OPEN WATER TESTING WORKSHOP I REPORT

OES Annex V

Ocean Energy Device Project Information and Experience

October 15-16, 2013
The Gresham Hotel
23 Upper O'Connell Street, Dublin 1, Ireland

Preface

The United States Department of Energy is funding the management and operational costs of the Ocean Energy System Annex V Workshops and the United States is serving as the Operating Agent for Annex V. Each of the participating countries is independently funding their activities in the Annex. Annex V workshops are managed and administered under the sponsorship of the Ocean Energy Systems Executive Committee by:

- Mike Reed, U.S. Member to the OES Agreement, U.S. Department of Energy
- Roger Bagbey, Annex V Operating agent, CEO Cardinal Engineering, LLC
- Robert Thresher, U.S. Alternate Member to the OES Agreement, National Renewable Energy Laboratory
- Samantha Rooney, Administrative Support, National Renewable Energy Laboratory

Disclaimer:

Ocean Energy Systems (OES), also known as the Implementing Agreement on Ocean Energy Systems, functions within a framework created by the International Energy Agency (IEA). Views, findings, and publications of the OES do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

Executive Summary

Worldwide there are number of national marine energy device open-water test sites currently in operation, in construction, or being planned for development. In addition, there are a number of ocean energy device manufacturers that have tested their devices at multiple open-water sites in varying environments. The goal of the Open Water Testing Workshop I was to bring together open-water test site operators and wave device developers to exchange information and experience on all aspects of planning, development, operation, and usage of open-water test facilities to identify possible improvements in the capabilities of these facilities for the mutual benefit of the entire ocean energy industry. Workshop participants included 36 representatives from 12 different countries. Specifically, the workshop facilitated documentation of the following:

- Presentations by participants
- Major discussion points
- Questions and answers
- Feedback on how to improve future Annex V Workshops
- Ideas on how the OES could work to improve testing of ocean energy devices and accelerate commercialization of the technology.

Workshop participants gave 16 presentations about open-water test facilities. Three categories of open-water test facilities were covered by the presentations:

1. Operating test centers – 6 presentations from 5 countries
2. Test centers under development – 5 presentations from 5 countries
3. Test centers operated by developers – 5 presentations from 4 countries

Each of the three sessions was followed by an open discussion by all participants. The many questions and answers discussed during the workshop are covered in the Summary section in this workshop report. The report also documents suggestions for future workshops in the Attendee Recommendations for Future Workshops section. The key ideas on how OES could work to improve the testing of ocean energy devices are summarized in the following.

During these discussion sessions, an overall workshop theme emerged that focused on defining a business model for test centers in order for them to most effectively accelerate the development and commercialization of the industry. Participants discussed whether or not the test centers should be publically funded facilities that serve the public good, or if they should be commercial service facilities that charge a fee to their customers, or if they should be a combination of the two. While the group did not reach a consensus, it seemed that the hybrid business model seemed to be the best fit for the current needs of the industry and the public agencies.

A second overall issue that emerged during the workshop was the clear preference of device developers to perform research and development (R&D) testing in open waters at or near full scale to validate stepwise device improvements and environmental effects over extended periods of time. In contrast, the test center operators were envisioning shorter term testing campaigns, where device developers would bring in a device and test it at a berth for short periods of 6 months to a year. The developers also wanted the test centers to be capable of providing a full spectrum of services. These services might include site sea characterization in support of logistics, deployment, and maintenance, as well as test device measurement and instrumentation support, and test data analysis. From the discussion, it appeared that not all of these capabilities were being planned at this time, but they could be developed with time and adequate funding.

The third theme that emerged was whether or not the test centers should provide some type of certificate attesting to the type and duration of testing accomplished during the open-water testing of a device. However, participants could not fully address what organization should specify the requirements for such a certificate. Although certification seemed to fall within the scope of the International Eletrotechnical Commission's Technical Committee 114 on marine energy (IEC TC-114), it was unclear whether this is within the current scope of that technical committee. This may be a topic of international interest for development of a recommended practice, which would help define the role of and the scope of services provided by open-water testing facilities worldwide. Recommended practices would also help to develop a set of standard tests for all wave tidal energy devices.

ABOUT THE IEA

The International Energy Agency (IEA) is an autonomous agency established in 1974. The IEA carries out a comprehensive programme of energy cooperation among 28 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The aims of the IEA are to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organizations and other stakeholders.

To attain these goals, increased co-operation between industries, businesses, and government energy technology research is indispensable. The public and private sectors must work together, share burdens and resources, while multiplying results and outcomes.

ENERGY TECHNOLOGY NETWORK

The IEA provides a framework for countries around the world, businesses, industries, international organizations and non-government organizations to work together in collaborative multilateral technology initiatives, which enable participants to optimize resources, speed progress and share results. Covering portfolios from basic research to deployment and information exchange on energy supply, transformation and demand, its 42 initiatives (also know as Implementing Agreements) focus on:

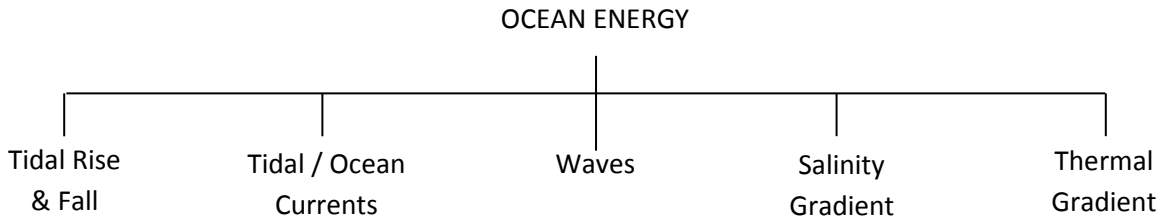
- Cross-Cutting Activities (information exchange, modeling, technology transfer)
- End-Use (buildings, electricity, industry, transport)
- Fossil Fuels (greenhouse-gas mitigation, supply, transformation)
- Fusion Power (international experiments)
- Renewable Energies and Hydrogen (technologies and deployment)

These IEA energy technology initiatives operate under the guidance of the Committee on Energy Research and Technology (CERT), which has in turn, established expert bodies or "working

parties" to assist with this task. The Renewable Energy Working Party (REWP) is the principal advisory body to the CERT on all matters relating to renewable energies. The Energy Technology Network comprises 10 "Implementing Agreements" on individual technologies.

ABOUT THE OCEAN ENERGY SYSTEMS (OES)

The Ocean Energy Systems (OES) Implementing Agreement is an intergovernmental collaboration between countries to advance research, development, and demonstration of technologies to harness energy from all forms of ocean renewable resources through international cooperation and information exchange. Ocean energy resources include tides, waves, currents, temperature gradient (ocean thermal energy conversion and submarine geothermal energy) and salinity gradient for electricity generation and desalination. The OES covers all forms of energy generation in which seawater forms the motive power through its physical and chemical properties (Figure 1). It does not cover offshore wind generation; because seawater is not the motive power (offshore wind is covered by the Wind Energy Implementing Agreement).



The OES international cooperation facilitates:

- Securing access to advanced research and development (R&D) teams in the participating countries
- Developing a harmonized set of measures and testing protocols for the testing of prototypes
- Reducing national costs by collaborating internationally
- Creating valuable international contracts between government, industry and science.

The OES Executive Committee (ExCo) is continuing to develop a suite of information dissemination tools that will assist the OES in becoming a leading international authority on ocean energy. Ocean energy is an emerging technology area that will benefit from the existence of the international collaboration mechanism offered under the Implementing Agreement contract.

OES Annex V: The Exchange and Assessment of Ocean Energy Device Project Information and Experience

Introduction and Scope

The OES Annex V will facilitate the exchange and assessment of ocean energy project information and experience from participating member countries to foster a better understanding and accelerate the development of ocean energy technologies. At this nascent stage of ocean energy development, there are many different configurations for marine energy converters and each has advantages and disadvantages. In addition, there are many competing approaches for modeling and testing these devices individually, or in arrays, at subscale and at full size. Furthermore, there are no generally accepted methodologies for design and cost analysis of these ocean energy converters. The sharing of project data and computational assessment methods will allow the participants to determine the most promising approaches for analysis, design, testing, cost estimation, and operation of these devices based on the collective experience of the group. This will facilitate an understanding of the current state of the ocean energy industry worldwide, and will help manufacturers determine the expected performance of a device, and ultimately, whether or not a particular device configuration has the potential to achieve competitive cost of electricity (COE) as new systems evolve.

This new annex will be executed through three tasks:

Task I - Establish the structure and outcomes of the annex. Include a plan of actions and milestones (POAM). This task began with meetings conducted on April 23, 2012, in Washington, D.C., USA, and on May 16, 2012 in Daejeon, South Korea. The initial Task III Workshop took place on October 15 and 16, 2012, in Dublin, Ireland prior to the LCOE bi-annual event.

Task II – Conduct data definition working group meetings to identify eligible projects, data sets to be exchanged and required characteristics and formats for information that will form the basis of the annex. Participants will establish the required data to be presented for projects and to describe the empirical and computational methods by which the data is obtained. In addition, this task will include planning for the Task III presentation of projects. Task II will last up to 18 months, will run concurrently with Task III over the last 6 to 18 months, and will include two or three meetings to refine the details of data collection and application. The initial Task II working group will be delayed until after the initial Task III Workshop, as the specificity of data characteristics is not needed for the initial workshop subject matter. The execution of Task II of the annex will be reviewed and potentially modified to ensure efficiency of effort, i.e., reduced travel requirements.

Task III – Conduct Exchange Workshops to present project information, experience, and data to the participating members. Where feasible, workshop participants will also integrate the resulting information into computational models to assess system performance, reliability and costs, resource characterization, and hydrodynamic interaction between the ocean resource and devices individually and in arrays. Three or four workshops will be conducted over approximately 36 months. It is anticipated that the workshop portion of the annex could be extended depending on the level of interest and a continuing need to share and collaborate.

This annex will compile as much usable data as possible to provide participating countries with a consistent and measurable means for rapid optimization of ocean energy production.

Objectives and Expected Results

The overarching objective of the proposed annex is to accelerate the development and deployment of ocean energy technology through a multi-country exchange of available ocean project information and experience to allow the participants to understand the current state of knowledge in the field, and to develop a consistent method of assessing the performance and cost of ocean energy conversion systems. The primary focus of these efforts will be to develop an assessment of the fundamental knowledge in the following four topical areas of direct interest to the ocean energy community:

1. Methods for estimating and verifying the ocean energy resources and characteristics, including instrumentation types and deployment methods to capture resource data
2. Methods for modeling the interaction of ocean energy devices with the resource and verifying the results
3. Methods for modeling and experimentally verifying energy capture, power system efficiency, and the resulting loads including extreme loads, from the interaction of the device and the resource
4. Methods for estimating and validating the cost and performance for ocean energy device arrays, including component, subsystem, and the electrical cable and supporting installation, operation, and maintenance, to enable assessment of the total cost of electricity

The methodologies used for data selection, validation, and assessment will closely adhere to the standards under development by Technical Committee TC 114 of the International Electrotechnical Commission.

Approach and Methodology

Clearly, the challenges of assessing this broad ocean energy knowledge base and the modeling and testing capabilities for ocean energy conversion devices are significant. The success of this effort relies on a thorough understanding of the resource characteristics, the fluid-device interaction, and the mechanical conversion of the captured energy to electricity. These challenges are certainly difficult for the device designer, but are many times more difficult for government agencies and potential private investors, as they attempt to compare and contrast one device to another, both to project the role that ocean energy may assume in their portfolios and to choose from among the designs for the best alternative for a particular site. The products of this annex will provide a basis for selection and investment in the most promising technologies and device designs.

After an initial Task I planning meeting, the approach for this annex will be to separate the work into two major tasks. During Tasks II and III, all required resource and device performance data will be defined and methods for data capture will be detailed. The data that is compiled and applied will be selected with the primary objective of providing insight into inputs and outputs of the full range of devices and their ability to achieve competitive cost of electricity (COE) production. Task II will address the development of a contracting approach that ensures the sharing of performance data for all publicly funded projects among participating countries (without direct public release of project-specific information). Specific contractual language that ensures wide dissemination of device performance data will be jointly developed as a means of ensuring that future government programs in the participating countries provide essential information to foster the acceleration of promising technologies, and, conversely, the early recognition and abandonment of inferior projects. This task will establish a common understanding of data requirements among the participating countries to ensure that data will be presented and compiled in a manner that can be understood and used to establish the current state of ocean energy conversion capabilities.

Task III will be devoted to collecting and reviewing specific project results, experience, and data from individual projects sponsored by the participating countries. The Task III review workshops will facilitate the presentation of publically funded project information including: designs methods, modeling methods and results, experimental designs and testing results, specific costing studies, and environmental studies and experiments. Generally, any publically funded ocean energy project should be considered for presentation at one of the workshops. The resulting information will be included in the assessment of the knowledge base for ocean energy. Each workshop will be documented by a report that contains the workshop presentations, a summary of the discussions, and any resulting conclusions. These reports will be made available to annex participants, but these working documents will not be released to the public or any non-participants. The compilation of data, excepting proprietary data excluded

by the developer of the subject devices, will be made available to participating developers. This will include nonproprietary design methods and techniques.

An appropriate project for presentation in a Task III workshop could cover a wide spectrum of funded activities for advancing the development of ocean energy devices. These may include:

- Development of a specific device or family of devices, including design methods and techniques, testing procedures, instrumentation to measure resource inflow and outflow, performance measurement methods, and data obtained to assess test conditions, environmental impact, and device performance.
- Testing procedures and processes, including: site-specific resource conditions and bathymetric metric consideration; development of test facilities; facility installation and operation experiences; test device experiences and data; and environmental impacts, regulatory considerations, and permitting requirements.
- Development of design tools, including code development and benchmarking. The establishment of computational models to assess the performance of ocean energy devices and to identify device design parameters that derive the overall performance and efficiency of devices. These models may focus on specific components or subsystems of an ocean energy device or apply to the overall performance of a device.

Time will be allotted at the exchange workshops to discuss the results and place them in perspective.

Specific project proprietary information and data will be protected from public disclosure through nondisclosure agreements, but the general conclusions derived from the data would be used to develop knowledge assessments for a final report, and some of these general results may be released in the public domain. Some data developed under the annex may be held for exclusive use by the participating countries.

Operating Agent, Working Groups, and Participants

The United States Department of Energy (DOE) is the Operating Agent for OES Annex V and will chair the program working closely with the other participants. Some participants will be asked to chair one of the project workshops, depending on interest and expertise. It is expected that the working groups will include participation of such organizations as the International Electrotechnical Commission (IEC) Marine Energy Technical Committee, TC 114, as well as other classification societies, standards groups, and protocol developers, such as Equimar. Each working group will plan and develop a specific work program for their topical area that results in a final report to be published in the public domain. The reports will summarize the data presented and will include recommendations made for evolving the methods to assess data and develop performance results. This annex is nominally planned for four working groups, with the exact number to be determined by the number of projects deemed appropriate and meaningful to the annex objectives.

Specific Responsibilities of the Operating Agent and Participants

In addition to carrying out the specific responsibilities enumerated in this annex, the operating agent will arrange meetings (generally teleconferences or videoconferences); facilitate the sharing of tasks among participants; and distribute (generally electronically) interim reports, workshop proceedings, and the final reports. Workshop chairs will lead one of the four workshops for the annex and perform functions similar to those of the operating agent for their workshop. Participants are required to contribute a minimum of one project presentation for the Task III Technical Exchange Workshops. In addition, participants will assist in identifying existing synthesis documents, crucial information gaps, existing and proposed monitoring methodologies and case studies, and will refine and finalize the draft reports and other interim results. These types of activities are part of each participant's in-kind contribution.

The Overall Schedule and Deliverables

OES Annex V is planned for a period of four years as shown in the schedule below. However, the annex could be extended with the approval of the executive committee. It is anticipated that the annex will prove to be viable and instrumental in progressing the adoption of marine energy as an alternative energy source for many years. Publications resulting from this effort will be distributed by the OES Operating Agent to the extent practicable; however, some results may be limited in distribution to the participating members and their funded constituents.

Activity	2011	2012				2013				2014				2015			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task I Develop Annex POAM	PAM		PAM														
Task II Data Definition Working Groups								WG					WG			WG	
Task III Project Workshops					WS				WS				WS			WS	
Deliverables • Updated Plans to ExCo • Workshop Reports • Final Report					PL	WR			PL	WR			PL	WR			PL WR FR

Table A –Annex Schedule

As the operating agent, the United States is underwriting the costs associated with managing and leading the annex. It is expected that the participant costs to execute this annex work effort will be limited to the in-kind contributions of the topical working group chairs, presenters, and participants. In addition, the time for individual researchers to prepare for and participate in the workshops and working group meetings is substantial and will be paid for by the participant's home organization. It is hoped that leadership and coordination of the workshops for Task III will be led by different member countries according to their interests with that cost borne by the leading country.

It should be noted that the benefits to the participants are significant. The Exchange Workshop will present results from numerous projects that probably have values ranging from a few hundred thousand dollars to a few million or more each. Thus each participant would be gaining access to the results of many millions of dollars in research results at relatively little cost.

Details for the inaugural workshop are provided in the next section; The Ocean Energy System Workshop on Open Water Test Sites: Inaugural Workshop under OES Annex V.

The Ocean Energy System Workshop I: Ocean Energy Device Project Information and Experience

Background

The purpose of the inaugural workshop is to exchange information and experience on open-water testing and site development and operation. Generally, open-water testing is a comprehensive technology demonstration and qualification of the device in all operating conditions, including survival conditions. Open-water testing can serve as a final research test to verify the performance, loads, and operation of a device design prior to finalizing the design. Often, open-water testing of a full-scale or near full-scale device can be the final engineering development step prior to larger-scale deployment of the first serial production units for commercial operation.

Open-water testing facilitates certification of the device to demonstrate the function of every component and subsystem and that the overall system meets required functional and economic requirements in a real open-water operating environment. Open-water testing verifies the following:

- Power production performance
- Structural and design integrity
- Mooring integrity
- Noise emissions
- Power system function and control
- Installation and removal
- Grid connection and integration
- Operating maintenance
- Environmental compatibility
- Identification and labeling

Additional research-oriented objectives of open-water testing may include:

- Tuning the device to improve performance
- Operations and maintenance validation and improvement
- Deployment and recovery process validation and improvement
- Component maintenance cycle requirements and lifetime estimates
- Corrosion and bio-fouling rates and maintenance requirements
- Environmental and ecological impact monitoring and mitigation development

As has been demonstrated in the wind industry, investors are unwilling to invest in a technology without the near full-scale demonstration and certifications that open-water testing provides. In short, the objective of open-water testing is to validate the design, integrity, and performance of the full generating system under all expected operating conditions to prove viability in a realistic open-water environment.

Goal of the Workshop

Worldwide there are number of national marine energy device open- water test sites currently in operation, in construction, or being planned for development. In addition, there are a number of ocean energy device manufacturers that have tested their devices at multiple open-water sites and in varying environments. The goal of this workshop is to bring together these parties to exchange information and

experience on all aspects of planning, development, operation and usage of open-water test facilities to improve these capabilities for the mutual benefit of the entire ocean energy industry.

Workshop Topics

This workshop seeks to bring together the foremost engineers, scientists, and technical specialists that are developing, operating, and testing devices at open-water testing facilities. The workshop includes presentations on the most promising approaches for development and operation of water testing facilities, as well as presentations from device developers that have taken experimental measurements at open water sites.

EXPECTED OUTCOMES

The primary goal of the meeting is to gather existing knowledge and document the current state-of-the-art in developing and operating ocean energy testing facilities. A secondary goal is to identify outstanding research concerns associated with current practices in operating testing facilities and make recommendations on future research and development to improve on current practices. Based on the knowledge gathered in the workshop, a workshop report will be compiled and released through the OES. The report will:

- Document presentations by participants
- Record the major discussion points covered by the participants
- Document the questions and answers
- Record participant feedback on how to improve future Annex V Workshops
- Document ideas on how the OES could work to improve testing of ocean energy devices and accelerate commercialization of the technology.

Agenda

Annex V – Ocean Energy Device Project Information and Experience
Workshop I – Open-Water Testing

Location: The Gresham Hotel, 23 Upper O'Connell Street, Dublin 1, Ireland
Parnell and O'Casey Room

Day 1 – October 15, 12:30 PM to 6:00 PM

Time	Subject of Presentation	Planned Speaker/Moderator
12:30	**Lunch is Available**	
1:00	Welcome and Introductions	John Huckerby, OES Chair; Mike Reed, US DOE; Roger Bagbey, Operating Agent
	Session 1: Operational Facilities	
1:30	Northwest National Marine Renewable Energy Center, US	Belinda Batten, Director
2:15	Galway Bay Wave Energy Test Site – SEAI, IE	Hannes Mac Nulty, Programme Manager
3:00	Aguçadoura Wave Farm, PT	Ana Brito e Melo, Executive Director, Wave Energy Center
3:45	Wave Hub Research and Test Facilities, UK	Claire Gibson, Wave Hub General Manager
4:30	The European Marine Energy Center, UK	Claire Gibson, standing in for EMEC
5:15	**Discussion**	Bob Thresher

Annex V – Ocean Energy Device Project Information and Experience Workshop I – Open-Water Testing

Location: The Gresham Hotel, 23 Upper O'Connell Street, Dublin 1, Ireland Parnell and O'Casey Room

Day 2 – October 16, 8:30 AM to 5:00 PM

Time	Subject of Presentation	Planned Speaker/Moderator
8:30	**Continental Breakfast**	
9:00	Welcome Back	Roger Bagbey
	Session 2: Planned or Under Development Facilities	
9:10	The Biscay Marine Energy Platform (*bimep*) - ES	Yago Torre-Enciso, Project Manager
9:40	Ocean Plug, PT	Ana Brito e Melo, Executive Director, Wave Energy Center
10:10	Fundy Ocean Research Center for Energy (FORCE), CA	Elisa Obermann, Atlantic Director of OREG
10:40	DanWEC Wave Energy Test Site, DK	Kim Nielsen, Wave Energy Consultant
11:10	Wave Energy Test Site (WETS), US	Mike Resner, representing US Naval Facilities Command
11:40	**Discussion**	Bob Thresher
12:30	**Lunch Presentation:** Tidal Testing Centre (Netherlands)	Peter Scheijgrond Infrastructure Manager
	Session 3: Device Developers	
1:00	WaveStar, DK	Jens Peter Kofoed, Professor, Aalborg University
1:30	OWC Pilot Plant, PT	Ana Brito e Melo, Executive Director, Wave Energy Center
2:00	Verdant Power, US	Ron Smith, President
2:30	OpenHydro, IE	Simon Cawthorne, R&D Director
3:00	ORPC, US	Jarlath McEntee, VP of Engineering and CTO
3:30	**Discussion**	Bob Thresher
4:30	**Recap and Findings**	Roger Bagbey

List of Attendees

Name	Organization	Email Address	Country
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Mathias, Damen	Ghent University	Mathias.damen@ugent.be	BE
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Thresher, Robert	Nat'l Renewable Energy Laboratory	robert.thresher@nrel.gov	US
White, Brooke	DOE Water Power Program, Fellow	Brooke.White@EE.Doe.Gov	US

Workshop Pictures

Workshop Summary

Workshop Participation by the OES Annex V Membership

At the inaugural workshop, 11 of the 15 Annex V member countries participated either as presenters or observers. In addition, Japan, China, and Mexico have recently confirmed that they will be joining Annex V. Finally, a representative from the Netherlands participated in the workshop as an observer, but was invited to give a luncheon presentation on the status of a tidal test facility that is currently testing intermediate-scale devices.

Participation by Annex V Members

Country	Participation in Annex V	Point of Contact	Workshop I Attendance	
			Observer	Speaker
Belgium	Affirmed	Mathias Damen	2	0
Canada	Affirmed	Tracey Kutney	0	1
China	Affirmed	Xia Dengwen	3	0
Denmark	Affirmed	Kim Nielsen	0	2
Germany	Affirmed	Jochen Bard	1	0
Ireland	Affirmed	Eoin Sweeney	4	2
Japan	Affirmed	Yasuyuki Ikegama	0	0
Mexico	Affirmed	Rosalba Cruz	1	0
Norway	Affirmed	Tore Gull	0	0
New Zealand	Affirmed	John Huckerby	0	0
Portugal	Affirmed	Ana Brito e Melo	0	1
Republic of Korea	Affirmed	Keyyong Hong	0	0
Spain	Affirmed	José-Luis Villaté	2	1
United Kingdom	Affirmed	Henry Jeffrey	0	1
United States	Affirmed	Bob Thresher	7	6
Australia	Undetermined	John Wright		
Italy	Undetermined	Gerardo Montanino		
Sweden	Undetermined	Maya Wänström		
		TOTALS	20	14

Attendance and Participation in the Workshop

The workshop was well attended by a total of 36 participants from 12 different countries, including one participant from the Netherlands that has not yet joined the Ocean Energy Systems Agreement. Over the day and a half workshop, there were 16 open water testing presentations given by the participants. Three counties had multiple presentations and two counties reported on more than one open-water test site. The categories of open-water test facilities presented at the meeting were as follows:

4. Operating test centers – 6 presentations from 5 countries
5. Test centers under development – 5 presentations from 5 countries
6. Test centers run by developers– 5 presentations from 4 countries

Summary of Workshop Discussion Sessions

Session 1: Operational Facilities

The discussion in Session 1 centered on the role of the testing centers and how results should be interpreted. Some questions discussed, but not resolved included the following:

1. Should test centers endeavor to be government funded facilities that serve the public good, or should they be commercial testing centers that provide a service to the industry for a fee? Almost all test centers are now striving to fund themselves on fees for testing services, *but the key question was whether or not this is the best approach for the development of the MHK industry*.
2. What services should they provide?
3. Should the testing requirements for devices be established by IEC TC 114?
4. What basic or applied research should the testing facility engage in?
5. What level of testing support should a testing center provide to the device developer?
6. What data should be provided by the test centers for their customers? For example, they should know the wave climate at their site and be able to best predict weather windows.
7. What does it mean to have a device tested at a test center? Should the test center provide some kind of certification for testing, and would that make a better business case? Also, what would be the legal implications of such a certificate?
8. How will the testing data and results be interpreted and who should do this?
9. Should interpretation of test data and results be established by IEC TC 114?

Session 2: Planned or Facilities under Development

The questions and discussion in Session 2 focused on the challenges faced during development and permitting of these new facilities. The following issues were discussed and resulted in the following conclusions:

1. The importance of stakeholder outreach to the permitting agency and to the local communities near the facility.

2. All facilities under development faced permitting challenges and were required to do some type of monitoring after the installation of test articles.
3. All facilities under development attempted to obtain broad environmental permits to enable testing of many types and configurations of devices. However, some post installation approval and monitoring for different device configuration will generally be required.
4. Safety standards were a primary consideration for personnel, the environment, for navigation, and the public.
5. Berth agreements were desirable, and often required a test readiness, technology readiness, and mooring integrity review.
6. The level of service to be provided varied. However, basic services such as the berth, basic ocean data, grid hookup, and revenue from power production were provided to the customer. Additional services beyond those basic services would need to be purchased.
7. For each test facility, the number of berths, power capacity, water depth, and wave resource varied widely.
8. A major question was whether there would be sufficient demand to support the 5 test centers in operation, and 5 more planned around the world. In other words, will the market be large enough to support 10 test centers?

Session 3: Device Developers Testing Facilities and Practices

The questions and discussion in the third session focused on how the testing facilities fit into the each developer's strategy for evolution of their technology. The discussion generally concluded that the developers had the following test center capabilities preferences:

1. Placing less emphasis on testing at subscale to perfect the concept, and much more emphasis on evolving the concept to a larger scale as quickly as possible.
2. Doing design modifications and continuing to testing at a full scale at the open-ocean test site.
3. Conducting extended testing and development campaigns over several years rather than shorter-term testing campaigns of several months to a year. Extended test campaigns provide developers with operational and maintenance experience, environmental impact effects, and infrequent storm data and experience at full scale.
4. Focusing environmental monitoring on questions and issues raised by regulators. Regulators required developers to perform extensive environmental monitoring at the beginning of their testing programs, but as experience and data were gained over time showing little or no impact, requirements were somewhat relaxed.
5. Tailoring site support to focus on site specific issues such as: wave and weather analysis, local support, and other local site issues.

Conclusions

During these discussion sessions, a primary workshop theme emerged that focused on developing a business model for test centers that would most effectively accelerate the development and commercialization of the industry. Participants discussed whether the test centers should be publically funded facilities that serve the public good, or if they should be commercial fee-based test centers that serve industry customers, or a hybrid business model that provides a set of specific publicly funded tests as well as fee-based service testing for customers. While the group did not reach a consensus, it seemed that the hybrid business model would fit the current needs of the industry and public agencies best.

A second theme that emerged during the workshop was the clear preference of device developers to perform R&D testing in open waters at near full scale to validate stepwise device improvements and environmental effects over extended periods of time. In contrast, the test center operators were envisioning shorter-term testing campaigns, where device developers would bring in a device and test at a berth for periods of 6 months to a year. In addition, developers would like for the test centers to be able to provide a full spectrum of services. These services might include: site sea characterization to support logistics, deployment, and maintenance; test device measurement and instrumentation support; and test data analysis. From the discussion, it appeared that not all of these capabilities were being planned at this time, but they could be developed with time and adequate funding.

The third theme that emerged was whether or not the test centers should provide some type of certificate attesting to the type and duration of testing accomplished during the open-water testing of a device. However, participants could not fully address what organization should specify the requirements for such a certificate. Although certification seemed to fall within the scope of the International Eletrotechnical Commission's Technical Committee 114 on marine energy (IEC TC-114), it was unclear whether this is within the current scope of that technical committee. This may be a topic of international interest for development of a recommended practice, which would help define the role of and the scope of services provided by open-water testing facilities worldwide. Recommended practices would also help to develop a set of standard tests for all wave tidal energy devices.

Attendee Recommendations for Future Workshops

Number of Recommendations	Description of Future Workshop
3	Explore approaches for the industry to share lessons learned and data without sacrificing intellectual property.
3	Hold a workshop on lessons learned in technology development for device developers and identify important R&D needs and best practices.
3	Hold a workshop on computational models developed by industry, government researchers, and academics with methods for validation.
3	Hold a follow-up workshop on the role for test facilities and on what the industry really needs for testing support, instrumentation, and data analysis.
2	Hold a workshop to explore approaches for combining computational models, laboratory experiments, and open-water testing iteratively to improve concepts.
2	Hold a workshop on the application of the IEC standards for performance testing that allows developer feedback on the role of certification and test results reporting.
1	Hold a joint workshop between regulators and developers on what they have learned about environmental effects from testing devices to date.
1	Hold a joint workshop with Annex IV on the role of testing facilities to perform combined performance and environmental tests.
1	Hold a workshop to explore whether the future of ocean energy devices is floating or seabed based.
1	Hold a workshop on marine infrastructure and on lifting, moving, and deploying large devices.
1	Hold a workshop just for test facility operators to dialog and work on best practices.

Appendix 1

WORKSHOP EVALUATION QUESTIONNAIRE

INSTRUCTIONS:

Please circle your response to the items. Rate aspects of the workshop on a 1 to 5 scale:

1 = "Strongly disagree," or the lowest, most negative impression
3 = "Neither agree nor disagree," or an adequate impression
5 = "strongly agree," or the highest, most positive impression

Choose N/A if the item is not appropriate or not applicable to this workshop. Your feedback is sincerely appreciated.

WORKSHOP CONTENT (Circle your response to each item.)

1. The objectives of this workshop were clear to me. 1 2 3 4 5 N/A
2. The content of the workshop was relevant to my work. 1 2 3 4 5 N/A

WORKSHOP DESIGN (Circle your response to each item.)

3. The topical coverage of the workshop was about right. 1 2 3 4 5 N/A
4. The discussion sessions added useful information. 1 2 3 4 5 N/A
5. The amount of time spent on presentations versus discussion was about right. 1 2 3 4 5 N/A
6. The pace of this workshop was appropriate. 1 2 3 4 5 N/A

WORKSHOP LOGISTICS AND FACILITATION (Circle your response to each item.)

7. The workshop logistics and facilities were suitable. 1 2 3 4 5 N/A
8. The facilitation of the workshop was helpful and appropriate. 1 2 3 4 5 N/A
9. The workshop length and scope was about right. 1 2 3 4 5 N/A
10. What I learned in the workshop was valuable and useful. 1 2 3 4 5 N/A

What topics would you suggest for future Annex V Workshops?

How would you suggest improving future Annex V Workshops?

Appendix 2

Test Facility Operator Presentations

Operators and developers of facilities are to present the following types of information:

1. A description of the test site being presented including: the location, bottom topography, wave and tidal climate with appropriate statistics and spectra, site access probabilities, and other physical oceanographic characteristics
2. The electrical infrastructure available or planned including: the electrical system with voltages and current capacities, cable route, transformers, disconnects (wet or dry), safety systems, and system cost where available
3. The ocean support infrastructure including: port distance, work area availability, vessel availability and costs, repair and maintenance capabilities
4. Installation and decommissioning technical support including; anchoring and mooring design, installation and removal
5. Testing support available or planned which could include: engineering and technician support, test planning, instrumentation, data acquisition (cable or telemetry), sensors, instrumentation technical support
6. Does your facility provide data analysis support and third party test results verification and reporting? and site licensing and permitting, including device type applicability
7. How are extreme events captured at the site and for a specific test device
8. Does your test facility qualify potential users to insure the integrity and survivability of test articles at the site prior to testing, if so how is this done?
9. New site characterization methods, or mapping methods, or unique problem solving approaches used in developing the site
10. Other topics of interest to the participants.

Device Developer Experience Presentations

Device developers are to present the following kind of information relating to their experiences in open water testing:

1. A description of the ocean energy converter including: type of converter, size, power, and basic dimensions, as well as a description of the devices basic operating modes, control means, and survival actions
2. A general description of the design operating environment needed for nominal power performance and good economic output. For example, what wave and tidal climate statistics and spectra is the device designed for.
3. Where did you test and what facility requirements were absolutely essential for you to accomplish your test objectives: wave or tidal resource, facility infrastructure, data acquisition support, grid connection and power level, other?
4. What ocean support infrastructure do you need including: distance to port, covered work area, lay-down area, and support vessel availability, repair and maintenance support?
5. What installation and decommissioning technical support is needed including; anchoring and mooring design, device installation and removal support
6. What test support or test planning is needed including: engineering and technician support, test planning, instrumentation, data acquisition, sensors, instrumentation technical support?
7. Did you need data analysis support or third party independent test results verification and reporting

8. What plans were made to handle extreme events that might disable your device and necessitate a rapid removal, or recovery of a lost or sunken device?
9. Were unexpected and unplanned events encountered during the testing that you feel should be identified as lessons learned, that you would recommend accounting for in future tests programs
10. Other topics of interest to the participants.

Appendix 3

The Ocean Energy System Workshop on Open Water Test Sites: Inaugural Workshop under Ocean Energy Systems (OES) Annex V

Presentation Content Guidelines

The following list provides discussion topics for guidance in preparing Workshop presentations. Please include other important information as thought important for your site or device testing. Your presentation will be included as part of the final Workshop report.

Test Site Developers and Operators

1. **Test Center Capabilities and Specifications**
    a. **Site host address and contact details**
        i. **Name of the test site**
        ii. **Contact details**
        iii. **E-mail**
        iv. **Web page**
    b. **Site location & infrastructure - A short description of the site, offices, permits, including a map indicating the site, the size of the area and the co-ordinates of the location.**
        i. **Distance to large town**
        ii. **Distance to nearest airport**
        iii. **Distance from nearest service port to site**
        iv. **Distance from nearest access harbour to site**
        v. **Distance from site to shore**
        vi. **Restrictions, availability & conditions if any**
        vii. **Resource Specifics**
    c. **Water depth and seabed conditions**
        i. **Water depths at site**
        ii. **The seabed material**
    d. **Ongoing projects and previous project/systems tested**
    e. **Equipment available at site**
        i. **Wave measurements**
        ii. **Wind**
        iii. **Water level**
        iv. **Current measurements**
        v. **Water/air Temperature**
        vi. **Other**
    f. **Facilities available - Vessels, Cranes, Engineering, Industry**
    g. **Is it possible to connect the device to the grid?**
        i. **At shore**
        ii. **Off/shore (at what depth)**
        iii. **Connection voltage and power level**

2. **Resource Description - *Please provide the following information to get an understanding of the wave and tidal conditions at the site (as appropriate)***
    a. **Design Wave data**
        i. **The design wave conditions, including return period and the direction from where the (design) wave is coming.**
    b. **Design Wind data**
        i. **The maximum wind speed (and most likely direction) with the same return period as the waves**
    c. **Design Current data**
    d. **Design water level variation**
    e. **High and low water extreme levels should be indicated. If Is there a correlation with wave and current conditions?**
    f. **Scatter diagram (wave power resource) - The wave power resource at the site based on statistical information indicating i.e. how many hours per year different sea states prevail in terms of:**
        i. **Hs - Significant wave height [meter] and Te – Energy**
        ii. **Period or Tz – Average Period [seconds].**
        iii. **The height and the period intervals (bins) will depend on the site.**
    g. **Current flow diagram (current power resource)**
        i. **The tidal flow resource in a table showing the duration of different flow velocities.**
        ii. **The division of flow velocity intervals would depend on the site.**
    h. **Other information - Can additional information be obtained such as:**
        i. **Typical wave spectra**
        ii. **Directional spectra**
        iii. **Tidal current profiles and turbulence**
3. **Lessons Learned / Advice to Others –**
    a. **Site choice**
    b. **Business model description – is it possible to have a financially self- sustaining facility?**
    c. **What is the demand for site? Is there a wait list?**
    d. **What would you do differently next time?**
    e. **How successful was your public outreach approach during development?**
    f. **Permitting lessons learned?**
    g. **Is the test site pre-permitted? What permitting requirements remain for developers who wish to deploy at the site?**
    h. **Are developers responsible for providing instrumentation/measurement systems?**
    i. **What capabilities exist for resource prediction/measurement? (ex: for wave sites, can each wave be predicted or measured in advance of arrival to allow for advanced control systems to optimize device performance?**

Device Developers

1. **Description of energy conversion system**
    a. **Device type**
    b. **Dimensions**
    c. **Average annual energy delivered in design resource**
2. **Test facility requirements**
    a. **Did you test at established test centers or develop your own site?**
    b. **Depth**
    c. **Resource**
    d. **Infrastructure needed**
3. **Description of test program**
4. **Lessons Learned / Recommendations**
    a. **What gaps exist in the presently available testing infrastructure?**
    b. **Recommendations to test facilities for future needs**
    c. **Advice to developers seeking to deploy**
        i. **Selecting a test site**
        ii. **Measurements and instrumentation**
            - **Did you capture all necessary data?**
            - **Did test data correlate well with predicted performance?**
        iii. **Installation**
        iv. **Operations and maintenance**
        v. **Any surprises?**
    d. **Is interaction between devices well understood for deployment of arrays?**

Appendix 4

The Operating Agent and Organizers of the Workshop

For additional information you may contact either of the following workshop organizers:

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Appendix 5

Presentations