EPRI

Quick Insights

Extending the Design Lifetime of Offshore Wind Facilities

RESEARCH QUESTIONS

Can the design lifetime of offshore wind facilities be extended beyond 20 years to improve return on investment (ROI) and decarbonization benefits?

KEY POINTS

- Worldwide offshore wind installations grew significantly in recent years and the industry is set for a 10-fold cumulative capacity increase through 2035.
- U.S. federal and state policy is expected to drive offshore wind growth in American waters, with non-binding federal goals of 30 gigawatts of fixed-bottom offshore wind capacity by 2030 and another 15 gigawatts of floating capacity by 2035.
- Energy uncertainty and supply chain challenges in Europe have increased interest in offshore wind expansion as a key resource for energy security.
- Reduced LCOE (levelized cost of energy) for offshore wind energy, technology advancements, and a desire to reduce environmental impacts are driving offshore wind project owners to investigate design lifetimes longer than the traditional 20 years.
- Future research into the reliability analysis, structural health monitoring, and potential failure modes of offshore wind equipment is necessary to build industry and regulatory confidence in the viability of longer design lifetimes and future project lifetime extensions.

INTRODUCTION

The long-discussed decarbonization potential of offshore wind is increasingly translating into real-world projects. In 2021 a total of 21.1 gigawatts of new capacity was added globally, led primarily by China[1]. The completed projects nearly doubled worldwide capacity and brought the global cumulative capacity to 56 gigawatts.

As of 2022, the U.S. had only 42 megawatts of installed capacity. But the U.S. appears ready for a large increase in offshore wind development, with nearly 15 gigawatts of offtake agreements signed as of 2022 and future offtake solicitations and offshore lease area actions coming

1 China Dominates Offshore Wind Rankings in 2021 – BNEF | Offshore Wind

between 2022 and 2025[2]. Bloomberg New Energy Finance (BNEF) expects the total installed capacity of offshore wind around the world to reach 504 gigawatts by 2035[3].

SUPPORT FROM THE FEDERAL AND STATE GOVERNMENTS

Policy and regulatory support from the federal government is one driver behind a quickly growing project pipeline. The Biden administration is calling for 30 gigawatts of new fixed-bottom offshore wind capacity to be built by 2030 and another 15 gigawatts of new floating offshore wind capacity by 2035.

The recently signed Inflation Reduction Act (IRA) includes provisions designed to spur offshore wind development. For example, the IRA extends and expands the Investment Tax Credit (ITC) for renewable energy, which is favored in offshore wind projects over the Production Tax Credit (PTC) due to their high capital expenditures. The law also provides $3 billion in grants to U.S. seaports, which play a central pivotal role in delivering the turbines and other equipment needed to construct offshore wind power plants.

States are also keen to incentivize offshore wind development. New Jersey and New York have the most aggressive offshore wind aspirations, with New York targeting 9 gigawatts by 2035 and New Jersey seeking 11 gigawatts by 2040. Additionally, each state's government is offering a broad range of incentives and support to spur offshore development, domestic supply chain expansion, and workforce development.

New Jersey, for example, recently signed an agreement[4] leasing a state-financed port to the developer Orsted to assemble components for the 1.1-gigawatt Ocean Wind 1 project. In July, New York announced[5] the state's third offshore wind solicitation, seeking at least 2 gigawatts of new developments. The state also launched what will ultimately be a total of $500 million in investments[6] to support the offshore wind supply chain, including ports and manufacturing facilities. Both New Jersey and New York have plans to upgrade transmission grids to better integrate offshore wind[7,8].

OFFSHORE WIND COST REDUCTION AND INDUSTRY MATURITY

Years of continuous price declines in the cost of turbines, foundation structures, and other equipment have made offshore wind projects economically viable. Improvements in the efficiency of installation and operation of offshore wind facilities have also contributed to increasingly favorable project economics.

Both trends are reflected in the LCOE of offshore wind farms. In the UK, for instance, the auction price for offshore wind electricity fell from nearly $190 to $72 per megawatt-hour from 2017 to 2022, putting subsidy-free offshore wind below the cost of natural gas competitors[9].

Technology improvements are also a significant contributor to cost declines. For example, in 2012 the longest offshore wind turbine blade was 75 meters for a 6 MW turbine manufactured by Siemens[10] and in 2022 the longest offshore wind blade measures 115 meters for a 15 MW capable turbine[11]. This represents an over 50% increase in blade length, resulting in a 133% increase in turbine capacity within only 10 years of development.

RECONSIDERING PROJECT LIFETIMES

One strategy to improve project economics is to modify the plant design, project certification objectives, and relevant design standards that govern the construction and operation of offshore wind.

2 Offshore Wind Market Report: 2022 Edition (energy.gov)
3 The Next Phase of Wind Power Growth in Five Charts | BloombergNEF (bnef.com)
4 Orsted Will Use NJ Wind Port to Build Offshore Wind Farm (usnews.com)
5 2022 Offshore Wind Solicitation - NYSERDA
6 Governor Hochul Announces Nation-Leading $500 Million Investment in Offshore Wind | Governor Kathy Hochul (ny.gov)
7 Board of Public Utilities | About BPU (nj.gov)
8 NY Sets First US 'Mesh-Ready' Rules to Link Offshore Wind Power | 2022-08-01 | Engineering News-Record (enr.com)
9 Analysis: Record-low price for UK offshore wind cheaper than existing gas plants by 2023 (carbonbrief.org)
10 Siemens unwraps 'world's longest' wind blade at 75 metres | Recharge (rechargenews.com)
11 Siemens Gamesa Begins Testing 115-Meter-Long Wind Turbine Blades – CleanTechnica

One of the primary international design standards referenced for both the onshore and offshore wind industry is IEC 61400 standard published by the International Electrotechnical Commission (IEC). Specifically, IEC 61400-1 defines the basic design requirements for wind turbine generators and specifies a minimum design life of the system to be 20 years. This minimum design lifetime was initially an industry target, but, as the industry and technology has matured, this lifetime has the potential to be re-evaluated. Nevertheless, there have been industry-wide struggles with systemic failures and maintenance challenges for components and wind systems well before their design lifetimes have expired, so experience and future research and development will be required to mitigate these risks.

Designing for longer lifetimes can potentially improve the overall cost structure and financial returns of projects—thereby potentially making investments in both onshore and offshore wind more attractive to investors and, ultimately, more affordable to the end user. This is inherently a trade-off between the costs required for designing longer lasting components versus additional energy production near the end of life of the system. Designing projects to operate longer may also maximize the decarbonization benefits by reducing the overall lifecycle emissions of the energy produced by the wind generation plant.

One reason offshore wind can be more expensive than onshore wind is because of the extensive and expensive infrastructure needed to build and operate farms located in the ocean. Additionally, permitting requirements for new infrastructure can be time-consuming and expensive. Planning to utilize the foundations and cables necessary for offshore wind projects longer may lower both costs and environmental impacts. Designing projects to operate longer after securing necessary permits can be another potential financial advantage.

The Bureau of Offshore Energy Management (BOEM) is responsible for issuing leases for wind power plants being built in American waters. U.S. law requires BOEM issue leases that have a minimum operational period of 25 years[12] with the option to terminate earlier. BOEM also has authority to provide leases with longer terms, which is already happening. For example, Dominion Energy's Coastal Virginia Offshore Wind project secured an operational lease term of 33 years[13].

There is also the possibility of repowering offshore wind farms with new turbines once their initial lease expires. Currently, there are no regulations governing repowering either in the U.S. or in more mature markets. But there is reason to believe there would be interest in future repowering, particularly because any existing offshore wind farm would have already gone through the extensive permitting necessary to be constructed in the first place. The viability of repowering, though, may depend on other factors, including the remaining design life of the foundations and blades, as well as the reliability and serviceability of the wind turbine generators.

Additionally, there is renewable energy market interest in extending project lifetimes to meet renewable energy portfolio standards, government goals, and to provide cost stability for ratepayers. The New York State Energy Research and Development Authority (NYSERDA) has utilized an industry leading term of 25 years to solicit Offshore Renewable Energy Credits (OREC). This longer-term energy offtake agreement potentially benefits the financial model for development of offshore wind resources and may be a coming trend as governments worldwide look to attract development in their waters.

INDUSTRY ADVANCES IN TURBINE DESIGN

On a variety of fronts, offshore wind technology innovation is accelerating quickly—with important implications for project lifetimes and economics. For example, manufacturers like Vestas and Siemens Gamesa are now releasing designs that deliver 50% to 100% more power than products released just a few years ago. Another key industry trend is the increased design lifetimes of offshore wind components, with most modern units being certified with stated lifetimes of 25 years[14,15,16]. Other manufacturers have shown interest in achieving 40-year design lifetimes[17], although banking on that much extended lifetime may be unlikely without extensive validation.

Another technology advancement aimed at allowing offshore wind farms to operate under the most extreme wind conditions has the potential to extend plant lifetimes. Over the past couple of years, wind turbine prototypes developed by manufacturers like Siemens Gamesa and GE Renewable Energy have been certified to withstand extreme-wind conditions. These so-called typhoon-class designs allow the turbines to bear up against Category 3 hurricane winds, with wind speeds up to 57 meters per second (127 mph) averaged

12 eCFR :: 30 CFR 585.235 – If I have a commercial lease, how long will my lease remain in effect? [ecfr.gov]

13 Microsoft Word – VA LEASE FORM 052213.docx (boem.gov)

14 IECRE.WE.TC.21.0093-R2 | IECRE Certificates [certificates.iecre.org] GE Halide X 12 MW

15 IECRE.WE.TC.20.0070-R2 | IECRE Certificates [certificates.iecre.org] SGRE 200DD-14MW

16 IECRE.WE.CC.18.0003-R0 | IECRE Certificates [certificates.iecre.org] Vestas V174-9.5 MW

17 TÜV NORD and GE Renewable Energy Announce first Design Conformity Statement for wind turbines with a lifetime of 40 years | GE News

over 10 minutes. Additionally, the typhoon-class turbine designs can handle wind gusts in excess of 70 meters per second (158 mph) for a short 3-second interval.

These typhoon-class turbines offer the possibility—though not the guarantee—of a longer design lifetime. If equipment is designed to be able to withstand intense wind but never actually experiences extreme loading, the robust design should allow for longer operation under nominal conditions. In other words, preparation for typhoons and hurricanes that may never show up may translate into a longer operational lifetime for turbines, foundations, and blades.

If design lifetimes can be extended with the use of typhoon-class turbines that improve reliability, the result could be lower overall LCOE, even while considering potentially higher capital costs for the typhoon-class wind turbine. This would be even more likely if wind farms using this technology were able to extend their project lifetimes. There is precedent for this in the onshore wind market. Bureau Veritas recently helped a U.S. onshore wind farm receive a three-year lifetime extension[18] through detailed analysis of historical operating conditions, corrective actions based upon wind turbine inspections, and the development of further maintenance plans.

It should also be noted that the design lifetime of offshore wind plants is not determined solely by robust turbine design. A host of other components must also match the extended lifetime of turbines, including the tower, foundation, and blades. And while typhoon-class turbines are designed specifically to handle the extreme loads created by high winds, extended lifetimes are also threatened by the long-term fatigue of load on components.

For example, blade root bolts, which connect the blade to the turbine, must withstand significant cyclical loading over the course of many years. This means that wind turbines need to account for fatigue loads versus extreme loads in order to achieve extended lifetimes. This requires planning that may include the replacement of fatigue load driven components as part of the operations and maintenance tasks.

Turbine lifetime assessments are also now being offered to help offshore wind owners gauge project lifetimes[19,20]. The analysis is intended to provide assurance that the system is designed to extend equipment lifetimes and increase the ROI of existing projects.

RESEARCH FINDINGS AND A ROADMAP FOR THE FUTURE

EPRI has conducted extensive research into topics relevant to design lifetimes, lifetime extension, and other topics that are relevant to maximizing the financial, operational, and environmental benefits of offshore wind.

For example, EPRI developed the Wind Network for Enhanced Reliability (WinNER), a web-based tool designed to identify both why turbines fail before they reach the end of their design lifetimes and to provide access to reliability data about components like blades, gearboxes, generators, and pitch and main bearings. To do that, EPRI created a database to store anonymized information about wind turbine deployments, including where it was installed, when, and who manufactured its major components. In total, the database has information about more than 10,000 turbines made by seven manufacturers totaling over 25 gigawatts of installed capacity. The database also includes information about turbine failures, including when it happened, how damage was detected, and the failure mode.

Project developers can use WinNER to guide their selection of components. The collection and analysis of data required to build WinNER has also surfaced lessons about why turbines and components fail prematurely—information that can be used to address the root causes of failures. Among the causes identified were issues with manufacturing quality, improper load design, inadequate maintenance, and the unique wind characteristics where turbines were installed.

Other EPRI research has investigated how to assess the remaining useful life of wind turbines, and operations and maintenance costs, over the life of wind farm assets.

Additional research is needed to better understand the quality and failure modes of other major offshore wind farm components. In 2022, EPRI and the National Offshore Wind Research and Development Consortium (NOWRDC) launched a project to investigate offshore wind turbine blade integrity during the manufacturing process[21].

18 P&U-LTE Case Study (bureauveritas.com)

19 Wind Turbine Generator Lifetime Assessment | TÜV SÜD (tuvsud.com) [tuvsud.com]

20 Lifetime extension of wind turbines DNV [dnv.com]

21 Project Database – National Offshore Wind Research and Development Consortium

There are numerous research questions that must be answered for offshore wind to reach its potential scale over the next decade. Among the topics that need to be addressed are differences between structural vulnerabilities and equipment fatigue. Tools for better estimating operational lifetimes are also needed, as are ways to guide decisions about the potential to extend project lifetimes and repower existing offshore wind developments. In these and other cases, real-world data and experience needs to be used to enhance reliability models.

EPRI Research on Reliability

- Assessing Remaining Useful Life of Wind Turbines (epri.com) – Remaining Useful Life (RUL) is analogous to LTE
- Reliability and Lifetime Estimates of DER-Based Planning Alternatives: Photovoltaic Systems, Energy Storage, and Inverters (epri.com) – inverter lifetime is the heart of power generation for a wind turbine
- Wind Turbine Blade Recycling: Preliminary Assessment (epri.com) – life extension of blades analysis; analysis also looks at varying blade lifetimes 15–25 years
- EPRI Research Roadmap: Large Scale Wind Plants – outlines research objectives to extend hardware lifetime (advanced data analytics, etc.)
- Wind Turbine Generator Reliability and Damage Prediction: Generator Technologies, Failure Modes, and Life Impact Factors (epri.com) – lifetime impact factors
- Program on Technology Innovation: Offshore Wind Turbine Technology Status (epri.com) – some impacts to lifetime for offshore turbines
- Wind Turbine: End-of-Life Management Infographic (epri.com) – impacts of short design life

EPRI Research on LCOE and System Costs

- 2019 Wind Technology Status, Cost, and Performance (epri.com)
- Renewables Insights: Wind Cost and Performance Trends from 2021 (epri.com)
- 2020 Wind Technology Status, Cost, and Performance (epri.com)
- Wind Operation and Maintenance Costs over Asset Lifetimes (epri.com)

CONTACT INFORMATION

Principal Investigators:

Program 206 Wind Generation

Curtiss Fox, Sr. Technical Leader. cfox@epri.com. (704) 595-2391

Brandon Fitchett, Program Manager. bfitchett@epri.com. (704) 595-2047.

For inquiries regarding the technical content of this brief or for general inquiries about EPRI's Quick Insight Briefs, please send an email to QuickInsights@epri.com.

Quick Insights are developed by EPRI to provide insights into strategic energy sector questions. While based on sound expert knowledge, they should be used for general information purposes only. Quick Insights do not represent a position from EPRI.

3002025892 December 2022

EPRI

3420 Hillview Avenue, Palo Alto, California 94304-1338 • 800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com