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Oyster® Environmental Impacts, Technical and Planning Barriers and Market Entry Issues.

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This report has been prepared for presentation covering the following themes:

Theme 1: Environmental Impact
Theme 2: RTD and Planning Barriers
Theme 3: Market Incentives

1. Theme 1: Key environmental impacts associated with the Oyster® device

The development of renewable energy technologies is viewed as an environmentally beneficial way of generating power for the future. However, although they do not generate greenhouse gas emissions, there are other environmental impacts associated with their development at the local level. It is therefore necessary to manage activities associated with renewable energy exploitation in a careful and enlightened manner - in keeping with modern principles of sustainable development.

Aquamarine Power Ltd's (APL's) Oyster® system consists of a Power Capture Unit (PCU) oscillator located offshore and Power Take Off plant (PTO) located onshore. This section on environmental impacts should not be considered a fully inclusive assessment of environmental impacts, but rather a discussion of potential key environmental issues. It has not considered general issues associated with, for example, installation and maintenance vessel activities, but more the issues specific to the Oyster® system design.

Location of device

As with any marine renewable energy development there are a number of environmental issues that need to be considered during the site selection process. The key issues associated with the Oyster® system are described below:

- **Seabed habitat loss**

  Each Oyster® PCU device requires a flat seabed area of 18 x 21 m (380 m^2) for operation. Site selection procedures will be required to identify suitable seabed habitat for installation of the device. It will be imperative to avoid seabed areas of conservation importance and/or sensitive habitats. In the UK, conservation designations and coastal surveys undertaken by the Marine Conservation Nature Review (MNCR) are key references in the identification of particularly sensitive sites. Comprehensive seabed surveys, including seabed photos and video etc., will also be undertaken to allow a robust assessment of the potential impacts on seabed habitats from the installation and presence of the Oyster® at proposed sites.

- **Potential interference with navigation and fisheries**

  As the device breaks the sea surface, its location in the marine environment has the potential to interfere with navigation and fisheries. Site selection will therefore avoid busy navigation routes and areas particularly important for fishing.

  The site selection process will involve consultation with appropriate marine coastguard agencies and if required, a navigational risk assessment study will be undertaken to fully assess and quantify the risk and development of suitable mitigation measures. This will include navigational marking of the area(s) occupied by the device(s).

  Consultation will also be undertaken with local fisheries organisations to establish the extent of potential impacts on fisheries; and, if required, develop of suitable mitigation measures.

Device installation

- **Seabed preparation**

  Prior to installation, the sea bed must be cleared of debris (kelp, etc). The amount of debris required to be removed and disposed of will be site specific. This will be considered on a site by site basis.

- **Foundation installation**

  The preferred method of installation is by drilling pins into the seabed. The preferred disposal method for any cuttings will be discharge to the marine environment. The proposed drilling method does not utilise 'drilling muds' therefore the drill cuttings will comprise natural bedrock only and no associated chemicals or mud.

  For array developments, it may be necessary to undertake drill cuttings modelling to understand the dispersion of the drill cuttings on discharge to the marine environment. This will enable demonstration of the drilling cuttings 'footprint' and assist in a robust assessment of impacts on seabed habitats. In locations particularly close to shore, it may also be necessary to monitor shoreline sediments to ensure no significant impacts on the shoreline sediment characteristics from dispersion of the drill cuttings.

Device operation

- **Coastline impacts**

  An issue associated with any marine renewable energy development is potential impacts on coastal processes from the presence of the device(s). It is expected that during an EIA a detailed assessment of potential impacts on coastal processes may have to be conducted. This may involve initial wave modelling to identify any potential shadow effect from the presence of the devices, and assessment of any requirement to undertake sediment transport modelling. Sediment transport modelling would only be undertaken if there was suitable input data for the model to allow meaningful results; and its merit would be fully discussed with statutory consultees e.g. Scottish Natural Heritage (SNH) or English Nature (EA) in the UK.

Wherever possible during demonstration projects APL will support any coastal monitoring programmes set up to further develop understanding of potential impacts on coastal processes and provide input to future EIAs.

- **Hydraulic system**

  The Oyster® device does not use any hydraulic oils. The PCU oscillator extracts energy from the passing waves and transmits it as hydraulic water power to the PTO system located onshore. The system will ultimately utilise an open seawater system which requires the use of a biocide to ensure no bio-fouling in the seawater system. At this stage of design the exact antifouling system is still to be decided. The final selection will take full account of environmental considerations.

- **Noise emissions from operation of the device**

  One of the potential key issues from the operation of any marine energy device is the generation of underwater noise and effects this might have on local wildlife, in particular whales and dolphins. Exposure to sound can produce a range of effects on marine animals. A low level sound can be audible to animals without resulting in any visible effect. At increased levels the sound may disturb animals and induce avoidance and other behavioural changes. If animals for any reason can't avoid a noise source, they may be exposed to acoustic conditions capable of producing negative effects, which may range from discomfort and stress to physical acoustic trauma. Exposure to very loud sounds, explosions at short range for example, can produce damage to many organs in addition to hearing.

  Noise from the operation of the Oyster® PCU oscillator is expected to be in the range of local ambient sea noise. Ambient noise levels will generally be high due to the strong wind and wave regime and the rugged nature of the exposed coastlines where this device will be installed.

  The PTO system is designed around a Pelton wheel, which has the potential to be relatively 'noisy'. During demonstration trials the PTO system will be located onshore and there will be the opportunity to take measurements to establish exact noise levels. Onshore facilities will be designed to ensure noise emissions meet regulatory requirements and include assessment of potential impacts on any sensitive wildlife populations.

  APL are committed to supporting wildlife monitoring programmes as may be deemed necessary to ascertain potential impacts on wildlife (terrestrial and marine) from the presence of wave power generation devices.

- **Visual impact (onshore and offshore)**

  When in its vertical position, the device protrudes above the sea surface at certain tide levels. Depending on the specific water depth at the installation site, the device may protrude 1 to 2 m above the sea surface (based on EMEC demonstration test site Orkney, UK). The majority of potential sites for deployment of the Oyster® system will generally be located close to shore and therefore will be visible from the adjacent coastal area, and will also include onshore facilities associated with the PTO.

  The onshore facilities will be designed to minimise visual intrusion and 'blend-in' with the local landscape features.

  Production of photomontages and consultation with local stakeholders, including statutory consultees and local communities will be an important aspect of the EIA process.

  Although the colour of offshore PCU devices can be designed to minimise visual effect, it must also meet any requirements of the navigational authorities to reduce risk to navigation.

2. Theme 2: RTD and Planning Barriers & Project Timescale

2.1. RTD Barriers

Oyster® is a small, bottom-hinged flap-type wave energy converter, deployed in a water depth of 10 – 15 metres. The original research on the hydrodynamics of Oyster® was performed by Queen's University Belfast (QUB) as part of a UK Engineering and Physical Science Research Council (EPSRC) research grant into the performance of flap-type wave energy converters in shallow water. This project was completed in 2003 and subsequently Aquamarine Power Ltd (APL) has led the development of Oyster®. APL is a Scottish start-up company committed to the development of wave energy technology. With an EPSRC grant and further funding from APL, QUB has conducted further studies on the hydrodynamics of Oyster®, both in the QUB wave-tank and using numerical models. APL has finalised the engineering designs for a prototype of the Oyster system, enabling real cost estimates to be produced. The Oyster® prototype will be deployed at the European Marine Energy Test Centre (EMEC) in Orkney during the summer of 2007.

A key RTD barrier is the difficulty with reliably and accurately estimating extreme survival loads on the foundations and structure. To provide some indication of the foundation loads, QUB performed load tests on a 1/40th scale model of Oyster®. At the proposed deployment depth the wave amplitude will be saturated due to depth-induced wave breaking. This means that the 50 year return wave amplitude is not relevant because the wave depth limits the maximum amplitude of the wave below that of the nominal 50 year return wave (from deeper water). A series of tests have been performed with wave breaking in front of, on and behind the oscillator. The objective of these tests was to identify the largest loads experienced. Testing was also performed with a number of different seabed bathymetries; as bathymetry will influence the type of wave breaking that occurs, i.e. plunging, spilling or surging. These tests delivered a set of values for the maximum foundation loads.

The first RTD barrier, or challenge for developers is the potential inability of that wave-tank model scale testing will not accurately estimate the loads experienced by the foundations; due to two main factors. The first relates to the different aeration factor in full-scale breaking waves. The QUB wave tank, in common with the majority of wave tanks, uses fresh water. However, salt water will typically have higher aeration content than fresh water, which may lead to differences. In addition to this factor, bubble size will not scale correctly, which may lead to potential differences between the model and full scale foundation loads when Froudian scaling is used to convert the model test results. These factors also make it difficult to accurately estimate the local structure loads that may occur, especially when the equivalent of green-water slam[1] occurs.

To compensate for the potential differences between tank testing and full scale tests at sea; the design team applied a very large safety factor in the final foundation designs.

A second RTD challenge is the lack of components and specifications for water-hydraulic components that are suitable for the power take-off (PTO) equipment to be used on Oyster®. “Off-the-shelf” components exist for the hydraulic circuit proposed for Oyster®. As the components have not been designed specifically for use with Oyster®, it is possible that the performance of the circuit will be lower than expected. As standard components are being utilised for a novel application, the key barrier is that the component specifications required to determine how they will perform in the Oyster PTO circuit are typically not available, either from the manufacturers or from standard component reference databases. This lack of available data may limit the accuracy of performance estimates, and makes it difficult to fully optimise the performance of the prototype. Similarly, there is no data available on the expected deterioration of hydraulic components or of their servicing requirements when operated in the Oyster PTO circuit. This makes it difficult to identify appropriate maintenance routines.

To overcome the former challenge, the team has delivered conservative performance estimates. To overcome the latter challenge, the team has adopted a worst-case-scenario approach. This means that it is possible that commercial devices will require less maintenance, once data on survivability and servicing is provided from prototype testing.

A further RTD barrier relates to a lack of specifications regarding the desired quality of power supplied by the wave energy converter to the grid. In the UK the G59 specifications specify constraints on the acceptable voltage and frequency output from plant. There are also constraints on the harmonic content of the power supplied to limit “flick”. However, these constraints are associated with rapid changes in power output.

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[1] Green water slam is the force on the structure from a body of water detached from the body - as in a plunging wave breaking onto a beach or the Oyster® device.

Wave energy converters will have a variation in output that will vary over periods of 5 seconds upwards. To design the wave energy converter it is necessary to know the acceptable variation in output power, and the time period over which that this can occur, so that the requirement for energy storage or power smoothing can be identified with the wave energy converter farm. Without the "cost" associated with power variation it is not possible to determine the optimum farm configuration.

Until there is a standardised measure or procedure for defining acceptable power variability, this barrier will remain and industry-wide issue.

The final major RTD barrier is the lack of knowledge on the costs of installation, operation and maintenance and how this relates to the system design. Clearly, for a new technology, there will be uncertainties associated with novel marine operations; however this is compounded by the absence of guidelines and standards from which the costs can be estimated. Whilst this clearly has a direct effect on operation costs, it also influences the optimisation of the design. Thus, the marine operations costs cannot be simply added to the total cost of power, nor is it sensible to use a simple percentage of the capital costs to estimate the O&M costs since this would mean that design improvements to facilitate maintenance would appear to increase the O&M costs, although they are intended to reduce these costs.

The design team will overcome this barrier following evaluation of installation, operation and maintenance required on the prototype to be deployed this summer at EMEC in Orkney.

2.2. Regulatory Burden

This section summarises the planning system in the UK. The company has not yet applied for planning permission outside Scotland. Therefore we cannot at this stage comment on other countries' planning process and the barriers. Thus the only barrier is a lack of available information about planning systems in other countries. We would welcome advice from other participants.

The first challenge for developers seeking consent to deploy wave power devices in the UK is that there 3 different regulatory regimes in the UK: England & Wales; Scotland and Northern Ireland.

The Department of Trade and Industry (DTI) have produced detailed guidelines on the consenting process for Wave Power Demonstration projects in England and Wales. The Scottish Executive's Consents and Emergency Planning Unit (CEPU) has not yet done so; due to the assumption that wave power demonstrators will be installed at EMEC (European Marine Energy Centre in Orkney). The DTI is working on, and the Executive plans to produce final policies and guidelines for Commercial Demonstration Projects. The DTI is also working towards harmonising international regulation and standards to ensure that devices can be designed for generic deployment across borders.

In Scotland, the first challenge with securing consent for marine energy deployment is that companies seeking consent for wave power projects have to apply for 3 separate licences from 3 different government departments for marine operations and deployment; they must undertake an EIA (environmental impact assessment) and provide an ES (environmental statement) reporting the findings of this process to support these applications, which must be approved by two further government agencies (responsible for Environmental Protection and Conservation) before licences can be granted.

Before submitting formal applications for the three licences required for marine operations and deployment; a pre-consultation exercise with all stakeholders is not obligatory, but strongly encouraged to ensure that the consenting process runs smoothly and quickly. There are 22 external, and 7 internal consultees. This process can take up to two months and the developer is also recommended to hold meetings with the statutory stakeholders and some NGOs (e.g. RSPB). If the developer does not carry out a pre-consultation; the formal consents application process can be significantly delayed.

Formal applications should also indicate a plan for ongoing research, including plans to disseminate results to interested stakeholders, known as a “stakeholder engagement plan”. This presents a challenge for developers deploying the first devices. Whilst knowledge about the impacts of offshore wind and oil and gas installations is available, and is relevant to marine energy installations; there is relatively little empirical evidence supporting the specific, potential impacts of marine energy converters on marine environments. As a result, full scale and detailed surveys are being set as conditions of consent by conservation agencies. The monitoring costs for MCT at Strangford Lough in Ireland over £2m. It would be impossible for Aquamarine, and other start-up developers to bear such costs at this time.

Developers also need to apply for planning permission from the Local Authority for any onshore civil infrastructure work associated with the installation. If the device is to be deployed within a harbour area, the developer needs to negotiate a lease and permission from the Harbour Authority to deploy.

Almost all of the proposed demonstration marine energy installations in Scotland will be deployed at the European Marine Energy Centre (EMEC) in Orkney. Aquamarine’s prototype Oyster® device will be deployed at EMEC in the summer of 2007. This offers a number of advantages in the planning process. EMEC has negotiated an exemption from one of the licensing requirements; and has negotiated a single sea-bed lease from the Crown Estate, on behalf of all developers deploying at EMEC. However, in the future, Commercial deployments outside harbour areas will require a sea-bed lease from the Crown Estate, which owns and leases the UK seabed up to 12 miles from the shoreline on a commercial basis.

This final requirement potentially places a heavy burden on developers when they move from demonstrating their technology at EMEC to installing full-scale commercial farms in UK waters. The Crown Estate has indicated they will require a bond for decommissioning costs as a condition for a seabed lease for commercial projects in the future. Their interest in marine renewables is motivated by anticipation of revenues from successful commercial ventures – they therefore wish to see a viable business plan for commercial projects. They will then set numerous conditions on the lease – covering insurance, compliance & consents, EIA, validation of business plan, etc. This substantially increases the regulatory burden on developers operating in this high-risk, start-up industry.

The final potential challenge is that, in line with the DTI's approach, the Executive has indicated that it may establish wave power development hotspots on the back of their own Strategic Environmental Assessment (SEA) of the North and West coastal waters. This is would create two potential barriers: developers will then have to compete for sites within these designated areas; and the hotspots may not be suitable for all of the wave power technologies emerging in this rapidly growing technology development field.

2.3. Project Timescale

Between 2001 and 2005, Queen's University and staff now working for Aquamarine Power Ltd completed Extensive wave tank tests using 1/40th and 1/20th scale models of a single oscillator. Numerical modelling and performance and load test results were used to deliver the baseline design and operational loads for the Oyster® prototype.

Aquamarine Power is pursuing the following milestones to take Oyster® from deploying its first pre-commercial device to commercial marketing.

Milestone 1 (2007- 2008)
Oyster® Prototype Demonstration

Build and install a single, grid connected prototype at EMEC in Orkney during summer 2007 to test performance and verify predictions from scale and numerical models.

Milestone 3 (2007-2007)
Wave farm research and development

Tank testing, cost engineering and R&D to model and validate array performance predictions. The results will deliver the final design and configuration for Oyster® MW wave farms.

Milestone 4: (2008-2009)
Array Demonstration as Precursor to Commercial Deployment

Install and test a cluster of Oyster® modules, with an installed capacity of over 3MW at EMEC in Orkney, as a first step deployment of further commercial farms in Scotland and the EU in partnership with project developers.

3. Theme 3: Market Incentive Schemes

Different EU countries offer different market incentives for wave power. The most competitive are offered in Spain, Portugal and the UK. The Scottish Executive is planning to introduce a revenue support tariff specifically for marine renewable energy. This revenue support will be set at a higher level than that available for other renewable energy sources, in recognition of the fact that marine energy technology is not as well developed as other sources of renewable energy, such as onshore wind. Marine energy production is an emergent sector of the renewable power market, and therefore, a market incentive system which offers additional support for marine energy is preferable.

Currently in the UK, the governments at Westminster (UK) and in Scotland (Scottish Executive) are also offering capital and revenue support for the first demonstrator array deployed by technology developers. The UK fund is administered by the Department for Trade and Industry (DTI). This fund is known as the Marine Renewable Deployment Fund (MRDF). Under the MRDF, developers are eligible to claim 25% of the total project cost as a capital grant, with the remaining 75% paid in revenue support at £100/MWh over seven years. The Scottish Executive offers the Wave and Tidal Energy Scheme (WATES). Under the WATES, developers can apply for 40% of capital costs and reclaim the remaining 60% in revenue support at £100/MWh over five years. As start up costs for this industry are very high, the preferred mechanism is the WATES funding, as this provides 40% of capital costs up front.