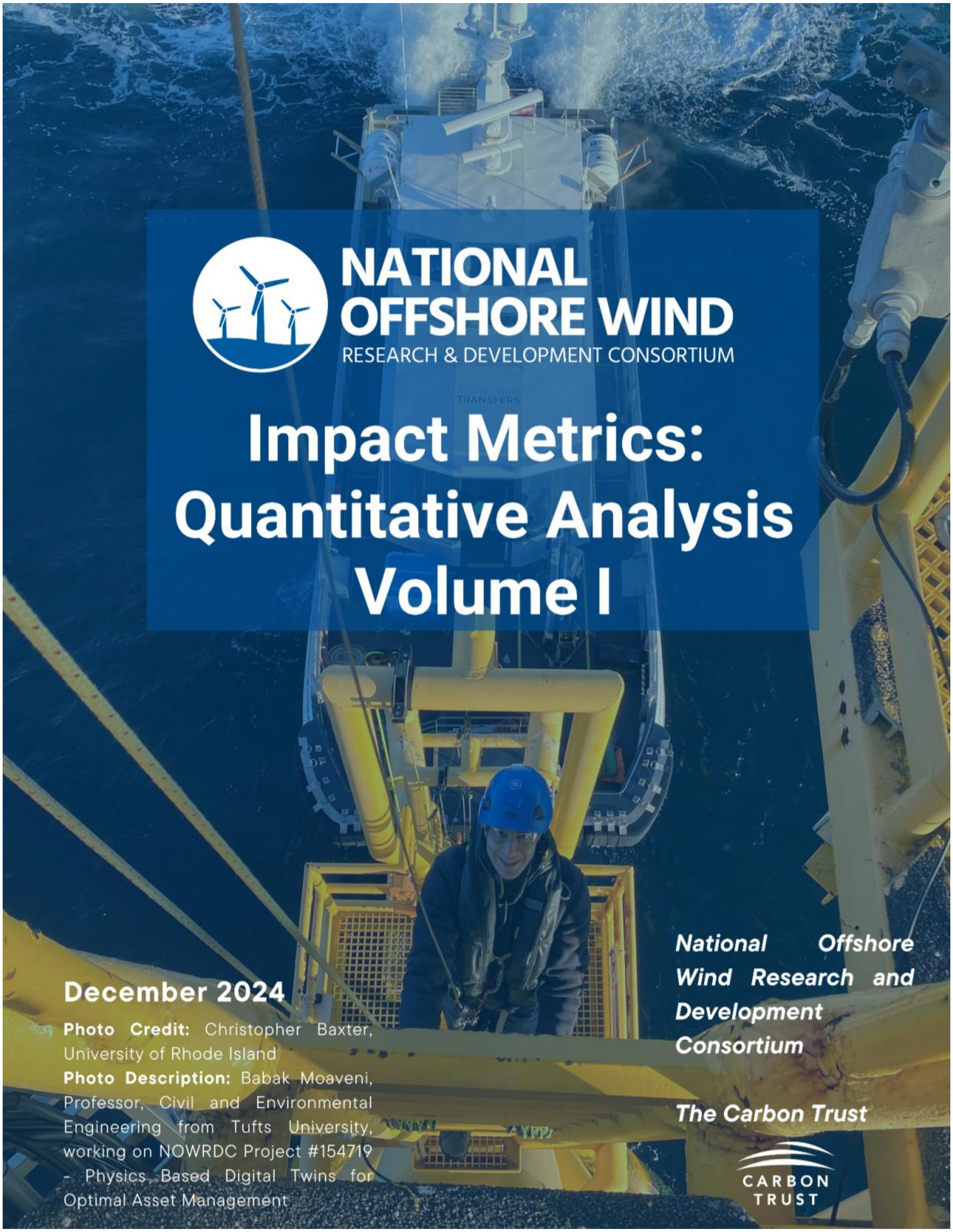

NATIONAL OFFSHORE WIND
RESEARCH & DEVELOPMENT CONSORTIUM

Impact Metrics: Quantitative Analysis Volume I

December 2024

Photo Credit: Christopher Baxter, University of Rhode Island
Photo Description: Babak Moaveni, Professor, Civil and Environmental Engineering from Tufts University, working on NOWRDC Project #154719 - Physics Based Digital Twins for Optimal Asset Management

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 Consortium Executive Director Lyndie Hice-Dunton, was produced by the Consortium's internal technical team of program managers, in collaboration with the Carbon Trust's offshore wind cost modeling team and with NOWRDC project awardees. The Consortium's Research and Development Committee provided extensive input. The primary authors are James Sinfield, Maria Gonzalez-Martin, Kori Groenveld, and Julian Fraize.

Version History

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

Executive Summary

The National Offshore Wind Research and Development Consortium (NOWRDC or the Consortium) has assessed the potential impact of our supported innovations on the levelized cost of energy (LCOE) and annual energy production (AEP) metrics of offshore wind in the US. This impact assessment comes at a critical time for the Consortium, as we are concurrently undergoing internal strategic planning efforts to help direct goals for the future of our organization. To conduct this assessment, we partnered with the Carbon Trust to provide third party input and modeling support. Individual project/innovation cost assessments were carried out during the respective projects NOWRDC funding and explanations of which are provided in their respective NOWRDC final project reports, published on our website. For the impact assessment we assumed each innovation has been fully commercialized. To achieve the full possible reduction in cost and/or increase in production from each innovation, we assumed they were deployed across three hypothetical baseline wind farms: nearshore fixed bottom, farshore fixed bottom, and a representative West Coast floating site. Modelling was conducted using parameters describing each of these hypothetical wind to attain current generic projections on cost and AEP, and then run again taking into account the projected effects of the selected NOWRDC supported innovations that apply to that scenario. In each case the individual contribution of the innovations, and a collective contribution are presented and discussed with respect to sensitivity of the assumptions. Results indicate notable LCOE reductions even when only a few innovations were deployed. Across each case, deploying innovation led to significant LCOE reductions ranging from 3-9.5%, and increases in AEP ranging from 1.5-3.5%.

This work is not intended to reflect a directive approach about which innovations should be adopted first, or on what timeline we think they will be adopted. Similarly, the results presented are not intended, and should not be conflated as projections for the price (bid price, ratepayer cost, etc.) of offshore wind in the US. The outcomes of this work are intended to enable relative understanding of the impact of our funding, provide context to NOWRDC's internal strategic decision-making, and enable quantitative self-accounting. Based on the promising results coming from NOWRDC funded projects, we are able to quantitatively validate the importance of the Consortium's work to date, and highlight the projected impact on the US offshore wind energy industry. We have demonstrated that utilizing a consortium approach allows resources to be directed in an efficient and targeted manner to continue to maximize impact and drive towards a successful large scale adoption of offshore wind energy in the US. As the cost of offshore wind development remains a crucial aspect to the success of this burgeoning industry, support for R&D and technology innovation must continue to be a priority to advance the industry.

1 Background

1.1 NOWRDC Mission and Desired Impact

The National Offshore Wind Research and Development Consortium (NOWRDC or the Consortium), established in 2018 as a not-for-profit public-private partnership, focuses on advancing offshore wind technology in the United States through high-impact research projects that enable cost-effective, responsible development and maximize economic benefits. The organization's mission is to collaborate with the industry on prioritized R&D activities to reduce the levelized cost of energy (LCOE) for offshore wind in the U.S. while maximizing economic and social benefits. Initial funding for the Consortium came from the U.S. Department of Energy (DOE) and the New York State Energy Research and Development Authority (NYSERDA), each providing $20.5 million, with additional funding from the Commonwealths of Virginia and Massachusetts and the States of California, Maine, Maryland, New Jersey, and Virginia, for a total investment of approximately $55 million. The Consortium administers several committees - including its Research and Development Committee for members, Research and Development Advisory Group for academia and other researchers, and State Action Network for state members.

1.2 NOWRDC Project Portfolio

NOWRDC has worked to fulfill its mission by conducting competitive solicitations that procure high-impact offshore wind research and development projects. To date, NOWRDC has hosted 4 competitive solicitations, resulting in 57 project awards comprising $55M in grant funding and $6M in leveraged funding.

NOWRDC projects are categorized into the following high-level technical topic areas, presented in Figure 1.

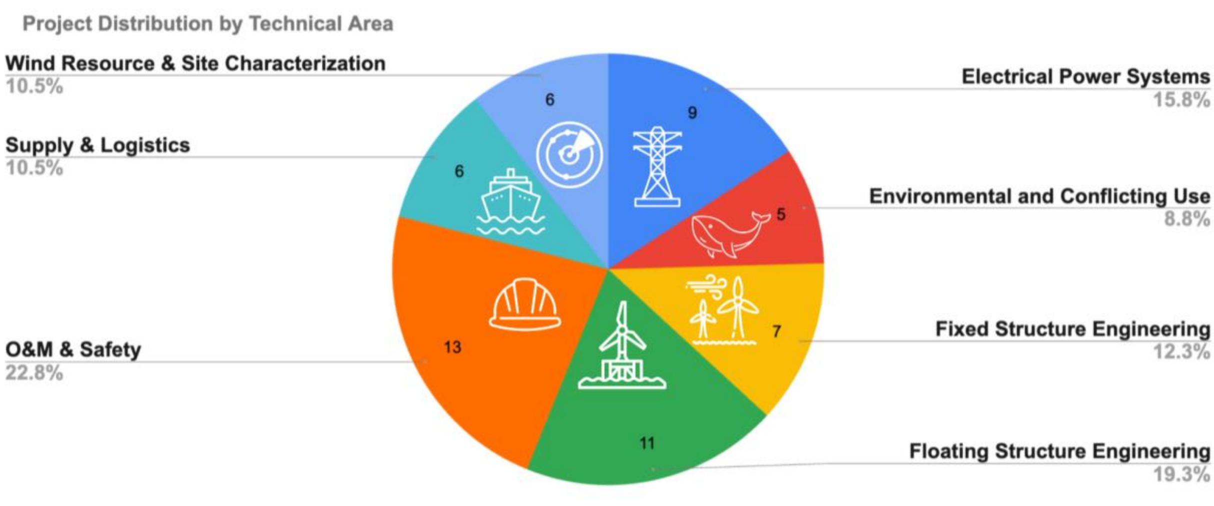

Figure 1: NOWRDC Technical Area Project Distribution

In addition to spanning a wide array of technical topic areas, NOWRDC's projects are geographically diverse. Project lead contractors, as well as subcontractors, are located across the United States. The following map indicates the number of project lead organizations and subcontractors in each state:

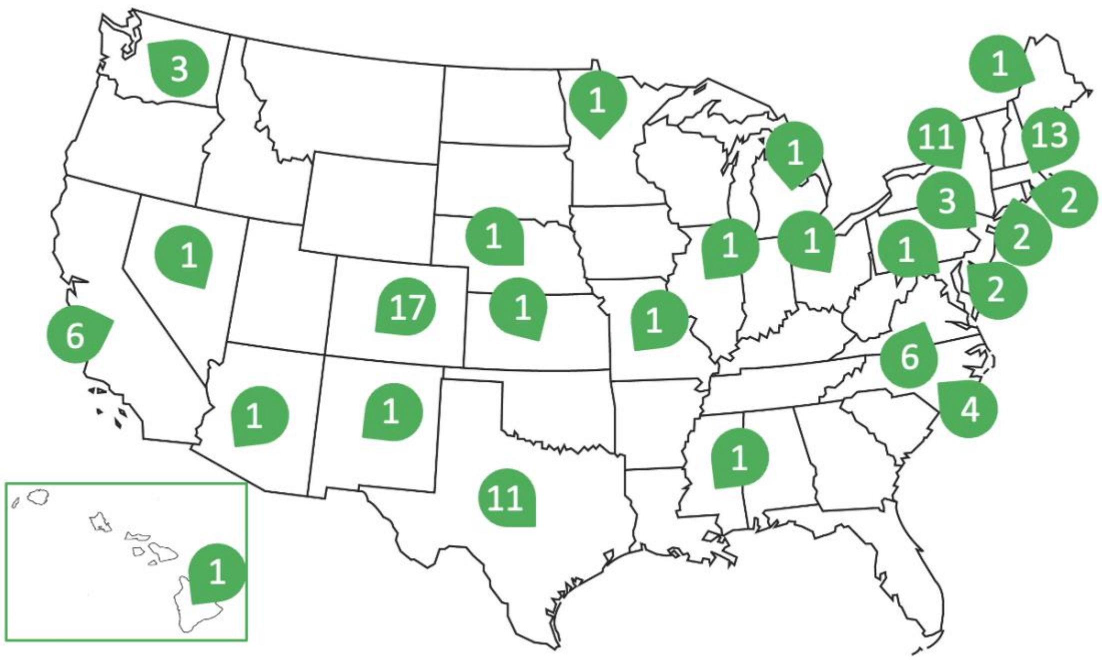

Figure 2: NOWRDC Geographic Project Distribution

1.3 NOWRDC LCOE Impact Analysis Overview

To date, 35 NOWRDC projects have reached completion. Through analysis of project results and tracking their ongoing commercial and technical progress, NOWRDC is able to evaluate the project portfolio's efficacy in lowering the levelized cost of offshore wind energy in the US.

As stewards of entrusted resources, we must ensure that our allocated funds lead to tangible benefits for both the organizations we support and the broader industry landscape. Given the dynamic socio-economic environment, the importance of rigorously evaluating our investments cannot be overstated. Therefore, we are committed to conducting comprehensive cost assessments of the projects we have financially supported. The primary objective of these assessments is to evaluate the broader impact of these initiatives on the industry, determining how our contributions have driven positive change, innovation, and growth.

NOWRDC has collaborated with the Carbon Trust to carry out this assessment. The Carbon Trust has over 16 years of experience managing offshore wind innovation and provides a neutral, third party validation of NOWRDC project portfolio. This document seeks to report on the assessment's methods and results as a resource to others who may be interested in the details of the models used, or about the methodology such that they may carry out a similar analysis or cite this work for other purposes.

In undertaking this assessment, we recognize that quantifying the value of social impact transcends financial metrics. While cost reductions are undoubtedly critical outcomes of these projects, we are equally committed to capturing the intangible yet invaluable contributions that our supported projects make towards fostering inclusivity, sustainability, and resilience within the industry ecosystem. An effort to capture these non-financial impacts has been carried out in parallel with this work, and is being distilled to highlight key findings. This includes individual review of the project reporting as well as individual interviews with all closed out NOWRDC projects. This effort has been partially captured on the "Our Impact" webpage released in conjunction with this work through the inclusion of project testimonials, and other sections of qualitative impact are planned for future revisions of the webpage.

Furthermore, this assessment report is not intended as a mere exercise in retrospective analysis. Rather, it serves as a cornerstone for informed decision-making, providing insights that will inform our future funding strategies, programmatic priorities, and partnerships. By distilling key learnings and best practices from our past endeavors, we work to enhance the efficacy and relevance of our interventions, ensuring resources are deployed effectively to maximize impact and advance our overarching mission.

1.4 Carbon Trust Capabilities and Track Record

The Carbon Trust has been at the forefront of the offshore wind Industry for over a decade, working closely with governments, developers, supply chains, and innovators to accelerate deployment and scale up of offshore wind. They support technology designers to reduce the cost of energy, deliver innovation programs to achieve cost and technology risk reduction, and work with governments to understand and implement offshore wind policy to create optimal and sustainable offshore wind markets. The Carbon Trust's case studies include detailed reviews and recommendations on offshore wind markets, focusing on: policy, technology and innovation, supply chain, infrastructure, skills, energy integration, and data, across both fixed and floating foundations. Notably, they have supported governments in Europe (Belgium, Denmark, Germany, Ireland, the Netherlands, UK), Asia (Bangladesh, China, India, Japan, Philippines, South Korea, Taiwan (China), Vietnam) the Americas (Caribbean countries, Colombia, US) and Africa (South Africa) to understand the various options for the development of offshore renewable energy, including the social and economic benefits available to the local communities and regions.

The Carbon Trust collaborates with governments, developers and industry stakeholders to access and expand the economic and social opportunities presented by offshore wind. Its work focuses on; **research and insight –intelligence** to inform market development, **strategic advice** – setting up optimal and sustainable market conditions, and **collaborative initiatives** – convening stakeholders to unlock barriers and scale up offshore wind.

The Carbon Trust combines unrivaled expertise in:

- **Delivering offshore wind technology assessment, economic and energy system modeling**, **and policy analysis** in various countries and regions with both developed and developing offshore renewables and other generation/enabling industries.
- **Recommending and designing effective policy** for the enhanced and sustainable deployment of offshore wind.
- **Ensuring just transition and social considerations underpin** our work across the developed and developing world.
- **Building opportunities for collaboration** by delivering program management and stakeholder engagement, designing and bringing together multi-sector or diverse actions

2 Model Approach and Assumptions

To model the LCOE impact of NOWRDC-funded innovations, NOWRDC and the Carbon Trust defined three hypothetical wind farms representative of the US market. We then applied the cost implications of selected NOWRDC funded innovations within the theoretical wind farms to evaluate the hypothetical impact of the innovation on the theoretical wind farm's LCOE.

The following modeling process and model assumptions were intentionally designed to be a reasonable middle of the road projection for the geographic areas that they represent. Sources for this information include NREL's Offshore Wind Market Assessment[1]

Modeling process:

- Baseline creation - Using publicly available data from a number of distinct sources, the key variables influencing the LCOE of an offshore wind farm were compared and accordingly a baseline wind farm was proposed. A number of industry collaborators then provided real variable ranges that they use for US calculations, to allow us to adjust the baseline to better fit industry expectations.

- Level of Detail - Granularity in the LCOE calculation was added as needed to incorporate cost changes from innovations. For example, if capital expenditures (CapEx) was reduced based on lower steel costs, the calculation would be refined to include the percentage of cost that steel contributes to CapEx in a typical farm, and then revised based on the innovation savings.

- Stakeholder agreement of the baseline - Data from Europe and the US were the primary sources that informed the baseline. The differences in the two markets were accounted for in refining the baseline wind farm and tailoring for the US market conditions. Stakeholder review and input was collected throughout the process to arrive at agreeable figures.

- Selection of a suitable portfolio of innovations - The innovations chosen for analysis were subject to specific criteria. These included the completion or near-completion of the project, the availability of adequate data from the innovators regarding the cost reduction potential of the innovations, and the feasibility of applying the portfolio concurrently on the baseline wind farms without constraint (as the innovations were not mutually exclusive).

- Investigation of the specific cost and/or efficiency/increase in AEP implications of each innovation - Via interviews with the innovators.

- Application of the cost implications and/or efficiency/increase in AEP of the innovations to the LCOE model - Having determined the cost implications with the innovators, this data was applied to the cost model to ascertain the impact on the LCOE.

- Sensitivity analysis - Each of the parameters that was varied was subjected to a sensitivity analysis.

[1] https://www.nrel.gov/wind/offshore-market-assessment.html

Model Assumptions:

- Baselines do not represent any particular physical location nor interconnection site - but costs are applied based on the understanding of available information for real wind farms in similar geographic areas.
- For all innovations - the technology/product has been fully commercialized and used/applied throughout the project lifecycle for the wind farm in question.
- A 15 MW turbine was used in this analysis given the near-term intended comparison and the observation of turbine models announced for US projects.

These assumptions coupled with the below highlighted comparison data (Table 1) yield the determination of the baseline data for the typical theoretical case, which we are referring to as nearshore fixed bottom.

Table 1: Public Source Baseline Comparison Data

Parameters	Units	Carbon Trust Analysis for NOWRDC	Guide to and Offshore Wind Farm, UK Data	Dominion published data	NREL, 2021 Cost of Wind Energy Review	GE Research (NYSERDA Project)
Wind Turbine Rating	MW	15	10	14.7	8	12
Discount Rate	%	3.0	6.0	3.6	5.29 (WACC)	2.3 (effective real)
Capacity Factor	%	50.0	51.05 effective	43.3	49.0 effective	47.0
Capital Expenditures (CapEx)	m$/MW	3.952	3.13	3.788	3.871	4.033
Operational Expenditures (OpEx)	k$/MW/yr	111.35	100.32	50	111	111.7
Net Annual Energy Produced (AEP)	MWh/MW/yr	4248	4471	3793	4292	3927
Number of Wind Turbines		100	100	176	Not given	Not given
LCOE	$/MWh	88.75	82.5	84	78	92.6

2.1 Baseline Scenario Downselection

To best represent current and near-term U.S. wind areas, we created 2 theoretical fixed bottom farms and 1 floating offshore wind farm compatible with the innovations intended for assessment. These farms were meant to represent a typical East Coast nearshore site (30 meters water depth, 30 miles from shore), a far-shore site (70 miles from shore with 60 m water depth) and a West Coast floating site (900-1000 meters of water depth, at 125 miles from shore). These distance and water depth parameters were taken from pipeline for lease areas (Fig. 3) for representative areas. The far-shore farm was included in the analysis particularly to accommodate the use of HVDC transmission enabling the assessment of a GE Research transmission project. The primary parameters of each case needed to create the cost models are presented in Table 2.

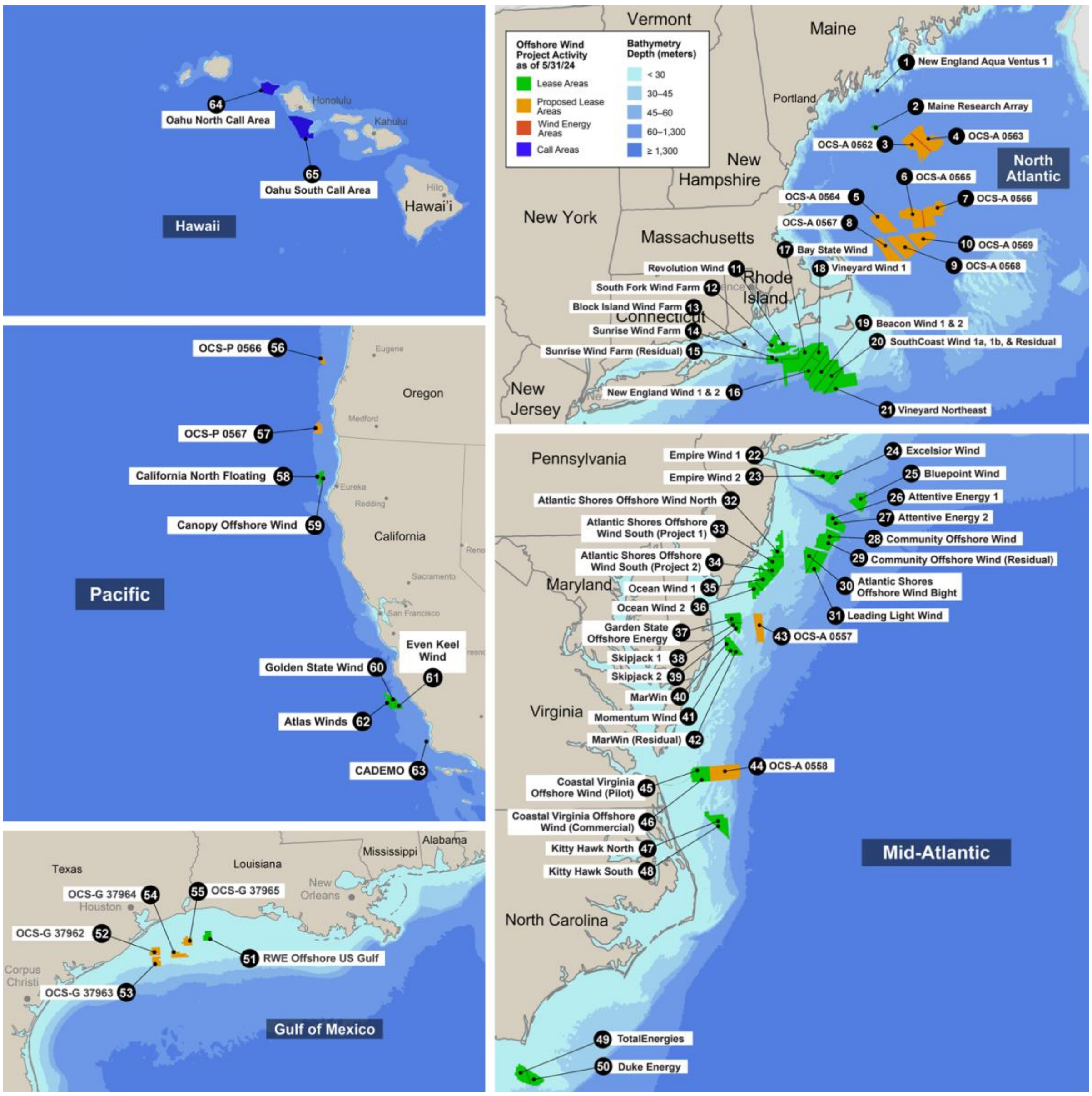

Figure 3: Locations of U.S. Offshore Wind Pipeline Activity and Call Areas (NREL Offshore Wind Market Report 2024 Edition [1 above])

2.1.1 Baseline Cost Assumptions for All Scenarios

Table 2: Baseline Cost Assumptions

Parameters	Units	Common	Nearshore Fixed	Farshore Fixed	Floating	Rationale
Wind Turbine rating	MW	15	-	-	-	Anticipated capacity for near-term full scale projects.
Discount Rate	%	-	6%	6%	6.5%	"Real" discount rate - higher for floating to reflect uncertainty.
COD	year	-	2030	2030	2035 *	* To represent first full scale projects.
Operational Life	years	35				A sensitivity analysis was undertaken around this value.
Distance from shore	miles	-	30	70	125*	* Taken as an approximation of the likely CA offshore sites distance to interconnection points and ports.
Water Depth	m	-	30	60	900 - 1000	Taken as an approximate average of the sites in the same distance from shore range
Number of Wind Turbines		100	-	-	-	

3 Analysis Description

3.1 Nearshore Fixed Bottom Scenario

3.1.1 Nearshore Fixed Bottom Baseline Farm

The nearshore case was set up to be a typically representative farm for the first round of US East Coast development. The distance to shore is set at 30 miles, and the water depth across the farm at 30m. 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 locking in the value for analysis. The results of this check are presented below in Figure 4.

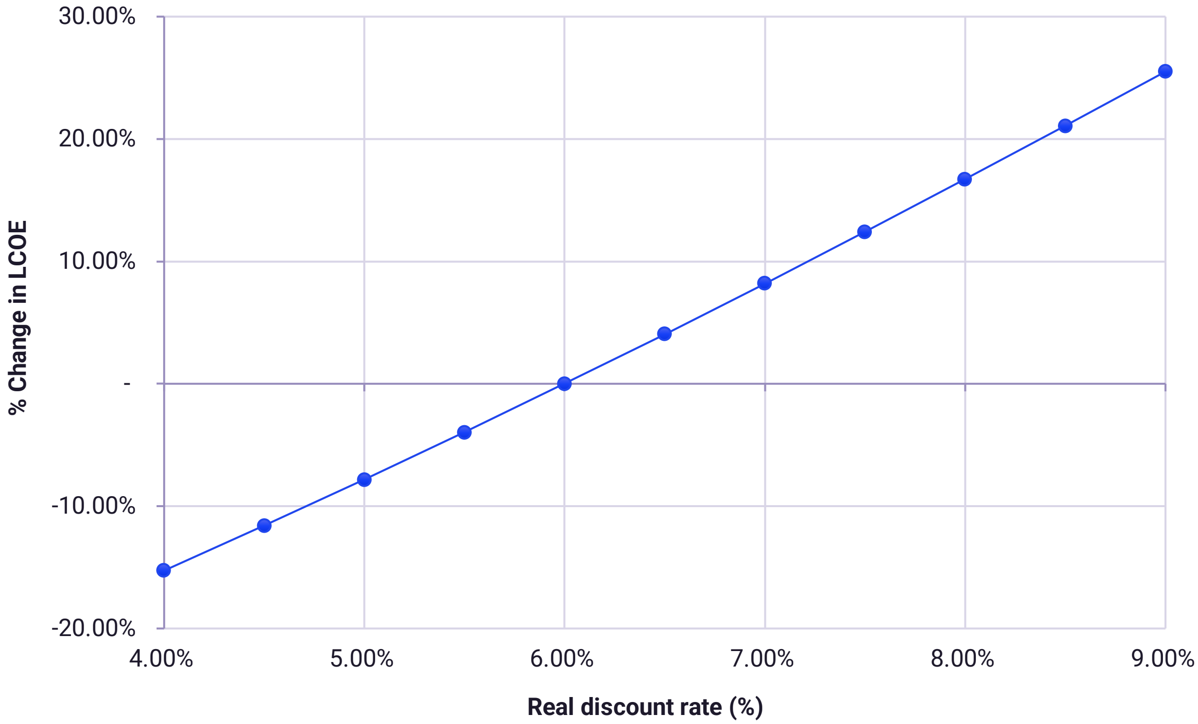

Figure 4: Nearshore Fixed Bottom Scenario - Sensitivity to Real Discount Rate

3.1.2 Innovation 1: Keystone Tower Systems - Tapered Spiral Welding for US Offshore Wind Turbine Towers[2]

Project Status

At the time of this version publication this project had not yet been completed.

[2] https://nationaloffshorewind.org/projects/tapered-spiral-welding-for-us-offshore-wind-turbine-towers/

Project Abstract

With this project, Keystone has partnered with major offshore wind turbine Original Equipment Manufacturers (OEMs) (GE and Vestas), major offshore wind developers Orsted and Equinor, structural/civil engineering experts at Johns Hopkins and Northeastern University, welding experts at Edison Welding Institute (EWI), and the wind installation vessel manufacturer GustoMSC, to investigate the potential and feasibility of multi-wrap steel wind towers, specifically in offshore applications. This investigation will proceed in two parallel tracks. In the first, Keystone and OEM partners will design spiral-welded offshore wind towers of the traditional, single-wrap type, where the entirety of the wall thickness comes from a solid steel plate. In the second track, Keystone will work with Northeastern and Johns Hopkins to computationally investigate the buckling and fatigue resistance of multi-wrap steel structures. The overall goal for these tasks is to establish a baseline level of performance of Keystone's spiral-welding technology in offshore applications, and to study and compare our experimental multi-wrap technology to that baseline.

Cost Analysis Considerations

The cost savings from this project are accounted for in the construction phase due to savings in materials, labor, equipment and shipping costs. The figure we cite from Keystone's project reporting is for total savings of $36,100 /MW installed. We use this value as the nominal value for the CapEx savings.

A sensitivity analysis was carried out that varies the total CapEx savings owing to Keystone's innovation to see the effect this has on the LCOE. The assumption being tested was that the variation of wind farm total CapEx savings ranges between $25k - $45k/MW.

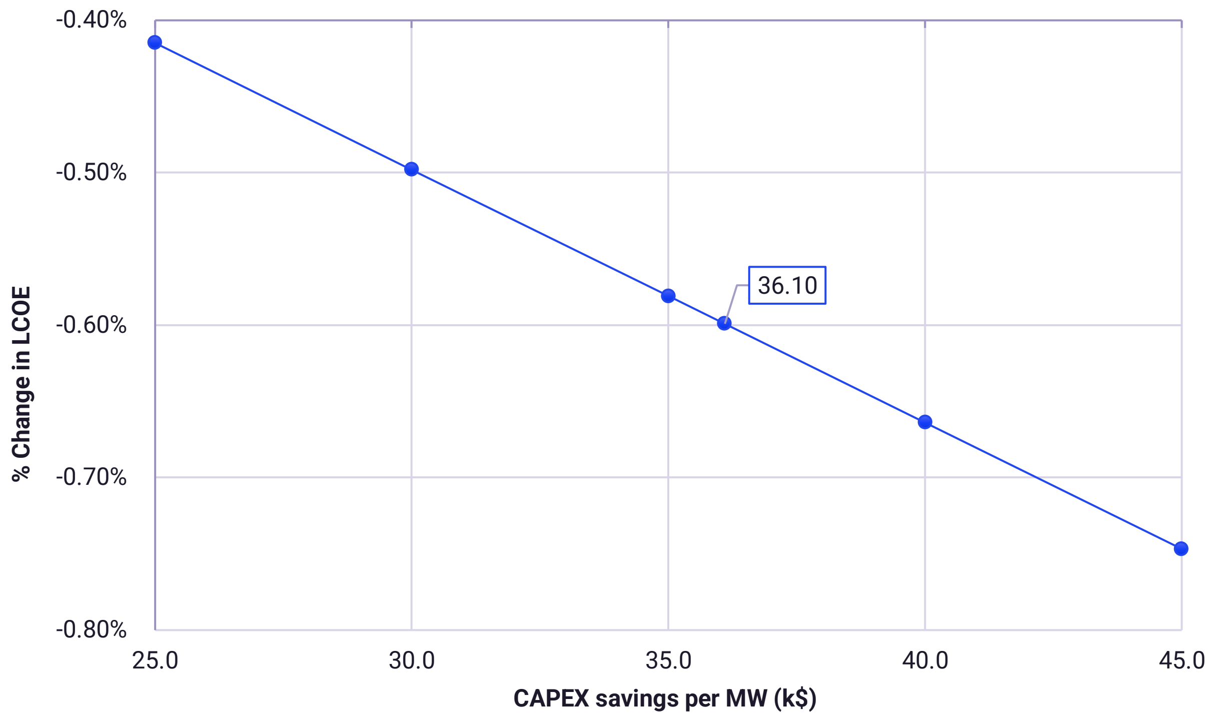

Figure 5: Innovation 1 - Sensitivity to CapEx Savings

3.1.3 Innovation 2: GE Renewable Energy - Self-Positioning Single Blade Installation Tool[3]

Project Status

This project was completed and closed out in Q3 of 2023. The project final report is live on the NOWRDC website in the project database.

Project Abstract

In this project, GE Renewables developed a new Single Blade Installation (SBI) tool which will use dual fans to control the blade position by counteracting environmental forces, thus eliminating the need for taglines. This will improve safety by eliminating tag lines running in the vicinity of workers as well as increasing the efficiency of offshore blade repairs (tag line system setup can take 12-24 hours in the offshore environment). General Electric will first design and construct an onshore field-scale prototype, and then conduct operational testing at an onshore wind farm in Lubbock, TX. After test data analysis, General Electric will undertake a conceptual design of the offshore-scale tool.

[3] https://nationaloffshorewind.org/projects/self-positioning-single-blade-installation-tool/

Cost Analysis Considerations

GE states that this technology achieves a savings of between $275k – $400k per installation. We use the mean value ($337.5k) as the nominal value around which the sensitivity analysis will be performed.

This innovation yields improvements in the CapEx, the OpEx and there is an AEP through reduced outage during maintenance. The CapEx savings are simply [Y x (number of turbines)]. OpEx saving is [Y x (number of turbines) x (failure probability)],where Y is the stated saving per operation.

The innovator estimated that approximately 1 day would be saved per maintenance operation. In practice this has a very small impact on the AEP thus most of the benefits come from CapEx and OpEx savings.

A sensitivity analysis was carried out to show how the LCOE varies against the saving per operation owing to GE's innovations. The assumption being tested is that the variation of saving per operation ranges between $275k - $400k. A mean failure rate of 0.155* is assumed; largely due to gearbox failures.

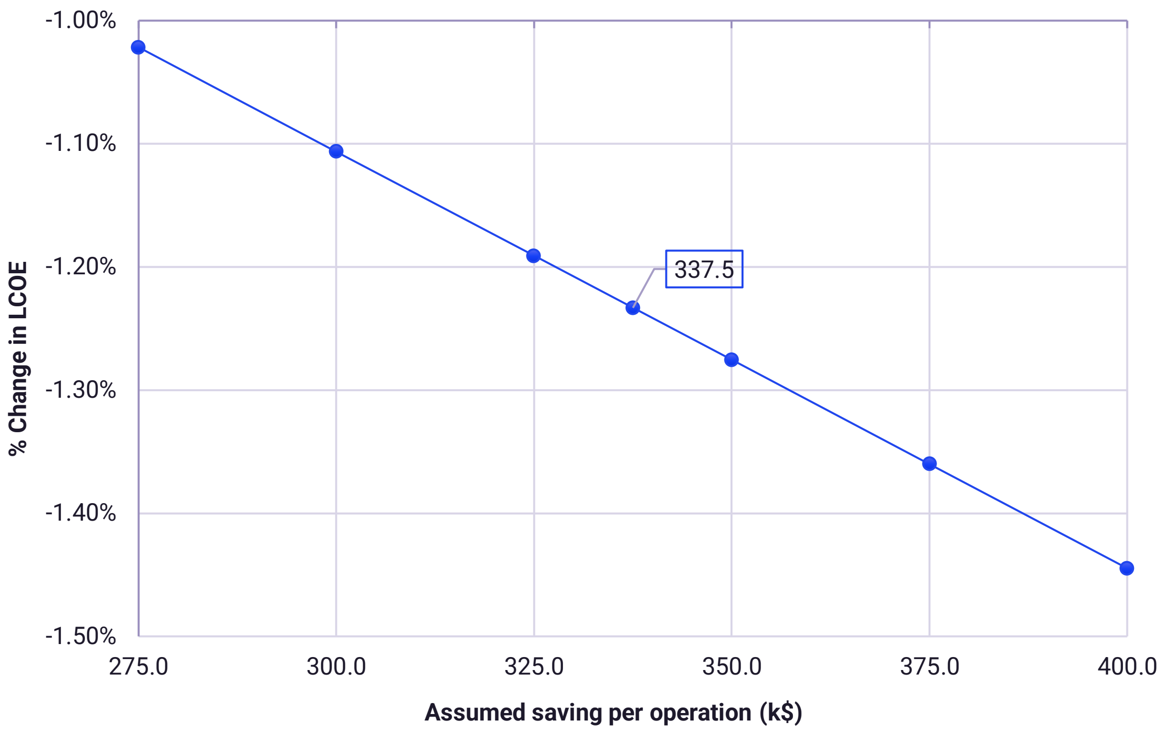

Figure 6: Innovation 2 - Sensitivity to Assumed Saving per Operation

3.1.4 Innovation 3: NREL - Wind Farm Control and Layout Optimization for U.S. Offshore Wind Farms[4]

Project Status

This project was completed and closed out in Q1 of 2023. The project final report is live on the NOWRDC website in the project database.

Project Abstract

In this project NREL developed and validated computationally efficient wind farm modeling and optimization tools and apply them to a detailed cost-benefit analysis. The project used high-fidelity modeling (HFM) tools to characterize offshore conditions for the U.S. and SCADA data from offshore wind farms in the EU. These were then used to calibrate the FLORIS engineering wake model for U.S. offshore conditions and apply the FLORIS tools to design and analyze optimal wind farm controllers and layouts for U.S. offshore locations. Finally, the project used cost-modeling tools to assess the impact from controls and layout optimization on LCOE for the U.S. offshore locations.

Cost Analysis Considerations

Using wake steering, NREL has shown how the output of a wind farm can be optimized. Their analysis has a 1.5% AEP increase as a conservative estimate of the increase for a hypothetical east coast project. A sensitivity analysis was carried out to show how the LCOE varies against the % increase in AEP owing to the application of wake steering in a wind farm. The assumption being tested is that the increase in AEP is assumed to range between 0.5% to 3%, with a nominal value of 1.5% owing to NREL's innovation.

[4] https://nationaloffshorewind.org/projects/wind-farm-control-and-layout-optimization-for-u-s-offshore-wind-farms/

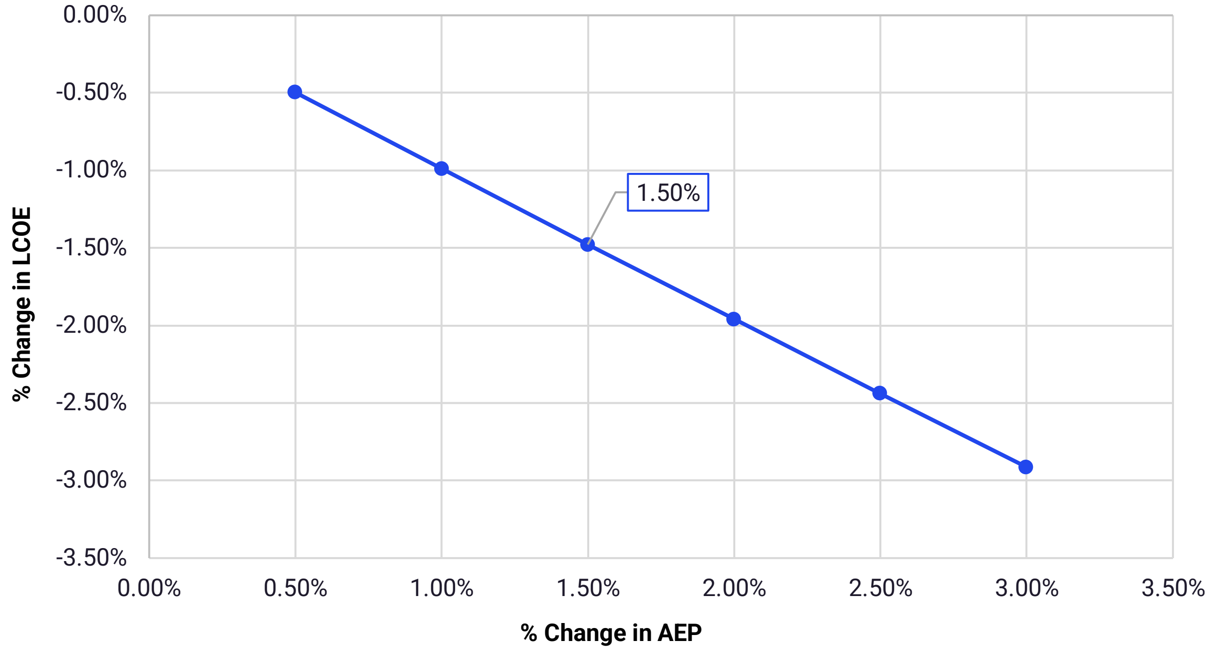

Figure 7: Innovation 3 - Sensitivity to % Increase in AEP through Wake Steering

3.1.5 Nearshore Fixed Bottom Scenario Conclusions

Based on the three applied innovations a potential increase in AEP of +1.59% and savings on LCOE of -3.15% has been calculated. The below figures have been normalized by removing the specific values for AEP and LCOE but it is included as a visual representation for the results.

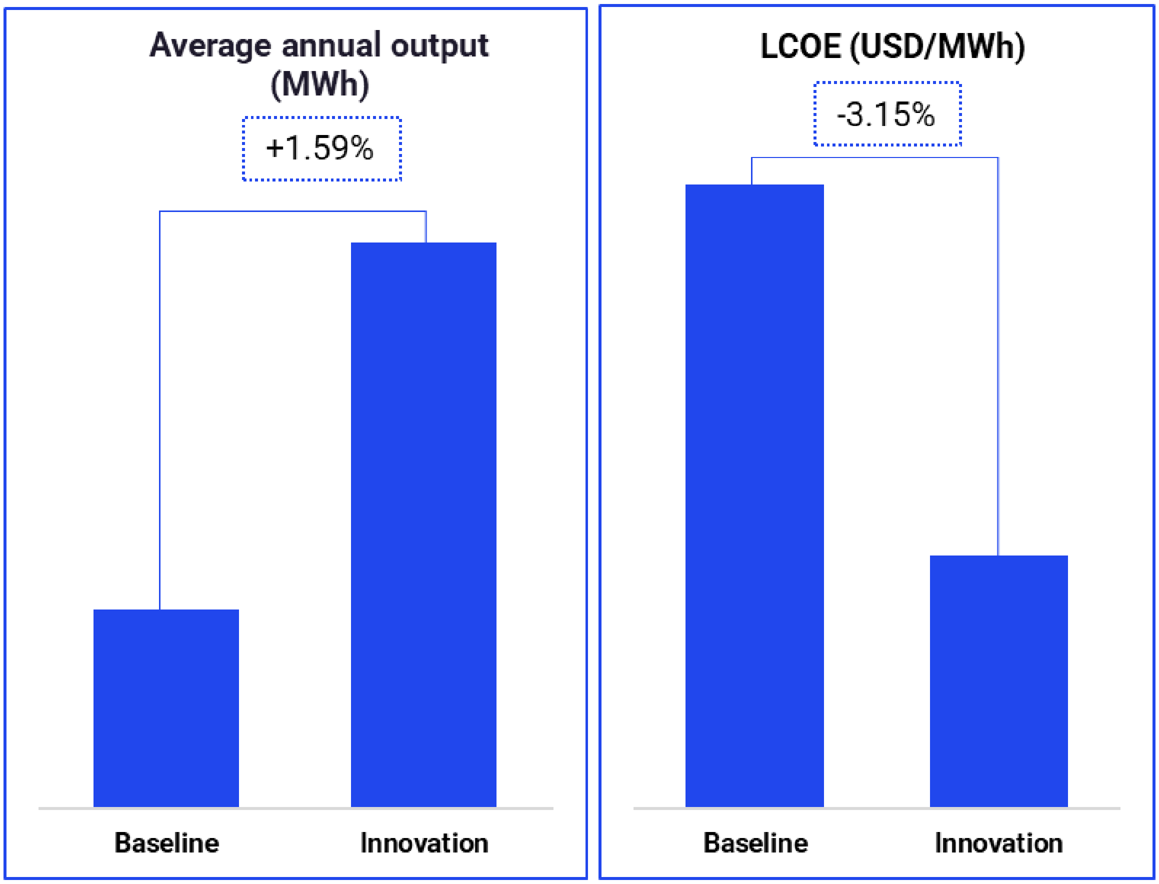

Figure 8: Combined Impact of All Innovations: Nearshore Fixed Scenario

3.2 Farshore Fixed Bottom Scenario

3.2.1 Farshore Fixed Bottom Baseline Farm

This farm layout replicates the nearshore case, but was shifted further away from land and into deeper water. This was done to help demonstrate the particular value of HVDC transmission in certain lease areas that fall within this distance from shore range (~70 m). For innovations, the three applied in the nearshore case are still applicable in this scenario, but we have added another which under NOWRDC funding investigated the cost implications of HVDC collection and transmission.

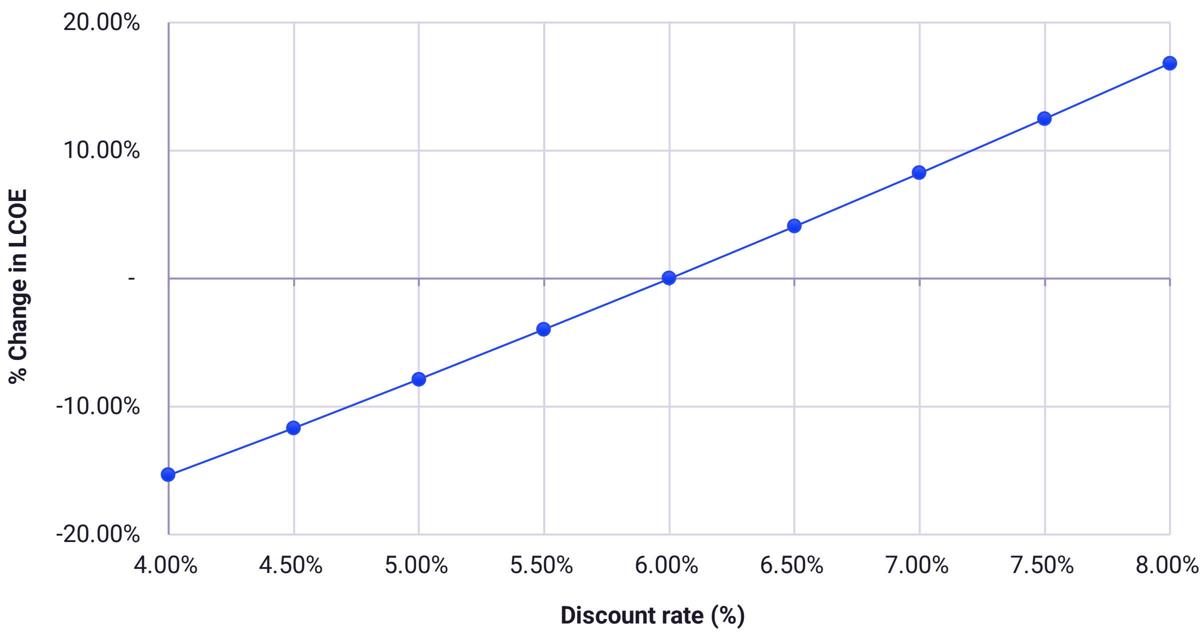

Figure 9: Farshore Fixed Bottom Scenario - Sensitivity to Real Discount Rate

3.2.2 Innovation #4: GE Research: DC Collection and Transmission for Offshore Wind Farms[5]

Project Status

This project was completed and closed out in Q1 of 2023. The project final report is live on the NOWRDC website in the project database section.

Project Abstract

In this project, GE Research sought to identify the most practical DC collector design and MVDC/HVDC converter topology (lowest CapEx and LCOE being driving metrics) to have an efficient, resilient, reliable and cost-effective collection and transmission system without the use of a DC circuit breaker. In order to do this GE examined different operating system voltages, turbine sizes and aggregation level, system configuration,

[5] https://nationaloffshorewind.org/projects/dc-collection-and-transmission-for-offshore-wind-farms/

converter topologies including isolated and non-isolated designs and ultimately down selected a preferred system architecture. Subsequently a system analysis was performed which included steady-state analysis, fault protection, overvoltage transient to specify the key components, estimate their costs and evaluate the LCOE generated by the proposed solution as compared to alternative solutions. Following the LCOE assessment a real-time simulation model was built to further demonstrate the system performance and validate the control architecture.

Cost Analysis Considerations

Using data provided by GE we estimated the impact of using HVDC transmission. Their project assessed the transmission efficiency increase if HVDC was to be implemented for transmission instead of HVAC, as is currently the plan for most US wind farms under development. Due to the change in technologies an efficiency gain is projected to be 1.9%. The project also estimates a 12% decrease in CapEx and OpEx costs due to the use of HVDC rather than HVAC. Due to the high uncertainty associated with achieving this projected savings we have not included this reduction as a part of our calculations.

For this innovation the sensitivity analysis was carried out with respect to assumed increase in transmission efficiency. Figure 10 shows how the LCOE varies against the assumed % efficiency increases owing to GE's HVDC innovations. With the assumption being that the variation of percent efficiency increase per year ranges between 0.5% - 3.5%.

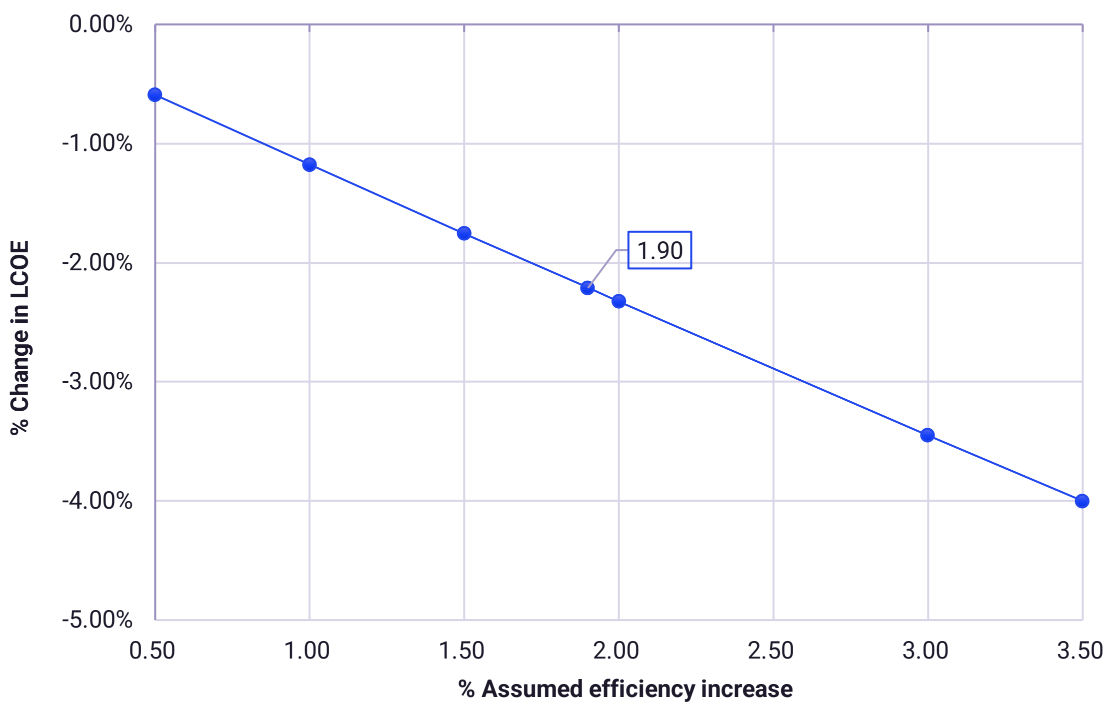

Figure 10: Innovation 4 - Sensitivity to increased efficiency due to fewer HVDC transmission losses

3.2.3 Farshore Fixed Bottom Scenario Conclusions

Based on the four applied innovations a potential increase in AEP of +3.86% and savings on LCOE of -4.90% has been calculated. The below figures have been normalized by removing the specific values for AEP and LCOE but it is included as a visual representation for the results.

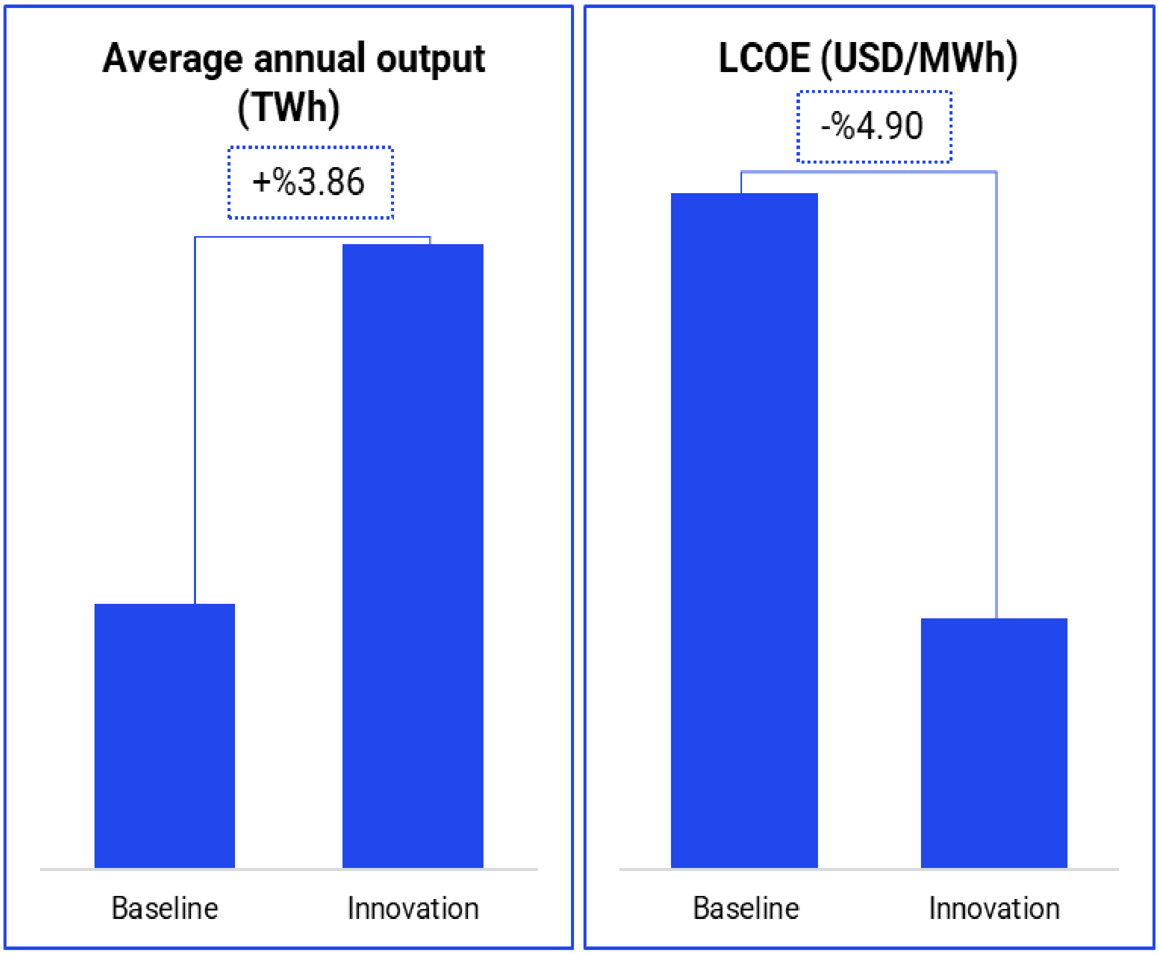

Figure 11: Combined Impact of All Innovations: Farshore Fixed Scenario

3.3 West Coast Floating Scenario

3.3.1 West Coast Floating Baseline Farm

The theoretical floating farm was designed to be representative of a typical US West Coast lease area, with a water depth of (900-1000m). The "distance to shore" for this case is set at 125 miles to represent the point of interconnect-farm distance which is likely to be larger than the direct shore-farm distance due to the typically larger farm to load center spacing on the West Coast. Another key aspect of this scenario is that the construction year is set at 2035 to represent when it is predicted that the first fully commercial farms will be going into construction on the west coast. As was done with the other cases, the discount rate sensitivity has been checked for this scenario and is presented below in Figure 12.

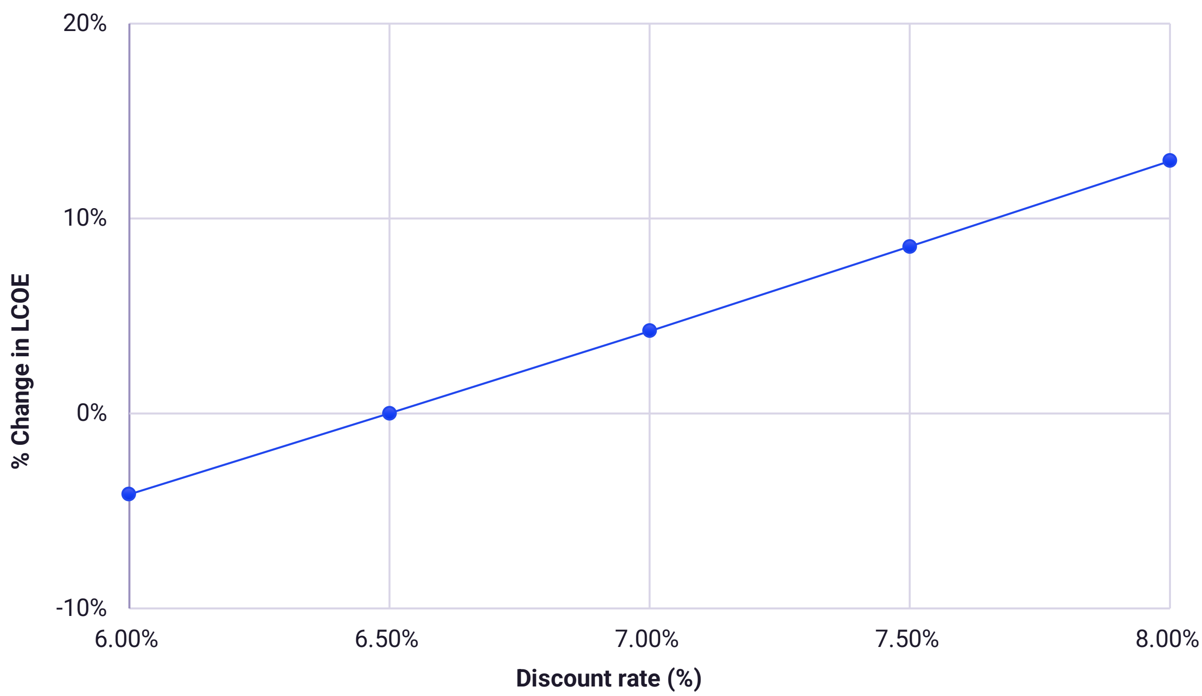

Figure 12: West Coast Floating Scenario - Sensitivity to Real Discount Rate

3.3.2 Innovation 5: ESTEYCO - Evolved Spar Concrete Substructure for Floating Offshore Wind US-Based Design[6]

Project Status

This project was completed and closed out in Q4 of 2023. The project final report is live on the NOWRDC website in the project database.

[6] https://nationaloffshorewind.org/projects/evolved-spar-concrete-subconstructure-for-floating-offshore-wind-us-based-design/

Project Abstract

The commercial trend of increasing size and weight of offshore wind turbines imposes challenges to the design and manufacturing of the support structures. This issue becomes more pronounced in the U.S. where the lack of a developed supply chain adds additional constraints. The WHEEL (formerly TELWIND) platform technology for floating wind has the potential to overcome these issues, to achieve a lower overall cost, while ensuring suitability for the specific conditions of U.S. offshore wind regions installations and future turbine designs.

This project carried out analysis of the WHEEL technology to show that it is suitable for the U.S. market, for upscaling to larger turbine sizes, and that it can be manufactured in series with local means in commercial harbors, thus facilitating the advancement of U.S. manufacturing capabilities. With these attributes and the advances in this project, the WHEEL floating design shall enable near-term access to the U.S. wind resource waiting beyond 60m water depth (DOE's recent estimate cites this area at approximately 2/3rd of what is available for development[7]).

Cost Analysis Considerations

Esteyco claims that their innovation reduces the cost of foundation, moorings and anchors (substructure) by 40%. Using data in the public domain, we estimate that these costs represent approximately 30% of overall project CapEx costs. Hence the overall reduction in the CapEx due to using the Esteyco innovation is 9%. For the sensitivity analysis, the graph. Figure 13, shows how the LCOE varies against the assumed percentage reduction in foundation and moorings costs varies between 20 – 40%.

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[7] https://www.energy.gov/eere/wind/floating-offshore-wind-shot#:~:text=About%20two%2Dthirds%20of%20U.S.,largest%20humankind%20has%20ever%20constructed.

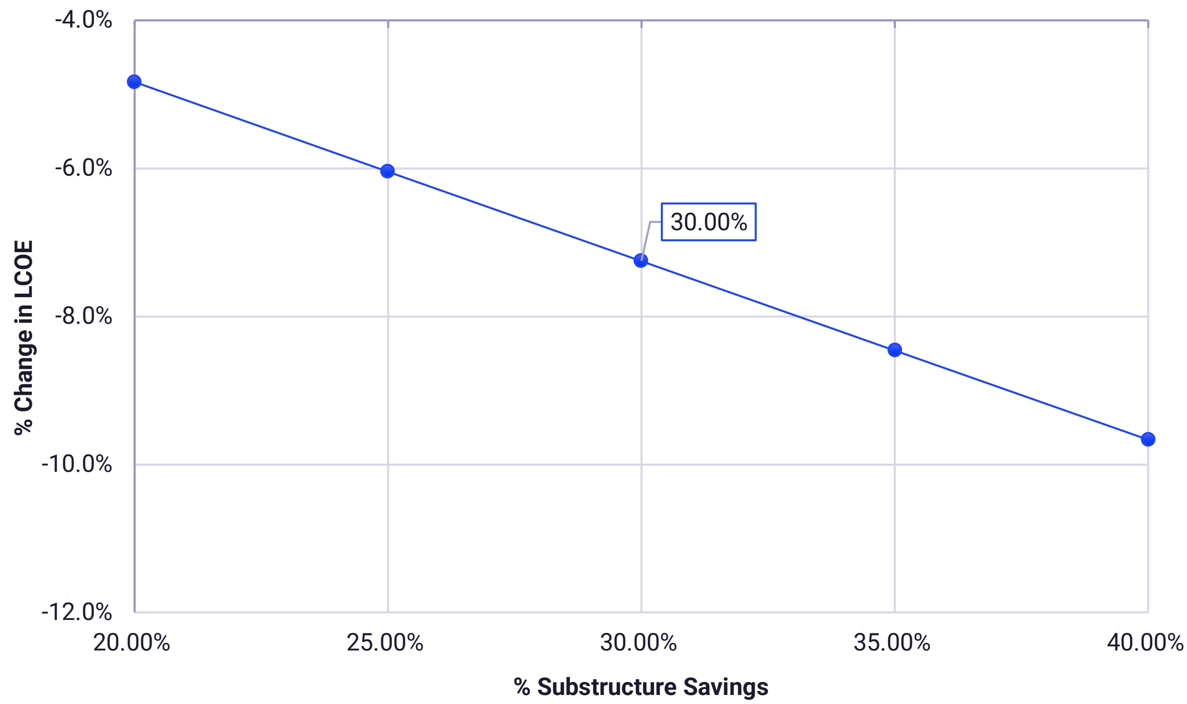

Figure 13: Innovation 5 - Sensitivity to % decrease in Substructure Costs

3.3.3 Innovation 6: Triton - Innovative Anchoring System for Floating Offshore Wind[8]

Project Status

This project was completed and closed out in Q2 of 2023. The project final report is live on the NOWRDC website in the project database.

Project Abstract

In order to address the challenges associated with anchoring floating offshore wind turbines, Triton is developing a novel offshore wind turbine anchoring system. The technology operationalizes the use of a helical-structured anchor to meet floating offshore wind requirements while reducing fabrication and installation costs. In this project, the Triton team designed the anchor, tested it at pilot scale, and conducted capacity tests to assess its subsea performance potential.

Cost Analysis Considerations

Triton provided us with information stating that their innovation would reduce the cost of anchors and anchor installation by 25% – 50%. Using data in the public domain, we estimated that anchor and anchor

[8] https://nationaloffshorewind.org/projects/innovative-anchoring-system-for-floating-offshore-wind/

installation represents 3.15% of overall project CapEx costs. Hence the overall reduction in the CapEx due to using the Triton innovation is between 0.63% and 1.57%. Figure 14 presents the sensitivity analysis which shows how the LCOE varies against the assumed percentage reduction in anchoring cost.

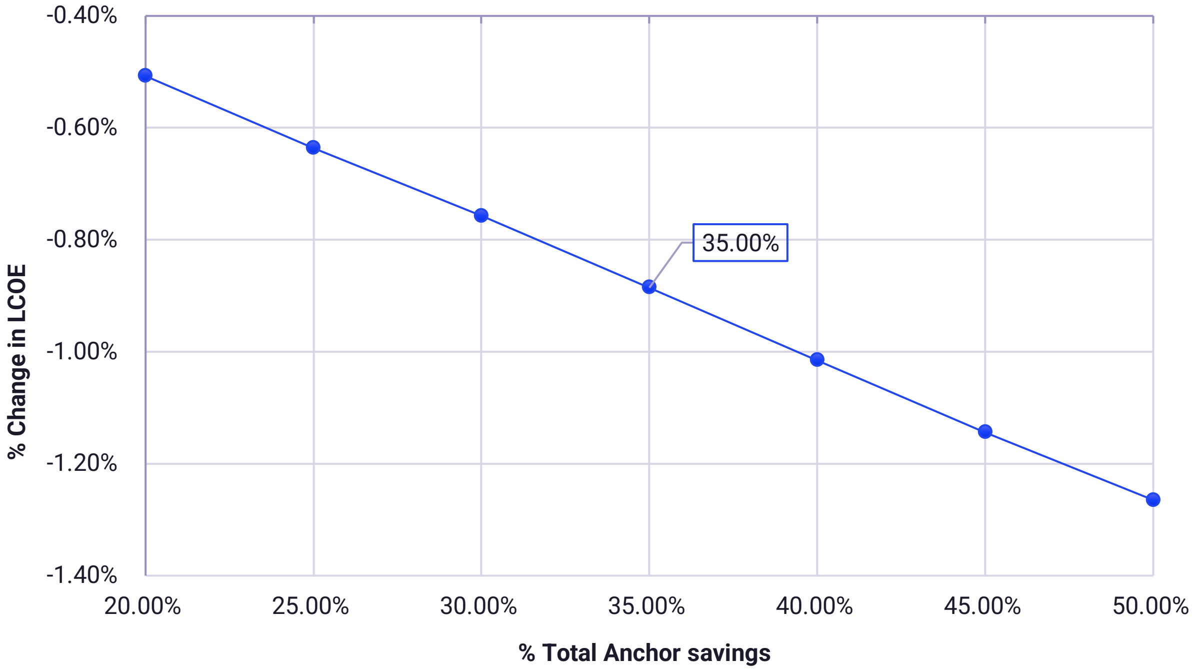

Figure 14: Innovation 6 - Sensitivity to % Decrease in Anchor and Anchor Installation Costs

3.3.4 West Coast Floating Scenario Conclusions

Based on the three applied innovations a potential increase in AEP of +1.5% and savings on LCOE of -9.49% has been calculated. The below figures have been normalized by removing the specific values for AEP and LCOE but it is included as a visual representation for the results.

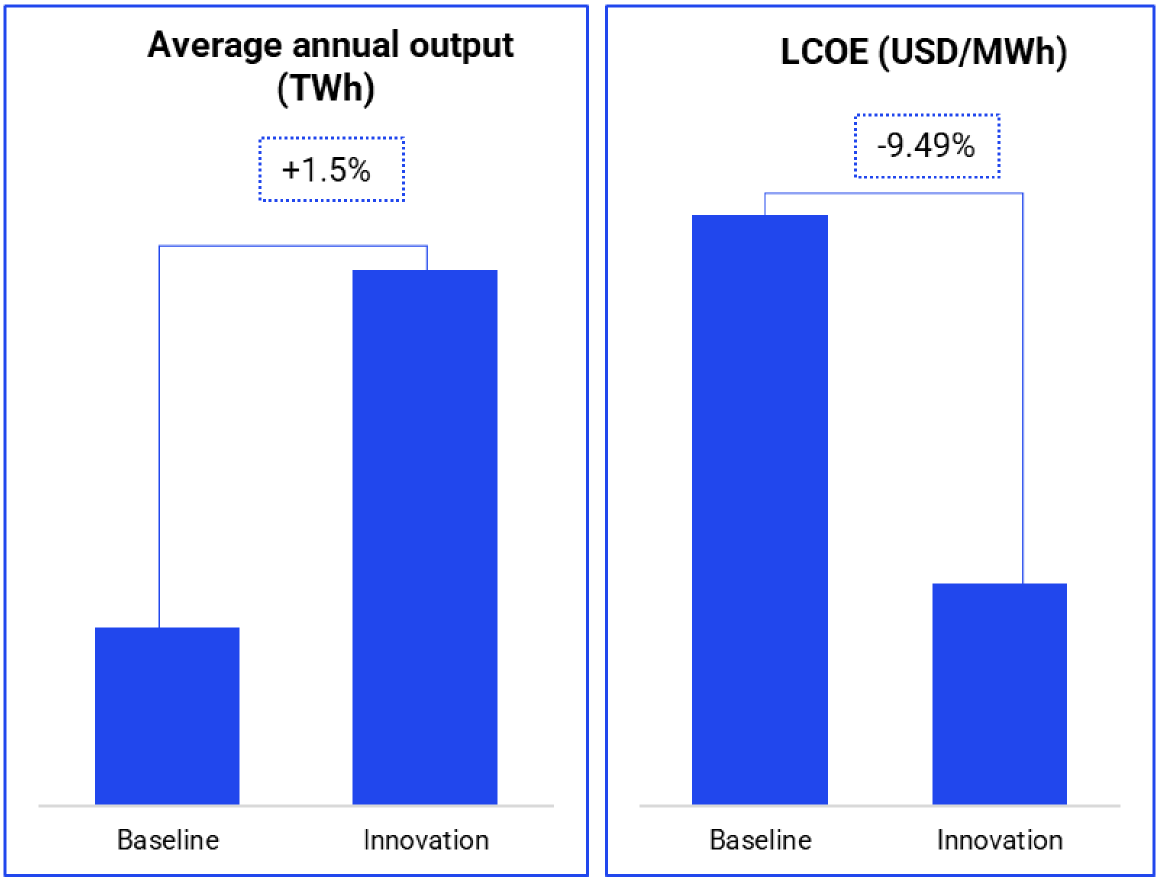

Figure 15: Combined Impact of All Innovations: Floating Scenario

4 Summary

Through this metrics assessment exercise we have been able to provide a high level takeaway about the impact of the innovations supported by NOWRDC funding. These results show that the US innovation landscape is strong and varied, and with the right support a tangible impact on the US Offshore wind industry can be achieved. NOWRDC provides a targeted and impactful source of funding across many technical areas and to entities across the nation, whose research is the key to being able to arrive at these results. While this captures just a small portion of our portfolio we can very clearly see the potential impact that innovation can have on this industry.

1.1 Key Results and Implications

By applying innovations against baseline theoretical wind farms, each yielded tangible cost savings and efficiency gains. Cost reductions were achieved through decreased LCOE, increased AEP, OpEx and CapEx reduction. The assessment demonstrated notable reductions in the LCOE across all scenarios. Nearshore fixed bottom scenarios achieved LCOE reductions of up to 3.15%, farshore fixed bottom scenarios saw reductions up to 4.90%, and floating scenarios experienced reductions up to 9.49%. All scenarios reported increases in AEP. Nearshore scenarios saw AEP increases of up to 1.59%, farshore scenarios up to 3.86%, and floating scenarios up to 1.5%. These results point to the real potential that the NOWRDC selected portfolio presents to the US Offshore wind industry at large, and provides insights into how innovations in general contribute to improving project economics as measured by macro metrics such as LCOE and AEP. They also provide insights into how innovations contribute to improving project economics as measured by macro metrics such as LCOE and AEP.

According to our results, the implementation of innovative technologies significantly enhances the efficiency and cost-effectiveness of offshore wind farms. These underscore the importance of strategic planning in wind farm design incorporating innovations to maximize economic and operational benefits. A comprehensive and methodical approach to modeling and sensitivity analysis is essential for accurately assessing the impact of these innovations. This report represents a first step to such methodological approach.

Broadly, our findings demonstrate the potential for substantial cost reductions and efficiency gains through innovative technologies which can guide policymakers and stakeholders in making informed decisions about future investments. This, in turn, can attract more investment into offshore wind, promoting its growth and contributing to the establishment of the industry. The development and deployment of these innovations create new economic opportunities, including job creation and technological advancements, which, in alignment with NOWRDC's mission, benefit both local and national economies.

1.2 Future Plans and Next Steps

This was the first iteration of this analysis, and updates and revision are anticipated for the future. We anticipate being able to add even more impactful innovations into this broader analysis as the consortium's closed out project portfolio grows. Updates may include new baseline areas, such as the Gulf of Maine, where more geographically specific technologies may provide an increased impact. If you are interested in helping us with this work in the future please reach out to Julian Fraize, at julian.fraize@nationaloffshorewind.org.

5 References

National Renewable Energy Laboratory (NREL): Offshore Wind Market Assessment. https://www.nrel.gov/wind/offshore-market-assessment.html. 2024.

National Offshore Wind Research and Development Consortium Project Database. https://nationaloffshorewind.org/project-database/. 2024.

DOE Floating Offshore Wind Shot. https://www.energy.gov/eere/wind/floating-offshore-wind-shot#:~:text=About%20two%2Dthirds%20of%20U.S.,largest%20humankind%20has%20ever%20constructed. 2023