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OES-IA Annex IV: Environmental Effects of Marine and Hydrokinetic Devices

Report from the Experts' Workshop
September 27th – 28th 2010
Clontarf Castle, Dublin Ireland

AE Copping
MJ O'Toole, Irish Marine Institute

December 2010

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Abstract

The purpose of Annex IV is to provide a collaborative project under the International Energy Agency's (IEA) Ocean Energy Systems Implementing Agreement (OES-IA) that will identify ongoing research and bring together data on the environmental effects of marine and hydrokinetic (MHK) energy development, analyze those data to understand effects, identify potential monitoring and mitigation strategies to address those effects, and share those results and data broadly. The U.S. has the lead for Annex IV; and the U.S. Department of Energy (DOE) is the overall Operating Agent, also partnering with the Federal Energy Regulatory Commission (FERC) and the Bureau of Ocean Energy Management (BOEM). The DOE Water Power Program has also tasked one of the U.S. national research laboratories, Pacific Northwest National Lab (PNNL), to carry out a significant amount of the Annex IV work. The database created to support Annex IV data will be built as an adjunct to the Knowledge Management System (*Tethys*) created for a similar PNNL project on environmental effects of MHK development. One of the first steps in implementing the Annex was to convene an experts' workshop in Dublin Ireland September 27th – 28th 2010. PNNL was responsible for organizing the content of the workshop, overseeing the contractors (Irish Marine Institute) hosting the event, presenting material on Annex IV and materials applicable to the workshop intent. PNNL is also overseeing a contractor (Wave Energy Center/University of Plymouth – WEC/UP) in the collection and analysis of the Annex IV data.

Fifty-eight experts from 8 countries attended the workshop by invitation, spending two days discussing the needs of Annex IV. Ahead of the workshop, each participant received an extensive matrix created by the Wave Energy Center/University of Plymouth (WEC/UP), identifying known or likely MHK environmental effects for wave and tidal energy, monitoring and mitigation methodologies, and references. Additional pertinent reports and literature were made available to participants on the workshop website ahead of the workshop as well. Presentations by DOE (background on Annex IV), PNNL (process for developing Annex IV; presentation of the draft database for PNNL project, plans for incorporating Annex IV data), WEC/UP on the environmental effect matrix, and four MHK developers (two from the UK, one from Ireland and one from Sweden; each discussing their own projects and lessons learned for measuring and mitigating environmental effects, as well as interactions with consenting [permitting] processes) helped provide background. The purposes of the workshop were to:

- Refine and prioritize the list of environmental issues of concern

- Identify MHK projects or other research where specific environmental impacts of concern are being monitored and data are being collected

- Identify gaps where information on environmental impacts of concern is lacking or will be difficult to collect in the near future

- Identify analogous sources of data from other industries that operate in the ocean environment

- Identify case studies for further analysis where extensive monitoring or mitigation of impacts was successful

- Review the database which will house all information collected on environmental monitoring and impacts and gather suggestions for improvements

Propose methods for data collection and submission to the database and identify responsible parties for data collection

An additional underlying purpose of the workshop was to engage the interest of a diverse group of experts to begin to create an international body of scientists to interact and promote scientific inquiry into environmental effects of MHK development. The workshop participants worked part of the time in the large group and most of the time in four smaller breakout groups. Participants engaged in the process and provided a wealth of examples of MHK environmental work, particularly in the European nations. They provided practical and actionable advice on the following:

• Developing the Annex IV database, with specific uses and audiences

• Strong consensus that we should collect detailed metadata on available data sets, rather than attempting to draw in copious datasets. The participants felt there would then be an opportunity to ask for specific sets of data as needed, with specific uses and ownership of the data specified at that time. This is especially important as many data collected, particularly in Europe but also in Canada, are proprietary; developers were not comfortable with the idea of handing over all their environmental effects data, but all said they would entertain the request if they specifics were clear.

• Collecting metadata via an online interactive form, taking no more than one hour to complete.

• Although the idea of cases representing the "best practices" was recognized as useful, the participants pointed out that there are currently so few MHK projects in the water that any and all projects were appropriate to highlight as "cases". There was also discomfort at the implication that "best practices" implied "lesser practices"; this being unhelpful to a new and emerging industry.

• Workshop participants were asked if they were willing to continue to engage in the Annex IV process; all expressed willingness.

The workshop was successful in adequately addressing its objectives through participation and interaction in the breakout sessions around the various topics. As a result of the workshop, many delegates are now better informed and have a greater understanding of the potential environmental effects of MHK devices on the marine environment. There is now a greater sense of understanding of the issues involved and consensus by those regulators, developers and scientists who attended the workshop. A strong network has also been built over the two days between European and US/Canadian technical experts in wave and tidal energy.

Contents

1.0 Introduction and Background

The first Annex IV Experts' Workshop of the International Energy Agency's Implementing Agreement on Ocean Energy Systems (OES-IA) was hosted by the Irish Marine Institute (The Marine Institute) at Clontarf Castle, Dublin, Ireland from 27th to 28th September 2010. The meeting, which was organised by the Pacific Northwest National Laboratory (PNNL) and sponsored by U.S. Department of Energy (DOE), was attended by over sixty scientific and technical experts from nine member countries including Sweden, Ireland, Spain, UK, Portugal, US, Canada and Norway. The objectives of the workshop were to provide input on environmental effects of marine and hydrokinetic (MHK) energy generation and to provide information on the following thematic areas: a) development of a knowledge management system database; b) environmental effects of MHK devices; c) case study projects; and d) data collection. Assessment strategies were also discussed in relation to environmental impacts, monitoring, and mitigation of potential effects.

The workshop was opened by a short address given by Yvonne Shields from The Marine Institute. She welcomed the organisers, DOE, and the delegates from around the world and expressed her delight that the Marine Institute was asked to host this first Annex IV workshop in Ireland. She provided an outline of the Marine Institute's role in fostering ocean energy research and development in Ireland through the *Sea Change* Strategy: "A Marine Knowledge, Research & Innovation Strategy for Ireland 2007-2013". She was encouraged by the support and coordinating role provided by the Irish government and the significant investment being made in research into sustainable sources of marine energy such as wind, wave, and tidal. She highlighted the fact the Marine Institute collected large amounts of marine environmental data from its test sites, metocean data buoys, and research vessels that increases the national knowledge base and provides input into a data management system to study environmental effects of MHK devices.

Eoin Sweeney (Sustainable Energy Authority of Ireland - SEAI) outlined the opportunities for ocean energy developments off the coast of Ireland with the possible creation of a new marine sector in the years ahead. He pointed out that Ireland has a large marine energy resource and seabed ten times the size of its land area and that SEAI were in the process of looking at ways to better utilise the seas with ocean energy as a key driver for marine resource development. SEAI has been very proactive in positioning its case with the government with some success. A target has now been set for 500 MW of generated electricity from wave energy devices by 2020. This poses big challenges and will bring together all components to make a dynamic and viable ocean energy commercial sector. A good international team for the sector was now in place and SEIA was in the final stages of producing a Strategic Environmental Assessment (SEA) for Irish waters covering ocean energy. The SEA was currently going through public consultation and SEIA will be seeking stakeholder feedback at regional and local community levels. Mr. Sweeney stated that this workshop would be an important milestone in relation to identifying environmental effects of MHK devices on marine ecosystems and in the creation of an integrated database for wave and tidal energy that can be accessed by member states. He congratulated DOE for taking the initiative and lead in this area and wished the delegates a very successful two days of deliberations.

1.1 Annex IV Project – Ocean Energy Systems Implementing Agreement

Hoyt Battey (DOE) welcomed the delegates from OES-IA Annex IV member states and provided a short account of the various Annexes 1 – IV and outlined the Mission Statement of the DOE Water Power Project. The Annex IV "Assessment of Environmental Effects and Monitoring" will run to the end of 2012. The member countries comprise Sweden, Ireland, Norway, Spain, Canada, Korea, New Zealand and the USA and each contribute €5000 per year as well as in-kind contributions.

He emphasised that the goal of Annex IV is to ensure that all monitoring data are widely accessible for interested parties including industry, national and regional governments, agencies and the public.

Year 1 will consist of designing the database (by PNNL), while Year 2 will involve collecting and entering the data into the database including analysis of case studies (Wave Energy Centre, University of Plymouth). A final report will be drafted in Year 3, during which the database will be tested and released. The database is envisaged to continue beyond the project with updates as required.

He provided a summary of the key workshop objectives:

- Advise on database construction, format, usability and access
- Consider a range of environmental effects and associated research
- Identify case studies and analyse those operations that are successful, including monitoring plans and mitigation measures
- Discuss issues around data collection and publications, reports, and other documents including "grey literature"

1.2 IEA – OES Annex IV – The Process

Andrea Copping (PNNL) further defined the background to the workshop and highlighted the need to identify the types of data collected by those operations already in the water and to assess monitoring and mitigation strategies. She pointed out that PNNL is developing "the searchable database" and that the information gathered would be analysed and processed by the Wave Centre, Portugal and the University of Plymouth, UK. The database would also incorporate environmental effects information from analogues such as offshore oil and gas industries and marine wind farms.

The Marine Institute was contracted to organize the expert workshop in conjunction with the autumn IEA-OES meeting. It was envisaged that a second Annex IV workshop might be held in 2012.

She described the first task as building a master list of the environmental effects of MHK devices including impacts, monitoring methods, and mitigation strategies. Gaps in knowledge will also be identified and prioritised. Part of the exercise will include organizing and selecting the right data and best practices. The second task is to obtain and enter the data into the database, which PNNL will monitor and keep functioning and updated. PNNL will also be responsible for quality assurance and quality control. The third task will be the analysis and reporting of developments, including synthesis of data, preparation of a preliminary report and incorporation of comments into a final report. She outlined the priorities of the workshop as follows:

- Refine and prioritise the list of environmental issues of concern
- Identify MHK projects or other research where specific environmental impacts of concern are being monitored
- Identify gaps where information on environmental impacts of concern are lacking or will be difficult to collect
- Identify analogous sources of data from other industries that operate in the ocean environment
- Identify case studies for further analysis where extensive monitoring or mitigation of impacts were successful
- Review the current database that will house all information collected on environmental monitoring and impacts and solicit suggested improvements
- Propose methods for data collection and submission to the database and identify responsible parties for data collection.

The overall goals of Annex IV were summarised as follows:

- Share lessons learned internationally on environmental effects of MHK devices
- Accumulate environmental effects data from projects around the world into an accessible database
- Organise data by case or project that can be searchable that will allow for:
    - Consolidation of early results and best practices into a location for future data population
    - Establishment of a common set of data for developers, regulators and researchers
    - Making data available for analysis by communities
    - Lowering interaction costs between regulators, developers and stakeholders.

The outputs of the project will include a database of environmental effects and supporting information along with reports on case studies with links to other sources of information. The database will be easily accessible and provide inputs to national policy and regional bodies that could help developers gain insight into the regulatory requirements.

Matrices within the database would be developed to act as an organizing tool to assist in scoping out all potential environmental effects and data gaps.

PNNL will archive and quality control Annex IV data and will provide datasets for analysis and results. The database will be maintained into the future and will not be used by governments as a means of restricting developers.

1.3 Organization of the Workshop Report

The following report sections summarize the presentations and discussions that took place during the two day workshop. Extensive backup material is available in the appendices: Appendix A is the agenda for the workshop; Appendix B documents the terms of reference for the experts' workshop; Appendix C lists the participants in each of the breakout groups; Appendix D lists the background material and outcomes of each of the breakout groups, and Appendix E lists the workshop participants.

2.0 Annex IV Process – Approach to Environmental Effects of MHK Devices

2.1 MHK Environmental Effects, Monitoring and Mitigation

Teresa Simas (Wave Energy Centre/University of Plymouth) provided an outline of the effects of MHK devices (stressors) on the marine environment and stated that impacts on the receptors (benthos, fish, marine mammals, etc.) should be significant enough to cause changes, if they are to be considered for further analysis. She profiled some of the existing knowledge in a matrix showing effects and mitigation measures for both tidal and wave energy devices; some of the effects and mitigation measures would be expected to be similar for the two technology types. The effects of MHK devices would depend on the severity, duration, intensity and direction of waves, tidal currents, as well as other factors.

A framework for evaluating the environmental effects of ocean energy devices was presented and an example was given of how two particular stressors, acoustics and electromagnetic fields, were likely to affect marine mammals, fish, sea turtles, benthos (including crustaceans), and humans. She emphasised that further information and feedback was needed for pilot scale projects and commercial-sized devices that are already operational.

Andre Moura (Wave Energy Centre/University of Plymouth) described "mitigation of effects" as the process for making an effect less harsh, and pointed out that there were a lot of unknowns at this stage due to insufficient data. However, mitigation effects can be taken into account in the early planning by avoiding locating MHK devices in sensitive areas. It was also advisable to select an appropriate scale of development, and to design moorings systems to minimize footprints and maximize hydrodynamic efficiency, in order to limit turbidity and scouring. Many mitigation measures are based on common sense with environmental impacts requiring very specific measures to address the effects on receptors. He concluded by saying that much can be learned from similar offshore technologies, e.g., wind and oil / gas, but in order for the database to be effective, it must have input from "experts", particularly at the "effects" level, and from developments that are already underway.

Scott Butner (PNNL) provided an overview of "*Tethys* – Knowledge Management to support Environmental Risk Modelling and Mitigation in MHK Power Systems". He pointed out that the identification, characterisation, and mitigation of environmental risks from MHK projects are seen as key obstacles to successful commercialisation of the technology. In response to this need, PNNL, in partnership with other DOE laboratories, industry and academic partners, is creating a risk-informed decision framework. This Environmental Risk Evaluation System (ERES) will supplement judgement based assessments and will inform site selection, risk screening, public and stakeholder interaction, as well as research and development agendas.

Tethys is a Wiki-based knowledge management system and will act as a knowledge portal and link to other knowledge sources such as the Annex IV database presently under construction. It will provide disparate datasets and documents, quantitative models and findings, qualitative datasets, as well as papers and PDF files. It will have the ability to sample and aggregate datasets into data packages and have effective software to provide access to Annex IV data sets currently under development. The platform for building *Tethys* is a Knowledge Encapsulation Framework (KEF), which is a tool for capturing and managing knowledge related to techno-social models. *Tethys* will manage tablular and geospatial data, as well as results from scientific literature, model outputs, and social media. Its key features will include automatic semantic encoding of many meta-data fields and semantic "pipeline" processing to aid in recognizing and tagging key types of entities, e.g., people, places, and specific vocabulary terms. A short demonstration of the *Tethys* knowledge management system was given.

In conclusion, he emphasized that there was a real need to find out what data have been collected and published, by whom, and where those data are located. It was also important to assess the limitations of current MHK risk data, determine online data sources, and identify the likely stakeholders who will create, view and use the data.

2.2 Monitoring and Mitigation Strategies – Case Studies

Daniel Conley University of Plymouth) provided a presentation on the Wave Hub as an example of an effective monitoring strategy, which includes the following key requirements:

- Relevant indicators must be determined
- Monitoring must be specific enough to detect expected impacts
- Monitoring must be broad enough to detect large unexpected impacts

- Monitoring must be designed for appropriate controls
- It must be achievable
- Must include appropriate analysis, and
- Allow for the dissemination of results.

In his methodology, he described the environmental receptors that would be physically impacted by MHK devices including the physical environment, pelagic habitats, benthic habitats and species, fish and fisheries, marine birds, marine mammals, ecosystems, and food chains.

Mr. Conley pointed out that the effects of wave power devices on the physical environment were varied and included alteration of wave patterns and water circulation, modification of local wave climate, increased mixing in the water column and alteration of sediment dynamics. Monitoring of such effects would have to include hydrographic surveys; current profiling; wave measurements; conductivity, temperature, and density profiling; turbulence characterisation; sediment transport measurements; and remote sensing of shoreline changes.

The effects of electromagnetic fields on receptors such as benthos, fish, marine mammals, and sea turtles were also described, which included interference with locating prey, orientation, reproduction, and migration. Various methods to study the impacts of electromagnetic fields were also outlined including tagging species, laboratory testing, monitoring changes in fish catches and landings, and scientific data collected by research trawls.

The effects of underwater noise from MHK devices on receptors such as marine mammals and fish were also outlined and included: physical auditory damage, behavioural changes, avoidance of area, chronic stress, altered acoustic sensitivity, and mortality. Monitoring of acoustic baseline data at sites and levels of noise emitted by devices could be undertaken with passive listening and detection devices.

Possible effects on marine birds by ocean energy devices were highlighted and included collision, entanglement, interference with migration routes, disturbance and disorientation due to lighting at night, habitat changes such as roost, nest and feeding sites and prey species disturbance, and mortality due to release of toxic chemicals. Background data on seabirds could be obtained from the literature and information about local populations could be collected through surveying, telemetry, and tagging.

In relation to tidal energy devices, he also pointed out some of the effects of strike and cavitation on receptors such as marine mammals and diving birds, and how these could be monitored.

A description was given of the High Frequency (HF) radar installation and operation off beach areas in Cornwall, which includes a transmitting and receiving array to give directional estimates of waves at 2 km resolution. There were some initial problems with accuracy of measurements. It was important to monitor beaches including the high impact zone as they respond to different wave conditions in a variety of ways including generation of rip currents. Data from surveys of sub-aerial beach topography were also gathered for input into models. Surf zone behaviour at two beaches was also monitored and their features characterised including longshore bars, troughs and rip currents. Numerical simulation of waves and directional spread would also have to be undertaken. Mr. Conley called for further information and suggestions regarding monitoring, costs and resources, and insights into dissemination of information, and concluded by proposing a biannual release of data and regular consultation with stakeholders.

3.0 MHK Project Presentations

3.1 OpenHydro, Ireland

Sue Barr – (OpenHydro) provided a comprehensive presentation on "The Reality of Environmental Compliance from a Tidal Perspective". The benefits of tidal energy are that it is predictable, has high energy density, and has little or no visual or noise impact. Great potential exists for the creation of an industry from tidal power. An abundant resource has been identified in Irish and UK waters with a potential supply of over 50 TWh of electricity generation. Globally, tidal energy could have an estimated value of €128 billion in equipment sales alone.

The European Marine Energy Centre (EMEC) was established by the UK and EU to support development of tidal and wave energy. It is an accredited marine laboratory with a global reputation as a centre for marine renewables. It is located in Orkney, Scotland where some of the strongest tides (8.5 knots) are found along with extreme weather and climate. The Centre has access to suitable locations and has strong political support for marine renewable industrial development from the Scottish authorities.

During 2008, OpenHydro built and deployed its first seabed mounted tidal turbine at a site off Orkney. OpenHydro also deployed a device at a tidal test site in the Bay of Fundy where a strong tidal resource exists and enjoys government support to promote its development.

The presentation also provided an outline on the processes involved in developing a tidal energy project, including initiation, development, pre-construction, construction, and operation. During the initiation of the project, feasibility studies and site assessment are undertaken followed by current measurements, environmental impact assessment (EIA), design, and financial consultations. Turbine manufacture, shipping, assembly, commissioning, and subsea cable installation then take place followed by deployment, operation, monitoring, and maintenance.

Meeting the necessary regulations and obtaining consent [permits] is an important part of the process, which should address both specific and generic issues. These include existing legislation, control of electricity generation, environment, navigation safety, technical status, health and safety, and socio-economics. Addressing the regulation and consent issues requires a flexible and informed approach to administration as well as consultation and data sharing between regulators, developers, scientists, and stakeholders.

Establishing tidal flow baseline and estimating tidal resource at specific sites is done using a seabed mounted upward looking Acoustic Doppler Current Profiler (ADCP). This information can be supported by current velocity data from navigational chart tidal tables, tidal stream atlases and charted tidal diamonds. Flow measurements using ADCP are usually collected over a period of 28 days to provide sufficient information on tidal velocity and direction. These data can then be used to predict future tidal flows using harmonic analysis.

Seabed composition in tidal sites often comprises exposed fractured rock with light coverings of sediment, boulders and algae / sponge growth. It is important that target areas selected for the subsea base are surveyed accurately and that sufficient data are collected to inform the engineering process. Surveys of cable routing to shore and access to and capacity of the local grid are other key issues to be taken into account in project design.

Environmental effects of the tidal turbine need to be addressed at an early stage including the identification of the main receptors. Impacts can be due to direct effects such as collisions with rotors, physical effects on the sediment regimes, and by the energy extraction itself, as well as underwater noise. The cumulative effects of a number of devices should be addressed as well. Baseline data including geophysical, tidal resource, ecological and physical oceanography, need to be collected and analyzed at all locations with on-going monitoring to understand the receiving environment. During site assessment, sensitivities are usually found at every location and have to be taken into account during the mitigation process.

In monitoring the environment, it is best to engage in best practices, using adaptive management and an ecosystem approach. Regular monitoring at the OpenHydro tidal sites includes remotely operated vehicle (ROV) surveys, continuous video, and noise profiling. No interaction between a device and marine mammals has been recorded to date. Fish observations have shown that feeding behaviour can take place around the device during periods of low tidal velocity but that the fish are invariably located downstream of the turbine.

Useful lessons learned by OpenHydro during their tidal energy developments include the following:

- Strong political support is needed for tidal energy projects
- High levels of environmental performance are required
- Monitoring requirements should be site specific
- Adaptive management and monitoring plans are needed
- Close coordination between regulators, developers, and stakeholders is essential.

In conclusion, Ms. Barr prioritised some future needs for both developers and stakeholders:

- Clarity and consistency in consenting and engagement process
- Good understanding of the environment including baseline measurements
- Clear guidance on data collection for baseline and post-installation monitoring
- Flexible, proportional, and adaptive monitoring plans
- Integration at high policy levels.

3.2 Marine Current Turbines, U.K.

David Ainsworth (Marine Current Turbines Ltd) made a presentation on “The SeaGen Tidal Turbine – An Exercise in Adaptive Management”. This device is operational in Strangford Lough, Northern Ireland, located in the “Narrows” opposite Portaferry. It was installed in April 2008 and achieved 1.2 MW electrical generation capacity by December 2008. Since its deployment, it has generated about 2.5 GWh of electrical power.

The initial open sea experience of deploying a smaller version of this device was not completely successful; after a comprehensive re-appraisal and site assessments, Stangford Lough was selected as the test site. The development process commenced with a Scoping Report in 2004 followed by an EIA and an Environmental Statement (ES). A licence was granted in 2006 following an Environmental Action and Safety Management Plan and a comprehensive Environmental Monitoring Programme (EMP). After the device was deployed, post-installation monitoring and reporting regime commenced and will continue until 2012.

A schematic of the SeaGen EMP Regulation and Liaison structure was presented showing the links between the regulator, operational managers, the science group, the surveillance activites and the wider stakeholders and funders. Details of the EMP were given including the various levels of risk associated with Strangford Lough Special Area of Conservation (SAC). Of particular interest, were the impacts of the development on other users in the “Narrows”, the threats to seals from turbine rotors, and whether the turbines would affect the extent, quality, or composition of the seabed communities. The EMP provided information that could support future EIAs in the region.

Monitoring the marine mammals and sharks in the area involved over 5 years of sighting data (collected by Queens University Belfast) supported by statistical models to determine spatial and temporal patterns in sightings. Monitoring of porpoise by observers as well as the deployment of passive acoustic sensors to detect presence of these animals in the area were also undertaken (by SMRU Ltd) to provide a detailed analysis of presence, abundance, location, and behaviour. Extensive surveys of common seal and their haul out sites were conducted along with a satellite tagging project to determine routes taken by animals through the “Narrows” and the overall region. Seal carcass surveys have also been routinely undertaken during 2008 and 2009 with autopsies to date showing no deaths being attributed to the turbine.

Diving birds and species with special protection status were also assessed to determine if any interaction with the turbine could occur. These included gannets, mergansers, black guillemot, razorbills, eider ducks, and terns.

The benthic community was studied by divers and broad scale mapping carried out to quantify the potential footprint of the installation, operational and decommissioning phases. Dive surveys are conducted on a regular basis to detect any changes in biotope structure as a result of sedimentation and /or scouring effects of the SeaGen turbine.

The confirmation of the presence of marine mammals in the area was done by a Marine Mammal Observation Team (Royal Haskoning). Their observations, together with their work of estimating the distance of marine mammals from the device, determined whether a threat existed and if SeaGen needed to be shut down. The critical distance for shut down was initially set at 200 m, but has been gradually reduced and is now 30 m. Sonar is also being used to locate presence of marine mammals within the vicinity of SeaGen, and initial trials have been successful. In addition, acoustic measurements have been taken to determine signatures of SeaGen operational noise and baseline levels during the construction phase. Models have also been developed and extrapolated for use in understanding the potential acoustic impacts of a number of devices or arrays.

The impacts of SeaGen on the tidal energy through the site is still being assessed. Baseline transects have been carried out by Queens University Belfast prior to installation and further work is to be completed to measure impacts during post-installation to determine the energy variation.

In conclusion, a short account was given on the adaptive management process currently being used in the operation of SeaGen and how this has varied over time. Changes in monitoring and mitigation strategies have to be agreed upon and reviewed with the Science Group, and any alterations to plans must be evidence-based. No significant or adverse impacts on SAC features have been detected to date.

3.3 Aquamarine Power, U.K.

Marc Murray, Aquamarine Power, provided a presentation on the wave energy device that their company has developed called Oyster which produces electricity from ocean waves. The company was established in 2005 with its head office in Edinburgh and its resources in Belfast and Orkney. The company has 55 staff and is both a technology and site developer.

He pointed out that wave power alone could produce up to 80,000 TWh/year of energy and was less intermittent and more predictable than wind. It was also more widely available than tidal energy.

The Oyster is a wave energy converter that harnesses wave energy close inshore through use of a water piston that drives water under high pressure to a small hydroelectric power conversion plant. Other key benefits of this wave energy converter are that the generation components are easily accessible, it is proven and reliable and has “no survival mode”. It naturally ducks under extreme waves and keeps generating. It also has a high capture factor, has economies of scale and, compared to alternatives, has a low weight to power ratio.

The Oyster 1 device has been operating through winter 2009 and into 2010 with over 4000 hours logged and is grid connected. Grants and private funding have raised over £34 million. A 1 GW development agreement has been signed with SSE Renewables and the first 200 MW site has been allocated by the Crown Estate. So far, it has generated 315 kW through a demonstration grid connected at EMEC.

Oyster 2 will comprise three devices generating 800 kW – 2.4 MW and is on schedule as a demonstration during 2011-2012, while an Oyster 3 is in the planning phase (1 MW – 10 MW) and will be commissioned in 2013 to 2014 targeting USA, UK, and Ireland. From 2015 onwards, the Oyster will be scaled up to 20 MW deployments.

The environmental impacts of the Oyster are well studied at the development site and modelling work is still in progress to understand the potential impacts of an array of devices. Visual and recreational impacts are likely to be the main concern. No effects were observed on marine mammals or migratory salmon. Benthic organisms could be enhanced through habitat creation and provision of shelter, and noise levels were low. There were positive socio-economic benefits for local communities from developments, although there could be potential interference to lobster and crab potting activities. Impacts on birds were found to be insignificant, but this is a high profile environmental issue due to known effects of wind farms.

He concluded with an outline of some of the current and future considerations facing Oyster:

- The consenting regime is the priority risk to investment; the process needs to be clearly articulated so that it will also allow for product innovation
- Understanding the environmental impacts of devices requires on-going monitoring and needs to be applied to scaled-up demonstrations
- Too much focus has been given to birds in the past due to the legacy of wind power generation
- Avoid generic regulatory approach as all technologies are different with varying degrees of impacts and mitigation needs
- Developers need to educate both regulators and stakeholders. This activity should be viewed as a part of the development costs
- Lessons learned : see Danish wind industry

3.4 Vattenfall, Sweden

Kristin Andersen (Vattenfall) gave a comprehensive presentation on "The Environmental Work within the Vattenfall Ocean Energy Programme (OEP)" in which she outlined the company's ocean energy programme, their projects and related environmental work, suggestions about environmental requirements, and research and conclusions. A roadmap of Vattenfall's OEP summarised the process from the pilot phase (tests) in 2009 to the demonstration phase (proof of concept) in 2012-2018 and finally through to the anticipated commercial phase by 2019 – 2022 where 100-200 MW of electricity would be generated using the best available technologies. Securing permissions and licences were key to success, and environmental research and monitoring were an essential part of the process. The OEP consists of three projects: Maren based in Norway off Runde Island; Aegir Wave Power off the Shetlands, UK, and AMETS off Belmullet, Ireland.

Maren consists of two test generators on the seabed linked to surface buoys and connected to the shore via a cable. The project has a licence for 5 years and has been operational for about two years. The test site is close to cliffs with large colonies of seabirds especially puffins. Important fishing grounds are found close-by with kelp trawling also taking place in the vicinity. Noise emissions from the devices are also being monitored. The development process of the Maren test site involved scoping, preparing an ES, obtaining consent (licences and permissions) and putting a monitoring programme in place. The Maren operation is currently at the monitoring phase.

The Aegir project off the west coast of the Shetland Islands will be a demonstration plant comprising between 14 and 26 Pelamis devices capable of generating 10-20 MW of electricity. It is currently in the scoping phase with devices to be deployed in 2014. The key environmental concerns are marine wildlife interactions including marine mammals and birds, fishing and aquaculture, navigation and sub-station, and cables to onshore.

The Atlantic Marine Energy Test Site (AMETS) will be a demonstration plant located off the Belmullet pensinula, County Mayo, Ireland operated in collaboration with Tonn Energy, the Sustainable Energy Authority of Ireland (SEAI), and others. It will be part of a national test site that will generate up to 5 MW of power. Deployment of Wavebob and Pelamis devices are expected to take place in 2013 / 2014 at two sites - a shallow water location at 50 m depth (6 km from shore) and an offshore location at 100 m depth (12 km from shore). The project is currently at the EIA phase. The main environmental concerns include rare birds near the cable route, Annex 1 reef structures (defined under NATURA 2000), loss of fishing grounds, marine mammals and underwater noise, insufficient information on coastal and oceanographic processes, as well as a general lack of data from the area.

The Vattenfall approach to addressing wave energy environmental research and development questions is to increase the level of detail from screening and evaluating risk to modelling, analysis, monitoring and learning from others. The screening of environmental impacts as a decision-based management tool was shown in a colour coded matrix table that summarised a rating of the effects of devices on various receptors. Andersen also outlined the strategy used for assessing the knowledge required to proceed with environmental research and development and stressed that there can sometimes be confusion between "need-to-know topics" and "nice-to-know topics". The latter increases the level of requirements on developers, which may be unnecessary. It was important to separate these issues and divide the responsibilities between the private sector and government agencies. The levels of required knowledge will be especially important when scaling up from pilot phase through demonstration to the commercial phase. Ms. Andersen emphasised that a phased approach is needed that focuses on ticking the right boxes and living with a certain amount of "unknowns".

Environmental information needed for a project can also be filled from common generic knowledge if standards, common guidelines, and protocols exist. Information can also be used from other projects and collected in a number of ways such as modelling and desk top research, baseline field work and assessment, and from deployment and monitoring.

Ms. Andersen concluded her presentation with the following suggestions:

- Developers need clarification in relation to the legislative context and processes
- Focus on large risks and take pragmatic view in relation to concerns
- Use a stepwise approach in risk assessment
- Have a clear division between research and development requirements of developers and government authorities

- Develop and streamline methodologies
- Field surveying needs key objectives and a robust design
- Share information and cooperate – tick boxes "forever".

3.5 MHK Development in Scotland, U.K.

Jennifer Norris (EMEC, UK) gave a short presentation on the legislation and consenting regime for wave and tidal energy developments in Scotland. She highlighted the requirements, environmental impact assessments, and appropriate assessment processes involved from project inception to development. Among the most important factors to take into account in EIAs included mariculture, fishing activities, vessel traffic, and underwater noise. Ms. Norris demonstrated the usefulness of matrices listing environmental concerns and impacts as well as mitigation especially as decision making tools for managers when given colour coded priority ratings.

4.0 Discussion Sessions

During the two day workshop, questions / answer and discussion sessions were held after the presentations on data collection and environmental effects of MHK devices. Although it was not possible to capture all the comments, the following is a selection of some of the main points made during the open discussion sessions.

4.1 Data Collection and Data Management

- Scientists would prefer that information on the full range of environmental effects be gathered since much of the data are new. Industry does not necessarily agree; data collection should be mainly on a "need to know" only basis.
- In managing knowledge and data collection, we need to understand the structure, which data we want to collect, and whether there are ways of organizing the information more effectively. Are there general concepts that we can apply to the data as they come in so that we can make sense of them later?
- Data input into the information system should be comprehensive with all the environmental effects addressed. Some of these will not be significant, but if we capture them all, then we can identify effects that are likely to be significant and evaluate them. A risk assessment of how important the effects are could also be built into the system.
- More policy discussion should be held on quantity, reference sources (including grey literature), and quality of the information that needs to be collected and classified. Who has

access to what data? Metadata should be available through the database, but raw data should be accessed through the individual organization or institution via negotiation.

- The database should be highly structured to allow others to use tools to extract data, subject to quality control. It is difficult to manage a database that crosses multiple disciplines and much easier to focus on narrow data streams of direct relevance.

- The database is seen essentially as a tool for developers to communicate with regulators to meet environmental regulations and to facilitate the consenting process.

4.2 Test Sites and Operation of MHK Devices

- WaveHub is test bed for a number of devices with good data available for generic design and modelling. Knowledge of environmental effects is quite low and modelling simulation is over a 4x2 km^2 spatial area. Unclear how much transmission (energy) would be coming through.

- Experiences from SeaGen, Strangford Lough indicated little impacts on the ecosystem and environment since deployment. The mitigation response to shut down rotors in event of threat to marine mammals (seals) is now activated much sooner. Electromagnetic Field (EMF) is no longer an issue in Strangford Lough as cables are buried. SeaGen has already spent $US 2.0 million on monitoring and mitigation, which is a large burden for the developers.

- Experiences from Vattenfall indicate that existing monitoring plans may not provide all the answers and that other strategies are needed to identify knowledge gaps. Focus should be on topics of concern (need to know) and research prioritized. There are still a lot of unknowns, but we can learn from the oil and gas and offshore wind energy industries. We need to know what causes the change in receptors and also decide on what is an “acceptable” impact.

- Test centres and platforms can be used to develop and address technology issues that can help the industry in environmental assessment and impacts. The Plataforma Oceánica de Canarias (PLOCAN) project, for example, can offer facilities to test devices and models and measure acoustic sources.

- How do we get the data from the best case studies? Is there enough value added to put data into the system and will it be protected?

4.3 Data Quality, Standards and Monitoring

- It is important to set standards for monitoring and mitigation and to collect lessons learned from experiences. We need to share all the information collected and add value to the data.

- Monitoring methodologies need to be standardised.

- In relation to tidal devices, decide what to monitor and tick the boxes. Share the data so that some of the research components do not have to be repeated.

- Fisheries catch data are sensitive and often flagged and restricted. Catches are often aggregated for areas but will not show actual data points of fish capture.

4.4 Environmental Effects and Impacts

- The importance of the International Council for the Exploration of the Sea (ICES) expert working group on environmental impacts of ocean energy devices was highlighted. Each technology will be different and greatly influenced by the site location. Look at the common impacts, the degree of change and magnitude of variability. It is not possible to look at effects on the whole ecosystem.

- We need to look at the physical impacts of the wave energy converters on the environment before and after they extract the energy from the waves as the impacts are likely to be different.

- Avoid placing wave energy converters in sensitive areas. Sites selected for development are nearly always sensitive.

- High wave energy sites are going to be sensitive and monitoring has to be undertaken for baseline, during construction and operation, as well as in the decommissioning phase.

- It is important to build predictive mathematical models and to monitor specific sites to determine what environmental impacts are optional and what is critical.

- We need to decide at what level and at what scale environmental effects will be assessed in terms of sensitivities, e.g., change in behaviour of species, populations, and early life histories.

- Data are also needed on the far-field cumulative effects of wave energy devices on the marine environment. Industry usually does not have funds to support research on this.

- Underwater acoustic conditions are heavily influenced by water conditions. More baseline information is needed to address changing water conditions and biological sources. No standards exist for shallow water noise except for ships. Specifications for acoustic sensors need to be developed in terms of monitoring capabilities.

5.0 Breakout Groups

Participants were divided into four breakout groups that were asked to address a number of questions related to following three thematic areas: a) Monitoring and Mitigation, b) Case Studies, and c) Data Collection. Members of the various breakout sessions, the questions posed and all of the information captured by the groups are shown in Appendix C. The following bullets capture the main outputs of the breakout sessions under the different headings.

5.1 Monitoring and Mitigation Breakout Groups

- It is important to establish how much information should be collected during baseline surveys and how much post-installation monitoring should be done. Should the same protocols be used for different countries and sites?
- In selecting case studies for monitoring and mitigation of environmental effects, what makes a good set of data? How much data should be shared?
- Individual developers should address their own site specific environmental effects, monitoring and mitigation issues, but broader generic issues could be addressed at test sites.
- Environmental impacts could be rated from 1-5 on how much is known about the effects and how damaging they are. If effects are likely to be large then they should be monitored; if small, probably not.
- Monitoring should be separated into research exercises done to detect whether an effect is taking place versus obligations imposed on the developer by the regulator.
- We need to get the best possible data to feed into the Annex IV study. The Scottish government is doing a great job in collecting information and data. We need to review existing parameters and protocols.
- The National Environment Research Council (NERC), UK is identifying knowledge gaps to be funded in this area. The US DOE also funds similar exercises.
- Data from installations and operation need to be prioritized and include information on baseline data, including how the data were collected.
- Acoustic data collection is very important. Effects on receptors are likely to be significant. Little information exists on how to collect it and how underwater noise varies at sites, e.g., seasonally, background sounds, tidal effects, and sea states. How much noise is emitted by MHK devices and what are its characteristics (frequency and quality)?
- Little is known about electromagnetic fields on marine organisms, but burying cables greatly reduces emissions.

- Blade strikes especially on marine mammals could pose a problem at some tidal sites, but little evidence is available to support this from monitoring to date (e.g., Strangford Lough).

- Entanglements can have negative environmental impacts (e.g., Minke whales and lobster pot ropes). Wave energy arrays will have many mooring lines and cables.

- Collision by birds have also been identified as a possible environmental effect due to low ambient light levels, use of mooring lights, and use of devices by some birds for roosting.

- Displacement of marine mammals due to noise from wave energy machines or cumulative effects could pose subtle long-term impacts.

- Hydrodynamic changes to oceanography and circulation can be caused by multiple structures and devices. Modelling needs to be done to study effects and environmental impacts.

- Wave height and quality of waves can be impacted due to wave energy devices and could affect recreational uses at a site (e.g., surfing).

- More monitoring of analogues to study environmental effects needs to be done to support data collection. Onshore birds can also be an issue for cable laying.

- Impacts of MHK devices and arrays on fishing activities need to be addressed, as well as how fishermen can be accommodated and effects mitigated. Monitoring fishing income and possible compensation may need to be considered.

- What research is required and what type of monitoring needs to be undertaken at specific sites. Governments need to fund long term research and studies. Developers are responsible for near-field research on their devices. Far-field research may require government funding and a consortium of developers to approach generic issues (e.g. The Electric Power Research Institute in the US).

- Site selection is very important in terms of minimizing impacts of devices on receptors and the levels of mitigation needed. Additional mitigation strategies might include: feedback to engineering design, making operational changes, shielding and putting deterrents in place.

5.2 Case Studies Breakout Groups

- Criteria for successful case studies should be established and information gathered on these.

- Data collection exercises should assess what projects are out there and developers should be contacted for data to establish what is there and how useful is it.

- Where environmental effects data are not available from MHK devices, analogue data will be evaluated.

- Developers who have operational systems may be hesitant to provide the raw data, in which case negotiations may have to be held on a case by case basis. Developers may also have site specific data they are willing to share, with possible constraints on how these data are used.

- How will the data from developers be analyzed and what happens in the case of "good" and "bad" data? Who owns the data? How will data from the governments, developers, and research organizations be shared?

- Developers who hold data need to feel the value of this "database exercise" and how best to address the requirements in relation to studies done, mitigation put in place, and how monitoring is conducted.

- The database should produce reports on case studies (e.g., fact sheets), but not rigorous statistical analyses.

- Little information is available for developers to produce environmental impact statements from current knowledge. There is a need to obtain information from the public domain as well as a list of relevant references.

- Case studies need to focus on "major issues" in relation to environmental impacts, but also to identify the less important ones.

- Some case studies may only have one to two priority environmental impact issues or threats, but still have little practical experience of occurrence of these (e.g., marine mammal strikes at SeaGen, Strangford Lough).

- All data holders should be contacted and a complete list of projects established. Wave Energy Center/University of Plymouth will find data and will assist Annex IV convenors in negotiating with data holders.

- In some examples (e.g., Pelamis off Portugal), very few environmental effects have been monitored apart from some limited data collected on seabirds. These data belong entirely to the developers.

- To start the list, the database should focus on a few cases and build up the matrix by expanding accross technologies, receptors, and geographies.

- Criteria for choosing cases are not that important now as there are too few projects with devices in the water to qualify.

- An annual review workshop on the "State of Marine Hydrokinetics" should be held to review progress, analyse cases, and address specific issues.

- Independent research projects may have non-site specific generic information (e.g., Oregon Wave Energy Trust, COWRIE and others), which will provide guidance to developers on whether to undertake site specific work.

5.3 Summary of Cases

The following are some of the main wave and tidal energy projects identified worldwide by the breakout groups, and the major environmental effects for each:

- **Maren, Norway:** wave energy project. Seabased AB – Vattenfall owned. Impact concerns benthic organisms, seabirds, fish, noise

- **Lysekil, Sweden:** wave energy project. Seabased AB – Vattenfall owned. Impact concerns benthic organisms, fish; in planning stage

- **Shetland, UK:** wave energy project. Pelamis – Vattenfall owned. 10MW, just finalising scoping and planning stages

- **Belmullet, Co. Mayo, Ireland:** wave energy Atlantic Marine Energy Test Site (AMETS). Tonn Energy / Vattenfall/ SEAI – test facility for Pelamis and/or Wavebob. Impact concerns benthic organisms, marine mammals, seabirds, reefs, fishing activities, archaeological; at planning phase

- **Reedsport, Oregon, USA**: wave energy project. Ocean Power Technologies (OPT). Start-up phase

- **Puget Sound, Washington, USA**: tidal energy project. OpenHydro – Snohomish Public Utility District owned. Impact concerns endangered whales, salmon, rockfish, noise impacts, electromagnetic fields; just finalizing scoping and planning stages

- **WaveConnect, California, USA:** test centre for wave energy. Technology not yet known

- **Galway Bay, Ireland;** ¼ scale test site for wave energy. Wavebob technology. Impact concerns cetaceans, birds, fishing, noise impacts and monitoring

- **East River, New York, USA**: tidal energy test site. Verdant Power technology. Impact concerns fish, hydrodynamic performance and noise

- **Eastport, Maine, USA**: tidal energy project. ORPC cross turbine technology. Impact concerns fish, marine mammals, noise, benthic organisms; device in place

- **Cook Inlet, Alaska, USA:** tidal energy project. ORPC cross turbine technology. Impact concerns marine mammals and noise

- **EMEC, Orkney, UK:** two wave and two tidal projects, multiple devices. Pelamis, OpenHydro, Aquamarine, TGS technologies. Impact concerns seabirds, marine mammals, benthic organisms, noise, fisheries; good baseline data

- **Strangford Lough, Northern Ireland:** tidal energy project.   MTC technology. Impact concerns marine mammals, birds, benthic organisms, fisheries; good baseline data and characterisation; deployed and operational:

- **Wavehub, UK:** wave test site. Cable and hub installed; consortium, SWRA Universities of Exeter and Plymouth. Baseline data collection on marine mammals, birds and waves; no devices in yet

- **Ramsey Sound, Wales, UK**: tidal energy project. Unknown technology. Impact concerns marine mammals and seabirds

- **Anglesey, Wales, UK:** tidal energy project. Unknown technology. Baseline studies undertaken

- **Pentland Firth, Scotland, UK**: wave and tidal energy project. No device yet. Baseline information on marine mammals, seabird studies, side scan sonar, noise; multiple groups to address issues through joint studies

- **Hammerfest, Norway:** tidal energy project. Hammerfest Strøm technology. Deployed for 3 years; no studies on environmental effects; proposed to deploy other turbines

- **Hanstholm, Denmark:** wave energy test site. Wave Star technology. Small test site, no environmental work

- **Sotenäs, Sweden**: wave energy project. Seabased AB technology. EIA finalised; Norwegian lobsters have become an issue; engineering tests

- **Bay of Fundy, Canada:** tidal energy project. OpenHydro and MCT technology. Little or no environmental monitoring

- **Race Rocks, Canada:** tidal energy project. Clean Current technology. Small tidal turbine; no post installation monitoring; some impacts studies including noise and effects on benthic organisms

- **Port Kembla, Australia:** wave energy project. Oceanlinx technology. One device deployed; engineering studies

- **Milford Haven, Wales, UK:** wave energy project. Wave Dragon technology. Planning stages – baseline studies only

- **South Korea:** tidal energy projects. Multiple projects, some test sites – no environmental data.

5.4 Data Collection Breakout Groups

- The main interest is getting access to the data and the template is to help find data sources, organize the information, and prioritize the environmental impacts.

- Sharing data is a major issue that needs to be addressed. Some countries have a requirement in regulations to share data if publicly funded by the government (e.g., Canada, Ireland, and US).

- The database requires information on data management plans, archival information, metadata required by governments, as well as protocols and types of data reports. A knowledge base is also required so that information on sites and project descriptions are put into the templates.

- Data or metadata should be made available on-line as well as environmental information and effects from other types of renewable technology (e.g., wind).

- The real challenges are the sharing of proprietary data, e.g., underwater noise emissions from devices.

- The draft template needs to be sent out to delegates for feedback and further input. It was recommended that the template not be changed once it begins to be populated with data. Another follow-up workshop would be useful and more user interaction is needed.

- The sharing of data by developers may be problematic since the industry is still so small with each company developing and managing their own data. Some exchange of data takes place between interested parties, but are seen as proprietary information exchanges. Ideally industry should share data, but is unlikely if data have negative connotations. More readily available data may be given out if the information covers broader geographic and topical areas.

- Developers need to know how often data should be collected (e.g., measurement of underwater noise). Certain data may also be restricted and flagged for a period because of research value or PhD studies.

- Some developers are gearing up to deploy arrays of machines in the near future to demonstrate commercial potential. The industry needs to be able to test arrays and start collecting data to monitor impacts.

- The use of acoustic sensors and arrays to monitor fish is a knowledge gap. How much can these data be shared since there are commercial opportunities around the development of acoustic sensor technology?

- Regulators need to decide what data to release and provide more clarity on the type and frequency of the various data to be collected.

- More data are required on acoustic monitoring in high energy areas to record marine mammal vocalization signatures and to establish baseline sound-scape maps.

- There are real opportunities for quality research and cost sharing studies where matching funds can be leveraged with contributions from both public and private sector.

- In many cases, there is insufficient information available to evaluate environmental impacts using data from existing studies. New knowledge needs to be generated from additional surveys and sources, including knowledge from fishermen and other marine users to guide the information and processes.

- The database should be used as a structured decision-making tool to support and empower stakeholders and regulators in reaching consensus on environmental and regulatory compliance.

- Information collected through pubic funding should be freely available and data protocols should be neutral. Data gaps including acoustics, fish and marine mammals interaction should be addressed. Cost sharing studies should be encouraged to build trust with 50/50 contribution through public and private partnership.

- The Wave Canter/University of Plymouth will capture available data and compile the various environmental effects. It will also seek out information from research studies and analogue sources where there are poor data in relation to MHK devices. Baseline data will be built up from case studies, projects and research studies.

- Obtaining data from developers is important and incentives may be needed. Publicly funded data should be freely available. OES-IA nations will have to obtain data within their own countries. Environmental monitoring data are expensive and developers need to be convinced of the value of contributing the information.

- Reports and analysis of data including metadata are very useful. Regulators will want short data reports, not raw data. We need a comprehensive metadata template for the collection of the relevant data and reports.

- It is easier to get data from government agencies. Grey literature also contains much useful data and is in the public domain. Getting developers to publish data may be difficult and they will have to persuaded to release data on a case by case basis for specific purposes.

- A forum to discuss specific data issues with developers and the Wave Energy Center would be useful. Data collected by developers are usually analyzed and reports produced in-house (raw data not usually released unless part of a collaboration effort with other groups).

- A Scottish compilation and analysis of data on environmental effects of wave and tidal energy devices will be available in few months. This will be a useful database for regulators. The recently published ICES working paper is also a valuable information and reference source.

6.0 Conclusions

The workshop was successful in addressing its objectives through participation and interaction in the breakout sessions around the various topics. As a result of the workshop, many delegates are now better informed and have a greater understanding of the potential environmental effects of MHK devices on the marine environment. There is now a greater sense of understanding of the issues involved and consensus by those regulators, developers and scientists who attended the workshop. A strong network has also been built between European and US/Canadian technical experts in wave and tidal energy.

A series of excellent presentation on case studies of wave and tidal power and their effects on the marine environment were given that highlighted various monitoring and mitigation strategies as well as the challenges facing developers in the operation of pilot and full scale MHK devices. Many of the developers stressed the importance of meeting the requirements of the consenting regimes and having clarity from the regulators on the processes that will enable a successful monitoring and mitigation strategy to be developed for a given wave or tidal energy site.

Most participants supported the view that the database should be developed slowly and pointed out that many of the case studies underway globally were still in the early stages of development.

PNNL and the Wave Energy Centre / University of Plymouth will work together to follow up on priority issues regarding establishing the database and collecting the data and metadata. DOE will ask the member countries to assist with gathering data within their own national agencies and operators, and will keep others informed on progress, interactions, and data inputs. It was suggested that another workshop be held in 2012 and that some expert working groups be established to address some of the key issues that were raised during the two days.

Appendix A
Workshop Agenda

AGENDA	
Monday September 27th	
8---9am	**Registration**
9.00am	**Welcome** *Hoyt Battey, U.S. Department of Energy (DoE)*
9.30am	**Purpose of the Workshop** *Andrea Copping, Pacific Northwest National Laboratory (PNNL)* • *Process for identifying key environmental effects* • *Knowledge Management System* • *Monitoring programs and mitigation strategies* • *Case study data* • *Analysis and reporting*
10:00am	**Environmental Effects of MHK Devices** • *Major interactions between MHK devices and marine resources* • *Review list of environmental issues (sent to workshop participants in advance), focus on areas needing further resolution* • *Link issues to specific projects, research or monitoring programs with useful information that could be incorporated into the database* • *Help to identify data gaps and reasonable analogous sources of information* • *Analogues to effects of MHK devices in the marine environment*
11.00am	**BREAK**
11.30am	**The Reality of Environmental Compliance - A Tidal Energy Perspective** *Sue Barr, Open Hydro* **Discussion**
12.30pm	**LUNCH**
1.30pm	**Knowledge Management System Database (KMS) –** Scott Butner (PNNL) • *Presentation by PNNL to demonstrate the database* • *Discussion of additional functionality needed to meet Annex IV needs; identify other key user groups and their needs* • *General feedback on usefulness, changes/additions needed*
2.45pm	**BREAK**
3.15pm	**Monitoring and Mitigation Strategies** • *Principles and details of successful monitoring programs* • *Mitigation strategies that meet permitting (consenting) requirements*
4.45pm	**SeaGen: An Exercise in Adaptive Management** *David Ainsworth, Marine Current Turbines Ltd.* **Discussion**

5.45pm	**ADJOURN FOR THE DAY**
AGENDA	
Tuesday September 28th	
9.00am	**Case Study Projects** • *Purpose of case study* • *Criteria for choosing cases* • *Identify projects that may become case studies to highlight successful monitoring and/or mitigation strategies;* • *Process for review and analysis of cases*
10.30am	**BREAK**
11:00am	**The Environmental Work within the Vattenfall Ocean Energy Programme –** *Kristin Anderson, Vattenfall* **Discussion**
12.00pm	**Data Collection** • *Identifying data sources, who holds the data, and how to acquire them* • *Template for collecting data and gathering case study information* • *Discussion of who will gather environmental effects data as well as case study data, and how*
12.30pm	**LUNCH**
1.30pm	**Data Collection (cont'd)**
2.30pm	**Wave Energy Development: Aquamarine** *Marc Murray, Aquamarine Power Ltd.* **Discussion**
3.30pm	**BREAK**
4.00pm	**Next Steps in Annex IV** • *Determine what actions are required of Annex IV member nations and possibly of other Ex Co countries*
5.00pm	**ADJOURN**

Appendix B
Terms of Reference for Experts' Workshop

TERMS OF REFERENCE

The purpose of the workshop was to bring together experts from the Annex IV member nations to provide input to the process of characterising environmental effects of MHK development, monitoring methods and mitigation strategies and to assist member nations in identifying and developing datasets and associated materials for the case studies.

The specific goals of the workshop were to:-

- Refine and prioritise the list of environmental issues of concern
- Identify MHK projects or other research where specific environmental impacts of concern are being monitored
- Identify gaps where information on environmental impacts of concern are lacking or will be difficult to collect in the near future
- Identify a range of case studies for further analysis where extensive monitoring or mitigation of impacts was successful
- Identify possible analogous sources of data from other industries that operate in the ocean environment
- Review the initial version of the database which will house all information collected on environmental monitoring and impacts with suggestions for improvements
- Propose methods for data collection and submission to database and identify responsible parties for data collection

The Marine Institute were contracted to plan, coordinate and facilitate the workshop and to develop the agenda in consultation with the Pacific Northwest National laboratory (PNNL) and the U.S. Department of Energy. As part of the organisation process, a website for the workshop was also established where relevant information, documentation and presentations were posted. This can be accessed through the following website: http://www.eventelephant.com/expertsworkshop

A session facilitator, Nick O'Neill (SRL Consulting, Dublin) ensured participation of all invited delegates through focused discussions and break-away groups. Michael O'Toole (Marine Institute) was appointed as overall note taker to accurately capture technical ideas, to prepare written summaries of all sessions and to deliver this comprehensive workshop summary report within thirty days of completion of the workshop.

Appendix C
Participants in Each Breakout Group

Breakout Session Groups

Group 1	Group 2
Facilitator: Andrea Copping Rapporteur: Sharon Kramer Kristin Andersen Glenn Cada Eric Delory Eugene McKeown Andre Moura Stephen O'Sullivan Brian Polagye Cibran Rey Dave Thompson	Facilitator: Keith Kirkendall Rapporteur: Michael O'Toole Harvey Appelbe Marcel Cure Russell Dmytriw Sarah Henkel John Huckerby Ruth Leeney Gregory McMurray Timothy Mulligan Owen Nicholas Louise O'Boyle Anna Redden Gerry Sutton Robert Thresher
Group 3	**Group 4**
Facilitator: Greg Mc Murray Rapporteur: Scott Butner David Ainsworth Juan Bald Stephen Bowler John Horne Paddy Kavanagh Tracy Kutney Jennifer Norris Anne-Marie O'Hagan Jesse Roberts Marc Murray Craig Wallace Gayle Zydlewski	Facilitator: Nick O'Neill Rapporteur: Hoyt Battey Sue Barr Stephen Barrett Joe Breen Martha Casa Agudo Daniel Conley Graham Daborn Gordan Hastie Stephen Kajiura Harry Kolar Annie Linley Julia Parrish Howard Platt Teresa Simas

Appendix D
Background Material and Outcomes for Breakout Groups

MONITORING AND MITIGATION STRATEGIES
BREAKOUT – GROUPS

DAY 1

QUESTIONS FOR DISCUSSION

Monitoring

Base line monitoring of sites

- How much information is enough?
- How much should be permitting (consenting) driven and how much science-driven?
- How should we link existing environmental data to what is needed for MHK?
- How uniform should protocols be?
- How much baseline monitoring needs to be developer supported vs supported by public funds?

Post Installation Monitoring

- How closely tied to baseline variables and protocols should post-installation monitoring be?
- What level of certainty is needed?
- How much should permitting (consenting) drive design, how much should be science-driven?
- How do we implement adaptive management?
- What about BACI? Other strategies?

Mitigation

- Site selection
- Feedback to engineering design
- Operational changes
- Shielding or protecting receptors from devices
- Deterrents
- Others

GROUP 1 – BREAK-AWAY SESSION – OUTCOMES

DAY 1

Regulation and Monitoring

- ‘’Monitoring” – many definitions , regulations, deploy and monitor
- Importance of setting priorities for monitoring needs
- Cast in stone regulations drive monitoring, but is there leeway?
- Minimum monitoring needs
  - installed operational MHK
  - effects data
  - contextual data

Process of Monitoring

- Classify monitoring / research needs
- Environmental monitoring – developers responsibility
- Monitor for a while –mixed funding
- Once off – government responsibility
- On-going monitoring: near-field (developer): far-field (government)
- COWRIE model
- FADs devices

Major aspects

- Acoustics (uncertainty and high potential effects)
- EMF (need data, uncertain effects)
- Physical interaction e.g. strikes and entanglement uncertainty
- Change in water transport
- Competing uses i.e. fisheries

GROUP 2 - BREAK-AWAY SESSION – OUTCOMES

DAY 1

Regulation & Monitoring

Proprietary information

- Public funding / public information
- Neutral protocol
- Legislation / regulators

Monitoring Cost-sharing studies

- 50/50
- Study design
- Trust built
- Public / private partnership

Matrix

- Fishery
    - assessing true value
    - baseline survey
    - regulations and social impact
    - historical
    - on-going surveys
    - migration patterns
    - exclusion zones and impacts
    - existing data insufficient for today's needs

Process of Monitoring

- Needs to be science-driven (not waste of time)
- Who decides on monitoring?
    - stakeholders (engage early)
    - prioritise issues
    - monitoring programme (1 year adaptive management)
- Ecosystem approach is needed
- Stop duplication of work

Data Gaps

- Acoustics
- Fish / mammals interaction

GROUP 3 - BREAK-AWAY SESSION – OUTCOMES

DAY 1

Regulation & Monitoring

Monitors

- Pre-deployment 1 buoy ok
- Post installation monitoring
- Tribal pre-history baseline
- Baseline – temporal and spatial signal
- Variance - multiple years
- Information sharing helps
- Adaptive management starts
- Variability – periodic and episodic
- BACI control
- Goal is applicable universal
- Parameters, measurements and metrics sensitive

Regulators

- Moving targets from regulators a problem – relates to well defined adaptive management
- BACI may not be exclusively empirical
- Difficulty of control sites
- Ecosystem based management (EBM) –model based strategy

Environmental data

- Physical, chemical, biological and geological ass needed if relevant
- Enough information for environmental consents
- Protocols may be uniform but must be flexible and comparable
- Preferable standards for models and metrics
- Public domain is good
- Validation and calibration
- How doe we narrow the field of measurements

Mitigation

- Site selection - resource vs protected resource
- Site selection – group process CMSP?
- Operational changes
- lost fishing gear protocols
- contingency protocols
- sonar stoppage on tidal
- acoustic deterrence ok but….
- habitation common

GROUP 4 BREAK-AWAY SESSION- OUTCOMES

DAY 1

Regulation & Monitoring

What is the reason for monitoring? Why are we doing it? We can't measure everything (fit for purpose) e.g. pile driving impacts on oysters: COWRIE (BWEA): Species displacement – migratory / indigenous

Area of monitoring needs:
Stressor / Receptor Relationships - Show stoppers

1. Mammals / fish (large, big, small)
2. Birds
3. Noise
4. Energy extraction, marine processes, habitats
5. Hydrodynamics / sediments
6. Migratory / resident organisms /abundance, time scale
   - long distance connections
   - endangered species, take limit ,agree with regulator

- Monitor offer – opening bid by developer
- Government responsibility / negotiation / scoping document
- Data bases , political will, what can be answered globally
- SEAI , focus, project EIA
- Protected sites vs non protected
- Burden of proof on developer
- Adaptive management – list done
- Recommendations re: MHK deployment
- What can be answered at project level – big question

Monitoring Needs Missed

- Acoustics
- Particle velocity – lateral line / sediments
- Vibration type measurement
- Turbulence
- Mixing processes

Mitigation – Operational Changes

Experience Database – inform regulator eg. Marine mammal interaction, Developers get references – informed discussion

- Know what we know and what we don't know (Data gaps)
- Developers to share information
- Prioritise
- Going into future – government format for sharing information
- Results release

DRAFT CRITERIA FOR CHOOSING CASES
BREAKOUT – GROUPS

DAY 2

QUESTIONS FOR DISCUSSION

Cases should:

- Be real MHK projects, either in the water, or in advanced stages of testing
- Be geographically distributed
- Include tidal and wave projects
- Include variety of technology types
- Be deployed (or deployment planned) in waters with range of receptors, ocean conditions, climatic conditions.
- Have data on environmental effects of MHK devices
- Include single devices and arrays (at least some)

Draft Data Collection Template

- Case Name
- Location: Country, region, specific location (latitude, longtitude, GPS, map coordinates, description)
- Proposer's Name and Contact Info
- MHK Technology Type

GROUP 1 - BREAK-AWAY SESSION- OUTCOMES

DAY 2

CASES

- Maren, Norway (Vattenfall)
  Wave, Seabased (pilot): benthic habitats, birds, noise

- Lyskile, Sweden (Uppsala University)
  Wave , Seabased (point absorber): bentos, fish

- Shetland, UK (Vattenfall) Wave, Pelamis

- Atlantic Marine AMETS , Belmullet, Co. Mayo, Ireland: Test Facility
  Vattenfall, Tonn energy, SEAI , technologies to be decided, Pelamis / Wavebob: benthos, marine mammals, seabirds, fishing

- Reedsport, Oregon, USA: OPT
  Wave point absorber: all receptors – everything

- Wave Connect, California, USA: (PG&E) technologies to be decided – test bed

- Galway Bay , Ireland (1/4 test) SEAI + MI: Wavebob - various receptors and impacts including noise

- RITE , New York, USA: Verdant: Tidal, 3 blade rotor: fish, hydrodynamics

- Eastport, Maine, USA: ORPC,Tidal, fish, marine mammals, benthos and noise

- Snopud, Puget Sound, USA :Tidal, OpenHydro : all receptors – everything

- Cook Inlet, Alaska, USA: ORPC : Tidal, marine mammals, noise

- EMEC, UK: Tidal, Wave, multiple receptors and varies

- Strangford Lough, Northern Ireland: MTC: Tidal, multiple receptors including marine mammals, benthos, seabirds and fish

- Wave Hub, UK test site: University of Exeter and University of Plymouth
  Wave, base-line studies only

- Ramsay Sound, Wales, UK: Tidal, technology to be decided: marine mammals and birds

- Anglesey, Wales, UK: Tidal, technologies to be decided: marine mammals and birds

- Pentland First, Scotland, UK: EON, SSE: Tidal, Wave: technologies to be decided: all receptors – everything

- Hammerfest, Norway: Tidal, Hammerfest Storm

- Hansom, Denmark: Wave, test-site on small scale: no environmental workave

- Sotenas, Sweden Wave , Seabased: lobsters, fisheries

- Bay of Fundy, Canada Tidal, OpenHydro, Allstrom, MCT: variety of receptors

- Race Rock, Canada: Tidal, Clean Current: Benthos

- Australia, Wave, Oceanlinx
- Wales: UK Wavedragon: planning phase

- South Korea, Tidal, test site.

Best cases : MCT, EMEC (OpenHydro, Aquamarine), Maren, RITE, Eastport, HydroGreen (fish), Hastings mix:

Consolidate all candidate cases: Case selection criteria not relevant in Annex IV except when devices are in the water.

"State of MHK" should have annual review - value added

Annual workshop with working groups/ experts valuable to analyze case specific issues.

Difficulties of how to account for independent research also needs to be overcome

Data Collection Template

- Study types – fish, sediments, marine mammals
- Date and duration
- Type of study (small number of choices)
- On-line check boxes set for each receptor group eg. Field, laboratory
- Methodology, base-line, post installation monitoring, research
- Max: 1 hr per project "Would you like to share"

Data Collection

- Advantages to developers to contribute data
- Metadata template for collection
- Summary reports O.K.
- Harder to get raw data
- Ask for raw data for targeted purposes. Getting people to provide data could be a lot of work involved.
- Bring data holders and data gathers together to discuss and evaluate data including those not published (grey literature)
- Accelerate retrieval of information for environmental assessments

- Data collection template should include:-
  - study type
  - environmental impact measured (where, when how)
  - Methodology (on-line tick boxes) e.g. marine mammals (t-pods, boat and land observations, field, labs.
  - References to base-line, post-installation and research
  - Type of data, archival, report details, etc..
  - Template easy to fill out
  - Boxes indicating data availability, on-line data, interests in sharing data, permissions required.

GROUP 2 BREAK-AWAY SESSION- OUTCOMES

DAY 2

CASES

- Protocols
- Review panels
- Data management
- Final reports
- Knowledge base not data collection

Challenge to share data and environmental information

- Description of site and project
- Information regarding environmental effects
- Private vs public funding
- User feedback needed

1. WaveHub – Cornwall, UK
   Coastal processes studies

2. Biscay Marine Energy Platform (BIMEP)
   Fishing

3. Admiralty Inlet – USA
   Orca
   Marine mammals

4. Bay of Fundy
   Fish tracking
   Sediment hydrodynamics
   Modelling

5. Strangford Lough - SeaGen
   Seals
   Nearfield turbulence
   Sonar

6. ORPC
   Pinger

7. Wave Connect – USA
   Crab fishing

8. OPT – Wave - USA
   Grey whales
   Modelling effects on ecosystem

9. Tacoma models – USA

Temperature
Dissolved oxygen
Tidal exchange

10. Tidal barrage / Bay of Fundy
    Impacts on fish

11. MUTRIKU – Basque Country – Spain
    Noise

12. Lysekil – Sweden - Seabased
    Benthos research

A lot of lessons also to be learned from offshore wind projects – NERI

GROUP 3 BREAK-AWAY SESSION- OUTCOMES

DAY 2

CASES

A project is a technology at a location ..may be cases in projects and case is a collection.

1. Reedsport OPT Wave Park (USA)
   - Settlement
   - Adaptive management
   - Baseline study plan
   - Proprietary is public information : RED FLAG

2. EMEC and Aquamarine Oyster – Scotland
   - STAC
   - Nearshore device
   - Consents conditions
   - If EIA: then public disclosure ..if not, not so
   - Potential environmental effects

3. Roosevelt Island Tidal (Verdant – USA)
   - Video data
   - Large data set
   - Hydro acoustic methodologies
   - FERC – exempt
   - Avians
   - Hydrodynamic / acoustics
   - Methodologies of interest to developers

4. ORPC Tidal in Marine (USA)
   - All data Public (Environmental)
   - 1.5 years baseline (Fish and Bentos)
   - FERC Pilot – Winter 2010-2011
   - Helical
   - Barge, then bottom mounted

5. Strangford Lough – Tidal –MTC
   - STAC
   - On the grid
   - Five years data
   - Sensitive area
   - Adaptive management – decision points

6. Fundy Test Centre – Tidal – OpenHydro
   - SEA

- Not grid connected
- Studied for x months
- Transferred data/methods from EMEC
- Carrot and stick –data
- Recommend OES IA : Exercise on data
    - researcher
    - regulators
    - developers
    - exchange

7. Research projects

8. EMEC – Tidal- OpenHydro (Scotland)

    - Atlantic & TGL same attributes as other EMEC

9. Galway Bay – Ocean Energy Wave site – Wavebob (Ireland)
    - ¼ scale
    - 2 years of data

10. Admiralty Inlet – Snopud OpenHydro (USA)
    - Not in water
    - FLA 1/2011

11. British Columbia – Clean Current – Tidal (Canada)
    - Biofouling

12. WaveHub
    - Baseline studies

13. Maren – Waves – Sweden

14. AMETS – Belmullet – Waves –Ireland

Attributes ……Criteria: Industry would probably be willing to provide something akin to FERC fact sheet.

Data Collection Template

- Project Description
- Device name and developer
- Spatial footprint and descriptors
- Technology type and classification system

- Mooring infrastructure/ type and cabling
- Location, point and area
- Landside infrastructure
- Connection to Grid WFO
- Looks like a FERC Pre-app document
- Permitting, site selection and where in the process

Search terms – advanced search parameters “faceted browsing”
Technology type, stressor and receptor
Social – cultural –economic descriptors
Associated literature, annotated pipeline, understand audience and what development phase

GROUP 4 BREAK-AWAY SESSION- OUTCOMES

DAY 2

CASES - monitoring that is useful to others

- Projects in the water
- Projects in the licensing phase
- Early stage projects with unique aspects
- Fact sheets with summary of particular issues

Research Institutes with relevant issues and hard data: highlight in a case i.e. SuperGen

- New Zealand – Subscale devices: Crest Energy –Court
- Australia Tom – Ocean Links
- Atlantis Resources – Singapore
- East Coast of Canada Network (Fundy Energy Research)
- US equivalent – National Laboratories Systems DoE eg. PNNL – Puget Sound acoustics

Follow up research on websites: Welsh Assembly Government: Scottish Natural Heritage, Crown Estates, JNCC books on Bays (Coastal Atlas)

- British Geological Survey – grab samples, data base, COWRIE website
- Southhampton Oceanographic Centre (SOC)
- National Oceanographic Centre (NERC)
- JNCC on-line marine monitoring handbook
- Designated site monitoring and background data

Use of Annex IV database for assessing Scoping Response Document

- Navigation issues – MCA not for commercial use eg. Movement of ships – shipping lanes Bay of Fundy
- Vessel tracking, fishing data often aggregated with raw data confidential and often not available

BVG Nov Report – Timelines: Uses in Scoping Study for developers (Orkney), informs regulators; data from projects need to exercise caution about transferability

Some data sharing, but mainly public domain.

Test site, demonstration arrays and research design stage.

Who is liable for this data? No transference of liability, it merely informs

Are there non disclosure agreements or IP rights?

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Is data peer reviewed – what level of quality control or quality assurance?

If data is submitted as part of licensing process, it remains confidential

Demonstration projects, collect data for short periods….how valuable? May

Appendix E
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