DECOMMISSIONING CASE STUDY

Circular Economy in the Wind Sector – Summary

SUMMARY REPORT

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INTRODUCTION

CEWS

The Circular Economy for the Wind Sector joint industry programme (CEWS) recognises that there are significant challenges for decommissioning offshore wind, and a looming materials crisis for new builds. To date, decommissioning of offshore wind turbines has been restricted to low numbers of demonstration turbines and individual turbines damaged beyond economic repair.

As demand for raw materials increases to meet global renewable energy installation targets, so too does the need for a circular economy and security of supply for strategic materials. Non-price factors are increasingly important within offshore wind leasing rounds, with some countries now including circular economy criteria within the bid process.

CEWS is focused on finding practical solutions to the inevitable and growing challenge of wind farm decommissioning, including future investment needs for specific materials, physical and regulatory challenges to wind farm decommissioning and the reclamation of materials. By linking in with other sustainability projects, such as SusWIND and CWIC, CEWS will avoid duplication and instead focus on the onward journeys for highly recyclable bulky materials such as steel and copper, and the hard to separate materials in smaller components.

The Challenge

The offshore wind sector is fast approaching the point where the earliest wind farms in the UK and across Europe will be decommissioned. With this major milestone there are several key considerations around the supply chain readiness to handle the materials arising in the most environmentally sustainable manner. ORE Catapult developed the CEWS programme as an industry-wide initiative to investigate the barriers and opportunities for a sustainable approach to decommissioning.

CEWS is building the body of knowledge required to establish standard practice and guidance for decommissioning offshore wind farms so that the sector may avoid the expensive and lengthy trial-and-error processes experienced by other sectors. This Decommissioning Case Study produced for Phase 1 of CEWS examines the readiness of the materials reprocessing industry to handle the quantity and types of materials arising from decommissioning of a generic geared and direct drive turbine.

MATERIALS MAPPING CASE STUDY

A generic 2MW geared and direct drive turbine have been estimated as a baseline for the current and future potential onward routes for materials. As the majority of components are the same between both turbine types, this was also applied to the direct drive breakdown, although the smallest turbine capacity offshore is 6MW. The findings use the waste hierarchy to estimate the relative environmental impact of different routes and identify gaps in both technologies and capacities for handling the types and volumes of waste that will arise.

Material breakdown and estimates were created using data from ORE Catapult's Levenmouth Demonstration Turbine in addition to publicly available sources such as current UK offshore wind farms (with approximations for wind farms with limited or sensitive data), manufacturer documentation and National Renewable Energy Laboratory (NREL) research data. Materials Industry experience and proprietary knowledge gained working with clients on validation testing provided the ability to anonymise and scale data for different capacities of turbine installed and for the size of wind turbines to be installed in future offshore wind sites. A specific breakdown was created for the nacelle due to the high number of sub-components in the nacelle.

The key assumptions made in the analysis include:

- The tower flanges, bolts and safety/access systems are based on a percentage of total tower structure. The safety/access system(s) is assumed to be steel and includes but is not limited to ladders, platforms, fall arrest systems, lighting protection, railings, base door, and lift access.
- Power electronics have been accounted for within the nacelle breakdown.
- System lubrication consists of hydraulic oil, grease, and gear oil (gear oil is excluded from direct drive).
- Generator type is permanent magnet synchronous generator (PMSG) for direct drive, and three-stage, high speed for geared.
- The mass of all components excluding the nacelle are the same for direct and geared turbines. the following components within the nacelle have mass differences between turbine type:
    - Gearbox (excluded from direct drive)
    - Generator
    - Mainframe
    - Power electronics (including convertor and transformer)
    - System lubrication
- Where a main component includes several sub-components and sufficient mass data was unavailable, the primary material was assumed across all sub-components.

In addition to the assumptions made, there are areas of uncertainty due to a current lack of available mass, material, and specific sub-component details. Key areas of uncertainty include:

- The component breakdown is to the lowest level possible using available material and mass data or relevant scaling formulas.
- The blade mass and material breakdown are based on ORE Catapult analysis developed from industry experience and knowledge of specific blade models. This provides an average value which can vary depending on manufacturer and turbine size.
- Scaling of some wind turbine parts has been based on a single market model or research data meaning other turbines may vary and could have a greater effect once scaling is introduced.
- Jacket and monopile masses will always vary slightly due to differences in water depth, met ocean environment and seabed conditions.
- Offshore substations were not included.

Each component was scaled individually based on the available mass and scaling data. Figure 1 shows the combined mass scaling for blades, tower and nacelle components against turbine capacity.

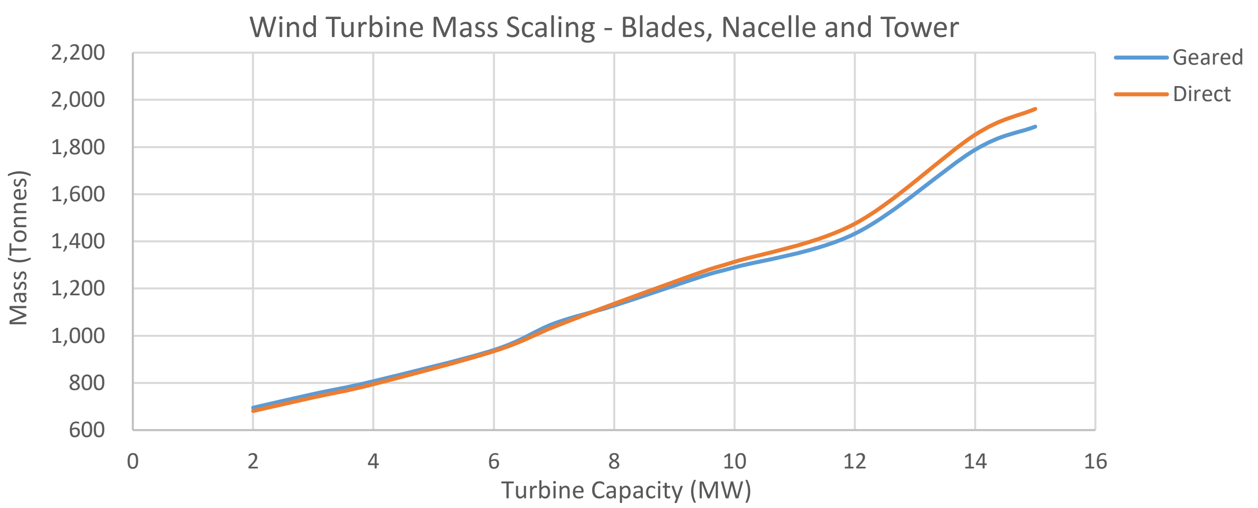

Figure 1 - Turbine mass (blades, nacelle and tower) against turbine capacity

RECOMMENDATIONS

Steps for the material management industry

Developing a circular economy supply chain focussed on the remanufacture, refurbishment and recycling is a crucial step for effective and sustainable offshore wind decommissioning. Due to the current uncertainty around the offshore wind decommissioning timeline, it is difficult for the material management industry to know when to expect the large volumes of decommissioned turbine material. Steps could be taken to ensure the industry is prepared such as identifying estimated material volume, ensuring facilities can process the expected volume and plan any onward routes for refurbished or recycled materials.

Material management companies will also be expected to track materials and the processing methods being used. Adopting the use of material passports would ensure this material data is captured and available throughout the entire product lifecycle. The global warming potential (GWP) can also be recorded and stored in the passport, which supports environmental reporting and the traceability of material recycling, for end of life and the use of recycled materials for manufacture.

Steps for the offshore wind industry

The supply chain is keen and ready to take on the challenge of offshore wind decommissioning. The critical information currently missing is the certainty of when large scale decommissioning is likely to take place. Uncertainty exists due to many factors including discussions around plans for life extension, the energy crisis, and an increased political interest in accelerating offshore wind installations as a means of energy security against global conflicts and instabilities in O&G resources.

Any means of providing certainty around timelines, materials and quantities will support the supply chain to have the technology and capacity in place to handle and process decommissioned wind farms. Operators could be more transparent about their decision-making process to enable supply chains to be more responsive and to prepare.

In addition, OEMs could utilise material passports to collect necessary data for the end of life stage such as material separability, dimensions and potential re-use options. Rare earth metals are of strategic significance for future electrification and decarbonisation projects and their recovery from end-of-life wind turbines is essential. Owner-operators must work with Original Equipment Manufacturers (OEM) to determine where, how and what quantities of materials should be recoverable at end of life. This information would support a more streamlined material management process and overall material recovery.

Technologies and experience should be sought and utilised from other sectors to support greater opportunities for material circularity in the wind industry. A focus on cross-sector collaboration and finding synergies between end of life materials from different industries will be essential in bringing the economies of scale and investment necessary, which are crucial to finding viable recycling solutions.

Steps for Government/policy makers

Clear and wind specific policy, regulation and legislation is required to support and guide decision making. Authorities have yet to make clear if all materials must be fully recovered on decommissioning or if some aspects could be abandoned and turned into artificial reefs to encourage biodiversity and marine habitat development. Discussions are ongoing with respect to the need to recover valuable materials for reuse; environmental impact of disturbing the seabed; health and safety implications for abandoning equipment and potential future impacts for new developments and other seabed users if all material is not recovered.

Waste management regulations dictate how materials are classified, how they should be handled and the necessary licenses and permits that are required for companies taking responsibility for them. These can vary between each of the four nations of the UK and the EU. While navigating necessary policy and legislative requirements will be essential for companies hoping to contribute to the successful decommissioning of wind farms, the single biggest contribution to ensuring that materials can be reused or recycled, is for assets owners not use words such as “disposal” and “waste” in decommissioning tender contracts. These instantly devalue the materials and classifies them as “waste” under the regulations, limiting the opportunities for them to be reused, remanufactured or more sustainably reprocessed.

Rare earth metals are essential for electrification and decarbonisation, it is absolutely essential that these materials are recovered. This will require greater cooperation with OEM to determine where, how and what quantities of materials should be recoverable at end of life. New legislation could be implemented to ensure that these materials are not lost in the general metal scrap heap.

The supply chain is keen and ready to take on the challenge of offshore wind decommissioning. The critical information affecting supply chain readiness is certainty over timelines for large scale decommissioning. Work to extend the useful life of wind farms will exacerbate this uncertainty. The key recommendations from this study are:

- Operator transparency around timelines, materials and quantities will support the supply chain to have the technology and capacity in place to handle and process decommissioned wind turbines. This could include publishing projected decision dates for late-life wind farms.

- Rare earth metals are of strategic significance for future electrification and decarbonisation projects and their recovery from end-of-life wind turbines is essential. Owner-operators must work with Original Equipment Manufacturers (OEM) to determine where, how and what quantities of materials should be recoverable at end of life.

- Technologies and experience should be sought and utilised from other sectors to support greater opportunities for material circularity in the wind industry. A focus on cross-sector collaboration and finding synergies between end of life materials from different industries will be essential in bringing the economies of scale and investment necessary, which are crucial to finding viable recycling solutions.

- The single biggest contribution to ensuring that materials can be reused or recycled when turbines are decommissioned, is for asset owners not to use words such as “disposal” and “waste” in decommissioning tender contracts. These instantly devalue the materials and classifies them as “waste” under the UK and EU regulations, limiting the opportunities for them to be reused, remanufacture or more sustainably reprocess.

Clear and wind specific policy, regulation and legislation is required to support and guide decision making. Authorities have yet to make clear if all materials must be fully recovered on decommissioning or if some aspects could be abandoned and turned into artificial reefs to encourage biodiversity and marine habitat development. Discussions are ongoing with respect to the need to recover valuable materials for reuse; environmental impact of disturbing the seabed; health and safety implications for abandoning equipment and potential future impacts for new developments and other seabed users if all material is not recovered.

Gaps

The current circularity and capacity gaps in the supply chain are:

- *Structural metals* – whilst scrap handling and steel recycling exist widely in the UK, the onward manufacturing supply chain for the offshore wind industry is not local. Several proposals exist for UK-based tower, monopile and floating wind foundation manufacturing facilities, however the earliest any of these facilities expects to be available for production is currently around 2026.
- *Rare Earth Metals* – technology solutions for the recovery and recycling of rare earth magnet materials are emerging and nearing commercialisation. The UK Government has recognised the critical role that rare earth elements play in achieving Net Zero as outlined in the Critical Minerals Strategy published in 2023. These materials must be recovered and reprocessed back into the supply chain.
- *Composite materials* – options for end-of-life blade processing are nearing commercialisation with some companies looking to stockpile material ready for when their facilities are established. Extreme fluctuations in supply are a major challenge for any business reliant on wind farm decommissioning. Storage for materials will be essential to maintain continuous operations.
- *Rubberised hydraulic hoses* – hoses are currently not widely recycled due to material separation issues. However, processing technologies for similar products such as those used for recycling car tyres could be adapted. Care is necessary when decommissioning these products to minimise oil contamination, and avoid the materials being classified and disposed of as hazardous waste.
- *Seabed structure recovery* – structural metals are widely recycled, however a technology challenge remains for the recovery of monopile and pile structures from the seabed. Scaled technology demonstrations have proven successful for some innovation, however the question remains in regards to the level of material recovery that will be mandated by the relevant authorities.
- *Subsea cable recovery* – export and array cables have been recovered from the seabed to conduct repair operations, such as replacing sections of the cable that have become damaged. The technology exists to recover the cables, however the technology challenge relates to the scale up necessary to recover an entire cable from the seabed.
- *Material volume challenges* – while there are some inspiring examples for what can be achieved with all the components of a single turbine, the challenge is how to manage the volume of equipment that requires processing when a whole wind farm or multiple wind farms are decommissioned.