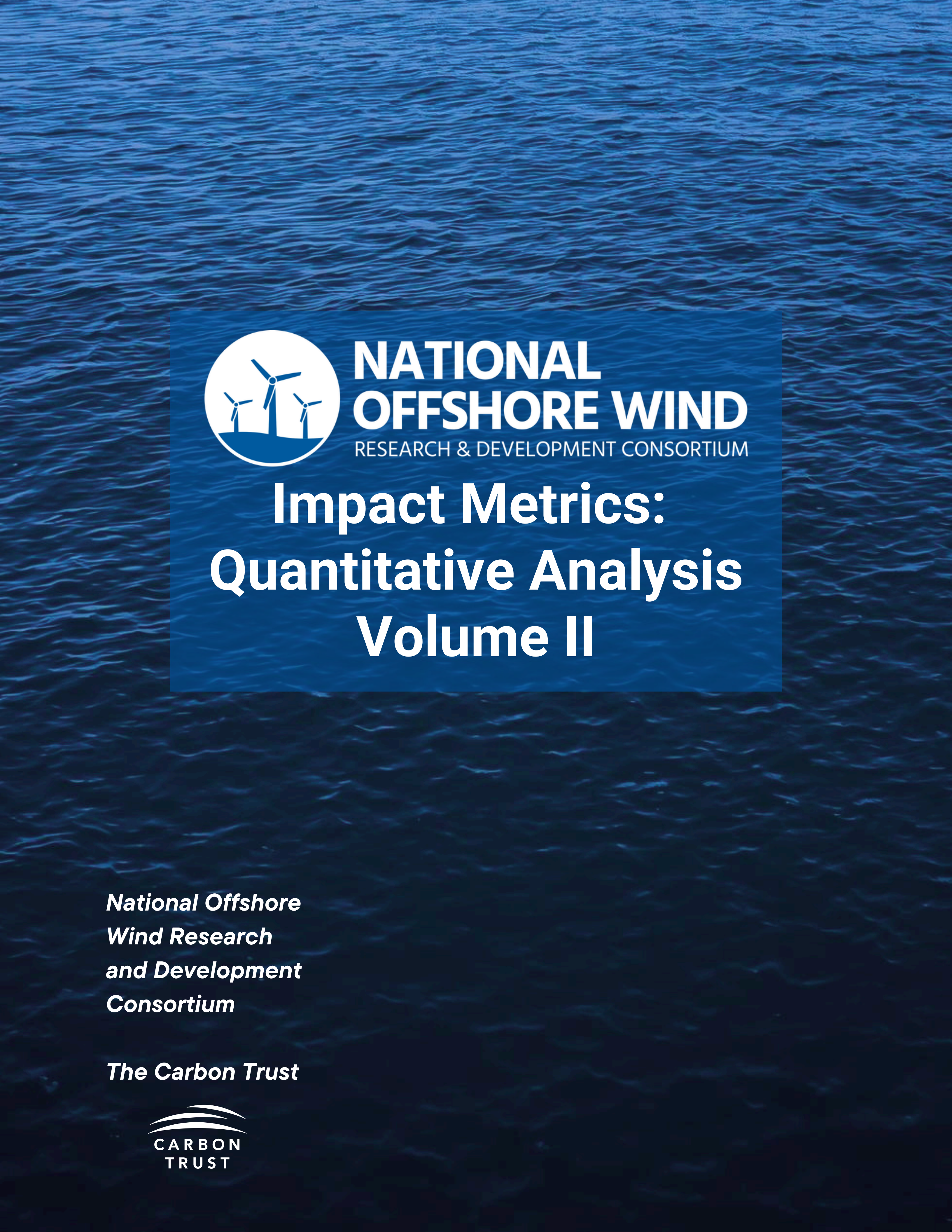

NATIONAL
OFFSHORE WIND
RESEARCH & DEVELOPMENT CONSORTIUM

Impact Metrics: Quantitative Analysis Volume II

National Offshore Wind Research and Development Consortium

The Carbon Trust

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Acknowledgements

This National Offshore Wind Research and Development Consortium Impact Metrics Quantitative Analysis Report, prepared under the direction of NOWRDC Executive Director Lyndie Hice-Dunton, was produced by NOWRDC's internal technical team of program managers, in collaboration with the Carbon Trust's offshore wind cost modeling team and with NOWRDC project awardees. NOWRDC's Research and Development Committee provided extensive input. The primary authors are James Sinfield, Maria Gonzalez Martin, and Kori Groenveld.

Version History

Initial Release (Version 1.0)........................December 2024

Second Release (Version 2.0).....................June 2026

Executive Summary

The National Offshore Wind Research and Development Consortium (NOWRDC) evaluated how the innovations it supports affect the levelized cost of energy (LCOE) and key performance metrics such as annual energy production (AEP), operational expenditures (OpEx), and capital expenditures (CapEx). This analysis builds on NOWRDC's 2024 LCOE Impact Report, which established the modeling framework and baseline assumptions used here. By modeling these innovations across three representative offshore wind farms reflecting the expected trajectory of U.S. offshore wind development in the 2030s, the analysis shows compelling results.

The methodology proceeds through three phases. First, three hypothetical baseline wind farms are constructed using public data, expert input, and inflation adjustments to represent distinct U.S. site conditions. The 2026 baselines place greater emphasis on floating offshore wind than the prior cycle, reflecting lease area awards on both coasts and the fact that roughly 60% of the U.S. offshore wind resource sits in waters too deep for fixed-bottom foundations.

Second, NOWRDC-funded projects are screened for inclusion using three criteria: full project closeout, completion of a credible techno-economic analysis, and plausible near-term commercial viability. Only projects meeting all three criteria are carried forward into modeling.

Third, each qualifying innovation is applied to the relevant baseline(s) to estimate its effect on LCOE, with granularity added as needed to capture specific cost drivers. Assumptions are informed by direct innovator interviews and stakeholder input from both U.S. and European sources, and a sensitivity analysis is conducted for each innovation. A notable finding in this cycle is that the most significant cost reduction opportunities appear in CapEx and OpEx rather than energy production gains, reflecting the fundamentally different cost structure of floating offshore wind.

Our analysis found NOWRDC R&D projects are driving cost reductions through three complementary mechanisms: reducing the cost of capital that makes offshore wind viable to finance, lowering the CapEx of mooring systems critical to floating deployment, and improving operational efficiency across all project types.

1 - Cost of capital is the single most powerful lever

Northeastern University's hurricane risk and bankability innovation delivers the largest individual LCOE reduction in every scenario, ranging from 3.9% (fixed-bottom) to 4.04% (shallow floating), underscoring that R&D which builds lender and investor confidence drives outsized returns.

2 - Mooring innovation is disproportionately impactful in floating scenarios

In the shallow floating case, UMaine, UMass Amherst, and NLR show that shifting from chain to synthetic rope and from individual to shared anchors account for the majority of CapEx reduction without changing the turbine or floater, with direct relevance to the commercially unsettled Gulf of Maine.

3 - O&M innovation delivers consistent returns across all scenarios

Tufts University's digital twin technology produces a reliable 10% OpEx reduction in every baseline, yielding LCOE reductions of 1.7% to 2.43%. Its benefits are substructure-agnostic, and potential gains from component lifetime extension were not modeled, suggesting these figures are conservative.

4 - The innovations are complementary, not overlapping

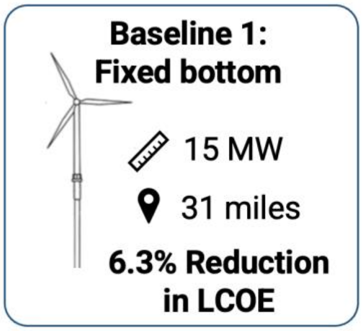
Each innovation targets a distinct cost driver: financing risk, mooring CapEx, or operational efficiency, making their impacts largely additive. The combined effect across all scenarios consistently exceeds what any single innovation achieves alone, pointing to the value of R&D portfolios diverse in cost lever, not just technology type.

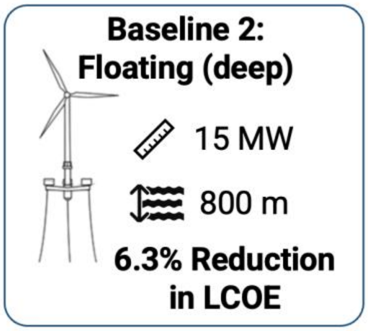
5 - Floating scenarios represent the greatest near-term opportunity

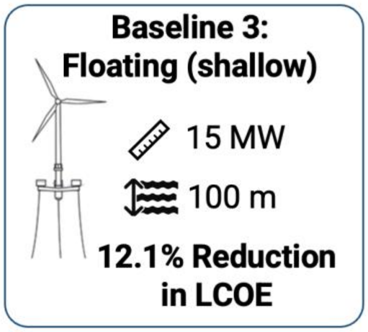
With Gulf of Maine and West Coast leasing underway, the 12.1% aggregate LCOE reduction achieved in the shallow floating scenario demonstrates that the cost gap between fixed-bottom and floating is not fixed, and that a targeted innovation portfolio can make a material difference to project viability.

These advances arrive at a pivotal moment. As the U.S. moves to assert dominance in global energy markets, a robust and cost-competitive offshore wind sector is a critical piece of that strategy. By driving down costs, accelerating deployment, and developing homegrown technology solutions, NOWRDC-supported innovations are helping position America as a world leader in offshore energy production. NOWRDC also recommends continued investment in the three cost levers identified here: financing risk reduction, mooring system innovation, and O&M efficiency, with prioritization of research targeting floating offshore wind deployment, where cost reduction potential is greatest and market readiness is most urgent.

Key Takeaway: Across all three model wind farms, NOWRDC-funded innovations delivered LCOE reductions ranging from 6.3% to 12.1% (USD/MWh), compared to the current state of the art. As offshore wind expands along both U.S. coasts at scale, these cost reductions stand to generate billions of dollars in savings for ratepayers, reinforcing offshore wind's growing role as a vast, reliable, and affordable energy resource.





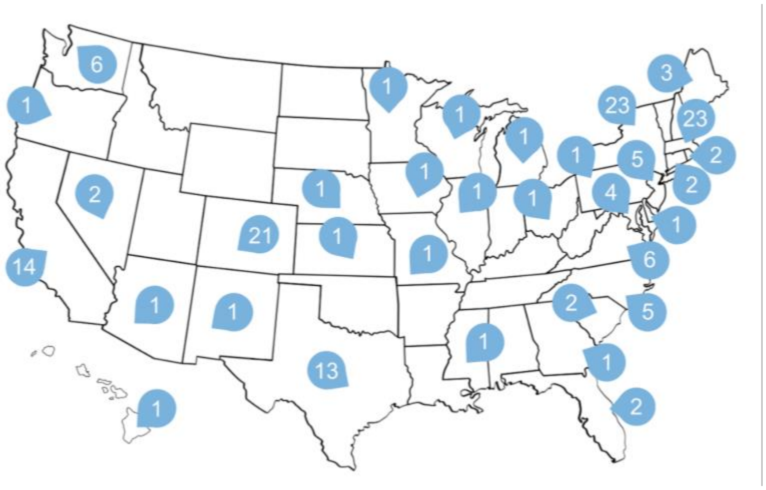


1 — Background

1.1 — NOWRDC's Mission Driven Portfolio

NOWRDC was established in 2018 through a founding partnership between the U.S. Department of Energy (DOE) and the New York State Energy Research and Development Authority (NYSERDA). From the outset, NOWRDC was built around a clear mission: to accelerate the deployment of offshore wind in the U.S., address critical industry challenges to maximize economic and social benefits, and reduce the levelized cost of energy (LCOE). To implement this mission, DOE and NYSERDA committed $41 million in joint funding, seeding a nationally significant innovation program that spans project leads and subcontractors across the country (Figure 1).

Figure 1: Geographic distribution of NOWRDC project award leads and subcontractors



A National Consortium of States and Industry

Since its founding, NOWRDC has embraced the consortium model, strategically expanding its membership to reflect the growing offshore wind market.

NOWRDC's state members ensure that innovation projects are well-aligned with the increasingly state-led nature of offshore wind development across the U.S. Their engagement supports the supply chain, workforce, and infrastructure build-outs that are supporting economies across the nation, both coastal and landlocked.

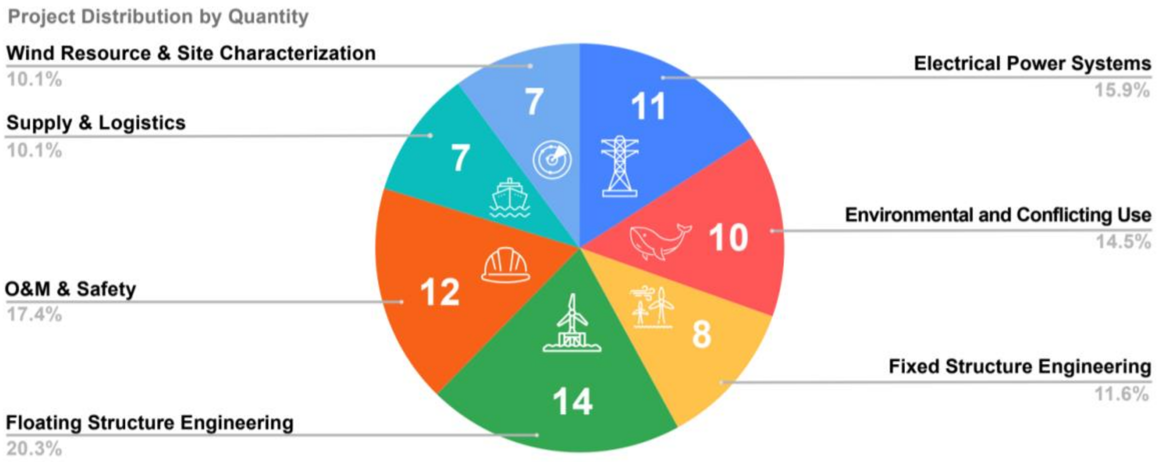
NOWRDC also includes offshore wind industry members, ranging from transmission entities to project developers. These industry partners play a pivotal role in directing NOWRDC's solicitations toward the most pressing needs, ensuring that publicly funded research addresses prioritized, real-world gaps. The result is a state-of-the art portfolio that is positioned for near-term deployment.

Insight-sharing and cross-sector collaboration are fundamental to how NOWRDC operates. Forums such as NOWRDC's Research and Development (R&D) Committee meetings and annual Technical Symposium bring state members, industry partners, and researchers together to directly shape R&D strategy and build strong networks across sectors. These touchpoints ensure that NOWRDC's work remains responsive, relevant, and informed by those closest to the challenges.

A Competitive, Results-Oriented Project Portfolio

Drawing on this deep reservoir of industry and state input, NOWRDC has conducted six competitive solicitations to date, yielding a portfolio of 69 funded projects (Figure 2). These projects span the full innovation continuum — from early-stage feasibility assessments and technology prototyping to product development and in-water demonstrations — reflecting NOWRDC's commitment to supporting innovation at every stage of readiness.

Figure 2: NOWRDC's Awarded Project Distribution by Topic Area



For active projects, NOWRDC employs several mechanisms to maximize value for its members and the broader offshore wind community, including the following.

Project Advisory Boards

- Approximately 135 project advisors have been engaged across the NOWRDC project portfolio, bringing deep expertise from across the offshore wind sector.
- Each project benefits from an average of six external industry advisors, providing direct, hands-on guidance to research teams throughout the project lifecycle.

Project Database

- NOWRDC maintains an accessible, publicly available repository on its website, offering key information on all funded projects for use by industry, researchers, and policymakers, etc.

Annual Technical Symposium

- This flagship annual event brings together researchers, state partners, and industry stakeholders in a multi-day conference format to showcase NOWRDC’s project portfolio and foster direct learning across research teams.
- The Symposium has attracted over 1,600 registrants over the past three years, underscoring the growing demand for a national venue dedicated to offshore wind R&D.

NOWRDC remains committed to collaboration with government and industry members to advance a results-oriented project portfolio. NOWRDC is well-positioned to continue delivering the research, partnerships, and innovations the industry needs to succeed.

1.2 — Measuring Mission Impact: NOWRDC’s Approach to Assessing Value

Lowering the LCOE for offshore wind in the U.S. sits at the core of NOWRDC's mission, but it is far from the only lens through which NOWRDC measures its impact. NOWRDC has developed a multi-layered approach to performance measurement that combines rigorous quantitative analysis with qualitative assessment, recognizing that the full value of R&D investment rarely fits neatly into a single metric.

This effort first took shape in 2024 when over 35 NOWRDC projects had reached completion. With a critical mass of work reaching maturity and entering industry use, NOWRDC was well-positioned to undertake a more structured evaluation of how effectively it was delivering on its mission. There were no ready-made templates to draw from; measuring R&D impact at this scale and specificity required building a framework largely from scratch, developed in close collaboration with NOWRDC members and partners such as Carbon Trust.

High Level Quantitative Impact

Some metrics lend themselves naturally to quantification; Technology Readiness Level (TRL) advancement, follow-on funding secured by project teams, and employee headcount growth are all relatively straightforward to track and compare across the NOWRDC portfolio. These indicators provide useful signals of project momentum and commercial viability, but they tell an incomplete story.

To capture a fuller picture, NOWRDC has also supported qualitative analysis. This has included in-depth interviews with completed project teams and a close examination of industry adoption pathways, tracing how research insights move from the lab into real-world use cases, inform subsequent work, or translate into R&D activity beyond NOWRDC's own portfolio.

High Level Qualitative Impact

NOWRDC has also turned its attention to impacts that do not register directly in cost metrics but are nonetheless central to responsible offshore wind development such as improvements in worker safety, environmental coexistence, and protections for marine mammals.[1] While these outcomes may not produce immediate LCOE reductions, they are integral to the sustainable, long-term deployment of offshore wind in the U.S., and in many cases, they contribute indirectly to cost efficiency by reducing project risk or accelerating delivery timelines.

While it’s difficult to express NOWRDC's full value to the U.S. industry through any single metric, the impact modeling covered in subsequent sections of this report represents the most powerful tool yet for demonstrating that value clearly and credibly.

1.3 — The Carbon Trust-Led LCOE Impact Analysis Overview

Analysis Overview

This LCOE impact analysis represents NOWRDC's most rigorous effort to date to quantify the cost reduction potential of its funded innovations. Conducted in partnership with Carbon Trust, who provided independent third-party modeling support and expert input, the analysis builds on an initial assessment first completed in 2024 and has been meaningfully refined and expanded for this 2026 iteration. Each innovation included here was required, as part of its funded scope of work, to conduct a formal techno-economic analysis and rigorous cost assessment. Those project-level findings served as the primary inputs into the LCOE models presented in this report, and are documented in full in each project's final report, available on NOWRDC's website. All innovations are assumed to be fully commercialized, ensuring the analysis reflects realistic deployment scenarios rather than theoretical potential.

The methodology proceeds through three distinct phases: baseline definition, innovation selection, and modeling and analysis.

Baseline Definition

The foundation of the analysis is a set of three hypothetical baseline wind farms, each designed to represent a distinct set of site conditions and foundation requirements likely used in U.S. offshore wind development. Parameters for each wind farm were derived from public domain data and expert opinion to produce credible cost estimates, subsequently updated with 2025 inflation data to align with relevant commercial operation dates.[2] Where necessary, estimates

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[1] Initial qualitative and high-level quantitative impact metrics are available on NOWRDC’s website here.

[2] Baseline cost assumptions draw on the following public resources: Arup (2025), *Guide to an Offshore Wind Farm*, https://guidetoanoffshorewindfarm.com/; Arup (2023), *Guide to a Floating Offshore Wind Farm*, https://guidetofloatingoffshorewind.com/wind-farm-costs/; Department for Energy Security and Net Zero / Frazer Nash Consultancy (2023), *Floating Offshore Wind: LCOE Report*,

were further refined through expert review to ensure they accurately reflect current market conditions.

One of the most significant methodological updates between the 2024 and 2026 analyses concerns the composition of these baseline wind farms. The 2024 assessment modeled a nearshore fixed bottom site, a farshore fixed bottom site, and a representative West Coast floating site. For 2026, the baseline portfolio was restructured to place greater emphasis on floating offshore wind, comprising a deepwater floating site, a shallow water floating site, and a fixed bottom site. This shift reflects the rapidly evolving U.S. offshore wind development landscape; wind lease areas have now been awarded on both the East and West Coasts, and approximately 60% of the nation's offshore wind energy resource sits in waters too deep for fixed bottom foundations, requiring floating technology.[3] Aligning the baseline assumptions with this trajectory ensures the analysis captures the most relevant and timely opportunities for R&D-driven cost reduction.

Innovation Selection

Not all NOWRDC-funded projects lend themselves to inclusion in an LCOE impact analysis. The nature of early-stage R&D means that many projects contribute foundational knowledge, data, or capacity-building outcomes that are valuable but not directly translatable into quantifiable cost reduction figures. Selection for this analysis follows a structured, criteria-based process designed to identify the subset of innovations best positioned for this type of modeling.

To be considered, a project must:

1. Be fully closed out;
2. Have completed a formal cost assessment or verifiable techno-economic analysis during its funded period, providing a credible quantitative basis for further modeling; and
3. Be currently positioned for a plausible near-term future in the industry, meaning the innovation is not merely a research output, but one with genuine commercial prospects.

Projects meeting these criteria are reviewed to create a shortlist of projects to carry forward into the modeling phase, using the cost impacts of each qualifying innovation. This rigorous selection process ensures that the LCOE reduction figures reported reflect innovations that are both technically validated and commercially viable. NOWRDC-funded projects that met this criteria and were selected for this impact analysis exercise are shown in Table 1.

Table 1: Innovation Studies Run Through Baseline Models

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https://assets.publishing.service.gov.uk/media/655371f7019bd600149f1ffa/floating-offshore-wind-lcoe-report_.pdf; National Renewable Energy Laboratory (2024), *Annual Technology Baseline: Offshore Wind*, https://atb.nrel.gov/electricity/2024/offshore_wind.

[3] Musial, W., Heimiller, D., Beiter, P., Scott, G., and Draxl, C. (2016). *2016 Offshore Wind Energy Resource Assessment for the United States*. NREL/TP-5000-66599. National Renewable Energy Laboratory. https://docs.nlr.gov/docs/fy16osti/66599.pdf

Innovator	***Innovation/study***	***Technical Challenge Area***	***Description***	***Model application***
National Laboratory of the Rockies (NLR, Formerly NREL)	*Shared Mooring Systems (and Anchors) for Deep Water Floating Wind Farms*	*Floating Structure Engineering*	*A feasibility study of using shared moorings (and shared anchors), which demonstrated a reduction in:* • *Number of anchors* • *Material and fabrication cost savings (incl. reduction in mooring line lengths)* • *Installation cost savings*	*Floating models only*
University of Maine (UMaine)	*Design and Certification of Taut-synthetic Moorings for Floating Wind Turbines*	*Floating Structure Engineering*	*Design and validate the use of low-cost nylon semi-taut synthetic rope mooring systems for 15MW floating offshore wind turbines at water depths of 45–80m. The use of nylon semi-taut synthetic rope moorings, compared to catenary chain moorings, leads to:* • *Lower major failure and replacement costs (O&M)* • *Significant savings in material/fabrication costs*	*Shallow floating model only*
Northeastern University	*Long-Term Availability and Bankability of Offshore Wind Through Hurricane Risk Assessment and Mitigation*	*Wind Resource and Site Characterization*	*The development of an improved hurricane prediction model instills confidence in banks and other sources of project financing by reducing uncertainty in hurricane predictions. This leads to:* • *Better interest rates* • *Lower upfront cost of capital*	*All models*

Innovator	***Innovation/study***	***Technical Challenge Area***	***Description***	***Model application***
University of Massachusetts Amherst (UMass)	*Techno-Economic Mooring Configuration and Design for Floating Offshore Wind*	*Floating Structure Engineering*	*A feasibility study of synthetic rope mooring systems for a semi-sub floater for the optimisation of mooring systems for floating offshore wind farms located in shallow waters. This leads to:* • *Reduced material costs* • *Reduced installation costs*	*Floating models only*
Tufts University (Tufts)	*Physics-based digital twins for optimal asset management*	*O&M and Safety*	*Physics-based digital twin technology, which can be used to track the development of structural fatigue within OWT components, leading to:* • *Longer offshore wind turbine service life* • *Reduced operations and maintenance (O&M) costs from early fault detection within the system*	*All models*

Modeling Process and Assumptions

Once the baseline wind farms are established and the innovation shortlist is confirmed, each selected innovation is applied to the relevant baseline or baselines to model its effect on LCOE. The analysis concentrates specifically on projects with robustly quantifiable cost reduction benefits, and a sensitivity analysis is conducted for each to explore the plausible range of cost impacts under varying assumptions.

The modeling process and assumptions are intentionally designed to represent a reasonable, middle-of-the-road projection for each geographic area. Public reports and private industry sources were used to determine the baseline models used.[4]

Modeling Process

- **Baseline creation:** Key variables influencing offshore wind farm LCOE were identified using publicly available data.[5] Industry collaborators provided real variable ranges used

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[4] Ibid.

[5] Arup (2025). Guide to an Offshore Wind Farm. Available at: https://guidetoanoffshorewindfarm.com/

in U.S. calculations, which were used to refine the baseline to better reflect industry expectations.

- **Level of detail:** Granularity was added to the LCOE calculation as needed to capture cost changes from specific innovations. For example, if a CapEx reduction stemmed from lower steel costs, the model was refined to reflect steel's share of CapEx before applying the relevant savings.
- **Stakeholder agreement:** European and U.S. data informed the baseline, with differences between the two markets accounted for in tailoring assumptions to U.S. conditions. Stakeholder input was collected throughout to arrive at agreed figures.
- **Innovation portfolio selection:** Innovations were selected based on several criteria: project completion, availability of sufficient cost reduction data from innovators, and the feasibility of applying the portfolio concurrently across the baseline wind farms without constraint.
- **Cost and performance assessment:** The specific cost and/or energy yield implications of each innovation were investigated through direct interviews with innovators.
- **Application to the LCOE model:** Cost and performance implications were applied to the model to determine each innovation's impact on LCOE.
- **Sensitivity analysis:** Each varied parameter was subjected to a sensitivity analysis.

Model Assumptions

- Baselines do not represent any specific physical location or interconnection site, though costs reflect available information on real wind farms in comparable geographic areas.
- For all innovations, the technology is assumed to be fully commercialized and applied throughout the wind farm's project lifecycle.
- A 15 MW turbine is used in this analysis, reflecting turbine models announced for near-term U.S. projects.

Arup (2023). Guide to a Floating Offshore Wind Farm. Available at: https://guidetofloatingoffshorewind.com/wind-farm-costs/
Department for Energy Security and Net Zero / Frazer Nash Consultancy (2023). Floating Offshore Wind: LCOE Report. Available at: https://assets.publishing.service.gov.uk/media/655371f7019bd600149f1ffa/floating-offshore-wind-lcoe-report_.pdf
National Renewable Energy Laboratory (2024). Annual Technology Baseline: Offshore Wind. Available at: https://atb.nrel.gov/electricity/2024/offshore_wind

2 — Core Innovation Modeling & LCOE Impact Analysis

2.1 — Baseline Scenario 1: Fixed-Bottom Nearshore Offshore Wind Farm

The nearshore case was set up to be a typically representative farm for the first round of U.S. East Coast development (Table 2). The distance to shore is set at 30 miles, and the water depth across the farm at 30 m. The Commercial Operations Date (COD) is set for 2030 to represent some of the projects currently in the pipeline which fit this approximate geographic profile. The sensitivity to real discount rate was checked before finalizing the value for analysis.

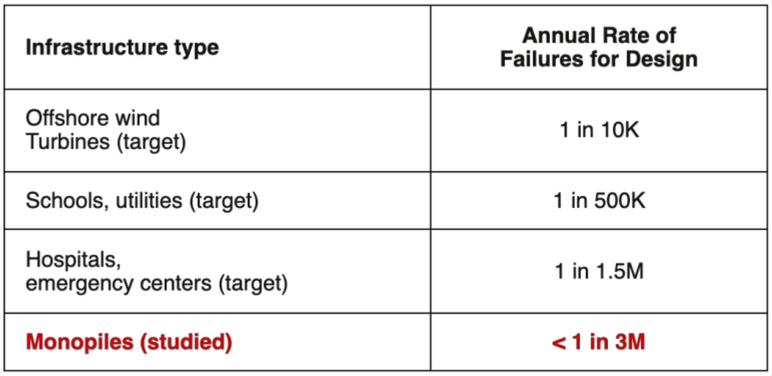
Table 2: Baseline Scenario 1 Model Assumptions: Fixed-bottom Nearshore (30 miles)

Parameters	Units	2025 Calculated Baseline	2024 Calculated Baseline	Guide to an offshore wind farm, UK data 2025	NREL 2024
Wind Turbine rating	MW	15	15	15	12
Discount Rate	%	6.5	6	6.5	6.61
Capacity Factor	%	50	44	51	49
Number of Wind Turbines		50	100	67	50
Distance to shore	Miles (km)	31 (50)	30 (48)	47 (75)	31 (50)

Innovation 1: Northeastern University, Long-Term Availability and Bankability of Offshore Wind Through Hurricane Risk Assessment and Mitigation

Project summary: NOWRDC and a seven-university research team worked to better understand and quantify the structural and grid risks that hurricanes pose to offshore wind systems. Phase I found that the risk of monopile failure from hurricanes is lower than current design standards assume, a finding that could reduce insurance and financing costs for offshore wind projects.

Table 3: Structural Design Failure Rate Targets by Infrastructure Type



Infrastructure type	Annual Rate of Failures for Design
Offshore wind Turbines (target)	1 in 10K
Schools, utilities (target)	1 in 500K
Hospitals, emergency centers (target)	1 in 1.5M
Monopiles (studied)	**< 1 in 3M**

Phase II built on this by improving hurricane forecasting, assessing climate effects, and evaluating grid resiliency impacts, funded through a NOWRDC-facilitated partnership between Maryland, Massachusetts, and New Jersey.

Cost Reduction Driver: By providing greater certainty during project development, this innovation can enhance investor and lender confidence in offshore wind projects, helping lower financing costs and improve overall project economics.

Resulting LCOE Impact: 3.9% Reduction

Table 4: Northeastern University Impact Metric Summary

Impact Metric	Reduction (%)
AEP	0 – no impact
OpEx	0 – no impact
CapEx	0 – no impact
LCOE	3.9

Innovation 2: Tufts University, Physics Based Digital Twin for Optimal Asset Management

Project Summary: Tufts University developed an algorithm that integrates a physics-based model of offshore wind turbines with live measurement data from turbines collected through strategically placed sensors. The software allows offshore wind asset managers to remotely access actionable turbine health data, providing them with predictive maintenance and failure prediction capabilities.

Cost Reduction Driver: The innovation drives savings in the operations and maintenance (O&M) phase due to streamlined servicing of substructure and other components when using digital twins to track fatigue life and general asset health. The Tufts University team has also explored how this innovation may contribute to component lifetime extension, which was not included in this analysis but may be explored in future reporting.

Resulting LCOE Reduction: 2.43%

Table 5: Tufts University Impact Metric Summary

Impact Metric	Change (%)
AEP	0 – no impact
OpEx	10
CapEx	0 – no impact
LCOE	-2.43

Aggregate Impact for Baseline Scenario 1: Fixed-Bottom Nearshore Offshore Wind Farm

Northeastern University assumes that reduced project uncertainty leads to improved investor confidence and a lower cost of capital, resulting in a discount rate reduction from 6.5% to 6.0%. Tufts University assumes an improved maintenance approach and enhanced asset health management program drives a 10% reduction in OpEx costs. Together, these two assumptions target distinct but complementary LCOE levers: financing cost and operational efficiency. Together these drive downward pressure on LCOE across the project lifetime under the Fixed Bottom configuration.

2.2 — Baseline Scenario 2: Floating Offshore Wind in Deep Waters (800 m)

Fixed-bottom foundations become infeasible beyond roughly 60 m depth, making floating offshore wind (FOSW) necessary in deeper water. This scenario represents offshore wind development on the West Coast, where 'ultra-deep' water conditions (modeled at 800 m) certainly require FOSW technology (Table 6). The U.S. West Coast holds over 200 GW of technical resource potential in waters deeper than 60m, and federal leasing areas off California and Oregon sit predominantly at 500–1,300 m depth, well within the range modeled here. Globally, the FOSW pipeline is projected to grow from under 200 MW of installed capacity today to over 250 GW by 2050.

No commercial-scale floating wind farm has been deployed in 'ultra-deep' water conditions. The deepest operational projects, such as Equinor's Hywind Tampen, only reach approximately 300 m. This scenario therefore sits beyond the current envelope of demonstrated technology, and cost parameters carry substantial uncertainty as a result.This leaves significant headroom for innovation-driven cost reduction. Mooring systems, dynamic export cables, and installation methodologies for ultra-deep conditions are still nascent with no direct commercial precedent, creating opportunities on both the component and CapEx sides. Early movers who establish cost-competitive solutions stand to capture outsized value as the market scales, mirroring the

~60% LCOE reductions seen in fixed-bottom offshore wind between 2012 and 2022.[6] The 100-turbine, 1,500 MW array modeled here reflects the scale of leasing areas being contemplated on the West Coast, and is broadly aligned with widely-accepted reference assumptions for deep-water FOSW.

Table 6: Baseline Scenario 2 Model Assumptions: Floating in Deeper Waters (800 m)

Parameters	Units	2025 CT Baseline	2024 CT Baseline	Guide to a FOSW Farm, UK Data 2023	DESNZ 2023	NREL 2022	NREL 2021	NREL 2020
Wind Turbine rating	MW	15	15	15	17	12	12	15
Discount Rate	%	7.5	6.5	NA	7.8	3.6	2.9	5.4
Capacity Factor	%	50	40	51	65	38.2	56	49-55
Number of Wind Turbines		100	100	30	58	50	84	66
Depth	m	800	800	100 (Shallow)	N/A	739	100-600	40-1300

Innovation 3: National Laboratory of the Rockies (NLR), Shared Mooring Systems for Deep-Water Floating Offshore Wind Farms

Project Summary: NLR, formerly known as the National Renewable Energy Laboratory (NREL), conducted a feasibility study into the use of shared mooring systems. In this project, mooring lines and anchors are shared between adjacent floating turbines rather than dedicated to individual units for deep-water FOSW farms. The study developed a shared mooring farm design, improved simulation tools to enable loads analysis, and compared the performance and cost of shared versus conventionally moored configurations (Figure 3). The project

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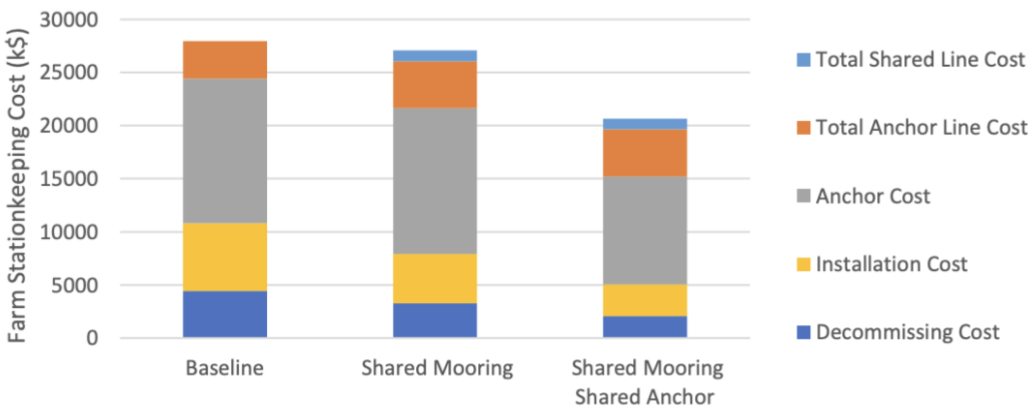
[6] International Renewable Energy Agency (IRENA). (2024). Renewable Power Generation Costs in 2023. IRENA. https://www.irena.org/Publications/2024/Sep/Renewable-Power-Generation-Costs-in-2023

demonstrated meaningful cost reduction opportunities and provided the industry with design tools that can be used to pursue these savings commercially.

Cost Reduction Driver: The innovation drives savings in the installation phase through reductions in the total number of anchors required, as well as material, fabrication, and installation cost savings from shorter overall mooring line lengths. Mooring installation costs represent approximately 3% of total CapEx in the deep-water floating baseline model. This analysis identified a 26% saving in anchor and mooring installation costs when using shared systems compared to a conventional individually moored farm.

***Figure 3: Station keeping cost comparison of the baseline, shared-mooring, and shared-mooring and anchor designs*[7]**



Resulting LCOE Reduction: 0.64%

Table 7: NLR's Impact Metric Summary

Impact Metric	Change (%)
AEP	0 – no impact
OpEx	0 – no impact
CapEx	-0.77
LCOE	-0.64

Applied to Baseline 2: Innovation 1: Northeastern University, Long-Term Availability and Bankability of Offshore Wind Through Hurricane Risk Assessment and Mitigation

Project summary: See above in Baseline 1 section.

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[7] Hall, M., Housner, S., Lozon, E., and Sirnivas, S. / National Renewable Energy Laboratory (2023). Shared Mooring Systems for Deep-Water Floating Wind Farms: Final Report. NOWRDC Report, Contract 142869. https://nationaloffshorewind.org/wp-content/uploads/142869_Final-Report.pdf

Cost Reduction Driver: Similar to the fixed-bottom scenario in Baseline 1, this project also contributes to cost savings here by reducing uncertainty in component fatigue and performance in extreme weather. This leads to a lower cost of the investment and lending capital used to finance the wind farm.

Resulting LCOE Reduction: 4.02%

Table 8: Northeastern University's Impact Metric Summary

Impact Metric	Change (%)
AEP	0 – no impact
OpEx	0 – no impact
CapEx	0 – no impact on - pre-discounted CapEx
LCOE	-4.02

Applied to Baseline 2: Innovation 2: Tufts University, Physics Based Digital Twin for Optimal Asset Management

Project summary: See above in Baseline 1 section.

Cost Reduction Driver: Similar to the fixed-bottom scenario in Baseline 1, this project also drives cost savings in O&M. In this floating scenario, the innovation streamlines servicing of the floating offshore wind substructure and other components. The digital twin model more efficiently and effectively tracks fatigue life and general asset health.

Resulting LCOE Reduction: 1.7%

Table 9: Tufts University's Impact Metric Summary

Impact Metric	Change (%)
AEP	0 – no impact
OpEx	-10
CapEx	0 – no impact
LCOE	-1.7

Aggregate Impact for Baseline Scenario 2: Floating in Deeper Waters (800 m)

NLR's shared mooring system targets a reduction in installation-phase CapEx through fewer anchors and shorter mooring line lengths, driving a -0.64% LCOE reduction. Northeastern University's hurricane risk assessment and mitigation framework reduces financing uncertainty, lowering the cost of capital and delivering a -4.02% LCOE reduction; this is the single largest impact across the three innovations in this scenario. Tufts University's physics-based digital twin improves asset health monitoring and maintenance scheduling for the floating substructure, contributing a -1.7% LCOE reduction through a 10% OpEx savings.

Together, the three innovations address three distinct cost levers: mooring installation CapEx, cost of capital, and operational expenditure. Their combined effect represents a cumulative LCOE reduction of approximately 6.36% reduction against the floating deep-water baseline. Given that this scenario sits beyond the current envelope of commercially demonstrated technology, the innovations carry added strategic significance. Cost reductions of this magnitude, applied at an early stage of FOSW market development, could meaningfully improve project bankability and accelerate the path to commercial viability on the U.S. West Coast and other ultra-deep water leasing areas globally.

2.3 — Baseline Scenario 3: Floating Shallow Water Offshore Wind Farm (100 m)

This scenario represents FOSW development in intermediate water depths, modeled at approximately 100 m, a depth at which fixed-bottom foundations become infeasible but ultra-deep mooring challenges do not yet apply. This depth is characteristic of the Gulf of Maine, one of the most significant near-term floating offshore wind markets in the U.S. BOEM's Wind Energy Area for the Gulf of Maine encompasses approximately 2 million acres with a combined capacity of 32 GW, and all identified areas are deeper than 60 m, meaning all potential development will likely consist of floating technology. Targets reinforce this pipeline, with Maine authorizing up to 3 GW by 2040 and Massachusetts targeting 10 GW in the same region.

Despite this significant pipeline, the intermediate depth range presents engineering challenges that are not yet fully resolved. The support structure design space has not converged on a single optimal technology; shallow-water mooring systems face particular difficulties around tension fluctuations and snap loads, with conventional all-chain catenary systems proving cost-ineffective at these depths. This makes mooring innovation especially high-leverage here. The NOWRDC R&D Roadmap reflects this directly, identifying the need for new mooring concepts, components, materials, and installation methods adapted to U.S. shallow-water site conditions, with feasibility to be demonstrated while achieving lower costs verified through techno-economic modelling.[8] The three mooring-focused innovations assessed in this scenario address that gap head-on, and their combined impact illustrates the scale of cost reduction available through targeted R&D at this depth range.

The baseline models a 100-turbine, 1,500 MW array using 15 MW turbines with a 7% discount rate. The resulting LCOE sits meaningfully lower than the deep-water floating baseline but higher than the fixed-bottom case, reflecting the added complexity and cost of floating substructures.

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[8] National Offshore Wind Research and Development Consortium (NOWRDC). (2023). Research and Development Roadmap 4.0. https://nationaloffshorewind.org/wp-content/uploads/NOWRDC-Research-Development-Roadmap-4.0.pdf

Table 10: Baseline Scenario 3 Model Assumptions: Floating in Shallow Waters (100 m)

Parameters	Units	2025 CT Baseline (shallow)	2025 CT Baseline (deep)
Wind Turbine rating	MW	15	15
Discount Rate	%	7	7.5
Capacity Factor	%	50	50
Number of Wind Turbines		100	100
Depth	m	100	800

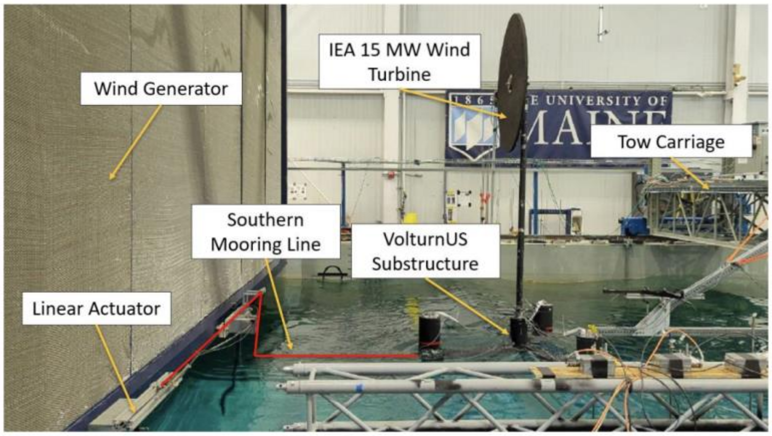
Innovation 4: University of Maine, Design and Certification of Taut-Synthetic Moorings for Floating Wind Turbines

Project Summary: The University of Maine (UMaine) designed, validated through scaled model testing, and qualified for use, a low-cost taut synthetic rope mooring system for 15 MW+ FOSW turbines at water depths of 45–80 m.

The project advanced this mooring technology to technology readiness level (TRL) 8 through scaled model and full-scale rope testing, with third-party reviews conducted by national labs and offshore classification societies to verify performance and cost effectiveness (Figure 4). The work targeted an LCOE of 7¢/kWh for East Coast floating wind sites at intermediate depths.

Cost Reduction Driver: Shifting from conventional catenary chain moorings to taut synthetic rope systems reduces both material and fabrication costs and leads to lower failure and replacement costs over the operational life of the project. The synthetic rope system is particularly well-suited to intermediate water depths where catenary chain systems face geometric and weight limitations. UMaine's analysis identified CapEx savings of 3.85% and OpEx savings of 1.1% under this mooring configuration.

Figure 4: Mooring Line Testing Arrangement in the UMaine Wind-Wave Basin[9]



Resulting LCOE Reduction: 3.31%

Table 11: UMaine's Impact Metric Summary

Impact Metric	Reduction (%)
AEP	0 – no impact
OpEx	1.10
CapEx	3.85
LCOE	3.31

Innovation 5: University of Massachusetts Amherst, Techno-Economic Mooring Configuration and Design for Floating Offshore Wind

Project Summary: University of Massachusetts Amherst (UMass Amherst) developed cost-optimized mooring and foundation system designs for floating offshore wind turbines, evaluating different material combinations and topologies to identify the most cost-effective configurations (Figure 5). The project produced a cost comparison and cost driver analysis across mooring system solutions, contributing to a broader design methodology for shallow-water FOSW deployment.

Cost Reduction Driver: By substituting synthetic rope systems for conventional all-chain mooring systems, this innovation achieves significant reductions in both mooring material and installation costs. UMass Amherst identified material cost savings of 93% and installation cost savings of 67% compared to an all-chain baseline. Mooring fabrication and installation costs represent approximately 6% and 3% of total CapEx respectively in the shallow floating model, making this one of the higher-impact innovations modeled in this scenario.

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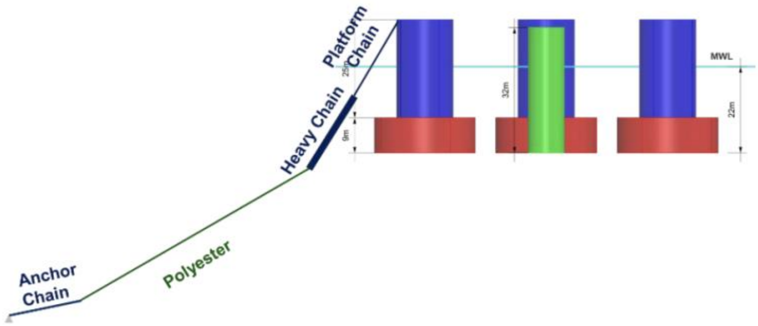
[9] Hallowell, S. and Viselli, A. / University of Maine (2024). Semi-Taut Synthetic Mooring System for a 15MW FOWT in Shallow Water: Final Report. NOWRDC Contract #154676. https://nationaloffshorewind.org/wp-content/uploads/NOWRDC-Final-Report_UMaine-Final.pdf

Figure 5: Mooring Line Configuration Developed in the Project: Platform Chain – Heavy Chain - Polyester Rope – Anchor Chain[10]



Resulting LCOE Reduction: 6.23%

Table 12: UMass Amherst's Impact Metric Summary

Impact Metric	Reduction (%)
AEP	0 – no impact
OpEx	0 – no impact
CapEx	7.7
LCOE	6.23

Applied to Baseline 3: Innovation 3: NLR, Shared Mooring Systems

Project Summary: See above in Baseline Scenario 2 section.

Cost Reduction Driver: As in the deep-water scenario, the shared mooring innovation reduces anchor count and mooring line material and installation costs. Mooring installation costs represent approximately 3% of total CapEx in the shallow floating baseline, and NLR identified a 26% saving in anchor and mooring installation costs under a shared configuration.

Resulting LCOE Reduction: 0.62%

Table 13: NLR's Impact Metric Summary

Impact Metric	Reduction (%)
AEP	0 – no impact
OpEx	0 – no impact
CapEx	0.8
LCOE	0.6

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[10] Sharman, K.T., AlShuwaykh, A., and Saleh, S. / University of Massachusetts Amherst; Maine Marine Composites, LLC; Technip Energies (2022). Techno-Economic Mooring Configuration and Design for Floating Offshore Wind Turbines in Shallow Waters: Final Report. NOWRDC Contract 154629. https://nationaloffshorewind.org/wp-content/uploads/D6.2-NOWRDC-final-Report.pdf

Applied to Baseline 3: Innovation 1: Northeastern University

Project Summary: See above in Baseline 1 section.

Cost Reduction Driver: As in the fixed-bottom and deep-water floating scenarios, Northeastern University's hurricane risk and bankability framework reduces development-phase uncertainty and drives down the cost of capital. In this scenario, the nominal case assumes a discount rate reduction from 7.0% to 6.5%.

Resulting LCOE Reduction: 4.04%

Table 14: Northeastern University's Impact Metric Summary

Impact Metric	Reduction (%)
AEP	0 – no impact
OpEx	0 – no impact
CapEx	0 – no impact
LCOE	4.04

Applied to Baseline 3: Innovation 2: Tufts University, Physics-Based Digital Twin

Project Summary: See above in Baseline 1 section.

Cost Reduction Driver: As in the other baseline scenarios, the digital twin innovation drives a 10% reduction in OpEx through improved predictive maintenance and asset health monitoring, applied here to the floating substructure and associated components.

Resulting LCOE Reduction: 5.27%

Table 15: Tufts University's Impact Metric Summary

Impact Metric	Reduction (%)
AEP	0 – no impact
OpEx	10
CapEx	0 – no impact
LCOE	5.27

Aggregate Impact for Baseline Scenario 3: Floating in Shallow Waters (100 m)

The shallow floating scenario benefits from the broadest innovation portfolio of the three baselines — five distinct interventions target complementary cost levers:

- UMaine's taut synthetic mooring system contributes a 3.31% LCOE reduction through combined CapEx and OpEx savings from replacing catenary chain with lightweight synthetic rope.

- UMass Amherst's mooring optimization study delivers the largest individual CapEx reduction of any innovation across all three baselines at 6.23%, driven by material and installation savings of 93% and 67% respectively on the mooring system.
- NLR's shared mooring system delivers a further 0.62% LCOE reduction through reduced anchor and mooring installation costs.
- Northeastern University's hurricane risk framework provides the largest single LCOE reduction in this scenario at 4.04% by lowering the cost of capital.
- Tufts University's digital twin contributes a further 5.27% through OpEx efficiency.

Together, these five innovations address three distinct cost dimensions: mooring CapEx, operational expenditure, and cost of capital. The combined effect of these cost dimensions represents a cumulative LCOE reduction of approximately -12.1% against the shallow floating baseline. This is the largest aggregate reduction across all three baseline scenarios and reflects the concentration of mooring-focused innovation applicable to the shallow floating depth range, as well as the outsized leverage that cost-of-capital improvements provide at higher baseline discount rates.

3 — Conclusions

This report has modeled the LCOE impact of five NOWRDC-funded innovations across three representative offshore wind baseline scenarios:

1. Fixed-bottom nearshore
2. Floating deep-water (800 m)
3. Floating shallow-water (100 m)

These scenarios cover the primary development contexts relevant to the current and near-term U.S. offshore wind pipeline. Together, the results demonstrate that targeted, early-stage R&D investment can deliver meaningful and measurable reductions in offshore wind costs across all phases of project development, from financing and construction through to operations and maintenance.

The aggregate findings across the three baselines are summarized below:

Table 16: Combined LCOE Reduction Summary

Baseline Scenario	Combined LCOE Reduction (%)
Baseline 1: Fixed-Bottom Nearshore	-6.3
Baseline 2: Floating Deep-Water (800 m)	-6.3
Baseline 3: Floating Shallow-Water (100 m)	-12.1

Key Findings:

The NOWRDC-supported R&D model shows reductions in offshore wind costs through three distinct and complementary mechanisms: financing risk reduction, mooring CapEx savings, and operational efficiency gains. Critically, these levers target separate cost drivers and their effects are largely additive.

Key findings bear emphasis. Hurricane risk innovation produces the largest single LCOE reduction across every scenario analyzed (-3.9% to -4.04%), confirming that R&D which strengthens lender and investor confidence generates outsized returns. Mooring innovation, specifically the transition to synthetic rope and shared anchor systems, accounts for the majority of CapEx reduction in floating configurations without modification to the turbine or floater. Digital twin technology delivers a consistent 10% OpEx reduction across all substructure types, with additional gains from component lifetime extension not yet reflected in the model.

Floating offshore wind represents the most significant near-term opportunity. The 12.1% aggregate LCOE reduction achieved in the shallow floating scenario demonstrates that the cost gap between fixed-bottom and floating is not a fixed constraint. Targeted innovation can make a material difference to project viability in the Gulf of Maine and beyond.

As the U.S. works to establish a competitive position in global energy markets, a cost-effective domestic offshore wind sector is a strategic asset. NOWRDC's portfolio illustrates what regionally grounded, coordinated R&D investment can produce and the scale of impact available as these innovations move toward deployment.

4 — Future Work

NOWRDC intends to continue modeling the LCOE impact of its innovation portfolio on an annual or biannual basis, ensuring that cost reduction findings are kept current as projects mature, new innovations are funded, and baseline market conditions evolve.

This work has been carried out in partnership with the Carbon Trust. NOWRDC and the Carbon Trust have collaboratively refined this methodology, with input from NOWRDC's Board of

Directors and R&D Committee, to make the modeling approach as robust, transparent, and representative as possible. That iterative process of review and refinement will continue in future editions of this report.

For organizations seeking to quantify and communicate the cost reduction potential of their funded research, whether in offshore wind or adjacent clean energy sectors, the methodology developed here provides a replicable and credible framework.

Interested parties are welcome to reach out to NOWRDC (kori.groenveld@nationaloffshorewind.org) or the Carbon Trust (James.sinfield@carbontrust.com and maria.gonzalez-martin@carbontrust.com) to explore how this approach might be adapted to their portfolio.