient OSW to fully utilize an export cable sized to carry 400 MW of offshore wind. Developing smaller projects with larger export cables would be uneconomical
- An open access transmission system could serve as a platform for individual offshore-wind procurements of smaller sizes, enabling OSW development without state-sponsored contracts
- A generation developer could build surplus transmission capacity into a project but would then likely have market power and be able to dictate prices in selling to third parties, whereas OSW generators would have to compete against each other to utilize independent transmission to sell to third parties

Case examples:

Microsoft and Google purchased 90 MW and 92 MW of OSW over independent transmission in the Netherlands and Belgium

The Texas CREZ served as a platform for third-party power purchase agreements (PPAs), enabling over 2 GW of onshore wind PPAs from 22 corporate buyers

In the Southwest Power Pool, ISO-planned transmission investment enabled 2.5 GW of corporate PPAs

Key Conclusions

We recommend a planned approach to offshore transmission

A planned approach can lower overall costs by making best use of scarce cable routes and POIs, by leveraging competition among transmission developers, and by enhancing competition between off-shore wind generators

Utilizing GLLs has distinct disadvantages over planned offshore transmission. While the GLL approach may appear to offer* lower costs in the short run, it is not aligned with the public interest in the long run, leading to:

- Poorer use of limited onshore POIs and cable routes
- Increased seabed disturbance
- Reduced competition for transmission and off-shore wind generation
- Higher onshore transmission upgrade costs and higher overall costs in the long run

Under the planned approach, OSW generation developers would be able to participate in transmission development,** but must be willing to develop open-access transmission for other leaseholders when participating in any transmission-only procurement (even if their generation bid is unsuccessful in the generation procurement)

Bundled procurement under the GLL approach could be transitioned to a planned approach through bid selection and an open access requirement

* Costs of transmission in bundled generation + transmission bids could also appear artificially low if bidders can shift costs from transmission to generation within projects

** This would require functional or physical separation of transmission and generation, similar to current FERC OATT requirements

Mitigating project-on-project risk with separate generation and transmission procurements

The GLL approach places development of generation and offshore transmission under a single developer and leaves onshore upgrades with incumbent (onshore) transmission owners

- This approach reduces coordination risk between OSW and offshore transmission, but there remains project-on-project risk related to the completion of onshore upgrades
- Furthermore, the misalignment between generation developer incentives and public policy objectives increase risks to the overall offshore wind development effort through more significant onshore upgrades, higher curtailment risk, less competition, and higher long-term costs

The planned offshore grid model reduces risks that could increase total costs and potentially inhibit achievement of overall OSW development goals. A planned approach can also address individual project-on-project risk through:

- Strong performance and completion incentives (rewards or penalties) for both transmission and generation developers to meet project deadlines
- Allowing generation developers to participate in transmission procurements, with the condition that the transmission will be open access
- Staggered transmission and generation project completion timelines (e.g., scheduling transmission project completion before generation)

Anticipatory planning will lead to lower and more predictable costs

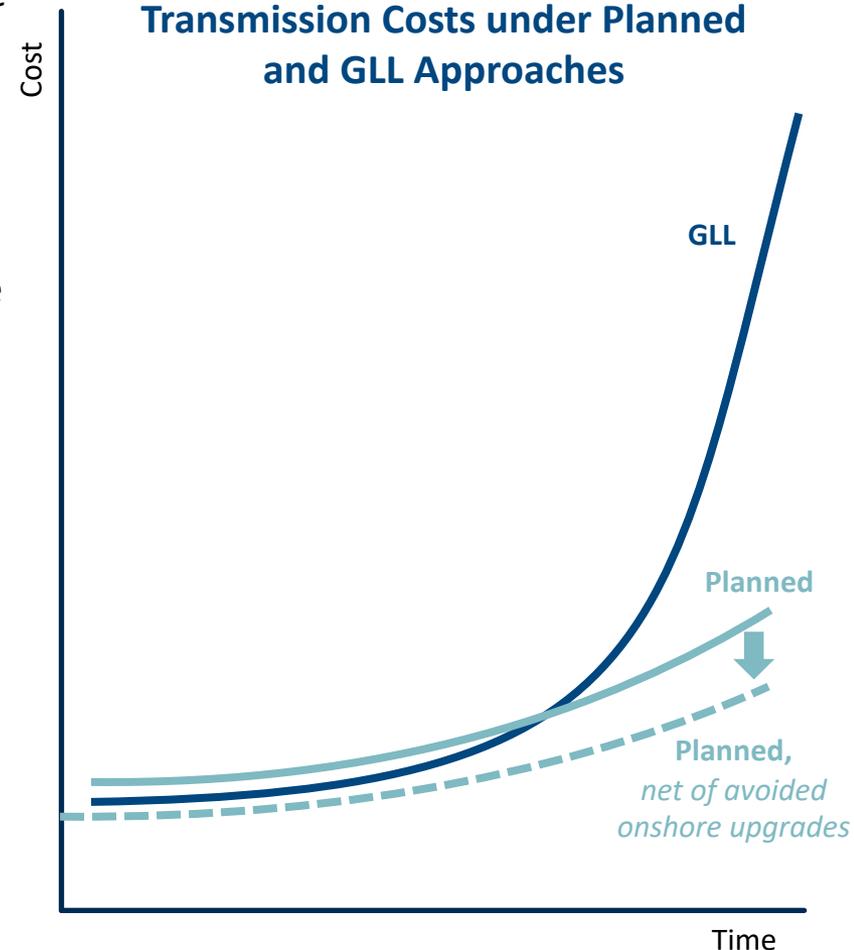
In addition to allowing more OSW to utilize existing landing points, with a well-planned offshore grid, the **overall transmission costs can be estimated more accurately and phased-in over time**

The GLL approach may appear to have low initial costs but those will likely increase substantially after the “low hanging fruit” is picked, when real costs are revealed through **inefficiently used landing points and more costly onshore upgrades.**

Lack of well-planned transmission to achieve New York’s objectives may continue to create barriers for the deployment of clean energy in New York

Passage of Accelerated Renewable Energy Growth (AREG) and Community Benefit Act and creation of the Office of Renewable Energy Siting will aid with transmission planning

Illustration of Potential Incremental Transmission Costs under Planned and GLL Approaches



Appendix A:

Support from Other Stakeholders for OSW Grid Planning

Support from Other Stakeholders for OSW Grid Planning

“Although current interconnection points currently may support individual radial project connections in New York State’s nascent offshore wind market, this approach has inherent limitations as a long-term transmission solution.... The coordinated approach is better suited to develop the offshore and onshore grids necessary to support the CLCPA’s offshore wind goals.”

- New York Power Authority

“A well-planned and coordinated effort to integrate New York State’s offshore wind resources with the land-based electric grid will yield cost-effective and efficient outcomes for customers and maximize environmental benefits.”

- Joint Utilities of New York

(Includes Central Hudson Gas & Electric Corporation, Con Edison of New York, New York State Electric & Gas Corporation, Niagara Mohawk Power Corporation d/b/a National Grid, Orange and Rockland Utilities, Inc., and Rochester Gas and Electric Corporation)

“A planned, regional transmission system will enable multiple uses in the future while providing significant advantages for an emerging US industry. By allowing for more options for consideration and fostering greater competition, a planned transmission system benefits the offshore wind industry, states, taxpayers, local communities, the environment, local businesses, and other stakeholders.”

- Building and Construction Trades Council of Nassau & Suffolk Counties

Support from Other Stakeholders for OSW Grid Planning

“As with all offshore development that will impact fisheries, advance planning and deliberate thought regarding a renewable energy transmission grid will provide significant benefits over the current piecemeal approach.”

- *Responsible Offshore Development Alliance (RODA)*

“For New York to position itself as the hub of the U.S. offshore wind industry and efficiently and cost effectively implement its OSW program over the longer term, the Commission also must remain focused on establishing well-planned, backbone transmission infrastructure...Developing a transmission backbone structure for implementation in future NYSERDA solicitations will produce a more robust market, increase market competition, reduce capital costs, and efficiently and cost effectively allow for the necessary necessary future system expansion to meet the CLCPA mandates.”

- *Shell Energy North America*

“By allowing for more options for consideration and fostering greater competition, a planned transmission system benefits the offshore wind industry, states, taxpayers, local communities, the environment, local businesses, and other stakeholders.”

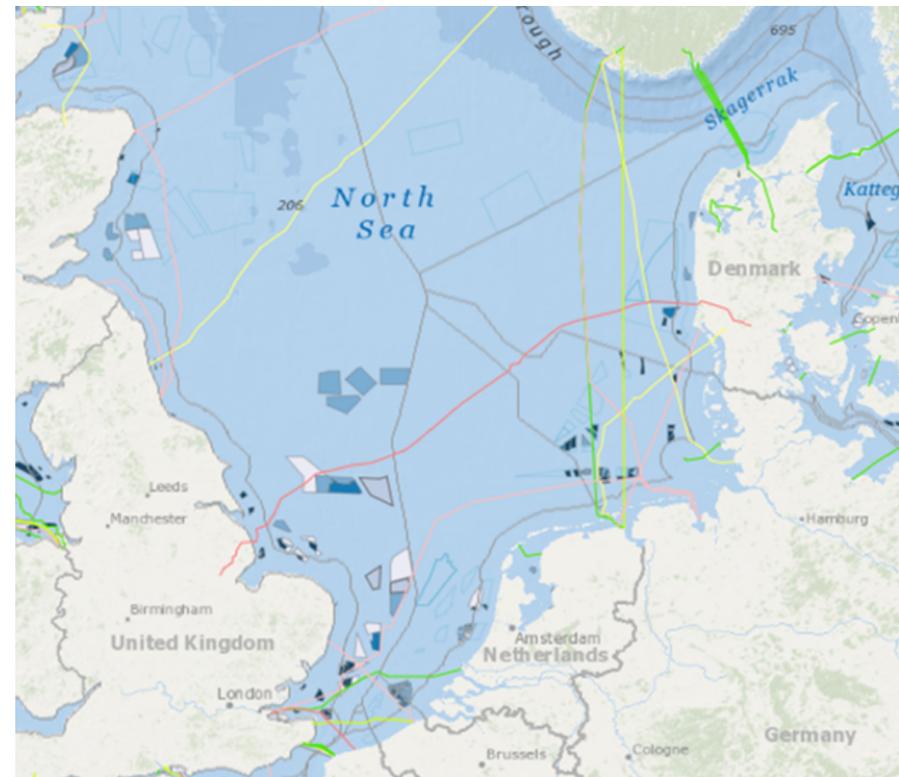
- *International Brotherhood of Electrical Workers (IBEW)*

Appendix B: Case Studies of Planned Transmission for Renewable Generation

Offshore transmission network in Europe

- Both Germany and the Netherlands have implemented a planned transmission approach, with offshore transmission developed separately and in anticipation of new OSW generation
- Offshore transmission developed by TSO and paid for by electric ratepayers (as with other transmission infrastructure)
- This approach has already enabled 8,600 MW of OSW connected to Germany and the Netherlands to date
- Approach has increased competition among OSW developers. Project costs have declined by over 50% in the last five years, leading to “subsidy free” PPAs for recent OSW in both Germany and the Netherlands

Existing Offshore Transmission Development in the North Sea

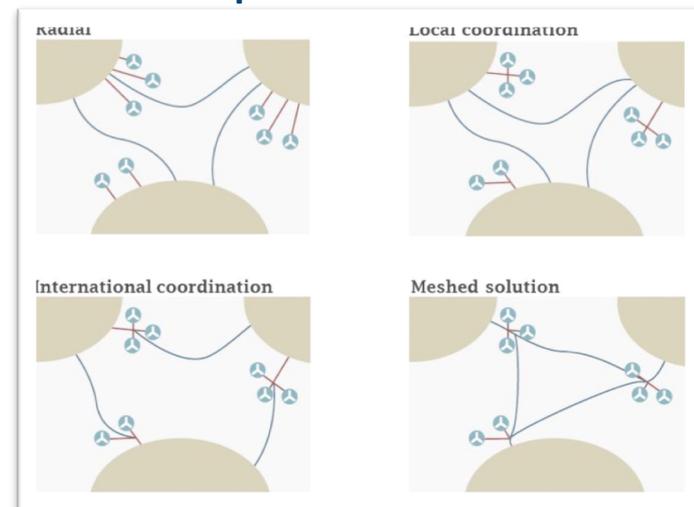


Sources: NY Power Authority, “[Offshore Wind: A European Perspective](#),” August 2019.
 Wind Europe, “[Offshore Wind in Europe](#),” February 2020.
 Interreg North Sea Region, “[Existing offshore linear energy infrastructure and grid connections.](#)”

Planning in the North Sea of Europe

- Planning ahead in the North Sea included analyses of “Radial” versus “Meshed” offshore grid
 - The North Seas Countries' Offshore Grid initiative (NSCOGI), formed in 2010, evaluated and facilitated coordinated development of a possible offshore grid that maximizes the efficient and economic use of renewable resources and infrastructure investments
 - Ten countries were represented by their energy ministries, supported by their Transmission System Operators, their regulators and the European Commission.
- A scenario-based planning approach was initiated in 2012; analysis then already showed benefits of having a planned meshed offshore system
- More recent 2019 planning and analysis of very high OSW penetration in the North Seas (380 GW by 2050) indicates substantial benefits of meshed offshore grids: lowering the environmental burden, using infrastructure more efficiently, and reducing costs

Models of Offshore Grid Development Considered



Offshore transmission network in the U.K.

- To date, all OSW transmission in the UK has a radial design, with the transmission developed by the OSW developer and then sold to a separate transmission owner
- However, this approach is reaching its limits, as ad-hoc onshore interconnections are pushed further inland with increasing community impacts.
- Ofgem is currently studying and strongly considering implementing an offshore transmission network.
- Various studies conducted by Ofgem, utilities, and industry groups show that such a coordinated design could lower overall transmission costs by 9 to 15 percent.
- An offshore grid to support 34 GW of capacity would cost £24.2 billion (\$31.5 billion), equivalent to a transmission cost of £5.36/\$6.98 per MWh

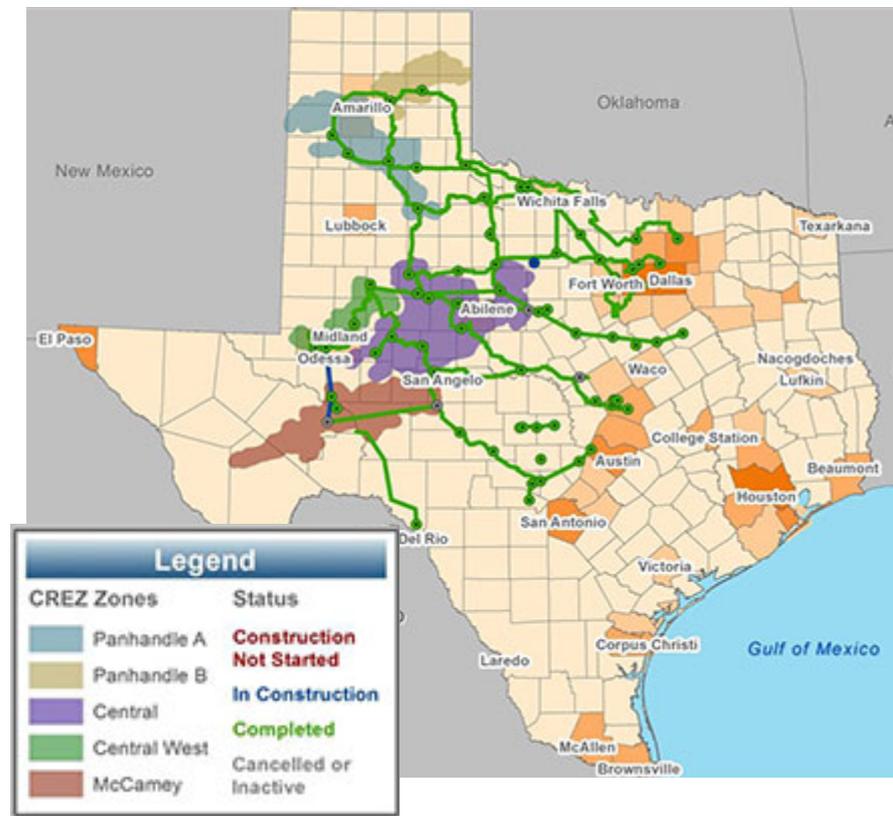
Ofgem Study of Possible Offshore Grid Design



Competitive Renewable Energy Zones (CREZ) in Texas

- \$7 billion transmission-first program
- Phased development of transmission enabled 18.5 GW wind from five “competitive renewable energy zones” to rest of state
- Allowed rapid merchant development of wind in W. Texas, reducing electricity costs by \$1.7 billion annually
- Process: ERCOT designed transmission system configurations to integrate each renewable energy zone through a staged, expandable approach. Desired configurations selected by PUC and developed by competitive transmission developers and incumbents

Texas CREZ Transmission Projects



Tehachapi Renewable Transmission Project (TRTP) in California

- Tehachapi was identified as a high wind potential region in southern California almost 20 years ago
- California policy makers solicited interest in building wind in Tehachapi
- California ISO developed a transmission plan for the region
- The transmission enabled 4,500 MW renewable power development
- 250 circuit miles, \$2.1 billion cost
- Built by transmission developer, with costs allocated using existing CAISO transmission cost allocation system

CAISO TRTP Transmission Projects



Appendix C: Pterra and Intertek Analyses

Attachments Provide Additional Details of Analyses

Anbaric retained Pterra and Intertek to perform analyses regarding the interconnection, transmission upgrades, and cable routing. Additional details regarding their analysis can be found in the following reports:

Pterra Consulting, **Study of Transmission Alternatives to Interconnect 9000 MW of Offshore Wind Generation in New York**. August 3, 2020.

Link: <https://bit.ly/3fBkUjP>

Intertek, **Anbaric Export Cables into New York Harbour: Cable routing through The Narrows and Export Cable Installation**. July 24, 2020.

Link: <https://bit.ly/3gymZOV>

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Mr. Pfeifenberger is an economist with a background in electrical engineering and 25 years of experience in the areas of electricity markets, regulation, and finance. Mr. Pfeifenberger specializes in electricity market design and energy policies, transmission pricing and cost-benefit analyses, analysis and mitigation of market power, strategy and planning storage and generation asset valuation, ratemaking and incentive regulation, and contract disputes and commercial damages.

Dr. Newell is an expert in electricity wholesale markets, market design, generation asset valuation, integrated resource planning, and transmission planning. He supports clients throughout the United States in regulatory, litigation, and business strategy matters. He frequently provides testimony and expert reports to Independent System Operators (ISOs), the Federal Energy Regulatory Commission (FERC), state regulatory commissions, and the American Arbitration Association.

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Dr. Spokas is an associate at The Brattle Group with a focus on electricity sector topics such as renewable and climate policy analysis, electricity policy design, and market design. He's worked for policy-makers, renewable energy buyers, and governments to evaluate clean energy policies to ensure strategies are feasible, create additional benefits, and are cost-effective.

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