Counting Costs
Decommissioning of offshore wind farm assets

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Introduction
To date, no offshore renewable energy project has decommissioned its assets, apart from a meteorological mast. This is simply because no offshore project has reached the end of its life. As a consequence, there is little practical experience within the industry to draw upon when it comes to estimating the costs for decommissioning guarantees / finance (e.g., a bond, mid-life accrual fund or letter of credit), other than lessons learnt from oil & gas.

Globally, offshore renewables are spreading from its well-defined routes in Europe to more emerging markets, where the need for electricity power is exceeding demands due to industrialization. Whilst the deployment of renewables may counter-balance future power demand short-falls and contribute to meeting CO2 emission targets, they are a long way from the prospect of decommissioning. Yet, planning appropriate decommissioning strategies and estimating their costs need to be considered early in a projects life-cycle to adequate secure bond finance and meet legislative requirements.

In the UK, offshore wind farm assets and associated infrastructure for Round 1 projects are now appearing on the horizon, yet detailed decommissioning of offshore renewables remains poorly understood. This paper discusses the major challenges facing anyone estimating the costs for decommissioning of offshore renewable assets for bond security purposes. It is not a review of different types of financing arrangements as there are already authoritative papers on the topic.

Avoiding the public burden
A common feature of all decommissioning regulations is the requirement of lease holders to follow strict protocols at the end of a projects life. These require assets to be removed, the site reinstated and clearance verified upon lease termination. Obviously, decommissioning regulations will vary in different countries, but they must all achieve their decommissioning objectives in a responsible manner that protects the public interest and commitments to international treaties (e.g., Convention for the Protection of the Marine Environment of the North-East Atlantic (“OSPAR”); International Maritime Organization (“IMO”) standards). Governments who fail to take prudent steps before consenting or permitting a project, may result in transferring unnecessary high cost burdens to the public. In this regard, regulators are mandated to ensure decommissioning bonds are secured, so all development entities provide adequate financial resources to protect the government from incurring any financial loss.

Estimating costs that adequately inform decommissioning bonds are critical, as too low an estimate then the financial burden of decommissioning may be placed on the public purse. Conversely, estimates that are too high

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1. A bond is similar to a loan from the borrower’s point of view and often takes the form of a tradable debt instrument, where the issuer (e.g., the Project Company) agrees to repay the bond holder the amount of the bond plus interest on fixed future instalment dates (see Yescombe, E. R. (2014). “Principles of project finance.” Academic Press 2nd Edition).


may become disproportionate costs to the developer, and so potentially compromising commercial viability. Realistic cost estimates also protect Governments from being financially responsible for the short-fall if the lease holder defaults.

**Decommissioning of offshore renewables**

Securing bond finance for renewable energy projects is slightly different from oil & gas projects, as they have a greater degree of certainty over their longer-term revenues (i.e. through a Power Purchase Agreement (“PPA”)), and so face less uncertainty over revenues towards the end of a projects life. This is important to regulators, as having the assurances that the project owner can ramp-up the necessary revenues to financially commit to decommissioning, when the time comes, provides confidence and so support at the planning stages.

It is common practice with many permitting authorities to ensure decommissioning plans are submitted before construction of a wind farm starts and in some cases permit approval. In the United Kingdom (“UK”), a decommissioning plan must be submitted to the licensing authority, the Department of Energy and Climate Change (“DECC”), at least three months prior to the planned decommissioning of the works. Typically, these initial plans contain sufficient information to describe anticipated activities and objectives, and include, for example, removal methods, site restoration, easement activity, schedules and confidential annexes to justify the expenditures for the decommissioning proposed.

Plans are updated when project assets are reviewed during the operations phase and at nominate time periods (e.g., at least 12 months, but potentially up to 5 years) before the end of operational life to ensure they reflect best practice (such as the principle of Best Practicable Environmental Option5 (“BPEO”)), at that time, and regulations. It’s worth noting that most Original Equipment Manufacturers (“OEM’s”) have their own authorised procedures for decommissioning wind turbine.

Critically, identifying decommissioning activities must be worked out in advance to promote liability management, regulatory and code compliance, cost and schedule containment, safety and environmental performance. It’s not uncommon to fine tune engineering design plans, as the project evolves during development. In some cases, these may have implications for estimating decommissioning costs.

The timescales for decommissioning must allow sufficient time to implement a cost-efficient decommissioning program. Typically, this ranges between one and two years after termination of lease. However, a word of caution, such timescales may not have a bearing on the size or scale of the project. This could pose a challenge for large wind farms like Round 3, for example, that are far offshore and where weather windows are more likely to restrict operations compared to nearshore projects.

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5. The principle of BPEO provides the most benefit or least damage to the environment as a whole, at an acceptable cost, in both the long and short term.
The ability to standardize decommissioning operations is largely accepted as general practise, but it is the scale of an offshore wind farm (e.g., number of Wind Turbine Generators (“WTGs”)) that will have the greatest bearing on costs. That said, offshore wind farms are considered more homogeneous compared to oil & gas facilities, as the ‘template’ for installing WTGs are typically the same and so ‘simply’ replicated across the project site. The timescales for decommissioning activities are variable depending on the size and complexity of the asset in question. Operations to remove buoys, bottom mounted moorings and meteorological masts, for example, can last from a just few days to several weeks. By contrast, the decommissioning of a large-scale wind farm involving hundreds of turbines may take months or an entire season or more. It’s worth noting that this has yet to be validated as no offshore wind farms has been decommissioned.

To date, decommissioning cost estimates within the European offshore wind industry have been considered by some to be underestimated, and for many viewed very simply as the reverse of installation. Whilst the latter view is largely true, simply removing physical assets underplay environmental considerations, which can lead to more complex environmental concerns than previously anticipated (e.g. presence of toxic gas, bentonite, noise, public safety issues, water quality and impacts on wildlife).

For cost estimate purposes, pre-empting such concerns based on project site location, design and installation strategies, may be beneficial to ensuring financial contingencies are proportionate. In some cases, an (“EIA”) may be required to inform the decommissioning process. This is the responsibility of the licensee / owner(s) and may include the commissioning and acquisition of any new site specific information (e.g., side-scan sonar, benthic surveys). In addition, survey evidence to support proof of seabed clearance and restoration, and any ongoing monitoring requirements.

Estimating decommissioning costs will always have a degree of uncertainty due to market and information constraints at the time of estimation. Anyone developing an appropriate model for calculating decommissioning costs needs to consider current market conditions and technology, and adjustments for inflation. Other factors include the influence of global economics, navigational safety, technical feasibility, and conservation and biodiversity objectives (e.g., leaving some of the structure(s) in place as artificial reefs).
Many operational elements of decommissioning can be well defined. They include, for example, vessel and cargo barge mobilization and demobilization, cutting and lift operations, or onshore transportation where components are being reused or disposed. However, less well defined element are costs incurred during the planning or review stages prior to commissioning operational activities. Typically, this review stage comprises of meeting contractual and regulatory obligations, scheduling the availability of services in the market place, procurement of services including work force and engineering management teams, and securing necessary permits to undertake decommissioning and disposal. Another area of uncertainty is whether developers will propose to undertake a comprehensive consultation process with other marine users prior to decommissioning and whether these costs become part of the decommissioning bond estimate.

**Decommissioning cost estimates**

Building cost estimate models for decommissioning offshore renewable energy facilities should be project specific, although the underlying methodology is applicable across all facility types. One of the challenges to estimating costs is extrapolating current costs and technologies into the future.

The decision to modify specific aspects of the decommissioning requirements (e.g., leaving facilities in-situ, partial removal, or reefing allowances) is typically permitted only on a case-by-case basis. This is not known until the decommissioning review process (if there is one) is completed. This level of detail and options for decommissioning (close to the end of a project) should already be accounted for when considering bond or other security financing. Therefore, cost estimate models should factor in different decommissioning options by developing scenarios that test the sensitivity of different strategies on costs.

To this end the highest price scenario that is practicable and proportionate to the project may be suitable for estimating the upper limits. Different decommissioning scenarios could include, for example:

- Is lifting or dredging scour protection practical? Given the potential seabed disturbance and release of particulate matter and other contaminants, which could have an impact on the ecology of the area; or
- Should electrical cables remain in situ? Given costs and level of potential environmental disturbance if they are already buried at a safe depth below the seabed.

All model assumptions should be future proofed to ensure cost estimates remain realistic. Model assumptions are best validated by expert consultants, and, where possible, through engagement with industry and the supply-chain sector (either by written correspondence, telephone or face-to-face meetings).
Developing a specific cost estimate per mega-watt hour may underestimate costs as turbine size, number and foundation type, for example, will vary across projects. Moreover, the methods for removal or partial removal, distance of project from shore, environmental conditions and ultimately disposal of components, will also vary across projects. Therefore, developing costs based on per mega-watt hour may not be representative of the actual costs incurred at decommissioning.

Cost models should also factor in less predictable variables in light of future market conditions, such as estimated vessel day rates (adjusted for anticipated inflation rates). A starting point for the model is to assume decommissioning is generally ‘installation’ in reverse, although as previously stated, decommissioning is not always that simple. Estimated costs need to be developed for each stage of installation from foundation, tower, transition section, nacelle, inter-array and export cables, and substations, scour protection, meteorological masts, and bottom fixed anchoring systems etc. Timescales for each stage and their components need to be estimated on a per-unit basis cost to build the model(s), and include contingency down-time associated with weather delays. In addition, costs for monitoring strategy (e.g., use of side-scan sonar surveys, divers etc.) where components are to remain in-situ.

Cost estimates typically use a number of theoretical models supported by the engineering literature and / or in-house engineering teams. They assist in parameterizing inputs from generation capacity, turbine capacity, and distance to port, installation vessel class, installation methods, day rate etc. In addition, data sources from the project or expert consultant teams involved in the cost estimation process, will further refine the reliability of cost estimates. All associated onshore infrastructure that requires decommissioning needs be factored in to the cost estimate modelling, but typically these items are best made available as a separate component. In addition, consideration of multiple project phases may need to be calculated.

Any innovative methods to reduce decommissioning costs may be possible despite the offshore renewable energy industry not yet undertaking its own decommissioning. For example, innovation against oil & gas standards could be adopted whereby suction bucket foundation technology could radically reduce the cost of decommissioning. It is worth noting that within the oil & gas sector, partial decommissioning is being considered as a management response to protecting biodiversity through ‘reefing’ because it may significantly reduce decommissioning costs.

6. Estimated costs for decommissioning a 300MW offshore wind farm is estimated around £40,000/MW or 2% of operating costs when spread over the lifetime of the project (Climate Change Capital, 2010).

7. It is unlikely that removal technologies will change dramatically over the next decade and so variations in cost estimates are likely to be small.
Decommissioning options for the various components of an offshore facility (e.g., foundation, tower, nacelle, mooring etc.) are typically determined and valued using a decision-tree.

Figure below shows a high-level example for a fixed WTG. The option(s) that result in the highest cost scenario is identified as an objective of this analysis.

Adapted from Fowler et al., 2014.

The same thought process could be applied across all facility / technology types and can be informed by more detailed data (Table 2).

<table>
<thead>
<tr>
<th>Design criteria characteristics</th>
<th>Decommissioning strategy</th>
<th>Projection parameters</th>
<th>Cost estimate parameters</th>
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</thead>
<tbody>
<tr>
<td>Nacelle</td>
<td>Complete removal, partial removal or leave in-situ, reuse, recycle, disposal approach, piles cut off just above the level of the bedrock seabed, monitoring strategy for components that remain in-situ, HDD bored capped etc.</td>
<td>Number, type, weight of key components, vessel types, distance of project site from port, onshore storage, disposal facilities etc.</td>
<td>Day rates, permits, vessels, dredging and barge boat mobilization and demobilization costs, seasonality, duration, lifting gear, labor, dive operation costs, etc.</td>
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<td>Tower section</td>
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<td>Transition piece</td>
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<td>Foundation</td>
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<td>Other subsea structures</td>
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<td>Inter-array cables</td>
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<td>Met tower</td>
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<td>Scour protection</td>
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<td>Substation top section</td>
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<tr>
<td>Substation foundation</td>
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*Table 2. Example only: summary of the type of attributes of decommissioning needed to inform cost estimation.*
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