Engineering X

Safer End of Life for Offshore Wind: Challenge Statement

Royal Academy of Engineering

LR Foundation

Contents

Royal Academy of Engineering
Prince Philip House
3 Carlton House Terrace
London SW1Y 5DG
Tel: 020 7766 0600
www.raeng.org.uk
@RAEngNews

Introduction

Offshore wind energy is becoming an increasingly important pillar of energy systems around the world. A sense of urgency to transition to renewable energy has been fuelling its development and expansion over the past 20 years, with accelerating growth. While this development is exciting and critical to enable a more sustainable energy supply for everyone, it also bears some challenges.

Offshore wind structures are designed and built for a certain lifetime, currently 20 to 25 years. What happens to the structures at the end of their planned life poses complex challenges, including relating to safety. These safety challenges range from the technical issues of dismantling large offshore structures and transporting these to shore, through to the safety implications of exporting potentially hazardous waste or second-hand parts for reuse from a European or US context to other geographies.

Such end-of-life safety challenges for offshore wind have received little attention so far. With a growing number of ageing farms, by 2035 we will see over 3.5 gigawatts of offshore wind turbines come to their end of operational life. This equates to roughly 600 wind turbines by 2030, and future waves will involve even bigger numbers and sizes of turbines.[1] Insufficient consideration and planning for the end of life of offshore wind could have significant safety and environmental implications. We have seen this play out in other industries, such as oil and gas or shipping, in addition to the economic implications – decommissioning the UK's offshore oil and gas infrastructure is set to cost taxpayers £24 billion.[2]

The Engineering X Safer End of Engineered Life programme has been exploring safety issues in traditional offshore structures and ships, where unsafe practices are prevalent in parts of the sector. More than 70% of obsolete ships worldwide end up in South Asia. Here, they are broken under rudimentary conditions on just three beaches with devastating effects to the workers – who are often exploited migrants – surrounding communities, and the environment.[3] While offshore oil and gas decommissioning is more regulated and generally safer, there are reports of an increasing number of floating oil and gas units being sold for scrap and decommissioned unsafely. Newer markets are also now ready for decommissioning with their own peculiarities to manage safely, such as in the ASEAN region.[4]

We believe that end of life must be planned for to prevent harm to human health and the environment. As the first wave of offshore wind is entering its end-of-life phase, we have an opportunity to learn from past mistakes and wins, to get in early and to develop together a safer and more sustainable system that considers decommissioning and end of life before it's too late. To do this, we are drawing on our previous experience, community, expertise, and our way of working that prioritises global and multidisciplinary conversations that include unheard voices. We plan to bring attention to this emerging issue and start a wider conversation on these safety challenges early.

In this statement, we set out some of the key safety challenges in end of life of offshore wind which we have collected from scoping activities and a roundtable held with academics and experts in November 2023. We close the challenge statement with how we view our role in the area and how you can join us as we seek to achieve safer end of life for offshore wind.

---

[1] End-of-life planning in offshore wind, Offshore Renewable Energy Catapult UK, April 2021, *https://ore.catapult.org.uk/wp-content/uploads/2021/04/End-of-Life-decision-planning-in-offshore-wind_FINAL_AS-1.pdf*.

[2] Oil and gas in the UK – offshore decommissioning, UK National Audit Office, January 2019, *https://www.nao.org.uk/press-releases/oil-and-gas-in-the-uk-offshore-decommissioning/#:~:text=The%20government%20estimates%20that%20decommissioning,by%20the%20National%20Audit%20Office*.

[3] The problem, NGO Shipbreaking Platform, 2024, *https://shipbreakingplatform.org/our-work/the-problem/*.

[4] Recycling Outlook: Decommissioning of North Sea Floating Oil and Gas Units, NGO Shipbreaking Platform, September 2019, *https://shipbreakingplatform.org/wp-content/uploads/2022/01/Shipbreaking-OG-Report_compressed-compressed.pdf*; Towards a safe and sustainable decommissioning process, ASEAN and South Asia Offshore Decom SEELOS project, 2024, *https://aseanoffshore-decom.org/*.

Starting point: Safety challenges and opportunities at the end of life of offshore wind structures

Following our scoping, we have summarised six key challenges and opportunities that have emerged across various sources. While this list is not exhaustive, it demonstrates the wide range of considerations necessary and offers a starting point for future work on this complex challenge. It will serve as a basis for the Safer End of Engineered Life programme's work on offshore infrastructure and inform how we continue to work with partners.

1. Offshore context: One of the key safety challenges for any end-of-life activity is the remote, harsh and complex offshore environment. Identifying ways to ensure safe late-life maintenance and decommissioning operations for wind installations that have been offshore for decades requires careful planning, as well as learning and adaptation from existing offshore end-of-life approaches.

Key challenges and opportunities include:

- **Unique offshore wind challenges:** despite existing experience in decommissioning offshore oil and gas structures, the number and different characteristics of offshore wind structures require new or adapted approaches.
- **Safe access of aged infrastructure:** ensuring safe access to offshore wind structures after several decades of operation is an immense challenge, especially as offshore wind structures are not built for the extended human operation on board at point of decommissioning.
- **Safety best practices:** establishing and disseminating safety best practices specific to offshore wind installations is crucial for minimising risks.
- **Cost of safety offshore:** working closely with all partners to understand the safety requirements at end of life and their cost implications. A lack of planning and appropriate budgeting for end of life creates severe safety issues at this stage.

2. International context: As current offshore wind structures reaching their end of life are concentrated in Europe, there is little consideration of the impact of end-of-life practices globally and in low- and middle-income countries in particular. A lack of understanding of what this may look like in other regional contexts could have grave safety consequences in the future.

Key challenges and opportunities include:

- **International adaptability of end-of-life practices:** the wind farms reaching their end of life are currently based in European waters. As such, this is where initial end of life activity will take place. However, precedent from ship recycling, and emergent practice for floating oil and gas platforms, indicates that unclear, unsafe and polluting end-of-life practices are likely to affect parts of the world that are often less well equipped to manage them. It is therefore critical to consider from the very beginning how to develop processes that are sensitive to their potential safety impact beyond the European context.
- **Exporting parts:** as calls for circular approaches and commitments to full reuse or recycling increase, turbine and infrastructure parts are being gifted and exported to regions with developing wind energy sectors. While second life can play an integral part in circular energy systems, there is a danger of neglecting the recipient regions' capacity and needs. This is both to receive and maintain structures, as well as deal with them at their end of life. Care must be taken that responsibility for end of life is not simply exported.
- **Contextual differences:** decommissioning practices developed in Europe will likely set the industry standard for offshore wind decommissioning more generally. As offshore wind energy continues to expand beyond Europe, throughout North America, into Asia and across the rest of the world, it is pertinent to consider how the decommissioning process might vary based on context. For instance, geographic aspects, scale of farms or lack of pre-existing offshore infrastructure may all play a role. Safer end-of-life processes for offshore wind will require geographically appropriate

and systemic approaches that include the perspectives of possible future offshore wind sites early on in this conversation.

- **Just transition:** offshore wind infrastructure is resource-intensive, particularly for raw materials and rare metals. As many high-consuming countries are transitioning to renewable energy sources, there is a lack of consideration for the safe sourcing and fair distribution of these materials and resources globally.

3. Infrastructure and skills: The existing supply chain, infrastructure and workforce are not yet set up or understood well enough to handle the impending surge in end-of-life activity for offshore wind installations. This is likely to create bottlenecks which could affect the safety of end-of-life processes.

Key challenges and opportunities include:

- **Technical challenges:** further developing technical solutions that meet the specific needs of dismantling offshore wind energy will be critical to better inform decommissioning infrastructure requirements, ensuring this can happen safely.
- **Supply chain limitations:** the existing supply chain capacity and use of it are unknown because there is no overarching understanding of what exactly will be needed, when and by whom. Scarcity of crucial infrastructure and skills for decommissioning will negatively affect safety.
- K**nowledge gaps:** as there is little experience of offshore wind decommissioning, best practice guidance and wider health, safety and environment rules are not yet established to inform safe decommissioning.
- **Skills development and transfer:** as the end-of-life sector develops, it will be important to ensure the workforce is skilled and that there is an effective knowledge transfer between life stages of offshore wind and from other sectors such as onshore wind and oil and gas.

4. Awareness and collaboration: Addressing the safety challenges in offshore wind end of life requires the wider system surrounding the sector to see the importance of safe end-of-life management – and to understand the implications if such safe end of life is absent. Awareness is key to enable collaboration across the system, to develop and share best practice.

Key collaboration challenges and opportunities include:

- **Systems approach:** raising awareness in and involving the entire system around end of life to ensure a holistic approach that avoids loopholes and unintended consequences. This means being inclusive and mindful of all stakeholders, structures and dynamics, resources, and motivations.
- **Building an evidence base:** creating a comprehensive evidence base to enable alternative end-of-life practices. This could for instance include developing transparent inventories of assets which would enable more circular use across operators.
- **Best practice development:** to ensure consistent and thorough safety standards for end of life.
- **Learning from other sectors:** drawing insights from sectors such as oil and gas decommissioning, onshore wind, and other large infrastructure decommissioning will be critical to ensure learning on safety best practices.

5. Circularity: There is a lack of consideration for the whole life cycle of offshore wind, including the end of life. This means that opportunities are lost to design structures that create minimal resource wastage, due to preventative maintenance, planning for life extension and repowering and collaborative reuse systems. Seizing these opportunities would save costs and resources – as well as potentially minimise unsafe end of life scenarios.

Key challenges and opportunities include:

- **Designing and planning for end of life:** the scale and complexity of the end-of-life process requires careful planning and realistic budget considerations from the very start of developing offshore wind infrastructure. Stakeholders from the entire life cycle must collaborate to ensure that structures and the systems around them are set up safely for the entire life cycle. Early understanding of what modular design, preventative maintenance, part replacement systems, dismantling practices or disposal systems could look like would improve safety throughout significantly.
- **Developing circular supply chains:** to enable circularity for offshore wind, it is necessary to support the development of innovative supply chains and infrastructure.

6. Regulation: Current regulation governing the end-of-life processes for offshore wind installations is underdeveloped and unclear. This creates significant obstacles for effective planning and budgeting for safety.

Key challenges and opportunities include:

- **Lack of specific regulation:** the lack of specific regulation in most jurisdictions that have offshore wind structures creates ambiguity around the decommissioning process from the outset and prevents robust planning. Currently, decisions are often made on a case-by-case basis, meaning there is little consistency to plan for. Examples include unclear requirements for what must be removed, the potential to extend leases beyond the original period for life extension or repowering, or lack of clear and detailed requirements for decommissioning safety. This in turn obstructs adequate planning and budgeting for a safe end-of-life process.
- **Ownership and responsibility:** ambiguity surrounding the responsibility for the end-of-life processes including decommissioning, dismantling and disposal is further stopping progress in improving safety. This lack of clearly defined ownership for different aspects of end-of-life planning, implementation and budgeting between original equipment manufacturers (OEMs), wind farm operators, and other parties means that there is no consistent safety approach for end of life.
- **Differences across jurisdictions:** where there is regulation, differences across jurisdictions contribute to the complexity. Those involved in end-of-life processes must navigate the varying regulatory contexts that interfere with more efficient, optimised processes.
- **Commercial pressures:** the strong focus on price in offshore procurement processes prompt operators to lower prices at the planning stage. As end of life lies far in the future, it is easy to assume technology developments and regulatory frameworks may have changed so significantly that end-of-life budgets can be reduced. Underbudgeting can severely affect safety if necessary, safety precautions are unaffordable at the end of life stage.

What we will do

The six challenges outlined in this challenge statement are just some of the most pressing ones in offshore wind decommissioning – this is not intended as an exhaustive list. They offer a starting point and demonstrate what is needed to address a complex issue. Some overarching activities that could address multiple challenges include:

- more visibility of the need to plan for end of life in offshore wind
- more communication and sharing of existing information across stakeholders and sectors
- more coordination of efforts to address these challenges
- inclusion of all stakeholders and unheard voices, including those at the very end of the life cycle, and from low- and middle-income countries with offshore wind potential
- looking at the whole system and entire life cycle from a circular perspective.

We are now seeking to keep building our understanding on this issue, raise visibility, and create spaces for stakeholders to develop ways forward that will lead to a safer and more sustainable system. Engineering X will bring its experience, network and resources to address this important challenge by:

- raising awareness of the need for safe practices at the end of life for offshore wind, focusing on safety and the impact on low- and middle-income countries
- facilitating collaboration by bringing together stakeholders from across regions, sectors and systems in order to develop safe end-of-life approaches.

The six challenges outlined in this challenge statement are just some of the most pressing ones in offshore wind decommissioning.

Join us

Working towards safety at the end of life of offshore wind will take an interdisciplinary community to consider and tackle it. If you are working in and around offshore wind, have experience or expertise in end-of-life management more generally, are from a region now expanding into offshore wind or are simply interested in understanding more about this work, please get in touch by emailing **Ann-Sophie Freund, Programme Manager Safer End of Engineered Life:** ann-sophie.freund@raeng.org.uk.

We are particularly interested in hearing from:

- health and safety focused organisations expanding into offshore wind
- international organisations pushing for a just transition to net zero
- members of the offshore wind industry working on end-of-life within their companies
- academic representatives researching circular end-of-life technologies
- other members of civil society globally who are working to improve safety at end of life in offshore wind
- regulators across the world who are developing end-of-life guidance for offshore wind.

Acknowledgements

We are extremely grateful to all those who have contributed to the development of this statement, including especially:

- all partners from our programmes and beyond, who contributed through conversations and sharing insights
- all participants of the roundtable 'Offshore wind decommissioning: key safety challenges and priorities' in November 2023
- Professor Susan Gourvenec, FREng, Engineering X Offshore Infrastructure and Ships theme lead.

Who we are

Engineering X

Engineering X is an international collaboration founded by the Royal Academy of Engineering and Lloyd's Register Foundation that brings global experts together to engineer change. We work in partnership across disciplines and sectors to implement our vision of engineers playing their key role in addressing global challenges.

There are currently 5 programmes in Engineering X which are:

- Transforming Systems through Partnership (TSP)
- Skills for Safety (SFS)
- Pandemic Preparedness (PP)
- Safer Complex Systems (SCS)
- Safer End of Engineered Life (SEEL)

We take a challenge-based approach and tackle our challenges in a variety of ways. We apply different mechanisms to our challenges as is appropriate (grants, communities of practice, workshops, high-level partnerships, global reviews) in recognition that challenges are complex and must be tackled from multiple levels and by engaging different stakeholders. More information about the programmes can be found here: *https://engineeringx.raeng.org.uk/*

Royal Academy of Engineering

The Royal Academy of Engineering is a charity that harnesses the power of engineering to build a sustainable society and an inclusive economy that works for everyone. In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public. Together we're working to tackle the greatest challenges of our age.

Lloyd's Register Foundation

Lloyd's Register Foundation is an independent global charity that supports research, innovation, and education to make the world a safer place. Our vision is to be known worldwide as a leading supporter of engineering-related research, training and education that makes a real difference in improving the safety of the critical infrastructure on which modern society relies. In support of this, we promote scientific excellence and act as a catalyst working with others to achieve maximum impact. Lloyd's Register Foundation charitable mission

- To secure for the benefit of the community high technical standards of design, manufacture, construction, maintenance, operation and performance for the purpose of enhancing the safety of life and property at sea, on land and in the air.
- The advancement of public education including within the transportation industries and any other engineering and technological disciplines.