Marine Scotland

Review of Approaches and Cost of Decommissioning Small Scale Offshore Renewable Energy Developments

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Introduction

Marine Scotland have commissioned Arup to assess the costs and approaches to decommissioning small scale offshore renewable energy installations (OREI) e.g. wave, tidal and floating wind. This report builds on a previous report completed by Arup, which reviewed offshore wind farm (OWF) decommissioning [1].

Offshore renewable energy is a developing industry with several different technologies being developed and trialled at small scale at a number of demonstrator sites in Scottish waters. Whilst OWF technologies have been proven and many commercial scale OWFs have been developed, other marine renewables technologies including wave, tidal and floating wind are still at lower Technology Readiness Levels (TRLs).

As covered in detail in [1], the Scottish Government, as of April 2017 is now responsible for the decommissioning of OREI in Scottish waters. As a result, Marine Scotland are interested in understanding the existing approaches, cost estimates and government guidance for decommissioning small scale OREI with the aim of providing recommendations to inform future Scottish policies and procedures.

This report draws on current government guidance, guidance and best practice from industry bodies, information on current and previous wave, tidal and floating wind projects and relevant decommissioning plans, where these could be obtained. Findings from the literature review have been supplemented with the outputs from consultations with technology developers, test centres and other stakeholders.

This report builds on the analysis in [1] and considers the differences between small scale OREI and commercial OWF. These differences, outlined at the start of this report, have been considered throughout this study and it is on this basis that recommendations are presented.

Structure of the report

The report is structured as follows;

Section 1: This section describes the variety of small scale OREI which have been developed in the UK and more specifically, demonstrated in Scotland. This section also provides a brief overview of the infrastructure installed on a wave, tidal or floating wind installations.

Section 2: This section considers the differences between commercial OWF and small scale OREI.

Section 3: In this section we consider the methodologies for decommissioning and removing all aspects of a small scale OREI.

Section 4: This section provides a brief summary of findings from a review of OWF decommissioning practice and guidance to assess any specific issues which are relevant to small scale OREI. This section also considers the consultees' experience of dealing with the regulator regarding decommissioning.

Section 5: This section examines the decommissioning costs or current small scale OREI and how these may change as the scale of the OREI grows. Provision of securities and how security arrangements could affect future technology development and testing is also considered.

Section 6: Conclusions are drawn and recommendations are made.

A glossary of key terms and bibliography is provided at the end of the report.

Consultations

Consultations with industry and the supply chain were undertaken to gain feedback on their views and experience regarding small scale OREI decommissioning approaches. The consultees included wave, tidal and floating wind developers, stakeholders and representatives from the supply chain in Orkney. The consultations took place as meetings with each organisation either by phone or in person. The organisations represented during the consultations are listed in the table below. Feedback from the consultations has informed the report and where relevant, specific stakeholder views are described, with key points highlighted. Other stakeholders including representatives from Scottish Government organisations (e.g. Scottish National Heritage, Transport Scotland), representatives of the fishing industry and environmental groups were consulted during the previous study [1]. The aim of the consultations during this study was to get specific input regarding wave, tidal and floating wind developments.

Table 1: Organisations who took part in the consultation

Organisations represented
• Crown Estates Scotland • Aquamarine Power[1] • Nova Innovation • Pelamis Wave Power[1] • Scotrenewables • Atlantis • Sustainable Marine Energy • Statoil • Kincardine Offshore Windfarm • Leask Marine • Europe Marine Energy Centre (EMEC)

[1] These organisations are no longer operational but in these cases, former employees were contacted.

1 The market context

This section describes the variety of small scale OREI which have been developed in the UK and more specifically, been demonstrated in Scotland. This section also provides a brief overview of typical infrastructure installed on a wave, tidal or floating wind installation.

The UK Government estimates that the wave and tidal energy has the potential to meet up to 20% of the UK's current electricity demand, representing a 30 to 50GW installed capacity [2].

Scotland is ideally placed for exploiting wave and tidal energy. The area off the North coast of Scotland, surrounding the Orkney Islands, is estimated to contain 50% of the UK's (25% of Europe's) tidal resource [3]. In addition, assessments suggest that up to 14GW of recoverable wave energy lies off the North and West coast of Scotland [4]. It is estimated that Scottish waters include 25% of Europe's offshore wind generation potential, much of which could be enabled with floating wind [5].

When considering wave and tidal devices, there are a great variety of concepts that have been installed and tested over the past 20 years, with the majority of demonstrating taking place in Scotland. Wave and tidal technology is still at an early stage of development relying heavily on Government and European grant funding to deploy demonstration devices. Floating wind however, has seen large investments with projects such as with Hywind, the world's first floating OWF, becoming fully operational in October 2017.

In order to discuss the variety of small scale OREI, the following categories will be considered throughout this report:

- Floating wave devices,
- Floating tidal devices,
- Fixed (seabed mounted) tidal and wave devices, and
- Floating wind.

1.1 Small scale OREI in Scotland

For the testing of wave and tidal devices, Scotland is home to the European Marine Energy Centre (EMEC) which provides test berths for wave and tidal devices off the coast of Orkney. Since 2003 EMEC has provided open sea testing facilities to developers of wave and tidal energy devices. Two full scale test sites provide subsea cables to allow devices to connect to the National Grid, and two scale test sites allow smaller devices to be tested in less challenging conditions without a grid connection. A map of EMEC's test sites is shown in Figure 1 below.

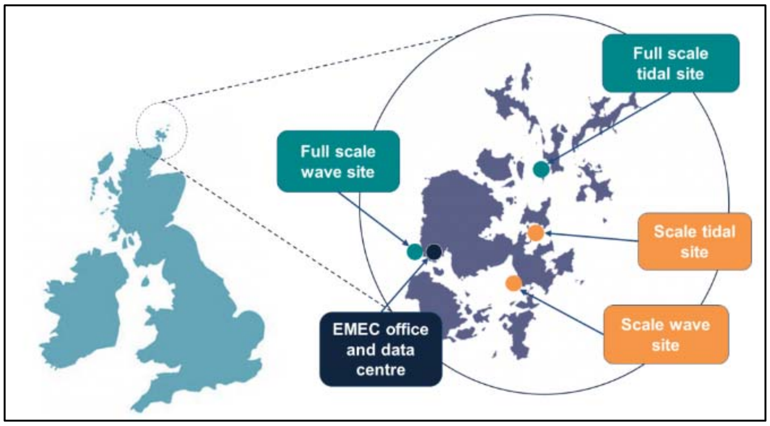

Figure 1: EMEC test sites around Orkney [6]

A selection of EMEC's past and present projects are listed in Table 2 below.

Table 2: Selection of projects at EMEC

Project	Status	Operational information
Floating wave devices		
Pelamis Wave Power	Decommissioned	1st generation device tested at EMEC between 2004 and 2007. 2nd generation devices tested by E.ON and ScottishPower Renewables between 2010 and 2014.
Seatricity	Pending decommissioning	Tested at EMEC between 2013 and 2014.
Wello Oy Penguin	Installed	First installed at EMEC in 2012. Current device installed in March 2017.
Laminaria LAMWEC	Planned	Testing planned at EMEC during 2018/2019
Floating tidal devices		
Nautricity CoRMaT	Installed	500kW turbine was tested in EMEC's scale test site during 2014, the device was installed at the full scale tidal test site in April 2017
Scotrenewables	Installed	Scotrenewables has been testing devices at EMEC since 2012. Their SR2000 2MW device was installed in October 2016.
Tocardo	Installed	Tocardo installed their first T2 turbine at EMEC in 2017, Tocardo will also test their Universal Foundation System (UFS) during 2018/2019. The UFS aims to provide a floating tidal power plant capable of integrating five tidal turbines.
Sustainable Marine Energy PLAT-O	Cancelled	The PLAT-O device was planned to be installed at EMEC in 2017, but the installation was cancelled.
Fixed wave and tidal devices		
Aquamarine power Oyster	Pending decommissioning	Two Oyster devices tested at EMEC. 2nd generation 800kW device was tested between 2012 and 2015.

Atlantis AR1000	Decommissioned	1MW device installed at EMEC in 2011
Andritz Hydro Hammerfest HS1000	Decommissioned	1MW device installed at EMEC in 2012
OpenHydro	Installed	OpenHydro have been using a test site at EMEC since 2006, their 7th generation 6m diameter turbine was installed in April 2014

In addition to the testing facilities at EMEC, Scotland is also host to a number of other wave and tidal developments, including MeyGen, Scotland's first 'commercial' tidal stream project. In terms of floating wind developments, as noted in [1], Scotland is home to Hywind, the world's first floating OWF, and other floating wind projects have been proposed. Consented small scale OREIs in Scottish waters are listed in Table 3 below.

Table 3: Future, consented small scale OREI in Scotland

Developer, Project, Location	**Status**	**Devices**	**Operational information**
Floating wave devices			
Albatern, WaveNET, Mingary Bay	Consented	Up to 6 'Squid' devices with maximum generating capacity of 45kW	Planned installation to provide power for the co-located Marine Harvest fish farm
Floating tidal devices			
Sustainable Marine Energy, PLAT-I, Connel, Oban	Operating	Multiple turbine floating platform with 4 x 70kW Schottel Hydro instream turbines	The platform was installed in Nov 2017 and will finish testing in April 2018 when it will be transferred to the Philippines.
Nautricity, Argyll tidal array, Argyll	Consented	1 x 500kW CoRMaT tidal turbine	Originally planned for 2015, the device is currently installed at EMEC and it is unclear when it will be installed at the Argyll site.
Fixed tidal devices			
Atlantis Resources, MeyGen, Pentland Firth	Operating	Phase 1A consists of 4 x 1.5MW turbines on gravity base foundations	Fully commissioned in late 2017, planned operational phase of 25 years.
Nova Innovation, Shetland tidal array,	Operating	Phase 1 consists of 3 x 100kW Nova M100 turbines	Final turbine of Phase 1 was installed in February 2017, the project has been fully operational since then. An earlier 30kW device was installed on the same

Yell Sound			site in 2014, decommissioned in 2016.
Atlantis Resources, Argyll Tidal Array, Mull of Kintyre	Consented	Up to 10 x 1MW tidal turbines on gravity base foundations.	Atlantis purchased the site from ScottishPower Renewables in 2016, and have stated they intend to build on the site in 2018.
DP Marine, West Islay tidal park, Islay	Consented	Up to 30 tidal turbines of between 1 and 2MW, total capacity not exceeding 30MW (either floating or subsea mounted)	Consent was granted in June 2017; project is in early planning stages.
Floating wind			
Statoil, Hywind, Peterhead	Operating	5 x 6MW Siemens wind turbines on floating spar buoy foundations	Fully commissioned in October 2017
Hexicon, Dounreay Tri, Dounreay	On hold	2 x 5MW wind turbines on a single semi-submersible floating foundation	Construction began in March 2017 but the project went into administration in July 2017.
Pilot Renewables, Kincardine Offshore Windfarm, Cromarty Firth	Consented	Plan to install 7 wind turbines beginning with a 2MW turbine on a WindFloat semi-submersible foundation. The 6 other turbines will be rated up to 8.4MW, ensuring total capacity is 50MW maximum.	Construction activities started in June 2018, with the installation of the moorings for the 2MW turbine. The installation of the WF is scheduled to be completed in 2020.

1.2 Small scale OREI infrastructure

This section describes the typical infrastructure for each of the categories of small scale OREI outlined above. It should be noted that as the technologies are still undergoing development and testing there are a variety of different devices in each category. Some of these differences will be outlined below but it is not the purpose of this report to outline all the available devices.

1.2.1 Floating wave devices

Figure 2. Example floating wave device – Pelamis Wave Power

Floating systems to extract energy from the waves using typically consist of the main structure of the device, e.g. a point absorber buoy or linear attenuator that moves as the waves pass by. The system will also include some form of power take off (PTO) equipment that converts the movement of the buoy or attenuator into electricity. There are a number of different PTOs including hydro turbines, hydraulic conversion systems and direct drive systems. In the majority of devices, the PTO is incorporated into the device structure. Together the device and the PTO are known as the Wave Energy Converter (WEC).

In addition to the WEC there will be station-keeping infrastructure such as mooring lines and embedment anchors, or seabed weights (concrete or steel), to keep the WEC in place and tethered to the seabed. Piles are not usually appropriate for floating WECs. There will also be electrical infrastructure to connect to shore, usually to an onshore substation. The cabling will typically consist of a single export cable from the device to shore. When considering an array of devices, there may be cables between devices and potentially a number of subsea junction boxes where cables from individual devices meet to connect to a single export cable.

1.2.2 Fixed wave devices

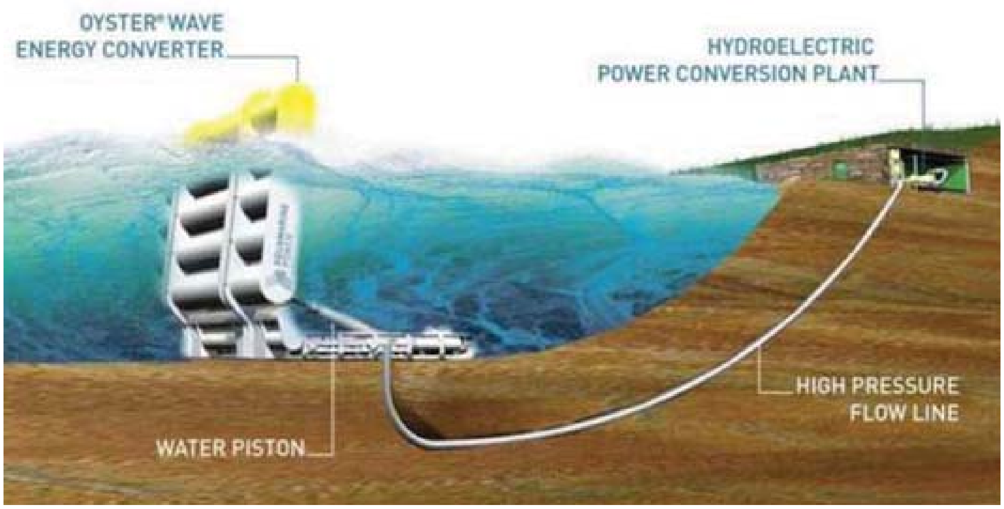

Figure 3. Example fixed wave device – Aquamarine Oyster

Fixed wave devices are typically seabed mounted in shallower waters, often designed to take advantage of the energetic nearshore wave conditions. As with the floating devices, the PTO would typically be incorporated in the structure, with an export cable to shore.

Some fixed wave energy devices transmitted high pressure water back to shore, and used this water to produce electricity in an onshore hydroelectric plant. However, this methodology was found to be inefficient for energy production and is widely only considered beneficial for desalination plants, where delivering high pressure water is able to drive more efficient desalination. As there is a limited market for this in Scotland, the decommissioning of high pressure water lines will not be considered during this study.

Experience from operating devices in shallow waters has also shown that this can be a challenging environment, exposing the device to more rapid corrosion and limiting maintenance access.

1.2.3 Floating tidal devices

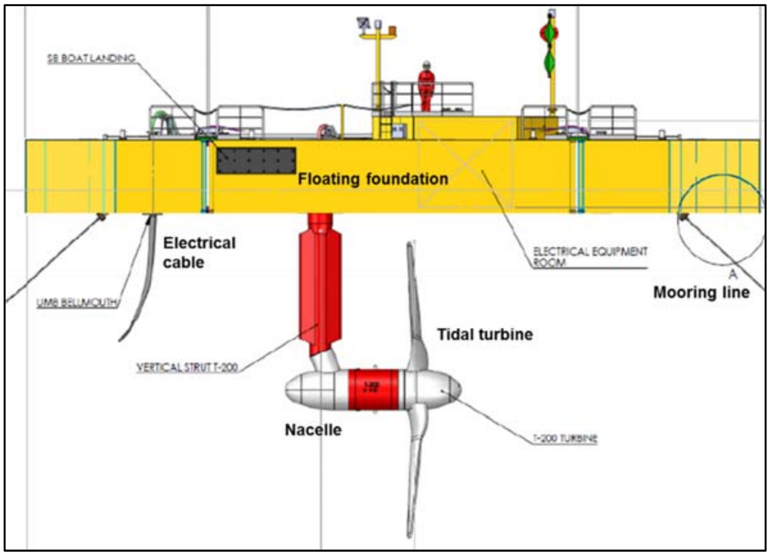

Figure 4: Example floating tidal device – Tocardo Tidal Power [7]

Floating tidal devices often consist of a buoyant structure which provides the foundation, that may sit on the surface of the sea, or in the water column, with a single or multiple tidal turbines attached.

The tidal turbine designs are analogous to a wind turbine generator, installed subsea and driven by the tidal stream. The tidal turbine usually consists of a nacelle, and at least one rotor assembly.

The nacelle houses the gears, generator and electronics to convert the rotation of the rotor into electrical energy. Some tidal turbines have two rotor assemblies (as shown in Figure 5) to capture tidal flows in either direction without having to rotate the nacelle. Other turbines have only one rotor assembly (as shown in Figure 4). Tidal turbines generally have two or three blades.

The mooring and electrical infrastructure is typically very similar to that of floating wave described in section 1.2.1.

1.2.4 Fixed tidal devices

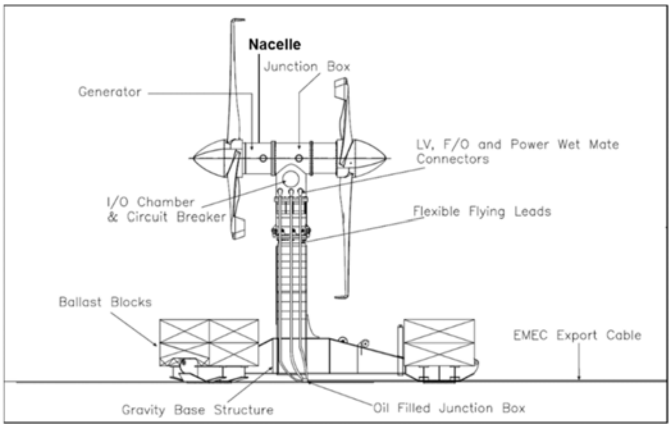

Figure 5: Example fixed tidal device – Atlantis Resources [8]

Fixed tidal turbines consist of a foundation, usually a gravity based foundation, but in some cases a monopile or jacket foundation, secured to the seabed with piles which may be driven or drilled into the seabed. The foundation will usually have an integrated tower or similar structure to which the tidal turbine is mounted. There will be an electrical connection between the tidal turbine and the shore. In Figure 5 this is annotated as the EMEC export cable, which connects to the tidal turbine via a subsea electrical connection.

The turbines for fixed tidal devices are typically similar to those used for floating devices described in 1.2.3. However, for fixed devices, the turbine nacelle may have the ability to adjust its orientation to optimally align with tidal stream when generating.

Fundamentally different designs of fixed tidal device do exist, such as the OpenHydro open centre turbine, as shown in Figure 6. The OpenHydro device uses a direct drive permanent magnet generator around the rotor's circumference to generate electricity. These devices are moored with gravity base foundations or piles.

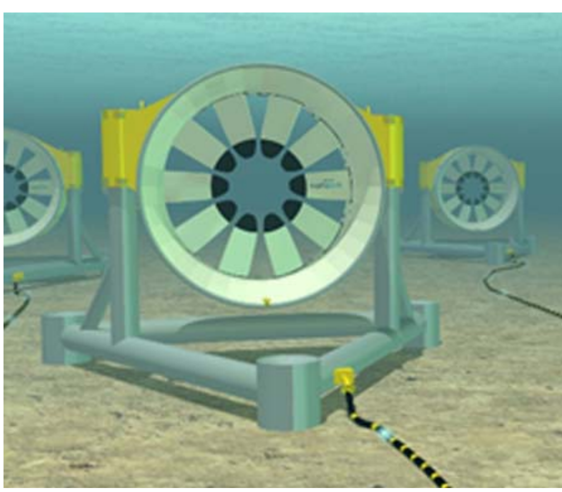

Figure 6: OpenHydro fixed tidal device [9]

1.2.5 Floating wind

Floating wind developments have similar overall infrastructure to traditional fixed foundation OWFs, consisting of wind turbine generators (WTG), floating foundations, inter-array cables between individual WTG and an export cable back to shore, as shown in Figure 7 below.

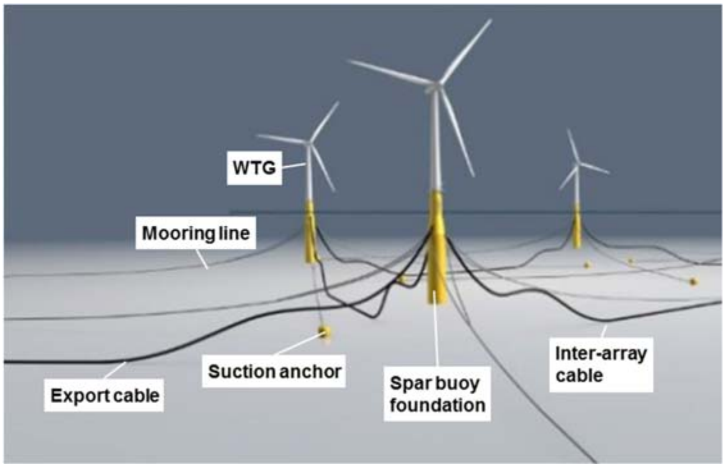

Figure 7: Hywind floating OWF – Statoil [10]

The major difference is that the floating foundations require anchors and mooring lines to connect to the seabed. There are principally three floating foundation concepts being researched, manufactured and deployed, illustrated in Figure 8.

Figure 8. Floating wind concepts

Hywind OWF uses a spar buoy foundation, other designs include those based on semi-submersible or tension leg platforms commonly used in the oil and gas industry. All of these concepts require some form of anchored connection to the seabed, typically comprising chains or synthetic ropes from the floating structures to anchors or piles on the seabed. Anchor types are summarized in Table 4.

Table 4. Types of seabed anchoring

Type	Embedment anchor	Driven or screwed pile	Suction pile	Gravity anchor
Description	Steel structure which is dropped to the seabed and pulled horizontally until it has embedded itself in the seabed.	Cylindrical steel structure which is hammered or screwed vertically into the seabed.	Larger-diameter steel can which is placed on the seabed and sucked into the clay/sand using a vacuum pump.	Heavy steel or concrete mass placed onto the seabed.
Decommissioning considerations	Easy to recover to a vessel.	Usually cut below the seabed and the underground section left in situ.	Designed to be recoverable by reversing the installation process.	Recoverable using vessel with suitable crane capacity.

2 Differences between small scale OREI and commercial scale OWF

Arup has previously investigated the decommissioning of OWF for Marine Scotland and provided recommendations regarding the development of process and guidance for their decommissioning [1]. Before examining the decommissioning of small scale OREI in detail it is useful to consider the differences between commercial OWF and small scale OREI as these differences could require different adjustments to decommissioning processes and guidance. Several important differences are outlined in Table 5 below.

Table 5: Differences between commercial scale OWF and small scale OREI

Parameter	Small scale OREI	Commercial scale OWF
Project financing	Generally, technology developers installing and testing products, largely using grant funding and venture capital.	Large, but risk-averse, utility companies and investors with bank finance to develop projects
Project CAPEX	For test projects estimated around £1m to £2m [11], [12]. For early stage commercial projects, greater than £10m [13].	Upwards of £100s millions, e.g. Beatrice OWF CAPEX is £2.6bn [14].
Project revenue	Limited revenue from test installations because generation is not reliable. Eearly commercial projects have difficulty securing government contracts for difference (CfD) due to high cost.	Government CfDs provide guaranteed revenue for first 15 years of operation.
Technology maturity	Low maturity, variety of designs still being tested, majority at TRL 5 or below.	Mature technology, turbine design well understood, incremental developments to increase turbine size.
Device design	Wide variety of devices, no consensus on preferred design, different companies pursuing different approaches.	WTG of standard design, 3 blades, may be geared or direct drive. Limited differneces in generation technologies, some variety in foundations.
Device rating	Most devices are less than 1MW.	Latest operational WTGs are 8MW, with plans to deploy larger devices on future projects.
Device deployment	Single devices deployed at test sites, or small arrays of devices on early commercial projects.	Large arrays of WTG, greater than 50 in an OWF becoming standard.
Device footprint	E.g. for fixed tidal turbines ~ 20m x 20m gravity base [8], smaller but more distributed footprint for floating installations.	E.g. Largest monopiles >8m diameter, jackets ~25m x 25m [15], concrete gravity bases ~30m diameter. Overall site areas are much larger.

Supply chain	Limited supply chain, generally small technology developers employing local vessel contractors for deployments.	Established supply chain, large consolidated technology suppliers for all aspects (WTG, foundations & balance of plant), specialist vessel market. Supply chain typically offers performance guarantees and warranties.
Project risk	High technology and organisational risk. Precedent for technology developers going out of business with operational projects, limited scope for other developers stepping in, infrastructure may be left to EMEC or organisations such as Wave Energy Scotland (WES).	Lower risk/precedent of developers going out of business during operational projects. If this does happen other developers/ investors are likely step in if project is profitable. Reasonable to expect investors to undertake good due diligence in projects.
Sites	Tidal devices installed on very specific sites with high tidal currents, tend to be rocky seabed close to shore. Floating wave devices can be installed in a variety of sites, usually sandy seabed with 50-100m waterdepth. Fixed wave devices in shallow waters near shore.	OWF are installed in a variety sites, increasingly further offshore and may experience mobile seabed conditions.

These differences should inform the approach to decommissioning small scale OREI, which as shown above have quite different characteristics to commercial OWF. Notably some of the differences will be particularly relevant when considering the requirements for security provision.

Consultation feedback

The feedback from the majority of consultees was that small scale OREI should not be considered in the same way as offshore wind with regards to decommissioning planning and securities. The majority of consultees stated that a case by case approach would be appropriate for small scale OREI (and fixed wind farms in some cases) however it was recognised that this would need greater engagement from the regulator.

Evaluating projects individually would allow the degree of documentation and securities to be tailored to the individual project circumstances. This may help reduce the perceived burden on smaller developers. Currently many developers feel ‘lumped in’ with fixed offshore wind but have fewer resources to complete the decommissioning plans and arrange securities.

3 Introduction to small scale OREI decommissioning

In this section we consider the methodologies for decommissioning and removing all aspects of a small scale OREI. These methods predominantly reflect devices which have been installed and removed from the EMEC test center. As such, the descriptions that follow may not reflect future technology which may have different requirements.

Consultation feedback

Generally, the device developers consulted with were comfortable with their decommissioning methodology. Many felt they had a good understanding of how the device would be decommissioned. Usually, the methodology was based on a reverse of the installation. Many developers were focusing on designing devices that could be installed with cost-effective multi-cat vessels, and this would be the intention for decommissioning as well.

It was discussed that it may be beneficial to involve the marine contractors in the decommissioning planning, particularly for newer, novel devices. This has been successful on a number of projects and could be a way to give the regulators assurance that the decommissioning plan is reasonable.

In some instances, contractors have also been engaged to support grant applications which have ensured the decommissioning cost is adequately covered by the funding. In some cases, the vessel contractor has become a partner on the project, instead of a supplier, and been able to secure funds to complete decommissioning work even in the event of developers going out of business.

3.1 Decommissioning floating wave or tidal devices

The decommissioning of floating wave or tidal devices will follow a broadly similar process. This process is outlined in Figure 9 below.

Figure 9: Basic process for removing floating devices

There are a number of different options for decommissioning depending on the device and the location. These considerations are outlined below.

3.1.1 Electrical connections

Isolating and disconnecting the electrical connection would generally involve disconnecting the subsea power cable from the floating foundation/device. The disconnection may involve the removal and retrieval of a connector, e.g. a cable or plug/socket arrangement that connects the subsea cable to the developer's specific device. The subsea cable may be capped and left on the seabed, as would be the case for EMEC where this cable would be reused. Or the cable may be recovered at a later stage.

In [1] the issue of removing cables or leaving cables in situ was discussed. For small scale OREI this is considered less of an issue due to the following:

- There will likely only be one cable, due to test sites having only one device deployed; and
- The length of cable is expected to relatively short due to test sites being in close proximity to the shore.

For these reasons it should be straightforward and less costly to recover a cable that is no longer needed.

3.1.2 Tow device

Floating devices will generally be towed back to a suitable harbour location. The devices will be towed using a suitable vessel and, depending on the nature of the work, a second vessel for backup/manoeuvring. The device will then be lifted onto the harbour using a harbour side crane or brought into a dry dock. From there the device may be dismantled or transported to another location. It is likely that parts of the device may be retained by the developer for inspection and potentially further testing. Options for recycling and waste management are described in section **Error! Reference source not found.**.

3.1.3 Mooring lines and anchors

The type of seabed connection and mooring lines used will determine the removal methodology. The mooring lines may be disconnected at the device or at the anchor/anchor chain. If the mooring line is removed at the device, it may be attached to a temporary buoy for retrieval after the device has been removed. The mooring chain and the anchor can then be recovered by a suitable vessel equipped with an appropriate winch and deck handling equipment.

If the mooring line is disconnected from the anchor or anchor chain, using a diver or a remotely operated vehicle (ROV), the mooring line can then be pulled (into or onto the device) and transported to shore along with the device. In this case the anchors will need to be recovered following the device removal. This will require a vessel with a winch and possibly a deck crane and may require a diver or an ROV to connect a line from the vessel to the anchor or anchor chain. The anchors and anchor chains can then be retrieved to the vessel and transported to shore.

Consultation feedback
The majority of developers with floating devices did not envisage any technical difficulties with the removal of their devices. The decommissioning methodology would be a reversal of the installation, towing the device away with a multi-cat vessel. It was noted that the removal of anchors and mooring lines can lead to some health and safety risks, particularly where divers are required, and that some issues could be avoided by reusing this infrastructure. The use of wet storage areas was also discussed as an option, to avoid bringing heavy weight anchors onshore, reducing the amount of lifting and handling involved.

It was also discussed that some larger devices may not be easily brought onto the quayside, or maybe too large for dry dock facilities local to the installation site and therefore breaking down the device on site might be a better option.

Although non-developer stakeholders were not consulted on the specific issues associated with wave, tidal and floating wind developments, their needs and those of other marine users should be considered when evaluating the designation of wet storage areas or the breaking up of a device onsite. As with any other activity in the marine environment, the environmental consequences of such measures should also be considered.

3.2 Decommissioning of fixed tidal devices

The decommissioning of fixed tidal devices will follow a similar process to that outlined in section 3.1 for floating devices. Figure 10 below shows the high level process.

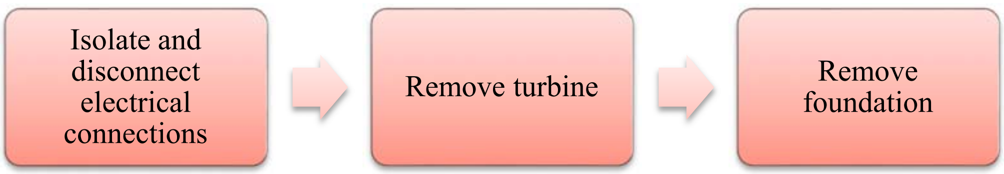

Figure 10: Basic process for removing fixed tidal devices

As with the floating devices the exact decommissioning methodology will depend on the nature of the device installed, particularly the foundation.

3.2.1 Electrical connections

Similar to the floating devices, the first step will be to disconnect any electrical connection from the device. This may be done with an ROV or a diver. Disconnecting the electrical cable should allow the removal of the turbine from the foundation and the foundation from the seabed.

The cable could be capped and/or removed as described in 3.1.1.

3.2.2 Remove turbine

The turbine (blades and nacelle) is likely to be removed as a single, complete unit. This would require a vessel with a suitable crane capacity. The vessel will likely need to be a jack up (JU) or dynamically positioned (DP) vessel with a heave compensated crane. In tidal sites it is often difficult to use a JU for the following reasons:

- The seabed conditions will typically be out of the JU operational range;
- There may be stability issues;
- Vortex induced vibration from tidal flow can be a problem; and
- The water depth may be deeper than the JU can accommodate.

Therefore, a DP vessel may be the preferred option.

3.2.3 Remove foundation

There are several configurations of foundations currently deployed for fixed tidal devices. The majority of test devices have been deployed using gravity based structures, some with removable ballast blocks. The gravity based structures can be fully removed by lifting them with a vessel crane. If separate ballast blocks are present these will be removed first, followed by lifting the gravity base frame. An ROV may be used to support the operations.

If the vessel used to remove the turbine has a sufficient crane capacity, the same vessel could be used to remove the foundation. For a single test device, both the turbine and the foundation may be lifted on to the vessel, provided there is enough deck space, for simultaneous transport back to shore. As with the turbine removal it is likely that a DP vessel will be required due to the constrains of using a JU in areas of high tidal flow.

Some fixed devices may be deployed with piled foundations. These could be monopiles, tripods, jackets or other designs where piles are required. Tidal areas usually have a rock seabed, as the overburden (sand or clay) has been removed by the strong tidal current. Hence piled structures will most likely need to be drilled and grouted in place.

As a very small number of piled foundations have been deployed for fixed tidal devices there is limited information about their removal. Usually decommissioned piles would be cut below the seabed, but for tidal foundations, the following issues will need consideration:

- Grouting of the piles may make them more difficult to remove;
- Cutting the piles below the seabed may not be possible if they are grouted;
- Cutting at the seabed may be sufficient if it is confirmed the rock seabed will not change substantially over time to expose more of the pile; and
- Deploying cutting equipment may be difficult if a JU vessel cannot be utilised.

Piled foundations use less material than gravity based foundations and may provide for cost reductions, therefore, may be favoured by developers. In addition, more projects could begin to investigate piled foundations as larger commercial arrays develop. For example, the Meygen project is planning to use piled foundations for Phase 2 of their tidal array. The regulator should ensure they are comfortable with the decommissioning options for these structures prior to approving their construction.

Consultation feedback

With regard to leaving infrastructure in place the feedback was that a pragmatic approach should be taken, considering the footprint of the infrastructure. For a small scale OREI the footprint will be much smaller than that of a fixed OWF and it may be acceptable to leave elements of infrastructure in place. E.g. buried anchors or piles which cannot readily be removed could be cut off at, or just above, the seabed.

There has been precedent for this with some consultees noting they were granted permission to leave a small protrusion above the seabed when removing infrastructure given that the infrastructure was often in a rocky, uneven seabed which was unlikely to change overtime. The consultees noted that projects would need to be considered on a case by case basis to agree the most appropriate approach in each circumstance. Part of this assessment would include evaluating the impact on other users of the sea, and the health, safety and environmental impact of leaving the infrastructure in place.

3.3 Decommissioning of floating wind turbines

Floating wind turbines will likely be towed away from site and dismantled, either in a port or in a sheltered area of the sea. The overall process is similar to that for floating wave or tidal devices, although the devices themselves are on a larger scale and will require larger vessels, and a port with sufficient draft that can handle the large structures. Notably the vessels and ROVs for intervening with the moorings would be significantly larger than for small-scale wave and tidal projects. Distances to port may be high, which will increase the overall task durations.

3.4 Reuse & recycling

It is expected that devices, turbines and the other infrastructure will eventually be disposed of in line with the waste hierarchy outlined in the previous report [1]. The amount of waste generated from the current installations should be small in comparison to that from offshore wind as a result of the smaller scale of projects and devices. Steel components should be recycled through existing channels. Cables may be stripped and the metal components reused, blades and other materials may need special handling but any metals that can be extracted are likely to have a scrap market value.

3.5 Decommissioning experience to date

Approximately 30 devices have been decommissioned at EMEC to date, and several other devices have been decommissioned at other locations. The majority of decommissioning operations have taken place without any significant issues. The supply chain in Orkney has built up expertise around the installation and removal of wave and tidal devices and is now in a position to offer developers services on the decommissioning methodology and costs.

The majority of decommissioning operations have been completed using small multi-cat vessels (see Figure 11), including the removal of some fixed tidal devices such as the Nova 30 with modest gravity base foundations. Larger devices such as the Atlantis device at EMEC required a larger heavy-lift vessel.

Figure 11: Leask Marine MV C-Odyssey multi-cat vessel [16]

However, there have been a number of cases where companies have failed to remove infrastructure. At EMEC the Aquamarine Oyster 800 is still in place following the closure of the firm in 2015. There is also some Seatricity infrastructure remaining in place at EMEC, including mooring blocks and coated pipelines, previously used for transmitting high pressure water to shore.

It is understood that EMEC have in place a proposal to fully recover the Seatricity infrastructure. However the Oyster device has deteriorated to the point where it is very challenging from both a technical and safety perspective to remove the equipment. The Oyster design did not incorporate any features to aid decommissioning and there is currently no plan to remove the remaining components.

Consultation feedback

During the consultations it was noted that the rigour around decommissioning planning had improved since the experience with Aquamarine, where it was understood that there was limited consideration in the design for the decommissioning of the device. It was also observed that of the many devices deployed at EMEC only two had failed to be decommissioned.

3.6 Decommissioning considerations in small scale OREI design

During the consultations various developers were asked how they considered decommissioning in the design of their devices. Their feedback is summarised below.

Consultation feedback

Most of the developers acknowledged that decommissioning had not been an explicit consideration in the design of their device. However, several had designed devices with low cost installation, operations and maintenance considerations which meant that their device was easy to install and remove, and so the design was inherently well suited to decommissioning. This included devices which had been designed to be towed to location and devices that could be removed in modules for maintenance.

Some elements of the design may have been excluded from consideration when thinking about the installation and maintenance of the device, for example the anchors and moorings. It was discussed by several consultees that their particular anchors were not really designed for removal and that there may be need for new designs or additional considerations during the design process. For example, lifting points that are designed for decommissioning must have a design life equivalent to the forecast operational life of the project.

Some companies are already working towards new anchor designs that are designed for removal or designed with a smaller footprint with a view to leaving in situ.

The consultees discussed some examples of designs, including anchors and clump weights that had improved from first installation to second installation to make things easier for both installation, maintenance and therefore decommissioning.

There was also discussion around what happens when the design fails. This could be a failure of the whole device, e.g. it sinks or a failure of a component such as a lifting/towing point. It is possible that some insurance policies may cover certain events such as sinking of the device.

There were some questions as to whether the lifting points and general component integrity would still be adequate to allow removal after the device had been deployed subsea for 15 or 20 years. If this is the intended operational time of the device, some modelling may be appropriate to demonstrate the integrity of the components over a longer period. This would give reassurance to the regulator that the device will be able to be removed as per the decommissioning plan. It may also be prudent to consider alternative options for decommissioning if the integrity of certain components is not guaranteed.

From the consultations, there is limited evidence of design for decommissioning however there is an emphasis on designing for low cost installation using multi-cat vessels and designing for simple operations and maintenance. This is beneficial for decommissioning, particularly on relatively short term projects where lifting points maintain integrity for the required period.

A further consideration is the need for the regulator to highlight decommissioning early to the developers to encourage diligence on this topic. While requesting a full decommissioning plan at the marine licensing stage may not be appropriate as the design is not fixed, highlighting the need for decommissioning early is appropriate to ensure that it is considered in the developer's subsequent designs. Although developers may have intentions to develop and deploy their devices responsibly, with the understanding that the device will eventually need to be decommissioned, ease of decommissioning is unlikely to be their primary design objective. Therefore, there is a role for the regulator to highlight the importance of decommissioning early in the design process.

Developers should be encouraged to engage with third-party design reviewers or certifiers to confirm that designs are decommissioning-ready, even in the event of significant failure modes. This would help avoid situation such as the Oyster device at EMEC which, along with the developer ceasing operations, the device failed in such a way that decommissioning has become extremely challenging.

4 Decommissioning regulation and guidance for small scale OREI

The international and national policy, legislation and overall regulatory framework governing OREI has been covered extensively in previous reporting to Marine Scotland on OWF [1]. This section provides a brief summary of these findings and assesses any specific issues which are relevant to small scale OREI. This section also considers the consultees' feedback on their experience of dealing with the regulator regarding decommissioning.

4.1 Summary of international obligations

Previous reporting [1] examined the international legislation, standards and guidance that govern OREI installations, considering their implications for OWF decommissioning. Key international obligations that apply to OREI decommissioning are The United Nation Convention on the Law of the Sea (UNCLOS) as implemented by the International Maritime Organisation (IMO) 1989 Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone. There is no specific international guidance or standards on wave, tidal or floating wind installations in the UK's IMO obligations.

As outlined in [1], UNCLOS and the IMO Standard refer to structures on the seabed and does not explicitly reference structures below the seabed. The IMO Standard outlines a general requirement to remove infrastructure from the seabed and states that decisions to allow infrastructure to remain on the seabed should be based on case-by-case evaluation.

In conclusion, the international standards and guidelines call for the removal of infrastructure on the seabed but are unclear on, or do not explicitly include, infrastructure below the seabed. This leaves the decision regarding infrastructure below the seabed down to state Governments.

4.2 Summary of UK legislation

The previous report [1] examined key UK legislation relevant to OWF decommissioning. The same legislation, the Energy Act (2004) [17] and the Scotland Act (2016) [18] are applicable to small scale OREI, as this legislation covers renewable energy installations defined as 'an offshore installation used for purposes connected with the production of energy from water or winds'. As stated in the previous report [1] the Energy Act (2004) gives the appropriate Minister the power to request, review, approve or request changes to decommissioning programmes, and the power to request an appropriate decommissioning security. These powers apply similarly to small scale OREI projects as for commercial OWF projects.

The Scotland Act (2016) transfers the Energy Act (2004) functions to Scottish Ministers, making Scottish Ministers the appropriate Minister in relation to projects in Scottish waters or in a Scottish part of the Renewable Energy Zone.

The arrangements for the transfer of powers were outlined in the concordat [19] described in the previous report [1]. The concordat included several categories of project that determine which projects passed to Scottish Ministers, or will pass to Scottish Ministers on the fulfilment of certain conditions.

As outlined in the concordat, the following projects passed to Scottish Ministers on 1st April 2017:

- Argyll Tidal Farm
- West Islay Tidal Energy Farm
- HS1000 Sound of Islay Tidal Farm
- Hywind (subject to an approved decommissioning programme being in place)
- Meygen Phase 1A (subject to an approved decommissioning programme being in place)
- Shetland Tidal Array (subject to an approved decommissioning programme being in place)
- Scotrenewables SR2000 (subject to an approved decommissioning programme being in place)
- Sustainable Marine Energy – EMEC projects (subject to an approved decommissioning programme being in place)

4.3 BEIS Guidance Notes

As discussed in [1] the Department of Business, Energy and Industrial Strategy (BEIS) provide the Decommissioning of offshore renewable energy installation under the Energy Act 2004 [20] guidance notes for industry. These guidance notes, originally published in 2006 and revised in 2011 by the Department of Energy and Climate Change (DECC), are currently undergoing revision and consultation by BEIS [21].

These guidance notes are discussed in detail in [1], outlining their content in the context of OWF decommissioning. The guidance notes apply the same rules to all OREI, and in many areas of the guidance there is no distinction between commercial scale projects and small scale OREI. However, there are a number of areas in the revised guidance [21] where small scale OREI are specifically discussed. These areas are outlined below.

Consultation feedback
Several consultees were familiar with the guidance notes but some felt that too much detail was being requested from developers, or that the level of detail required, and the overall purpose of the decommissioning plan was not clearly spelt out in the guidance. Some consultees understood from the guidance that the decommissioning plan was a high level overview of the proposed decommissioning methodology. However, in subsequent discussions with BEIS it became apparent to the consultees that a comprehensive method statement for decommissioning was required. This methodology should be of sufficient detail to allow a contractor who was not previously familiar with the project to execute the decommissioning. It was expressed by some that this level of detail requires a lot of time to prepare and is not proportionate to the scope of the project, in comparison to the scale of a contemporary

commercial offshore wind farm. Some developers would also not be comfortable sharing this level of information in a document that was in the public domain, or seen by all consultees, and would prefer to submit this as a confidential annex to the regulator, in the same way that a decommissioning cost estimate is handled.

It was also noted that small scale OREIs need to be evaluated individually to determine the requirements of each decommissioning plan based on the scale and technology readiness of the project. This would help the regulator determine the risk associated with the project and communicate the requirements for the decommissioning plan that will allow the regulator to get comfortable with the level of risk. Communicating the requirements clearly, and early enough in the process would allow developers to prepare sufficiently.

4.3.1 Test centre infrastructure

In BEIS' draft guidance notes, published in February 2018 [21], there is a new section on test centres under the chapter on the scope of the decommissioning scheme. Under this section the guidance states:

> *BEIS expects offshore renewable energy test centres in England and Wales to take responsibility for the decommissioning of their tenants, in line with international decommissioning obligations and environmental standards and all relevant legislation.*

This makes the test centres responsible for decommissioning any infrastructure at the test centres and is further explained in the statement below:

> *Developers wishing to deploy their assets at a test centre should engage the test centre on this matter at the earliest possible opportunity. It is expected that tenants will have to make their own decommissioning arrangements and financial securities with the testing centre, and BEIS does not expect to receive or approve such decommissioning programmes. BEIS would expect test centres to require security to be in place before the start of any deployment.*
>
> *Where financial security has not been taken, BEIS will expect test centres to step in and pay for the removal of any assets on its site at the end of the operation period.*

However, BEIS intends that the test centres themselves to have a decommissioning plan in place for their own infrastructure at the end of the test centre's life, and sufficient securities may be required for this decommissioning:

> *Test centres should submit decommissioning programmes for their own central infrastructure. This should set out how they will ensure that the overall site is returned to its natural state at the end of the centre (including removal of tenant infrastructure) and how they will enforce the decommissioning programmes of their tenants.*

It is also stated that BEIS does not expect the test centre decommissioning plan to be updated as client infrastructure is installed and removed, and that securities, with BEIS as the benefactor, for the test centre will be required to cover only the central infrastructure, not that of the test centre's clients. However, BEIS expects the test centre to require appropriate securities to be in place, with the test centre as the benefactor, for the tenant's infrastructure prior to deployment.

The implications of this latest draft guidance is that the test centres have greater responsibility for ensuring clients are able to decommission infrastructure and that managing decommissioning within the test centre is left to the test centre, with little intervention from BEIS.

Consultation feedback
Some consultees could not envisage the BEIS guidance for test centres being applicable in Scotland, and that EMEC may be reluctant to take on the decommissioning liability. It is not clear how this would work given the current, previously-agreed, responsibilities of EMEC and the Scottish Government.

4.3.2 Form and timing of securities

Small scale OREI are referred to in the BEIS guidance notes in the context of acceptable forms of security and the timing of securities.

> ***Examples of acceptable securities – Upfront cash***
>
> *Cash set aside up front to cover expected decommissioning liabilities would reduce the risk to Government to a negligible level and would therefore be acceptable. This is likely to be the most appropriate form of security for pre-commercial deployment where the risks to the taxpayer are the greatest. This would need to be held in an account where deductions could not be made without the prior agreement of the Secretary of State, or officials on his behalf, if the owner fails to remove the asset in line with its approved programme.*
>
> ***Timing of securities***
>
> *Securities upfront of construction will generally be expected for pre-commercial projects. We believe that these projects pose a higher risk to the taxpayer than more mature deployments. The nature of pre-commercial projects can mean that there are increased technological, financial and commercial risks associated with the deployment of the asset.*

Pre-commercial projects would cover the majority of small scale OREI outside of test centres. The expectation from BEIS is that these projects would provide up-front securities. The implications of this are discussed further in section 0.

4.3.3 Review of decommissioning programmes

The guidance notes provide a suggested review period for shorter term projects, stating that the review of the decommissioning plan will be considered on a case-by-case basis. However, for all projects exceeding 12 months, the following review schedule is advised.

> *We would envisage a report / summary of issues discovered during construction which might impact on decommissioning (this should be provided within 6 months of construction), and a review prior to the actual decommissioning of the installation, to finalise the decommissioning measures envisaged.*

Consultation feedback
Consultees were positive and open about reviews of the decommissioning plans, particularly if knowledge is gained throughout the project following installation or maintenance of the device. The consultees also noted that reviews could include reviews of the security arrangements and that these may lead to a change in the security requirements throughout the project as the project begins to generate revenue and/or the risk profile changes.

4.3.4 Post-decommissioning monitoring, maintenance and management of the site

The guidance notes acknowledge that there may be different requirements for ongoing monitoring of the site after decommissioning of small scale projects.

> *Monitoring arrangements for wave and tidal demonstrator projects are normally expected to be limited, or not required at all if full removal is involved and any post-decommissioning survey shows this has been achieved.*

This highlights the importance of the post-decommissioning survey following the removal of infrastructure. If all infrastructure has been removed to the satisfaction of the regulator, then the current guidance implies that further monitoring would be limited or unnecessary.

Consultation feedback
A number of consultees felt the current guidance was too onerous for small scale OREI. One area discussed was ongoing site monitoring. Hence guidance changes which highlighted particular aspects that would not apply to small scale projects would likely be welcomed.

4.4 Interaction with the regulator

One aspect covered by the consultation was the interaction with the regulator, either BEIS or Marine Scotland, during the decommissioning planning and approval process. It is understood that many projects were subject to decommissioning plan approvals following the same process as fixed OWF described in [1]. This meant submitting a decommissioning plan for approval prior to installing a device.

Consultation feedback
The consultees had various experiences of dealing with BEIS. Feedback included an observation that decommissioning plans were not being reviewed in a timely manner. Even though the plans were submitted prior to devices being installed, they were not reviewed and commented on until long after the devices had been installed. Further feedback was received around the time-consuming “back and forth” nature of communications with BEIS discussing the proposed decommissioning methodology, cost and securities, with cost and securities being the most contentious issue (more feedback below). There were also comments around BEIS tending towards a more standardised approach for decommissioning whereas the consultees felt a case by case approach would be more appropriate for the projects. It was acknowledged that decommissioning guidance could be used to set out a framework for the decommissioning planning process but that individual circumstances should be considered when reviewing individual projects, and the guidance should accommodate this approach.

Those consultees who had dealt with Marine Scotland in relation to decommissioning planning (and other licencing requirements) were positive about the experience.

5 Cost and Securities

In this section we examine the decommissioning costs and the driving factors behind these costs, for current small scale OREI and how these may change as the scale of the OREI grows. We also consider the issues in relation to the provision of securities and how security arrangements could affect future technology development and testing.

5.1 Cost drivers

The main cost driver for all decommissioning is the cost of the vessel(s) required to remove the infrastructure. The majority of developers for wave and tidal devices have designed devices to allow installation, and therefore removal, with low cost multi-cat vessels, illustrated in Figure 12. Floating wind turbines may require larger vessels for towing the assembled wind turbine and floating foundation, for example an anchor handling tug supply (AHTS) vessel, see Figure 13. Floating wind turbines will typically be sited further offshore, and will require task-specific cable-lay vessels to recover electrical cables.

Figure 12: Leask Marine MV C-Odyssey multi-cat vessel [16]

Figure 13: Normand Ranger AHTS was used to tow the assembled Hywind turbines [22]

Additional costs will arise from the breakdown and handling of material. For smaller test devices, this is generally not substantial because materials can be easily stored or potentially repurposed. For larger arrays, including floating OWF, there is likely to be some cost associated with the dismantling and recycling of the WTGs and foundations.

There will be additional costs associated with project management and internal company overheads.

5.1.1 Cost estimates and uncertainties

A number of baseline cost estimates for the different categories of small scale OREI have been calculated, as shown in Table 6. These are based on discussions during consultations and Arup's independent view of the decommissioning costs. It should be recognised that given the different scale of devices, the costs will vary from device to device. It should also be noted that if device concepts change substantially in the future then the methods and costs may also change.

Table 6: Basic cost estimates for project categories

Device	Vessels	Day rate	Days	Other costs	Total per device
Floating wave and tidal	Multi-cat	£4-5,000	~15	~+30%	~£100,000
Fixed tidal device (Gravity Base Foundation)	Multi-cat & tooling	£6-7,000	~20	~+30%	~£200,000
Fixed tidal device (monopile)	Multi-cats, & cutting tools	~£20,000	~20	~+30%	~£500,000
Floating offshore wind	AHTS & Cable vessel	~£60,000	~7-10 days per turbine	~+30%	~£800,000

The costs in Table 6 are an indication of the order of magnitude of the expected vessel costs. Some developers have estimated removal costs as low as £20,000, for small floating devices, however this may not include removal of subsea cables or large anchors. The 'other costs' noted above would include project management costs, including planning, permitting, the cost of bespoke tooling and harbour fees. Cost estimates should also build in some time and cost for weather risk.

Importantly, these costs do not include for any diver or ROV requirements, which would be highly specific to the design of individual devices, particularly the connection between devices and their foundations where some form of underwater intervention may be required for disconnection.

There is potentially less uncertainty in the vessel rates for wave and tidal decommissioning than for fixed offshore wind decommissioning, particularly those operating around EMEC. There is an established supply chain in Orkney working in wave and tidal, supplying the required multi-cat vessels. Unlike large vessels required for fixed OWF decommissioning, these vessels are not as widely shared with industries such as oil and gas, and not subject to the large and unpredictable variations in day rates. The shorter time between installation and decommissioning of test devices also reduces the uncertainty in vessel rates. It may also be possible to secure a vessel rate, or fixed price for the decommissioning at the time of installing a device.

Moving towards larger vessels increases the uncertainty around the day rate as these vessels are utilised by other industries and there are many factors driving their market rates. A level of uncertainty should be attributed to the costs of the vessels required for floating OWF and larger wave and tidal devices.

The uncertainties in costs highlight the need to review each developer's cost estimate on a case-by-case basis. The regulator should seek to understand how the cost has been built up and whether the developer has consulted with the supply chain to help develop the decommissioning cost estimate.

5.2 Decommissioning securities

As outlined in section 4.3.2 the current guidance from BEIS implies that for pre-commercial scale projects or demonstration devices an upfront cash security is likely to be required. However, it should be noted that if the draft guidance [21] is published verbatim, this would not apply to devices deployed at test centres where it will be up to the test centre to determine the required securities.

Various security mechanisms were described and compared in previous reports [1]. As stated, upfront cash presents the lowest risk to government but it has the highest cost for the developer.

Decommissioning securities were a concern for many developers. Feedback from the consultation is outlined below.

Consultation feedback
It was generally agreed that accrual was an acceptable form of putting in place a security, but the need to allow for VAT and inflation was questioned as the impact of this can be significant. A late life accrual was preferable but the developers were open to considering a mid-life accrual. Developers commented that they felt "lumped in" with offshore wind on the one hand, and considered highly risky on the other, and being required to come up with the full decommissioning fund upfront. They communicated that this does not help them as small businesses and it is especially problematic when the security request comes too late in the process (e.g. after devices are in the water) and may not have been factored into the company's expected cash flow. There is a strong preference among developers to be able to draw down from securities to execute decommissioning. The consequence of not doing this is that developers need to raise double the amount, both the cost of executing the work and the sum to be set aside for security. This is only relevant to upfront cash or accrual securities. There was a suggestion that if the deployment of a device is part of a grant funded programme then the decommissioning cost should be factored into the funding. Funding agencies should be encouraged to insist that decommissioning is included in work scopes, and that any discussions about options to leave infrastructure in place are had in advance of drafting a decommissioning plan.

In response to the comments above the Scottish Government noted that in the event of Government being required to undertake decommissioning as a result of a developer not being able to do so, the Government would be required to fund inflationary increases and VAT. Therefore, if Government budgets are to be fully protected by decommissioning securities, then fully estimated costs should be compiled and reserved for the Government to complete decommissioning.

5.3 Considerations regarding securities

As with fixed OWF decommissioning, the Scottish Government seeks protection from the decommissioning liability in cases where the developer does not have the funds to complete the decommissioning. Therefore, the decommissioning security requirement needs to balance the risk to the government and the requirements of the developer.

In the case of small scale OREI it is recommended that the Scottish Government considers the individual circumstances of the developer and their technology rather than applying a standardised approach to all projects. To achieve this the Scottish Government will require robust financial information relating to the project, financing, operator and parent company balance sheets as well as security proposals in order to assess the risk profile and required security.

A number of suggested security approaches are described below, considerations as to when the security would be applicable are also described.

5.3.1 Security options

Upfront security accounted for in grant funding

If the project is being funded by a grant from a government or international agency, then the decommissioning cost should be accounted for in the funding application and part of the funds should be set aside to cover decommissioning.

This type of security arrangement would be applicable for projects that are short term, e.g. less than two years, and that are not expected to generate much, if any revenue, e.g. there may be no grid connection. This type of project could be early stage tests on novel devices, where the decommissioning operation should be considered a vital part of the project, to provide additional information about the device's performance. Therefore, the funding organisation should be willing to support the decommissioning as part of the overall project.

Marine Scotland could help by informing developers and funding organisations on the importance of securing funding for early stage, short term trial projects up front. It is likely to be easier to secure the funding as part of the original grant funding application rather than seeking more funding for decommissioning at a later time. There appears to be some precedent for including decommissioning costs in grant funding as some consultees had experience of this.

The security should be set up in such a way that the fund is ring fenced, in case the developer is unable to complete the decommissioning, but it should also be available for the developer to complete the decommissioning when it is required. The funds could reside (still ring-fenced) with a nominated contractor who could complete the decommissioning at an appropriate time.

Upfront cash security

Similar to the option described above where the cash reserve would be provided by the developer prior to decommissioning, either via grant funding or from another source. The cash would be placed in an account where deductions were not possible without the approval of the Scottish Government. The intention would be to deposit the amount expected to cover the total decommissioning cost.

This option is favoured by Governments as it poses the least risk to public funds. If the amount of cash reserved is sufficient to cover the decommissioning costs, then the risk to government is greatly reduced. As with the upfront grant funding security outlined above it would be beneficial for the developer to be able to draw down on this fund in order to complete the decommissioning work.

Early or mid-life accrual

If the project is expected to generate reasonable levels of revenue, then an early or mid-life accrual may be an appropriate form of security. This means additional funds for decommissioning would not be required upfront.

This type of security could be applicable for projects that are longer term e.g. 10 to 15 years. It is assumed that these projects will have already undergone testing of the devices and that Marine Scotland should feel more comfortable about the project's risk profile, longevity and potential for revenue generation.

As with the upfront securities it would be beneficial for developers to access the accrued fund in order to carry out the decommissioning works. However, it is noted that this would increase the risk to public funds if decommissioning was not completed and security funds were exhausted. In order to release the funds, the Scottish Government would need to undertake a review of the security and finances of the operator prior to allowing access to accrued funds. This is potentially resource intensive and time consuming.

Bonds

A number of consultees stated their projects had a bond in place for decommissioning and that this was an acceptable arrangement. However, throughout the consultations it was found that this option was only available to certain companies, i.e. those with a balance sheet to support the bond payments.

Alongside the bond, the developer will need to ensure they have enough money available to fund the decommissioning at the appropriate time. It is expected that the developer would set aside a decommissioning fund, as well as having the bond in place, and that this decommissioning fund would be available to pay for the decommissioning when required.

Parent company guarantee (PCG)

Some of the consultees mentioned a parent company guarantee as an option, however, for many of the companies involved in small scale OREI development there is unlikely to be a parent company involved with suitable creditworthiness to be an acceptable guarantor. Where there is a suitable parent company involved, a PCG may be acceptable if the Scottish Government is comfortable that the parent company can pay for the decommissioning. However, it should be noted that the draft of new BEIS guidance [21] will not allow a PCG, primarily on the basis that if the parent company is outside the UK then the security may be hard to access.

Insurance / industry fund

A number of consultees mentioned the possibility of an insurance fund or an industry fund for decommissioning which could be managed by the Scottish Government. The main issue with this is that many developers could pay into a fund and receive no benefit, and these developers could be of the view that they are paying for irresponsible developers who had not properly planned the decommissioning of their device.

Having such a fund would still mean that developers needs to set aside funds for decommissioning, assuming the insurance fund would only cover decommissioning in the event that a company defaulted on their liability.

Government funds decommissioning in case of default

One suggestion from consultees was that instead of requesting a decommissioning security, Scottish Government could simply accept the risk that they may act as decommissioner of last resort if required. This may be viewed as unacceptable by Scottish Government, however as discussed in section 3.5, the industry's track record is arguably better than it may be perceived to be[2]. However there is the a that this approach could result in material asks on the Scottish Government's budget.

This approach would not mean that all developers would be absolved of their decommissioning obligations. Guidance would still be followed, and a decommissioning plan would be submitted and reviewed, to give the regulator the opportunity to review the project's scope and the financial standing of the developer.

In the event that the risk profile was deemed to be acceptable, not requiring a security would reduce the burden on developers when raising funds for R&D and initial trials.

This approach could form part a proportionate, staggered framework where early stage testing could proceed without securities but subsequent larger-scale projects would trigger more onerous requirements. As part of this framework, subsequent marine licences and other consents could be withheld until the regulator is satisfied that the decommissioning of the earlier, smaller-scale project is completed satisfactorily.

5.3.2 Security approach

An appropriate approach for small scale OREI is likely to be a combination of the options above, with some sort of test or check by the regulator to inform the type of security that is generally acceptable. However, it recommended that each

[2] Although it should be noted that there is no data to confirm in how many instances securities have been drawn on.

project be assessed on a case by case basis considering their funding, technology maturity and previous experience.

Overall the approach to securities should be encouraging developers, and funding partners, to develop the technologies responsibly, whilst protecting public finances. Whatever the approach to decommissioning securities is, this should go alongside Marine Scotland having early dialogue with the developers regarding decommissioning, and informing the funding partners to ensure decommissioning funds are considered as part of a project’s finances.

6 Recommendations for changes to the OWF decommissioning regulatory regime

This study has built on the work previous completed by Arup [1]. In that report Arup considered how the Scottish Government should implement their Energy Act 2004 functions in relation to OWF decommissioning.

This report concluded with the following recommendations:

1. Take an evidence based approach to decommissioning based on sound, peer reviewed evidence;
2. Define decommissioning so developers know what they are expected to achieve at the end of the OWF life;
3. Set out the expectations of decommissioning programmes;
4. Set out expectations in relation to decommissioning securities; and
5. Ensure consistency in policy with the rest of UK.

These recommendations can be built on, considering the findings in relation to small scale OREI. It is important to note that there are several differences between small scale OREI and fixed OWF developments and hence the recommendations aim to recognise these differences and provide guidance for Marine Scotland to develop policies and guidance that accommodate the different types of OREI projects present in Scotland.

Typically, developers pursuing small scale OREI projects are small or medium sized enterprises with funding constraints. This, and the more novel nature of the technologies involved, exposes the projects to greater risk. However, the scale of the industry is small so the aggregate cost of decommissioning is far less than for offshore wind. With this is mind, it is recommended that the regulator assesses and responds appropriately to the risks so as to not dis-incentivise the small-scale OREI industry.

Building on recommendations 1 and 2 above these are equally applicable to small scale OREI. For small scale OREI it is important to highlight that the evidence to support the decommissioning options and the decommissioning definition should be considered on a case by case basis.

Although evidence regarding infrastructure left in situ can be gathered on an industry wide basis, there will be circumstances unique to small scale OREI which will require consideration on a case by case basis. For example, the sites for tidal devices will likely have an immobile seabed and so conclusions regarding the removal of OWF infrastructure in certain locations may not be applicable to a tidal site.

Recommendation 3 above is particularly applicable to small scale OREI. Feedback from consultees was that small scale projects are being required to provide a disproportionate level of information and from the existing BEIS guidance it was not completely clear what information was needed and why. The Scottish Government should set out expectations for decommissioning programmes clearly in guidance, and if more information is likely to be required from small scale OREI developers, such as a breakdown of the decommissioning operations, then this should be stated clearly to ensure that enough detail is available to the regulator in the event of developer default.

Building on this recommendation it is also suggested that decommissioning obligations are highlighted to developers early on in the design process, at the marine licencing stage or in even earlier discussions. This gives developers the prompt to consider decommissioning when finalising their device design and when considering their funding applications. The regulator could encourage developers to engage with third-party reviewers or certifiers to confirm that designs are decommission-compatible.

Recommendation 4 is equally important for small scale OREI. There were a number of examples discussed in the consultations where decommissioning security requirements were not set out by BEIS until devices had been installed. For small scale OREI it is suggested that a case by case approach to decommissioning securities be applied, supported with guidance as to what security would be acceptable in a variety of cases. It is recommended that a combination approach is considered: upfront security, the requirement for which should be built into grant funding, and early/ mid-life accrual where the project will generate revenue. Bonds or PCG could be considered where these are an available and acceptable option.

Recommendation 5 is perhaps less applicable in the case of small scale OREI where Scotland has an established industry and supply chain for wave and tidal devices and is arguably ahead of other regions in the UK. While it is important that Scotland remains an attractive location for developers, consultation feedback suggested that passing decommissioning responsibility to test centres (as BEIS are considering in [21]) would not be acceptable to the relevant stakeholders.

In addition to the recommendations above there are two more recommendations that are currently more applicable to small scale OREI, in particular wave and tidal projects. These are:

- Involve the supply chain in the decommissioning planning at an early stage; and
- Ensure that knowledge from decommissioning operations is captured and shared as widely as possible.

The supply chain in Orkney has built up experience of installing and decommissioning wave and tidal devices and would be well placed to advise on decommissioning methods and costs. For short term projects, supply chain input would be particularly helpful as they may be able to provide and/or review decommissioning costs to support grant funding applications.

As several wave and tidal devices have already been decommissioned at EMEC, it would be beneficial for the industry if this knowledge was captured and shared. Lessons learned from decommissioning operations could be used to inform designs to insure that they are suitable for decommissioning. This is happening internally at device developers, where second generation devices have been designed with more thought regarding decommissioning. Nonetheless several consultees commented that this knowledge has not been disseminated throughout the industry. A central stakeholder such as Marine Scotland, EMEC, ORE Catapult or The Carbon Trust would be well placed to facilitate a programme of dissemination.

The existing floating wind developments sit somewhere between wave and tidal developments and fixed OWF developments, in terms of their scale and level of technology development. Floating bases are new designs but the wind turbine technology is mature and well understood. The developers behind floating wind projects are mixed, with some being backed by established OWF developers and some being funded by the public sector, involving smaller companies. These characteristics highlight the requirement to assess the projects on a case by case basis.

In summary the recommendations from the previous report, [1] are applicable in the case of small scale OREI, with the following additions and emphasises being applicable for these projects:

- Ensure that the developer understands the requirements of the decommissioning plan, and what Marine Scotland expects from the document;
- Ensure the decommissioning requirements are discussed early in the project so that decommissioning considerations can be built into funding applications and device designs;
- Assess each project on a case by case basis to agree the most appropriate decommissioning methodology and the most appropriate security option; and
- Capture, share and utilise existing knowledge within the marine energy industry, particularly in relation to wave and tidal devices, and emulate this for floating and fixed OWF as these projects near decommissioning.

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