NATIONAL OFFSHORE WIND
RESEARCH & DEVELOPMENT CONSORTIUM

ROADMAP 5.0

2026

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ACKNOWLEDGMENTS

The Roadmap Version 5.0 for the National Offshore Wind Research and Development Consortium (NOWRDC), prepared under the direction of NOWRDC Executive Director Lyndie Hice-Dunton was produced with assistance from NOWRDC's technical team of offshore wind experts from the Carbon Trust. The NOWRDC's various advisory group members and offshore wind developers serving on NOWRDC's Research and Development Committee provided input. The primary authors are Christine Sloan and the Carbon Trust.

Version History

Initial Release (Version 1.0)……………………………..………………November 2018

Version 2.0…………………………………………………………………….October 2019

Version 3.0…………………………………………………………………….June 2021

Version 4.0…………………………………………………………………….April 2023

Version 5.0…………………………………………………………………….September 2026

EXECUTIVE SUMMARY

The U.S. offshore wind industry is at a critical inflection point. Project development has slowed due to rising capital costs, supply chain constraints, permitting complexity, and policy uncertainty. These challenges have increased risk and delayed timelines. At the same time, long-term fundamentals remain strong. Electricity demand is projected to grow significantly[1], driven by electrification, advanced manufacturing, and data center expansion. Offshore wind remains one of the few scalable, domestic energy resources capable of meeting this demand while supporting grid reliability, energy security, and economic growth.

In this context, strategic investment in research and development (R&D) is essential. Offshore wind cost reductions have historically been driven by innovation[2], not by deployment alone. Today's market conditions present an opportunity to reduce cost, address technical uncertainty, and improve project economics through targeted R&D. Without continued investment, the U.S. risks higher long-term costs, slower deployment, and reduced global competitiveness.

"Offshore wind cost reductions have historically been driven by innovation, not by deployment alone."

The National Offshore Wind Research and Development Consortium (NOWRDC) plays a central role in advancing this innovation agenda. By convening states, industry, innovators, and federal partners, NOWRDC funds high-impact research that addresses shared challenges and accelerates commercialization. This coordinated approach maximizes the impact of public and private investment while reducing duplication and risk.

NOWRDC's portfolio demonstrates that targeted R&D delivers measurable results, including reductions in levelized cost of energy (LCOE) and improvements in annual energy production (AEP)[3]. These outcomes directly enhance project bankability, reduce investor risk, and support scalable deployment.

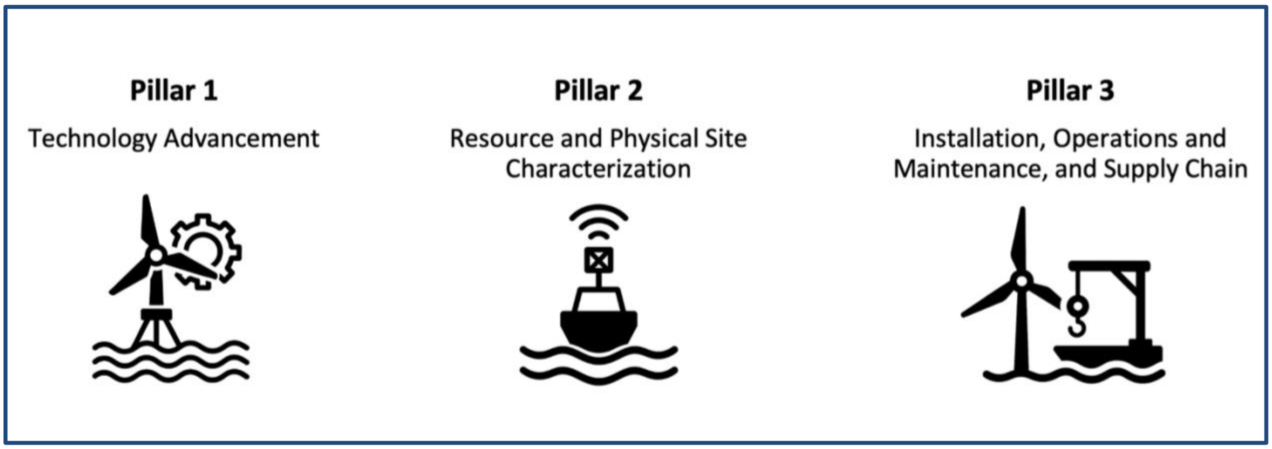
This Roadmap provides a strategic framework to guide future R&D investment across three priority areas:

- **Pillar 1: Technology Advancement** focuses on reducing capital cost and improving system performance through innovation in turbines, floating systems, electrical infrastructure, and

[1] International Energy Agency, "Electricity 2026 – Demand," 2026, https://www.iea.org/reports/electricity-2026/demand.
[2] IEA Wind Technology Collaboration Programme, "Task 26: Cost of Wind Energy," accessed July 2026, https://iea-wind.org/task26/.
[3] NOWRDC and Carbon Trust, "Impact Metrics Quantitative Analysis, Version 2.0," June 2026, https://nationaloffshorewind.org/wp-content/uploads/NOWRDC-Impact-Metrics-Quantitative-Analysis-Version-2.0-1.pdf.

coexistence technologies. These advances enable deployment in deeper waters and more complex environments.

- **Pillar 2: Resource and Physical Site Characterization** addresses key sources of uncertainty through improved metocean data, environmental sensing, and modeling. Reducing data gaps strengthens project design, supports better siting decisions, and advances understanding of offshore oceanographic systems.
- **Pillar 3: Installation, Operations and Maintenance, and Supply Chain** targets lifecycle cost reduction and scalability through installation innovation, digital and remote operations, infrastructure planning, and workforce development. These efforts improve reliability, reduce offshore exposure, and support long-term industry growth.



Across all pillars, the Roadmap emphasizes a systems-based approach. Many offshore wind innovations (e.g., floating platforms, advanced sensing, and grid integration tools) serve as shared infrastructure for the broader marine economy, delivering value across sectors such as maritime operations, ocean monitoring, and national security.

The need for coordinated action is immediate. Without targeted investment, the U.S. faces continued delays, higher costs, and increased reliance on foreign supply chains. Strategic R&D investment offers a clear path to reduce risk, unlock private capital, and accelerate deployment.

This Roadmap provides a framework to maximize impact. Investment in these priorities will reduce risk and uncertainty, strengthen domestic capabilities, enhance energy security, and expand U.S. opportunities in the evolving offshore wind and broader energy economy. NOWRDC and its partners are uniquely positioned to lead this effort. Sustained, coordinated investment today will determine the pace, cost, and competitiveness of offshore wind deployment in the years ahead.

This Roadmap is both a technical guide and a call to action. By investing in the priorities outlined here, funders and policymakers can reduce uncertainty, accelerate progress, and unlock the full potential of offshore wind as a cornerstone of the U.S. energy system and marine economy.

INTRODUCTION

Powering the Future: Overcoming Headwinds

The U.S. offshore wind industry is in a period of adjustment. After years of rapid momentum driven by state procurement targets, federal leasing, and private investment, project development has slowed amid rising capital costs, supply chain constraints, permitting timelines, and policy uncertainty, prompting major developers like EDP[4] and RWE[5] to pause development or exit the U.S. market.

These near-term challenges do not change the industry's long-term fundamentals; offshore wind remains one of the few large-scale domestic energy resources capable of driving grid modernization and reliability, diversifying domestic energy generation, and supporting energy independence, while addressing increasing energy demand.

Electricity demand in the U.S. is expected to grow significantly over the coming decades. Electrification of transportation and buildings, advanced manufacturing, and the expansion of artificial intelligence (AI) data centers are projected to increase electricity consumption by 35–50% between 2024 and 2040[6]. More recent federal outlooks are somewhat more measured but confirm the same trend: the U.S. Energy Information Administration projects consumption growing 0.9–1.6% annually through 2050[7], while the International Energy Agency projects U.S. demand rising roughly 2% annually through 2030[8], with data centers a leading driver in both. Offshore wind represents an important opportunity to meet this demand with reliable, domestic generation.

At the same time, substantial progress continues across the country. More than $25 billion has been invested in ports, vessels, manufacturing facilities, and research infrastructure to support offshore wind development[9], and roughly 40 federal offshore wind leases have been awarded since 2018[10], though a number have recently been surrendered amid shifting federal policy[11]. More than 16 GW of projects

[4] reNEWS, "EDP Pauses Three US Offshore Wind Projects," April 16, 2026, https://renews.biz/111109/edp-pauses-three-us-offshore-wind-projects/.

[5] reNEWS, "RWE Ending US Offshore Operations," April 25, 2025, https://renews.biz/100227/rwe-ending-us-offshore-operations/.

[6] American Clean Power Association, "U.S. National Power Demand Study," Executive Summary, March 2025, https://cleanpower.org/wp-content/uploads/gateway/2025/03/US_National_Power_Demand_Study_2025_ExecSummary_FINAL-v2.pdf.

[7] U.S. Energy Information Administration, "Annual Energy Outlook 2026," April 8, 2026, https://www.eia.gov/outlooks/aeo/.

[8] International Energy Agency, "Electricity 2026 – Demand," 2026, https://www.iea.org/reports/electricity-2026/demand.

[9] Oceantic Network, "Offshore Wind by the Numbers," accessed July 2026, https://oceantic.org/.

[10] Bureau of Ocean Energy Management, "Lease and Grant Information," accessed July 2026, https://www.boem.gov/renewable-energy/lease-and-grant-information.

[11] Congressional Research Service, "Offshore Wind: Status and Issues for the 119th Congress," IF13034, updated April 28, 2026, https://www.everycrsreport.com/reports/IF13034.html.

remain under contract[12], and several commercial-scale projects — including South Fork Wind, Vineyard Wind 1, Revolution Wind, and Coastal Virginia Offshore Wind — are now delivering electricity to the grid[13].

The past year has also brought continued volatility in federal policy. Since early 2025, new federal offshore wind leasing and permitting have been paused, several developers have surrendered leases in exchange for federal reimbursement, and multiple in-construction projects received temporary stop-work orders that were later lifted by federal courts[14]; litigation over several of these actions remains ongoing. At the same time, state-level procurement targets, permitting support, and infrastructure investment have continued in many regions, underscoring sustained regional commitment to offshore wind even as federal posture shifts.

Periods of decelerated deployment are common in emerging energy industries and often provide an opportunity to advance innovation that reduces cost and technical risk. Continued investment in research and development during these periods helps strengthen supply chains, improve system reliability, and prepare the industry for the next phase of growth.

The National Offshore Wind Research and Development Consortium (NOWRDC) plays a central role in this effort. By convening states, federal partners, industry, and research institutions, NOWRDC supports collaborative research that accelerates innovation and addresses cross-sector technical challenges.

Sustained investment in research, infrastructure, and collaboration is essential to navigating current market uncertainty and ensuring offshore wind remains positioned to contribute to the nation’s long-term energy, economic, and technological leadership.

NOWRDC and the Roadmap

NOWRDC was established in 2018 as a not-for-profit, public–private partnership dedicated to advancing offshore wind and related sector innovation in the U.S. Through competitive research funding and collaboration across industry, innovation, and government, NOWRDC supports high-impact projects that reduce technical risk, improve system reliability, and strengthen domestic supply chains.

Initial funding for NOWRDC was provided by the U.S. Department of Energy (DOE) and the New York State Energy Research and Development Authority (NYSERDA), with additional support provided by the Commonwealths of Virginia and Massachusetts and the States of California, Maine, Maryland, and New Jersey.

[12] Oceantic Network, “Offshore Wind by the Numbers,” accessed July 2026, https://oceantic.org/.
[13] Utility Dive, “Coastal Virginia Offshore Wind Begins Delivering Power,” March 26, 2026, https://www.utilitydive.com/news/coastal-virginia-offshore-wind-begins-delivering-power/815874/.
[14] Congressional Research Service, “Offshore Wind: Status and Issues for the 119th Congress,” IF13034, updated April 28, 2026, https://www.everycrsreport.com/reports/IF13034.html.

Since its launch, NOWRDC has awarded over 65 research projects across six competitive solicitations, representing over $67 million in grant funding and additional leveraged investment. In addition to its project portfolio, NOWRDC is a founding partner of the Offshore Wind Innovation Hub (OWIH)[15], which provides a collaborative platform to accelerate early-stage technology development and industry engagement. The OWIH complements NOWRDC's competitive funding model by fostering targeted innovation, knowledge exchange, and cross-sector coordination, together strengthening the pipeline from research to deployment and expanding opportunities for emerging technologies to advance toward commercialization. NOWRDC's funded projects span technology development, system integration, environmental monitoring, and grid innovation, and are supported through collaboration with industry partners, research institutions, and government stakeholders.

NOWRDC convenes multiple advisory and coordination bodies, including its R&D Committee, R&D Advisory Group (RDAG), and State Action Network (SAN), to ensure research priorities reflect industry needs, policy objectives, and emerging technical challenges. Figure 1 illustrates this process: NOWRDC identifies the shared challenges facing the industry, funds targeted research to address them, translates results for decision-makers, and enables adoption across the sector.

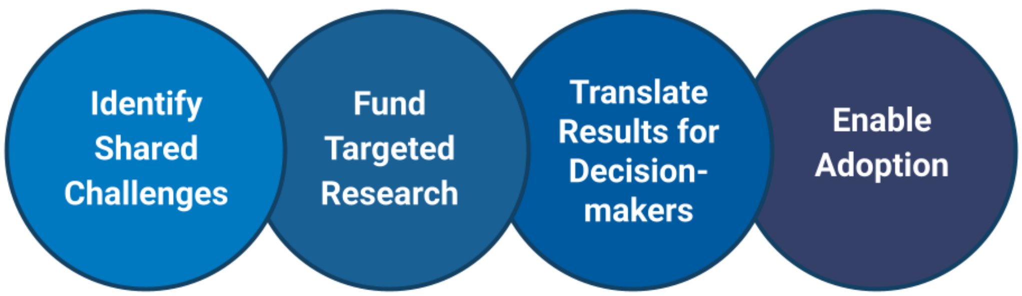


Figure 1: NOWRDC's unique role is to bridge the gap between research and deployment — bringing together industry, government, and academia to identify the most pressing technical challenges, fund collaborative R&D, and validate solutions that enable offshore wind to be planned, permitted, built, and operated more effectively.

The NOWRDC Roadmap is the strategic framework to guide these investments. Updated periodically to reflect changes in technology, markets, and policy conditions, the Roadmap identifies priority innovation areas where targeted research can deliver the greatest benefit to offshore wind deployment and the broader marine energy economy.

The Roadmap is informed by input from NOWRDC members, technical experts, and industry stakeholders, and draws on NOWRDC’s growing portfolio of funded projects. It organizes research priorities across three core pillars:

1. Technology Advancement;
2. Resource and Physical Site Characterization; and
3. Installation, Operations and Maintenance, and Supply Chain.

[15] Offshore Wind Innovation Hub, Urban Future Lab at NYU Tandon, with NOWRDC and NYSERDA, https://www.offshorewindnyc.com/.

Together, these pillars highlight the technical capabilities required to reduce project risk, improve system performance, and support long-term growth of offshore wind in the United States.

As industry evolves, the Roadmap serves as a living guide for aligning research investment with emerging challenges and opportunities. By identifying high-impact innovation priorities, it helps ensure that public and private research funding accelerates technological progress and strengthens the foundations of the U.S. offshore wind sector. Figure 2 shows the geographic reach of NOWRDC's funded portfolio to date, reflecting the breadth of institutions and states contributing to this work.

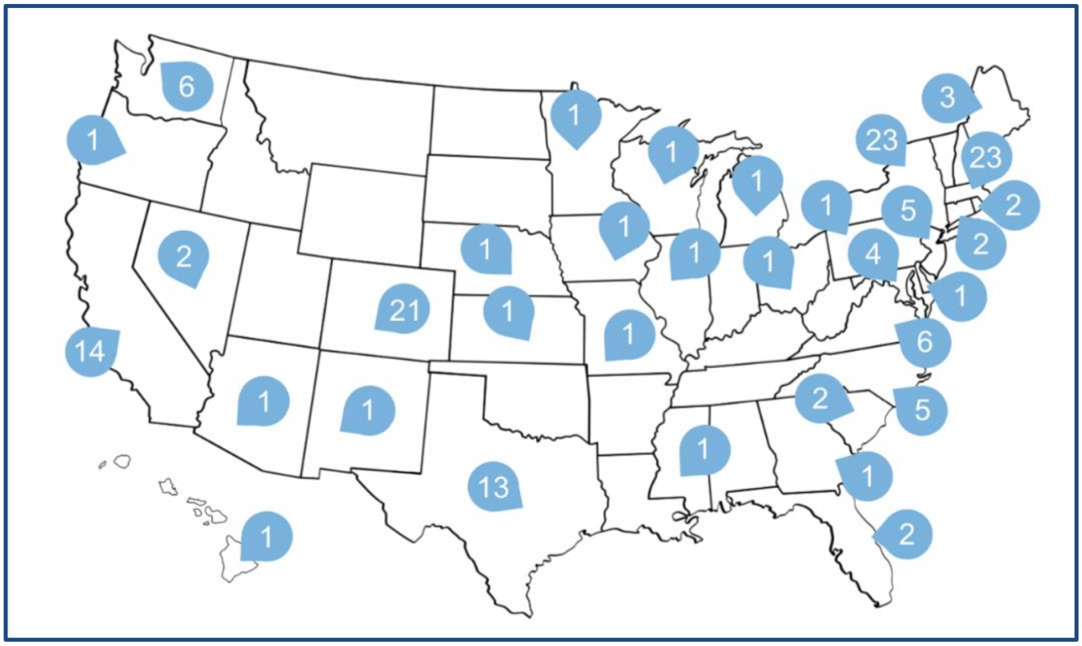


Figure 2: Map of NOWRDC's primary grant awardees and subcontractors to-date. Each pointer marks the state where an R&D project has been funded and the number of principal investigators and/or subcontractors in that state.

The focus areas of NOWRDC's awarded projects span the entire lifecycle of offshore wind development, from planning, permitting, and siting, to operations and maintenance, as shown in Figure 3.

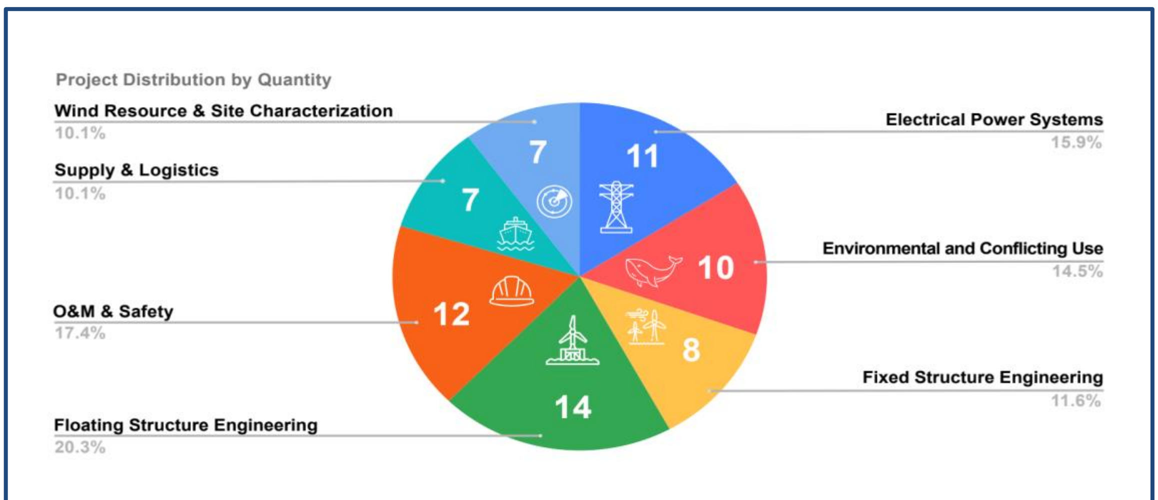


Figure 3: NOWRDC funding Distribution by Focus Area to-date.

The Value of Innovation

In June 2026, NOWRDC evaluated how the innovation it supports affects the levelized cost of energy (LCOE) and key performance metrics such as annual energy production (AEP), operational expenditures (OpEx), and capital expenditures (CapEx), publishing its findings as the NOWRDC Impact Metrics Quantitative Analysis, Version 2.0[16]. This analysis builds on NOWRDC's original 2024 LCOE Impact Report (Version 1.0), which established the modeling framework and baseline assumptions used[17]. 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.

Conducted with the Carbon Trust, the analysis applied a rigorous modeling approach across three representative project types: fixed-bottom, deep water floating offshore wind, and shallow water floating offshore wind.

The results, shown in Figure 4, demonstrate the value of NOWRDC's targeted innovation model. NOWRDC-supported technologies delivered measurable economic benefits, including LCOE reductions of 6.3 to 12.1% (USD/MWh). These findings validate NOWRDC's strategic focus on high-impact R&D aligned with industry needs and U.S.-specific conditions.

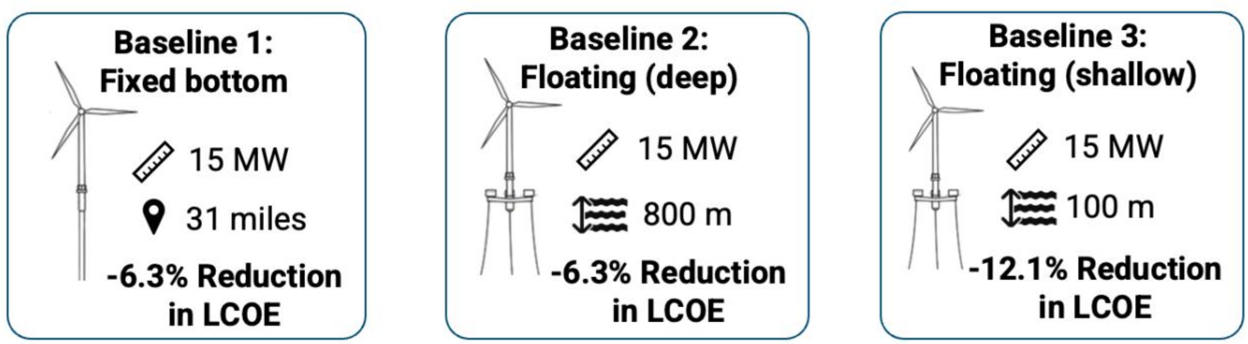


Figure 4: Combined impact of five applied innovations across three model offshore wind farms.

This analysis also highlights the strength of a portfolio-based approach, where multiple innovations, spanning fabrication, installation, transmission, maintenance, etc., are layered to deliver system-level gains. By modeling fully commercialized deployment scenarios, the analysis reinforces the importance of continued investment to advance promising technologies from development through demonstration and scale.

[16] NOWRDC and Carbon Trust, "Impact Metrics Quantitative Analysis, Version 2.0," June 2026, https://nationaloffshorewind.org/wp-content/uploads/NOWRDC-Impact-Metrics-Quantitative-Analysis-Version-2.0-1.pdf.
[17] NOWRDC and Carbon Trust, "Impact Metrics Quantitative Analysis, Version 1.0," December 2024, https://nationaloffshorewind.org/wp-content/uploads/NOWRDC-Impact-Metrics-Quantitative-Analysis-Version-1.0.pdf.

The Broader Energy and Marine Economies

The research priorities outlined in this Roadmap reflect a systems-based approach. Many NOWRDC-supported innovations serve as foundational capabilities for the broader ocean and energy economy, extending their impact beyond wind and increasing the return on public and private investment. These include:

- **Floating platforms, mooring systems, and subsea infrastructure** that enable floating offshore wind while supporting wave and tidal energy, offshore hydrogen, aquaculture, and marine mineral development.
- **Transmission, grid integration, autonomous inspection, and predictive maintenance technologies** that improve reliability, safety, and scalability across offshore energy and marine infrastructure.
- **Advanced metocean data and modelling tools** that strengthen site characterization, risk assessment, data collection and validation, and long-term planning across ocean-based industries.

By advancing innovation in these shared challenge areas, NOWRDC extends its impact beyond offshore wind without diluting focus. Offshore wind research remains the foundation, but its deployment acts as a catalyst for broader infrastructure modernization and marine innovation. Through this integrated approach, NOWRDC is positioned as a strategic bridge across offshore wind, transmission, marine technology, and broader energy sectors, strengthening the systems that underpin the U.S. energy future.

How To Use This Roadmap

This Roadmap reflects U.S. and global offshore wind updates, evolving policy and market conditions, and external drivers such as rising electricity demand from AI data centers. It also incorporates research projects newly awarded by NOWRDC since the previously released Roadmap 4.0.

By establishing a clear, forward-looking framework the Roadmap guides offshore wind and related energy research, enabling strategic prioritization of R&D investments in the near term.

The sections that follow outline NOWRDC's three research Pillars, the associated innovation focus areas, and representative R&D projects supported by the Consortium.

Throughout the Roadmap, the following icons are used to visually highlight key, cross-cutting metrics relevant to the U.S. market. These metrics and their application to specific R&D topic areas were determined with the help of NOWRDC's R&D Committee and the Carbon Trust.

Technology Readiness

This icon identifies innovation areas with a high level of technology readiness. Technology readiness refers to the maturity of a technology as it progresses from research to commercial deployment, demonstrating reliable performance, safety, and scalability under representative conditions.

Impact on Decreasing LCOE

This icon identifies innovation areas that are likely to have the greatest impact on decreasing the Levelized Cost of Energy (LCOE) by lowering costs and/or increasing performance. The LCOE is the average cost of producing electricity over a power plant's lifetime, calculated by dividing total lifetime costs by total energy generated.

Urgency for U.S. Conditions

This icon identifies those innovation areas that are most urgently needed. This refers to the immediacy with which technologies must address U.S.-specific challenges (e.g., regulatory requirements, grid constraints, environmental conditions, and supply chain limitations) to enable timely, cost-effective project deployment.

International Applicability

This icon identifies those innovation areas that are most applicable internationally. This include the extent to which a technology, approach, or research outcome can be adapted and deployed across global markets.

Opportunity for U.S Supply Chain

This icon identifies those innovations most likely to support U.S. supply chain leadership. This refers to the potential for a technology to enable domestic manufacturing, services, and workforce participation while strengthening U.S. leadership and competitiveness in markets both domestically and internationally.

PILLAR 1: TECHNOLOGY ADVANCEMENT

Overview

This Pillar addresses the core technical challenges that determine whether offshore wind can be deployed at scale, cost competitive , and across the full range of U.S. operating conditions. The topic areas, spanning floating wind station keeping, model development and validation, adaptation for new markets, scaling to 15 MW turbines, array design and control, electrical infrastructure, and impact mitigation, represent the system-level capabilities required to reduce risk, improve performance, and enable bankable projects.

As policy and market conditions have become less predictable, the role of applied R&D in maintaining deployment readiness has become more critical. Advancing these technologies during periods of slower deployment helps avoid capability gaps, preserve domestic expertise, and shortens the path to scale when conditions are realigning.

Across both fixed-bottom and floating systems, three technical imperatives underscore the need for focused R&D investment:

- **Scaling to 15 MW turbines**, which demands sustained system integration and validation to manage loads, reliability, and installation risk;
- **Designing for diverse U.S. and global conditions**, where environmental extremes increase complexity but also create opportunities for transferable, exportable solutions; and
- **Advancing from turbine-level to array-level engineering**, where optimized layouts, controls, and wake management unlock substantial performance and cost gains.

Collectively, these capabilities position offshore wind as a cornerstone of future energy systems. As grid expansion accelerates, offshore wind technologies will also deliver critical transmission, high-voltage direct current (HVDC), grid-forming, and offshore substation solutions that strengthen long-term system reliability and resilience.

System Adaptations for 15 MW Turbine Platform

Fixed-bottom offshore wind will underpin near-term U.S. deployment, making system adaptations for 15 MW turbine platforms essential to controlling cost, reducing risk, and maintaining global competitiveness. As development projects scale, U.S.-specific site conditions, rather than imported design assumptions, will determine performance and bankability. These adaptations are technically mature and transferable[18], creating an opportunity to standardize designs, accelerate deployment, and position U.S.-optimized solutions for international markets.

Cost-Optimized Designs for a 15 MW Market

The evolution from 10 MW to 15 MW offshore wind turbines requires not just simple upscaling, but system-level optimization. Substructures developed for European offshore wind markets are designed for conditions that differ materially from those in the U.S., where seabed variability, permitting constraints, weather exposure, vessel availability, and port infrastructure may require site-specific design adaptations[19]. Achieving competitive economics will require cost-optimized, locally adaptable substructures that reduce dependence on imported steel and mitigate supply-chain concentration risks, particularly the reliance on monopiles.

Strategically, industrializing a diversified portfolio of fixed-bottom substructures tailored to deeper waters, variable soils, and regional regulations is critical. These solutions can lower capital costs, reduce schedule risk, strengthen domestic manufacturing and installation capacity, delivering resilience in an increasingly volatile global market.

At the turbine level, 15 MW platforms[20] offer flexible architectures that enable optimization for local wind regimes. In lower-wind regions such as the South Atlantic and Gulf of Mexico, reducing specific power can materially improve capacity factor and project economics. However, the industry focus has largely remained on scale rather than optimization. Aligning turbine design with U.S. manufacturing, logistics, and standardization pathways is therefore essential to unlocking the next wave of cost and performance gains.

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[18] National Renewable Energy, "2024 Annual Technology Baseline: Offshore Wind," 2024, https://atb.nrel.gov/electricity/2024/Offshore_Wind.
[19] U.S. Department of Energy, Wind Energy Technologies Office, "U.S. Conditions Drive Innovation in Offshore Wind Foundations," https://www.energy.gov/cmei/systems/articles/us-conditions-drive-innovation-offshore-wind-foundations.
[20] W. Gaertner et al., "Definition of the IEA 15-Megawatt Offshore Reference Wind Turbine," NREL/TP-5000-75698, March 2020, https://docs.nrel.gov/docs/fy20osti/75698.pdf.

Testing and System Readiness for 15 MW Turbines

While 11–15 MW turbines represent the near-term design standard for most U.S. projects, continued turbine scaling beyond 15 MW is anticipated, underscoring the importance of scalable testing and validation infrastructure that supports cost-optimized designs today while enabling flexibility for longer-term technology evolution. This advancement unlocks major gains in energy yield while introducing new risks. On this scale, rigorous full-scale testing is critical to identify design and manufacturing issues early, before failures occur in the field where costs escalate sharply.

Certification standards set by the International Electrotechnical Commission (IEC), such as IEC 61400-23[21] (blades) and IEC 61400-04[22] (drivetrains), require testing of major components, yet U.S. facilities currently lack the capacity to test components of this size. As a result, modified test methods are increasingly used, introducing uncertainty into reliability assessments and weakening confidence in long-term performance. These gaps directly affect project bankability, increasing insurance premiums, financing costs, and perceived risk.

Existing laboratory tests[23] capture many loading conditions but not the full complexity of next-generation turbines. Advanced approaches, such as accelerated lifetime testing, enhanced strength testing, and improved prototyping, are needed to detect defects before serial production. Blades exceeding 100 meters underscore this challenge, as current test setups cannot replicate the full range of real-world stresses. Upgrading U.S. testing infrastructure is therefore essential to ensure compliance, reliability, and domestic manufacturing viability.

At the system level, larger turbines introduce new aerodynamic and structural interactions, including wake effects, resonance risks, and upscaling challenges, issues that are amplified in floating wind systems. Addressing these risks early through targeted R&D, protects cost-reduction trajectories, ensures infrastructure compatibility, and supports large-scale U.S. deployment. A coordinated research approach, spanning modeling, prototype testing, and full-scale demonstration, is required to ensure next-generation turbines deliver the performance and reliability the market demands.

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[21] International Electrotechnical Commission, "IEC 61400-23: Wind Turbines – Full-Scale Structural Testing of Rotor Blades," 2014, https://webstore.iec.ch/en/publication/5436.
[22] International Electrotechnical Commission, "IEC 61400-4: Wind Energy Generation Systems – Design Requirements for Wind Turbine Gearboxes," 2025, https://webstore.iec.ch/en/publication/63497.
[23] U.S. Department of Energy, Wind Energy Technologies Office, "Blade and Drivetrain Testing Advance Wind Turbine Efficiency and Reliability," May 16, 2024, https://www.energy.gov/cmei/systems/articles/blade-and-drivetrain-testing-advance-wind-turbine-efficiency-and-reliability.

Floating Wind: Mooring Systems Optimization

Floating offshore wind faces distinct challenges driven by limited large-scale deployment data and the complex dynamics of floating turbines, which operate with six degrees of motion that affect wakes, performance, and structural loads. Optimizing mooring systems is central to commercial viability, as materials and installation costs are a driver of LCOE.

Key R&D priorities include:

- **Modeling Large Floating Arrays:** Wake behavior is less predictable due to platform motion and yaw control, requiring improved models to manage downstream turbulence and array performance. Deeper waters also introduce new challenges for cable protection, anchoring, and submerged equipment;

- **Deepwater mooring systems:** Pacific and Central Atlantic sites reach depths of 1,300–2,600 meters, necessitating innovative anchoring and mooring concepts that manage large anchor footprints, reduce array spacing constraints, and meet IEC standards; and

- **Shallow-water mooring concepts:** In 60–90 meter depths, conventional catenary systems face snap loading, anchor uplift, and resonance risks, requiring alternative designs tailored to site-specific seabed and environmental conditions.

While the oil and gas industry provides a technical baseline, floating wind demands fit-for-purpose solutions optimized for different load profiles, array configurations, and cost targets. NOWRDC has already supported a range of innovations[24] from taut synthetic moorings to shared deepwater systems and shallow-water demonstrations, underscoring both technical readiness and urgency.

Advancing optimized mooring systems is therefore a strategic priority to unlock cost-competitive floating wind, build durable U.S. industrial capability, and support global deployment at scale.

NOWRDC IN ACTION

NOWRDC-funded research led by the National Renewable Energy Laboratory evaluated shared mooring configurations, in which adjacent floating turbines share anchors and mooring lines, to reduce material, fabrication, and installation costs for deep-water floating wind farms[25].

[24] NOWRDC Project Database, https://nationaloffshorewind.org/project-database/.
[25] NOWRDC Project Database, "Shared Mooring Systems for Deep-Water Floating Wind Farms" (National

Coexistence: Balancing Offshore Generation with Wildlife and Ocean Users

To support offshore wind and other ocean-based activities at scale, the U.S. requires advanced marine monitoring, environmental sensing, and situational awareness technologies that enable safe, efficient, and coordinated use of shared marine spaces. Technologies such as acoustic and optical sensing, radar and communications mitigation tools, and integrated data platforms function as shared infrastructure for the marine economy. In addition to supporting offshore wind, these technologies enable improved navigation, fisheries and aquaculture management, maritime safety, environmental stewardship, and national security. By reducing uncertainty and improving real-time visibility, advanced monitoring supports better siting decisions, safer operations, and more effective ocean planning.

Critically, innovation in this space also expands our ability to collect high-quality environmental data in complex ocean environments, including benthic and seafloor conditions, and in deeper or more challenging offshore locations. Advances in uncrewed, non-extractive sensing and data collection approaches enable more continuous, lower-impact observation of marine ecosystems, improving baseline understanding and long-term monitoring capabilities.

Within offshore wind, these technologies are essential for managing interactions with wildlife and other ocean users. Enhanced detection and predictive tools can enable more targeted and adaptive operational approaches, helping to minimize disruption while maintaining project efficiency, expand safe construction and operations windows, and increase regulatory confidence. These capabilities also strengthen domestic supply chains by driving demand for

BROAD APPLICATIONS

NOWRDC-funded projects illustrate both sides of this challenge: Cornell University's Right Wind project models North Atlantic right whale distribution within Wind Energy Areas to inform siting decisions[26], while Saildrone's uncrewed surface vehicles use real-time acoustic sensing to detect and track marine mammals near active project sites[27].

Renewable Energy Laboratory), https://nationaloffshorewind.org/projects/shared-mooring-systems-for-deep-water-floating-wind-farms/.

[26] NOWRDC Project Database, "Right Wind: Resolving Protected Species Space-Use Conflicts in Wind Energy Areas" (Cornell University), https://nationaloffshorewind.org/projects/right-wind-resolving-protected-species-space-use-conflicts-in-wind-energy-areas/.

[27] NOWRDC Project Database, "Renewable Powered, Uncrewed Mobile Assets to Monitor Protected Marine Mammals" (Saildrone Inc.), https://nationaloffshorewind.org/projects/renewable-powered-uncrewed-mobile-assets-to-monitor-protected-marine-mammals/.

specialized sensing, analytics, and monitoring services.

Importantly, the value of marine monitoring and environmental data technologies extends beyond early-stage siting and coexistence. As detailed later in Pillar 3, many of the same technologies enable improved operations and maintenance, supporting data-driven asset management, safer access, and more efficient long-term performance across offshore energy and broader marine infrastructure.

Integrated Electrical Systems and Grid Resilience

There is an increasing demand for energy generation to be dispatchable, reliable, and resilient, accelerating innovation across offshore wind farms and the broader marine and energy system. Electrical infrastructure, from turbines and dynamic cables to offshore substations and interconnections, already represents a large project capital expenditure (CapEx) and will grow as projects move farther offshore, making these systems strategic investments with value beyond wind alone.

Reliability risks extend across offshore energy infrastructure. European experience shows cable failures account for about 80% of insurance claims[28], largely from construction damage. Dynamic cable systems for floating wind remain under development, with implications for offshore transmission, marine energy, and subsea infrastructure more broadly. Shared transmission and export systems can reduce cost and risk while enabling scalable solutions across offshore sectors. Expanding domestic manufacturing of these components strengthens supply chains and positions U.S. technologies for global deployment.

Cable failures account for about 80% of insurance claims in European offshore wind.

Offshore wind must also integrate seamlessly with the broader power system alongside other offshore and distributed energy resources. Ambitious state and federal decarbonization targets make energy storage and advanced grid integration essential to manage variability, enhance reliability, and support long-term energy security. On-site and system-level storage, paired with improved understanding of extreme weather and operational limits, informs planning across wind, transmission, and marine energy systems.

[28] D. Maloney, DNV, "80% of Insurance Claims in Offshore Wind Are Related to Subsea Cable Failures – How Can the Industry Manage These Risks?" https://www.dnv.com/article/80-percent-of-insurance-claims-in-offshore-wind-are-related-to-subsea-cable-failures-how-can-the-industry-manage-these-risks.

Additionally, as offshore infrastructure scales, cybersecurity and black-start capability[29] become system-critical across the grid. Grid-forming, inverter-based technologies, developed initially for offshore wind, will increasingly support power restoration, replace retiring synchronous generation, and strengthen resilience across interconnected marine and terrestrial networks.

Together, these innovations ensure offshore wind and related marine and transmission infrastructure function as integrated, reliable assets, advancing decarbonization, energy security, and U.S. industrial competitiveness across the energy economy.

WHY THIS MATTERS

Reliable, resilient electrical infrastructure underpins bankability and insurability, supports integration of growing electricity demand, and provides shared value across offshore wind, transmission, and the broader marine energy economy.

[29] Centre for Emerging Technology and Security (CETaS), The Alan Turing Institute, "Enhancing the Cyber Resilience of Offshore Wind," 2024, https://cetas.turing.ac.uk/publications/enhancing-cyber-resilience-offshore-wind.

PILLAR 2: RESOURCE AND PHYSICAL SITE CHARACTERIZATION

Overview

Accurate power resource and site characterization are foundational to offshore wind development, yet remain key drivers of cost, risk, and delay across offshore infrastructure. Limited availability of reliable offshore data, particularly at hub height, constrains project planning, while uncertainty around extreme conditions (e.g., hurricanes, sea ice, and seismic activity) affect turbines, transmission systems, and offshore substations. Variable seabed conditions further complicate foundation, cable, and anchoring design, increasing complexity and extending timelines.

These challenges are compounded by long-term climate variability, evolving offshore conditions, and the lack of standardized technologies, reference sites, and integrated modeling frameworks. More broadly, gaps in offshore oceanographic and metocean data limit both project-specific design and our broader understanding of offshore systems. This constrains regional planning, cumulative impact assessment, and the ability to anticipate changing ocean conditions.

These data limitations hinder industry-wide learning, reduce cross-sector coordination, impact cost, schedule, and investor confidence across offshore wind, marine operations, and grid-connected infrastructure.

This Pillar strengthens the technical foundation for offshore development through improved data collection and validation, enhanced measurement and modeling, and rigorous validation of analytical tools and datasets. In parallel, it advances understanding of offshore oceanographic systems and metocean dynamics. These capabilities support more accurate forecasting, safer operations, and better-informed investment decisions across offshore wind, transmission, and marine infrastructure.

By reducing time, cost, and uncertainty in site characterization on the U.S. outer continental shelf, this Pillar improves predictability, enhances bankability, and accelerates deployment.

Validation of Power Resources and External Conditions

Validated power resource and site characterization are foundational to offshore wind development and to the broader marine and energy systems that rely on accurate environmental intelligence. These assessments[30] inform critical decisions, including energy yield, design limits, construction planning,

[30] M.J. Fields, "An Overview of Wind-Energy-Production Prediction Bias, Losses, and Uncertainties," Wind Energy Science 6 (2021): 311–365, https://wes.copernicus.org/articles/6/311/2021/.

operations, and insurance, each with direct implications for project cost, risk, and bankability.

Most assessments rely on mesoscale atmospheric and ocean models, yet results vary significantly based on model configuration and assumptions. Despite recent advances, additional validation is required to accurately represent turbine-scale and site-specific conditions. Direct offshore measurements provide the most reliable validation, but high costs and logistical challenges limit data availability, forcing continued reliance on sparse datasets such as reanalysis products and limited buoy networks.

These constraints introduce uncertainty. Measurements are often collected near the surface and extrapolated to hub height without fully accounting for atmospheric stability, surface interactions, or seasonal variability. Persistent model biases, inconsistent validation practices, and limited consideration of long-term climate variability further reduce confidence in multi-decade projections.

This Pillar prioritizes coordinated validation studies, improved measurement and modeling methodologies, and data sharing among developers, researchers, and public institutions. Strengthening these capabilities reduces uncertainty, improves predictability, and supports more informed investment and permitting decisions.

NOWRDC IN ACTION

Inter-Array Wake Impacts Joint Industry Project (JIP)

This project successfully brought together federal[31] and state agencies, alongside developers and leading research institutes to:

- Understand and quantify intensity and frequency of regional meteorological conditions leading to the persistence of downstream cluster wakes.
- Assess the performance impacts on existing lease areas from possible new leases by considering thousands of new lease area scenarios.
- Through JIP collaboration, recommend metrics for inter-array spacing to aid in future lease area identification.
- Calibrate multi-fidelity modeling tools to the participants-specific needs to allow independent inter- and intra-array impact analysis.

[31] The Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE) have since been reunified into the new Marine Minerals Administration (MMA).

Reducing Uncertainty in Wake Losses

Reducing uncertainty in wake losses is essential to improving offshore wind performance, reliability, and cost predictability. Advancing the accuracy and validation of wind farm modeling tools directly addresses uncertainty in wake behavior, turbulence, fatigue loading, and energy output, key drivers of project economics and long-term asset performance.

Improved array-scale models require higher-quality atmospheric and operational data, including wind profiles, wake interactions, low-level jets, and seasonal variability. This data must be supported by advanced measurement technologies, such as LiDAR, and validated against operational datasets to ensure models reflect real-world conditions. Strengthening this foundation improves confidence in wind farm layout optimization, energy yield estimates, and Wind Energy Area siting decisions.

As offshore projects scale in size and density, new modeling approaches and control strategies are needed to manage inter-array effects. Current tools often underestimate wake-induced loads, increasing maintenance and downtime. Optimized array layouts and system-level innovations[32] can significantly reduce component loading, extending turbine life, lowering operations and maintenance costs, and improving overall system efficiency.

Together, these advances reduce technical uncertainty, improve predictability, and enable more resilient, cost-effective offshore wind deployment**.**

Hurricane Resilient Systems and Environmental Extremes

Offshore wind must be designed to withstand hurricanes and other environmental extremes to remain reliable, insurable, and cost-effective over their full operating life. In several U.S. regions (i.e., the Atlantic coast, Gulf of Mexico, Hawaii, and the Central Atlantic) design criteria based on extratropical storms underestimate tropical cyclone severity, increasing technical uncertainty, insurance exposure, and financial risk.

While IEC Class 1 turbines and oil and gas standards provide a baseline, additional innovations are required, including hurricane-resilient components, yaw system redundancy, and improved modeling of gusts, shear, and veer. Although these measures may increase upfront capital costs, they are essential to reducing catastrophic failure risk and improving long-term bankability.

[32] Ocean Engineering (2026), on optimized array layouts and system-level load reduction, https://www.sciencedirect.com/science/article/pii/S0029801826003781.

Other environmental hazards further constrain deployment. Seismic risk in the Pacific[33] affects anchors and mooring systems for floating wind, while freshwater ice presents unique challenges for potential Great Lakes projects[34]. Addressing these conditions through targeted R&D expands offshore wind into new regions, enables deployment in deeper and more dynamic environments, and reduces visual and environmental impacts.

Importantly, these innovations extend beyond offshore wind. Advancing technologies and design approaches for extreme conditions strengthen the broader ability to deploy, operate, and maintain infrastructure in harsh and variable ocean environments. These capabilities are increasingly relevant across marine energy, maritime infrastructure, and national security applications, supporting safe and reliable operations in deeper waters and more complex conditions.

NOWRDC IN ACTION

The NOWRDC-funded "Ensuring Long-term Availability and Bankability of Offshore Wind through Hurricane Risk Assessment & Mitigation" is a multi-phase project led by Northeastern University. This project has successfully brought together federal and state agencies, alongside developers and leading research institutes to:

- Quantify hurricane risk to turbines, foundations, and other offshore assets across U.S. regions prone to tropical cyclones; and
- Develop engineering and risk-mitigation guidance to strengthen resilience and support insurability and long-term bankability.

High-quality metocean data is central to managing these risks. One example is the metocean reference data collected near Martha's Vineyard[35], which provides a valuable benchmark dataset for model validation. However, comparable reference sites remain limited across other U.S. regions. Most hub-height data come from privately owned LiDAR systems with limited access, and LiDAR alone does not fully capture turbulence and atmospheric stability. Additional public, industry-accessible metocean reference sites in the South Atlantic, Gulf of Mexico, and Pacific would improve model validation, support consistent standards, and accelerate learning.

Industry feedback highlights low technology readiness for many extreme-condition adaptations,

[33] RPS Group (a Tetra Tech company), "BOEM Report: Potential Earthquake, Landslide, Tsunami, and Geohazards for U.S. Offshore Pacific Wind Farms," https://www.rpsgroup.com/projects/boem-report-potential-earthquake-landslide-tsunami-and-geo-hazards-for-the-us-offshore-pacific-wind-farms/.

[34] L. Zuo et al., "Offshore Wind Development in the Great Lakes: Challenges, Resources and Technical Solutions," Ocean Dynamics 75, art. 21 (2025), https://link.springer.com/article/10.1007/s10236-025-01666-7.

[35] A. Kirincich (WHOI) and C. Draxl (NREL), "Metocean Reference Station Best Practices: MORS-1 Case Study," prepared for NOWRDC, July 2023, https://nationaloffshorewind.org/wp-content/uploads/WHOI_154677-Metocean-Reference-Station-Best-Practices.pdf.

reinforcing the need for continued R&D, pilots, and demonstrations. Advancing resilient designs and shared metocean infrastructure reduces uncertainty, strengthens domestic supply chains, and delivers scalable solutions applicable across offshore industries and global markets, positioning U.S. industry for long-term competitive advantage.

Physical Site Characterization and Seabed Survey Challenges

Accurate site characterization[36], encompassing wind, wave, current, and seabed conditions, is fundamental to optimizing turbine siting, designing cost-effective foundations, and ensuring safe, timely offshore wind development. Strengthening these capabilities directly reduces cost and technical risk, shortens development timelines, and improves project bankability. Industry feedback underscores that advances in physical site characterization deliver some of the highest-impact reductions in LCOE for U.S. projects.

A key constraint is the lack of a robust, national seabed database to inform current and future Wind Energy Areas. Existing sediment assessment methods are often insufficient for geophysical design, increasing uncertainty and driving higher costs for geotechnical data collection. Improved seabed characterization is essential for ground modeling, cable routing, geohazard identification, substructure selection, environmental planning, and long-term asset performance. As floating wind leasing expands, new geotechnical and geophysical approaches[37] are also needed to assess anchor placement across a wider range of depths and sediment conditions, requirements not fully addressed by oil and gas methodologies.

While detailed, project-specific surveys fall outside the scope of this Roadmap, regional and geospatial seabed assessments remain critical inputs to development decisions. Targeted research and innovation to update seabed datasets can reduce pre-finance risk, support permitting, improve cost estimates, and enable more informed lease area selection, providing developers with the confidence needed to advance offshore wind efficiently and safely. These efforts also align with global initiatives to improve seafloor mapping, such as the Nippon Foundation–GEBCO Seabed 2030 Project, which aims to produce a complete map of the world's ocean floor by 2030[38].

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[36] Bureau of Ocean Energy Management, "Renewable Energy Geohazard Guidelines," June 2024, https://www.boem.gov/sites/default/files/documents/about-boem/Renewable%20Energy%20Geohazard%20Guidelines_0.pdf.

[37] B. Cerfontaine et al., "Anchor Geotechnics for Floating Offshore Wind: Current Technologies and Future Innovations," Ocean Engineering 279 (2023): 114327, https://discovery.dundee.ac.uk/ws/portalfiles/portal/102180255/1_s2.0_S0029801823007114_main.pdf.

[38] Nippon Foundation–GEBCO Seabed 2030 Project, https://seabed2030.org/.

PILLAR 3: INSTALLATION, OPERATIONS AND MAINTENANCE, AND SUPPLY CHAIN

Overview

Installation, operations and maintenance (O&M), and supply chain capabilities are central to whether offshore wind can be deployed at scale, on schedule, and at competitive cost in the United States. While technology advancement defines what is possible, execution across these areas determines whether projects are delivered efficiently, reliably, and safely under U.S.-specific conditions.

Constraints in vessel availability, port infrastructure, grid integration planning, and workforce readiness are among the most immediate risks to deployment timelines and project economics. At the same time, projects are increasing in size, complexity, and distance from shore, requiring new approaches to installation, logistics, and asset management.

This Pillar advances the systems, strategies, and infrastructure needed for efficient project delivery and long-term performance. Priorities include installation approaches that reduce reliance on constrained assets, digital and remote-enabled O&M strategies that improve reliability while reducing offshore exposure, strengthened domestic supply chains, and improved coordination between offshore generation and onshore grid and port infrastructure.

A key priority is shifting from reactive, project-by-project approaches to integrated, data-driven strategies. In addition, workforce development remains foundational, requiring a skilled workforce across trades, engineering, digital systems, and public-sector roles.

By addressing these challenges, this Pillar reduces lifecycle costs, improves reliability and safety, and supports scalable offshore wind deployment and broader marine energy development.

Installation Strategies

Heavy-lift wind turbine installation vessels (WTIVs) are essential to installing 15 MW turbines, which require lifts exceeding 900 metric tons and crane boom heights over 160 meters. Under the Jones Act[39],

[39] N. Shoemate and M. Franklin, Hatch Ltd., "Jones Act Externalities to US Offshore Wind Development," May 2019, https://www.hatch.com/About-Us/Publications/Technical-Papers/2019/05/Jones-Act-Externalities-To-US-Offshore-Wind-Development.

vessels moving components between U.S. ports must be U.S.-built, flagged, and owned. With only one Jones Act compliant WTIV currently operating, limited vessel availability presents a clear risk to deployment timelines. Ports face parallel constraints, often requiring dredging, channel widening, and reinforced quaysides to accommodate these vessels and floating substructures.

To avoid bottlenecks, the industry must pursue parallel strategies, including hybrid installation approaches using foreign heavy-lift vessels with U.S.-flagged barges, repurposed domestic vessels, new vessel designs, and modular turbine and installation innovations. Floating wind introduces additional complexity but also creates opportunities to reduce cost and schedule risk through alternative assembly and transport concepts.

Sufficient marshalling port capacity[40] is equally critical. Multiple ports with unrestricted ocean access, deep channels, and ample laydown space are needed to support manufacturing, assembly, and load-out. Targeted feasibility studies can guide strategic upgrades along the Atlantic, Pacific, and Gulf coasts to meet near-term 15 MW turbine requirements and future scale.

NOWRDC IN ACTION

In March 2024, South Fork Wind became New York's first commercial-scale offshore wind farm. Delivering the 12-turbine, 132 MW project required innovative solutions to transport wind turbine components efficiently from marshalling ports to offshore installation vessels.

To address this challenge, NOWRDC funded Crowley's research project, Technical Validation of Existing U.S.-Flagged Barges as a "Feeder" Solution for the U.S. Offshore Wind Industry. The project demonstrated that a Cargo Feeder System (CFS) — using minimally modified U.S.-flagged barges and tugs to transport components to offshore wind turbine installation vessels (WTIVs) — could improve installation efficiency, reduce downtime and costs, and leverage the existing U.S. maritime fleet.

Crowley successfully applied this innovative feeder approach during construction of the South Fork Wind Farm, using U.S.-flagged vessels operated by members of the Seafarers International Union.

This topic prioritizes technology solutions that accelerate infrastructure readiness and prevent

[40] Energy Policy (2022), on marshalling port capacity for U.S. offshore wind, https://www.sciencedirect.com/science/article/pii/S0301421522000428.

bottlenecks across vessels, ports, transmission, and workforce development, key determinants of long-term deployment success. Industry feedback underscores their high impact on reducing LCOE, urgency under U.S. regulatory constraints, and potential to strengthen domestic supply chains. Proactive investment will expand U.S. manufacturing capacity, build specialized workforce capabilities, and improve project efficiency at scale.

Operation and Maintenance Innovations: Digitization and Strategy Development

Operations and maintenance (O&M) account for over 30% of offshore wind lifecycle costs[41], making O&M strategy a critical driver of long-term project economics. Addressing O&M early — through design, data, and digital systems — offers one of the most effective pathways to reduce cost, improve reliability, and enhance workforce safety by limiting unnecessary offshore exposure. Industry feedback reflects growing recognition of O&M's importance as projects scale and fleets mature.

"Operations and maintenance account for over 30% of offshore wind lifecycle costs."

Historically, offshore wind O&M has been largely reactive, responding to failures after they occur. Advances in analytics, sensing, automation, and digital platforms now enable more proactive, data-driven strategies that reduce cost, improve reliability, and enhance safety. These innovations also support the development of remote monitoring and diagnostics capabilities, allowing operators to assess asset condition, identify issues, and plan interventions without requiring frequent offshore visits.

While turbine supervisory control and data acquisition (SCADA) systems provide performance data, many high-risk components (e.g., foundations, cables, and subsea systems) lack continuous monitoring, delaying fault detection until infrequent inspections. Expanding sensing and remote monitoring across these systems enables earlier detection of issues, reduces the need for routine inspection trips, and supports more efficient, targeted maintenance planning.

This area of focus prioritizes partnerships with original equipment manufacturers (OEMs) and developers to expand component-level monitoring, integrate fault detection during construction, and deploy data-driven O&M strategies across the asset lifecycle. These approaches reduce technician time offshore, minimize vessel trips, improve safety outcomes, and directly lower LCOE.

[41] Matos et al., "Optimising O&M scheduling in offshore wind farms considering weather forecast uncertainty and wake losses," Ocean Engineering (2024).

NOWRDC IN ACTION

NOWRDC-funded research led by GE Research combined physics-based digital twins with machine learning to estimate blade leading-edge health, enabling condition-based maintenance strategies that reduce unnecessary inspections and unplanned downtime[42].

As U.S. offshore wind scales from pilot projects to commercial deployment, advancing O&M tools for U.S.-specific conditions[43] is essential. Harsher weather, deeper waters, floating platforms, and challenging access require solutions that expand safe operating windows while reducing reliance on offshore intervention. With the global offshore wind O&M market projected to grow 17% annually to $12 billion by 2028, innovation in this area is critical to ensuring the U.S. fleet of 15 MW turbines is cost-competitive, reliable, and scalable.

Strengthening the Supply Chain

Building a robust U.S. offshore wind supply chain is essential to capturing domestic economic value and achieving long-term cost reductions, particularly for floating wind. Strong domestic capabilities reduce reliance on imported components, improve schedule certainty, and support long-term cost reductions. Industry feedback highlights that while technology readiness remains uneven, urgency is high to address U.S.-specific conditions, making supply chain development a cross-cutting priority across the NOWRDC Roadmap.

In the early stages of industry development, U.S. projects will rely on a mix of domestic and international suppliers. Over time, strategic investments can expand domestic manufacturing capacity across key components. The first wave of deployment presents a critical opportunity to invest in enabling technologies and infrastructure, including factory retooling for large components, port and grid upgrades, expanded U.S.-flagged vessel availability, and subsea manufacturing capabilities relevant to transmission, marine energy, and offshore infrastructure. Transitioning from land-based wind to offshore systems will require targeted retooling, workforce retraining, and the development of coastal industrial hubs capable of supporting 15 MW-class turbines and associated grid assets.

Industrialization is central to cost reduction and system resilience, especially for floating wind. Substructures must move rapidly from prototypes to serial production to meet cost targets near

[42] NOWRDC Project Database, "Enabling Condition-Based Maintenance for Offshore Wind" (GE Research), https://nationaloffshorewind.org/projects/enabling-condition-based-maintenance-for-offshore-wind/.
[43] Sandia National Laboratories and NREL, prepared for U.S. DOE Wind Energy Technologies Office, "An Operations and Maintenance Roadmap for U.S. Offshore Wind," May 2024, https://www.energy.gov/sites/default/files/2024-05/operations-and-maintenance-roadmap-for-us-offshore-wind.5.17.24.pdf.

$45/MWh by 2035[44]. Coordinated R&D across substructure design, port infrastructure, turbine integration, and export cable systems will be required to achieve scale. Modular floating designs enable parallel manufacturing, reduce transport risk, and support flexible deployment, while also creating transferable capabilities for broader marine technology applications.

NOWRDC IN ACTION

NOWRDC-funded research with Keystone Tower Systems, Johns Hopkins University, and Northeastern University advanced automated spiral welding for turbine tower fabrication, a flexible, domestic manufacturing approach with potential to reduce cost and expand U.S. supply chain capacity[45].

Finally, long-term strategies for repowering and life extension can further strengthen energy security and reduce lifecycle costs. While turbines may require replacement after 25 years, transmission assets, cables, and substations can operate significantly longer. Extending asset life through upgrades and repurposes improves capital efficiency, maximizes return on investment, and reinforces resilient offshore energy and transmission infrastructure.

Grid and Port Infrastructure Readiness

Ambitious offshore wind deployment depends on timely upgrades to grid and port infrastructure. Transmission constraints and insufficient port capacity remain among the most significant risks[46] to deployment timelines, with challenges varying by region due to differing technical, regulatory, and economic conditions. Early, coordinated, and data-driven planning is essential to avoid delays and stranded investment.

In the near term, projects will rely on existing interconnection points to manage cost and complexity. Over time, however, integrating large volumes of offshore generation[47] will require not only new transmission capacity, but also more deliberate planning for how offshore power is delivered into and

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[44] National Renewable Energy Laboratory, cost-competitive floating substructure target analysis, NREL/TP-5000-86020, 2023, https://docs.nrel.gov/docs/fy23osti/86020.pdf.
[45] NOWRDC Project Database, “Tapered Spiral Welding for US Offshore Wind Turbine Towers” (Keystone Tower Systems, with Johns Hopkins University and Northeastern University), https://nationaloffshorewind.org/projects/tapered-spiral-welding-for-us-offshore-wind-turbine-towers/.
[46] National Renewable Energy Laboratory, transmission and port capacity risk analysis, NREL/TP-5000-90525, 2024, https://docs.nrel.gov/docs/fy24osti/90525.pdf.
[47] National Renewable Energy Laboratory and Pacific Northwest National Laboratory, “Atlantic Offshore Wind Transmission Study,” DOE/GO-102023-6116, 2024, https://docs.nrel.gov/docs/fy24osti/89304.pdf.

managed within onshore transmission and distribution systems. This includes considerations such as power aggregation, onshore grid upgrades, distribution-level impacts, and the interaction with load centers. Without improved data and planning frameworks, system operators and policymakers face uncertainty in how to sequence investments and maintain reliability as offshore capacity scales.

Targeted research is needed to evaluate offshore-to-onshore integration pathways, including transmission architectures, grid impacts, energy storage, and system reliability under high-penetration scenarios. Close coordination with independent system operators (ISOs) and regional transmission organizations (RTOs) will be critical to ensure that offshore generation is efficiently integrated and does not create downstream bottlenecks within onshore networks.

Port infrastructure remains a parallel constraint. Multiple marshalling ports[48] with deep channels, unrestricted ocean access, and sufficient laydown and assembly space are required to support manufacturing, assembly, load-out, and long-term servicing of offshore wind projects, particularly for floating offshore wind. Strategic port upgrades — guided by feasibility, engineering, and logistics studies — are needed across U.S. regions to accommodate larger turbines, floating systems, and evolving installation methods.

This topic focuses on advancing planning tools, data, and technical solutions that enable coordinated development of offshore generation alongside grid and port infrastructure. By improving integration planning and reducing infrastructure uncertainty, these efforts support more efficient investment decisions, enhance system reliability, and accelerate offshore wind deployment at scale.

Workforce Development

The growth of U.S. offshore wind presents significant opportunities for domestic job creation across fabrication, construction, operations, and maintenance, particularly along the Eastern Seaboard. As the industry scales, however, workforce readiness[49] has emerged as a critical constraint on project delivery, innovation capacity, and supply chain resilience. Recent analyses by NOWRDC and the National Renewable Energy Laboratory highlight strong regional assets alongside persistent gaps in specialized offshore wind skills, including CNC operators, rolling machine setters, composite blade technicians, crane operators, and marine construction personnel.

[48] BW Research Consulting, prepared for Renewable Northwest, “Floating Offshore Wind Manual: Port Requirements, Opportunities, and Impacts,” 2024, https://renewablenw.org/sites/default/files/Reports-Fact%20Sheets/Floating%20OSW%20Manual_2024.pdf.

[49] B. McDowell et al., National Renewable Energy Laboratory, “National Wind Energy Workforce Assessment: Challenges, Opportunities, and Future Needs,” NREL/TP-5000-87670, rev. March 2024, https://docs.nrel.gov/docs/fy24osti/87670.pdf.

At the same time, workforce needs extend beyond traditional trades. Continued advancement of offshore wind depends on a skilled workforce in research, engineering, digital systems, and environmental science, as well as within the public and regulatory sectors. Strengthening capacity among regulators, permitting agencies, and public institutions is essential to enable efficient project review, adaptive management, and effective oversight as technologies and deployment models evolve.

Workforce readiness varies[50] by state and port, reflecting differences in complimentary industries transferable skills, training capacity, commuting patterns, and local industry support. Regions such as Wilmington (NC), Hampton Roads (VA), Sparrows Point (MD) on the East Coast and Eureka/Humboldt Bay (CA) on the West Coast for floating offshore wind development[51] are relatively well-positioned to support new manufacturing activity, but all would benefit from stronger regional coordination and targeted training programs. Expanding accessible training pathways, wraparound services, and inclusive outreach is essential to ensure the workforce can scale with industry demand and that economic benefits are broadly shared.

Emerging technologies like floating offshore wind introduce additional workforce requirements, including expertise in mooring systems, dynamic cables, deepwater installation, and offshore operations in more complex environments. Preparing the workforce for these applications will require new training programs, updated standards, and closer alignment between industry, academia, and training providers.

Beyond workforce supply, training quality and job pathways are central to offshore wind's long-term viability. A skilled, locally trained workforce supports timely project execution, strengthens domestic supply chains, and builds confidence among policymakers and communities. At the same time, developing a globally competitive U.S. workforce positions domestic workers and firms to participate in international offshore wind and marine energy markets.

Sustained investment in education, training, R&D talent pipelines, and public-sector capacity is therefore essential to meet current project needs, prepare the workforce for future technologies, and ensure the U.S. remains a leader in offshore and marine energy innovation.

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[50] National Renewable Energy Laboratory, regional offshore wind workforce readiness analysis, NREL/TP-5000-92377, 2025, https://docs.nrel.gov/docs/fy25osti/92377.pdf.

[51] M. Shields et al., National Renewable Energy Laboratory, and Moffatt & Nichol, "The Impacts of Developing a Port Network for Floating Offshore Wind Energy on the West Coast of the United States," NREL/TP-5000-86864, September 2023, https://docs.nrel.gov/docs/fy23osti/86864.pdf.

OUTLOOK AND NEXT STEPS

The U.S. offshore wind industry is entering a defining period. Near-term deployment uncertainty, driven by policy shifts, market volatility, and infrastructure constraints, has not diminished the long-term need for offshore wind as a cornerstone of a reliable, all-of-the-above energy strategy. Instead, it has sharpened the importance of targeted research and development to reduce risk, preserve momentum, and ensure the industry is positioned to scale efficiently as conditions realign.

Despite this policy volatility, several developments underscore the industry's underlying momentum. Coastal Virginia Offshore Wind, Revolution Wind, Vineyard Wind 1, and South Fork Wind are now delivering power to the grid, demonstrating that commercial-scale U.S. offshore wind is achievable[52]. State-level procurement targets, permitting support, and infrastructure investment have also continued in many regions, sustaining regional supply chains and workforce pipelines even as federal posture shifts. In the near term, R&D areas such as 15 MW turbine adaptation, floating mooring systems, and grid and port integration planning offer some of the clearest opportunities for near-term cost reduction and risk mitigation. Many of these technologies also retain strong international relevance: hurricane-resilient designs, deepwater mooring systems, and advanced site-characterization tools developed for U.S. conditions remain valuable and exportable even where U.S. deployment timelines shift.

This Roadmap articulates a clear strategy for navigating this moment. Across technology advancement, site characterization, grid integration, environmental coexistence, and workforce development, the Roadmap identifies where uncertainty most directly affects cost, schedule, reliability, and bankability, and where applied R&D can deliver the greatest system-level value. It also reflects an intentional evolution in NOWRDC's role: anchoring offshore wind innovation while advancing foundational capabilities that support adjacent marine, transmission, and energy grid sectors.

		
Pillar 1: Technology Advancement	**Pillar 2: Resource & Physical Site Characterization**	**Pillar 3: Installation, Operations & Maintenance, & Supply Chain**
Turbine scaling to 15 MW, floating mooring systems, electrical infrastructure and grid resilience, and coexistence technologies.	Metocean data validation, wake-loss modeling, hurricane and environmental-extreme resilience, and seabed characterization.	Installation logistics and vessels, digital and remote O&M, domestic supply chain development, and workforce readiness.

[52] Utility Dive, "Coastal Virginia Offshore Wind Begins Delivering Power," March 26, 2026, https://www.utilitydive.com/news/coastal-virginia-offshore-wind-begins-delivering-power/815874/.

Looking ahead, NOWRDC will continue to prioritize R&D investments that address three overarching objectives:

1. **Reduce technical and financial risk early in the project lifecycle** by improving system-level understanding, validation, and design tools, particularly for larger turbines, floating systems, complex seabed conditions, and extreme environments.

2. **Strengthen readiness across the offshore energy system** by advancing shared infrastructure and cross-sector technologies, including electrical systems, monitoring and data platforms, grid integration solutions, and site characterization capabilities that benefit offshore wind and the broader marine and energy economy.

3. **Build durable domestic capability** by supporting U.S.-based supply chains, workforce development, and exportable solutions that enhance competitiveness and resilience over the long term.

In the near term, NOWRDC will advance these objectives through continued competitive solicitations, portfolio-based R&D investments, and partnerships with states, federal agencies, industry, and research institutions. Ongoing impact assessment and data-driven portfolio evaluation will remain central to ensuring that funded projects align with industry needs and deliver measurable outcomes, including cost reduction, performance improvement, and risk mitigation.

Over the longer term, NOWRDC will use this Roadmap as a living framework, updating priorities as technologies mature, markets evolve, and deployment pathways become clearer. By sustaining innovation through periods of uncertainty, NOWRDC helps ensure that offshore wind is not only deployable, but dependable: a scalable, integrated, and resilient component of the U.S. energy system.

Through this work, NOWRDC is positioning the offshore wind sector, and the broader marine and energy industries it enables, to move from early deployment to enduring impact, supporting national decarbonization goals, energy security, and long-term economic growth.