Open Sea Operating Experience to Reduce Wave Energy Costs

Technical Note

Workshop on first practical experiences of open-sea operation at the Bilbao Marine Energy Week 2017

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1. INTRODUCTION

Since 2005, Bilbao has hosted a range of different international symposia on marine and offshore wind energy. Now, after almost a decade of development, these separate events have come together to form the Bilbao Marine Energy Week event (www.bilbaomarinenergy.com), a week where the debate centres on the development and future of marine energy.

The third edition of this event was held in Bilbao from 27-31 March 2017 including main issues of relevance for leading agents, companies, researchers and decision-makers involved in the development of marine energy sources. Particularly, Thursday 30 March 2017 was devoted to Ocean Energy.

The conference provided the perfect framework for the organisation of the first industrial workshop of the OPERA project (www.opera-h2020.eu). This workshop is part of the dissemination and communication activities of the project. Events are aimed at ensuring the involvement of target groups, raising key stakeholders' awareness and facilitating knowledge sharing.

In this case, the workshop session was aimed at learning from the first practical experiences of open-sea operation, identifying common challenges, best practices and needs. The workshop brought together technology and project developers, marine contractors and test sites/pilot projects as catalysers of experience generation.

The workshop had a round table format with a moderator, Mr Pablo Ruiz Minguela, Head of Wave Energy at TECNALIA and Coordinator of the OPERA project, and four speakers.

- Mr Carlos López Pavón, Project Manager. CoreMarine
- Dr Sarah Thomas, Head of R&D. Floating Power Plant
- Prof Tony Lewis, Chief Technical Officer. OceanEnergy
- Mr Borja de Miguel Para, R&D Engineer. Oceantec

The workshop was structured in three main sections:

- Introduction of global challenges, research goals in project OPERA and topic of discussion.
- Presentation of real experiences from different perspectives: problem faced and solutions or recommendations.
- Open discussion with panellists and attendees.

Around 80 persons attended this session. In order to increase the dissemination impact, this report aims at sharing the outcomes of the workshop to all stakeholders with interest in the experience of open-sea operation of ocean energy devices.

2. WORKSHOP SUMMARY

2.1 INTRODUCTION

Mr Pablo Ruiz-Minguela introduced the workshop topic before going through the presentation of real experiences from different perspectives.

Mr Pablo Ruiz-Minguela is Head of Wave Energy at TECNALIA, where he leads R&D activities related to the development of wave energy technologies both at national and international level. From 2008 to 2010 he also acted as the General Manager and Technical Director of OCEANTEC. He is MSc in Industrial Engineering, MSc in Advanced Manufacturing Technologies and MBA. He offers 24 years of experience in R&D in TECNALIA, 12 of them in Wave Energy, is author or co-author of more than 21 conference communications and 5 patents for marine energy. He is the coordinator of the H2020 OPERA project.

The workshop was designed with two main motivations in mind. On the one hand, there is a need to learn from previous experiences in order to avoid repeating early engineering mistakes across the ocean energy sector. On the other hand, the H2020 OPERA project will contribute to filling this gap by collecting, analysing and sharing for the first time high-quality open-sea operating data and experience.

Annex 1 of this report provides the full contents of the workshop presentation. The official OPERA video can be found at https://www.youtube.com/watch?v=57T5yorqHSg.

2.2 SHORT PRESENTATIONS OF SPEAKERS

2.2.1 CARLOS LÓPEZ PAVÓN

Mr. Carlos López Pavón. He leads the technical office at CoreMarine, where he is in charge of moorings and marine operations calculations. Carlos has been involved in offshore design and testing since the last 10 years. He has solid background in hydrodynamics and has led offshore renewables engineer team at Acciona for 6 years. In summer 2016, he was involved in the design of the Transport and Installation operation of the MARMOK A5 WEC device at BiMEP, including his role as on site project manager of these operations.

CoreMarine is a small company developing efficient solutions for the Blue Economy. Its team of naval engineers and marine warranty surveyors brings wide experience form the Oil and Gas (O&G) Industry.

In 2016, they were hired to manage the operation and teams involved in the transport and installation of the MARMOK A5 WEC, encompassing the load-out, towing, up-pending and hook-up operations. They also prepared all supporting documentation conforming to DNV GL and other relevant standards.

The MARMOK A5 device is a SPAR buoy type OWC wave energy converter. It has a 42 m length; 5 m buoy diameter, and around 75 tons in weight.

The transport and installation documentation, including offshore manuals, towing project, and documents for local authorities, was prepared in just 3-4 months.

The load-out, towing, up-pending and hook-up operations were planned for one working day but performed incidentally in two days due to DNV GL α-factor. All offshore operations were completed in these two days.

The transport and installation operation was made in 1.0-1.2 m significant wave height (final value varied depending on the source of wave information consulted). The limiting aspect was the work of the divers supporting the operations. This opens the opportunity to performing this sensitive operation in a medium harsh environment.

The load-out was made at Navacel quay, the steel manufacturer company in charge of building the prototype. The operation started before dawn in order to have the device ready for transport with daylight and favourable tides. It was positioned in the water with two cranes.

Extensive testing prior the operations were carried out, in order to avoid any uncertainty since it was not possible to go back to port if the operation could not be finalised.

Time was saved by using two towing lines which are the same connecting lines with the mooring system of the “Karratu”.

Towing was made in two different areas: inside the Bilbao river (two tug boats) and outside the port (one tug boat and one escort rib).

It took 3-4 hours to complete the towing operation since the maximum design speed was 3 knots. However, this speed is considered highly conservative and consequently it can be increased for future operations, so there is room for optimization this marine operation. Besides, the towing along the river was designed with sunlight but could have been performed at night in order to optimise the transport and installation.

Proprietary software (i.e. DNV GL SIMO) was used to simulate the up-pending operation and assess the time required to complete (about 40 min).

Different mooring lines colours were used in order to prevent any misunderstanding with the divers and tug boats during the offshore operations. A clear operation schedule for everyone was defined.

A GPS was used to track the position of the device during the up-pending operation. The device was left to drift freely due to currents, which incidentally caused a delay of around 30 min to recover its position (the time lost could be improved).

At the end of the first day, two mooring lines were connected and another two temporary lines were used to secure the device (part of the plan B if the operation was not completed in a single day). The operation was not completed in one day due to delays in all phases including learning curves of divers. The second day the two remaining lines were installed (just the small vessel was needed).

As a conclusion, Carlos highlighted that it is very important to spend time and resources in designing and planning. Every euro spent in planning, meeting with divers and vessels, is well spent. It is equally important sharing the same information in all vessels as well as work cards and graphical diagrams for divers.

2.2.2 SARAH THOMAS

Dr. Sarah Thomas. She is head of R&D at Floating Power Plant, a Danish floating wind technology with integrated wave energy. This position gives her a good overview of all major aspects of the technology and business development. She holds a Master of Mathematics from the University of Leeds and a PhD in Renewable Energy from the University of Manchester. She has an academic and research background in numerical modelling.

Floating Power Plant is a small company that has developed and tested offshore a combined floating wind and wave technology, namely the P37 R&D platform (a 37 m wide platform, 10 wave energy devices and 3 wind turbines; single point disconnectable turret mooring). This is the first platform in the word to deliver to power the grid from wind and wave.

They have implemented a staged testing programme over four years, taking the device out of the water in between the individual phases. The device was tested in different configurations and conditions:

- Stage 1: no wind turbines, only wave energy.
- Stage 2: wind turbines added.
- Stage 3: power take-off changed from water hydraulics to oil hydraulics.
- Stage 4: winter test phase of full device with oil hydraulics (storm conditions).

Main purpose of the testing programme was to collect data for numerical model validation. Testing also proved that the concept works (combination of technologies, disconnectability for maintenance, and efficiency of control strategies). Finally, it contributed to build confidence of potential investors and gain experience in an offshore environment.

Data acquisition is important for numerical model validation, but difficulties arise when using data afterwards. It is highly recommended to build sensor redundancy since it is not easy to spot errors in the instruments at the moment. It is also vital to ensure that the sampling frequency of sensors is not too low for the intended use (get early involvement of component providers when defining the frequency).

There was also missing data when changes to the device configuration were made. Changes should be logged very carefully using any kind of media such as videos and photos, because one year later you will not remember the change made. Document everything.

During the testing period the ADCP, which cost a significant amount of money (€50,000), was washed away in a storm and never found again. Luckily for FPP it happened at the end of the 4^{th} test phase. However, it calls for the need of back-ups and contingency plans.

Small developer companies are tempted to use all the money for testing, but forget to allocate part of the money to analyse the data as soon as possible. It is unwise to wait until the end of the testing period. Furthermore, it is recommended to plan data processing and think about their use during the deployment and afterwards.

2.2.3 TONY LEWIS

Prof. Tony Lewis. He is Chief Technical Officer at OceanEnergy, a technology development company working in the field of offshore renewable energy, developing floating wave energy devices. He is also co-principal investigator in the Centre for Marine and Renewable Energy Ireland. Formerly he had a long-standing career as Professor of Energy Engineering at the University College Cork and Academic Director of Beaufort Research. Prof. Lewis has special competence in ocean energy development, maritime systems and offshore engineering, maritime civil engineering, laboratory tank testing and field measurements in the marine environment.

OceanEnergy has undertaken practical deployments in Galway Bay, with can illustrate some experiences when moving from tank testing to open-sea. A stage testing approach was adopted in those deployments.

Three different campaigns were conducted with a prototype 12m long, 6m wide and that weighs 30 tons in steel. The size of the device is still modest for handling.

- Measure the airflows to determine pneumatic power
- Well turbine to measure performance
- Impulse turbine (FP7 CORES project)

Marine fouling is very difficult to predict. Completely different marine fouling activity was experienced in Galway Bay depending on the period the device was deployed. No specific anti-fouling was applied to the prototype because the testing periods were short and because anti-fouling is extremely expensive (e.g. for Stage 4 testing at Hawaii, anti-fouling paint costs $250,000). The prototype had a Bitumastic tar-type paint which has thought to have some deterrent to fouling.

In the first deployment (November 2006 to August 2007) the fouling ended up as a combination of hard mussels plus a whole series of soft fouling including kelp and other types of fouling activity.

The fouling was cleared off and painted again with the same paint for the second deployment (October 2007 to August 2009). No soft fouling was detected at recovery.

In the third deployment (March to June 2011) the prototype was not repainted, just cleaned due to the short deployment time. Again no soft fouling was present, but the fouling consisted in barnacles which cause severe corrosion of steel (not good news at all).

Each time they put the device at sea the mooring ropes that link the device close to the water line had a very rough fouling of mussels (3x line diameter). This is not normally taken into account when calculating mooring forces on the device. Therefore, marine fouling in mooring lines can be an issue as important as for the device hull structure.

Measurements are very important. One of the fundamental measurements is the force acting on the structure. The standard way to measure this force is using a strain shackle. A cable connects the strain shackle into the instrumentation system. It was found that the cable became damaged only after 3 months and the sensor measurements became lost. It is not easy to replace the communication cable alone. It has to be shipped to the manufacturer with the shackles for repair. Measurements are important, but integration of these measurements into the monitoring system is not so straightforward.

The next phase for OceanEnergy is to move to a larger scale device (1:4) to be tested in the Marine Corps test site in Hawaii: 700 tons, 35m long, uniformly scaled up from Galway's prototype.

Scaling of mooring make more difficult to handle shackles and making connections. In Galway Bay it could be done with a couple of people in a rib. This is not possible with a 120 ton and 120kg shackle.

After the Hawaii testing the device is expected to be repowered and tested at EMEC (same hull strengthened). In the scale up from Hawaii to EMEC, that doubles the design wave height from 6m to 12m, calculations point out that a 6% steel increase in the structure will be sufficient.

The mooring attachments from Galway Bay were simple pad-eyes. For Hawaii, the same solution with a lot of stiffening is still possible. However, scaling that up to EMEC is impossible (240 tons loads). Transfer of technologies from other sectors could be a possibility. There are solutions for semi-submersible platforms, such as swivelling pulleys. However, cost is prohibitive for marine energy applications. A single unit could cost $250,000.

2.2.4 BORJA DE MIGUEL PARA

Mr. Borja De Miguel Para. He is R&D Engineer at OCEANTEC since 2011. His professional development has been entirely focused on the renewable energy sector, the last 6 years in wave energy. He is a Mechanical Engineer (BSc and MSc) from the University of the Basque Country (2009), Spain and also holds an MSc in Thermal Power from Cranfield University (2010), UK.

OCEANTEC experience focused on the influence of O&M and marine operations in prototype design. OCEANTEC, a company owned by Iberdrola and Tecnalia, develops an OWC wave energy device since 2012. A reduced power prototype was deployed at BiMEP and connected to the grid last year. The device will be operating for two more years as part of the H2020 OPERA project. All the learnings for the testing will be implemented in the commercial size device.

The reduced power device is 42m long, 5m diameter at the top and displaces 160 ton. It has water ballast, 2 Wells turbines and electric generators of 15 kW rated capacity each. It is moored with 4 catenary lines and drag anchors (a submerged cell absorbs pretensions to avoid interference with heaving motion).

The transport operation introduced some requirements into the device design. A ballast tank emptied for transport and filled with water for operation. Geometrical constraints such as minimum volumes and structural constraints for achieving roll stability during transportation (compartments) must be taken into account. These transportation requirements should be early inputs to structural design.

Main drivers for turbine selection are usually efficiency and cost. However, when a prototype is being designed, it is wise to prepare for failures. Therefore, there are other aspects to be considered, such as availability, installability and maintenance, which can determine the number and size of turbines. Two smaller turbines were selected instead of using a single larger turbine. In the case one turbine fails, the WEC can still generate power.

Another advantage for maintenance is that turbines can be dissembled very easily using the on-board crane and a small vessel.

WEC accessibility is a third example. Wave energy devices are designed to move as much as possible in order to generate power. However, maintenance can require the maximum stability to safely board the device. Resonance in some sea states can present some issues.

Hopefully, a third hole with a flange was manufactured just to allow installing more sensors or any other kind of uses. The solution was installing a boarding valve in that hole. When the valve is closed the device can have a big resonance. However, when the valve is tuned the WEC is damped (minimum response).

In summary, it is highly recommended to consider marine operations and O&M in the design and build some flexibility to the design of the prototype.

2.3 OPEN DISCUSSION

An open discussion with panellists followed the individual presentations of lessons learnt regarding the challenges of deploying ocean energy devices at the sea. Attendants made the following comments, contributions and questions.

Which regulation applies to an ocean energy device that will accommodate persons for maintenance operations? Does SOLAS apply?

Sarah Thomas – FPP is undertaking certification with Lloyds Register of Shipping at this moment. FPP is very clear that only in emergency situations staff will be on the platform. Mostly the same regulations as floating/fixed offshore wind will apply.

Tony Lewis – There are new regulations coming into force now for offshore wind turbines and some countries have introduced them. There could be a great temptation to apply O&G regulations when no existing country regulation is established. That is completely wrong since they are based on very different requirements. If no regulation exists, it is recommended not to take O&G regulations as baseline.

Ocean energy projects can be exposed to ecologist pressures. For instance, the Mutriku wave power plant required many years to convince the population of its benefits. How to deal with ecologists concerns?

Tony Lewis – First of all, Galway Bay is very much a test site. This means it is pre-consented and all the consultation with locals was performed before becoming operational. Besides, devices are deployed there with a limited duration. There is no permanent installation for 20 years that could cause significant impacts. Studies were carried out at the time including monitoring of excitations as well as measurement of noise with hydrophones and seabed modification. After a 3.5-year deployment of the device, there was no measurable impact in the environment. The results were fed back into the certifying authority. In the Hawaii situation, again it is a marine protected area. There is marine fauna and sensitive mammals such as hunchback whales. A risk assessment has been done which shows a low impact. However, monitoring will be done during the deployments to gain more information.

Sarah Thomas – P37 was installed in Danish waters, namely in a region without much industry. It got a lot of public support and attracted international interest to the region. They spent a lot of time with fishermen and local communities which put them on the map (i.e. international TV channels). Besides, there were many organised tours from different environmental groups. This is great for the economy.

Could you highlight one or two key points during the different phases of marine operations? That is, when planning operations, during the execution and after testing?

Carlos López – It is very important to influence the design phase considering the limited but available equipment and resources in the area. Divers and tugboats should be involved in designing the installation. They also provide valuable information, such as local knowledge to define actual constraints (e.g. weather conditions that enable safe operations).

Detailed planning of operation is paramount for avoiding any risks! Also, it is the availability of vessels, since there is not a big range in the BiMEP area.

Borja de Miguel – In the planning phase it is extremely important to engage with all people involved in the different operations and to listen to their feedback. Another advantage of involving them early in the project is that they will be committed to the project and help solve problems that may arise during the execution phase. It is also important to work with experienced people. As this type of projects is not very common in the Basque Country, you should work with the best experienced people available.

Sarah Thomas - In the planning stage lessons learnt for FPP will be to allow for mistakes since mistakes most certainly will happen. For instance, they hired engineers and consultants to make some structural calculations, but they did not account for resonance of the semi-submersible platform with wind turbines in all ocean frequencies. During the operation phase it is highly recommended to plan for using the data as you get it. Do not wait one year to realise it was not good enough.

Tony Lewis – Murphy rules were mentioned in the morning sessions: “if something can go wrong, it will go wrong”. In early stages, it is very important to have sufficient resources to deal with problems when they happen. For example, OceanEnergy had a situation during the first deployment of the Wells turbine in Galway Bay. After about a month of operation, there was a mechanical coupling between the turbine and the generator, which normally works for 30 year in a manufacturing situation without any failure, that failed and the whole machine had to be brought back ashore. This implies tugboats costs. Incidentally, the failure was caused by a flaw in a mechanical casting of the steel, which is very unusual. Had the resources not been available to recover and redeploy the device, the whole project would have failed. It is the most important thing to ensure sufficient resources (always difficult for small companies) to deal with problems because there will ever be problems arising.

During the presentations it was highlighted the importance of dealing with sensor errors and other gaps in collecting data. Data is the most valuable asset of the testing phase. What would you recommend if you could plan the deployment again?

Sarah Thomas – It is important to have people involved whilst tests are done to look at the data real-time, to analyse data, to put it in the numerical model, and to check if sensors measurements are correct. These activities should happen at the same time and not afterwards.

Tony Lewis – There is a need for assessing when data is good or bad. Also, different ways of measuring the same parameter should be implemented as a way for comparing and spotting errors. It is very important to duplicate sensors and have a back-up. The cost of the sensors is almost the same as to the cost of visiting the device. Adding more sensors is very easy. The cost of storage is also low. Make sure that you always have a back-up on board. This is particularly important for the communication and transmission system and cables, since it is impossible to repeat testing with the same environmental conditions. If a measurement is missed, there will not be another option.

Borja de Miguel – He really agrees with the observation of having a back-up for everything. Moreover, he encourages having different sensor types to measure the same thing, since a huge amount of data is collected per day and it is very difficult to evaluate the quality of data at sea.

A high level of detail in the planning stage can help to anticipate problems and avoid uncertainties. This is the case of identifying mooring lines with different colours to avoid errors. Do you recommend making a detailed planning?

Carlos Lopez – The more information it can be provided to the different parties involved in the marine operations, the better. Particularly divers, who have a limited number of immersions every day, need clear indications to work underwater and all the tools they may require ready. Operations with divers are costly and time consuming, although you can expect some learning curve for repeated operations. Risk analysis is very important in planning operations. Involving in the design of operations the various actors can provide with alternatives in case anything fails. Onshore meetings save valuable time offshore.

Tony Lewis – Detailed planning of offshore operations is surely needed since every hour out there is very expensive. OceanEnergy is taking a different philosophy in terms of the design of operations. They tried to design divers out of their system by performing all the operations from the boat. Divers can only have a certain amount of operation time underwater. The entire hook-up will be done from surface vessels. Even the connection of the umbilical will be dome from the surface using winches and similar equipment. Subcontractors at Hawaii have done a very detailed installation plan and FMEA analysis. As said before, if it can go wrong it will go wrong. Therefore a plan B is needed.

Sarah Thomas – She agrees with Tony’s approach. Simplicity is key for FPP. Wherever possible they do everything without divers. Connection and disconnection is without divers. Simple tug boats are used for the towing-out. They key no moving parts below water.

3. CONCLUSIONS

This workshop of the H2020 OPERA Project brought to light some useful learning, common challenges, best practices and needs from the first practical experiences of open-sea operation.

Detailed planning of operations is paramount for avoiding any risks and uncertainties at sea. It is therefore strongly recommended:

- Do extensive testing and simulations prior performing the operations.
- Perform a risk analysis using standard tools and procedures (HAZIP, HAZOP, etc.)
- Account for delays in your schedule.
- Have a Plan B if the operation cannot be finished in time.
- Engage with all people involved in the different operations. Listen to their feedback, they provide valuable information to solve problems that may arise during the execution phase.
- Onshore meetings save valuable time offshore.
- Visual aids such as work cards, use of different colours and graphical diagrams to prevent any misunderstanding at sea.

Regarding data acquisition, processing and its use afterwards, the panellists highlighted the following:

- Build sensor redundancy since it is not easy to spot errors in the instruments at the moment.
- Have a back-up and contingency plans should anything fails.
- Different ways of measuring the same parameter should be implemented as a way for comparing and spotting errors
- Ensure the sampling frequency of sensors is not too low for the intended use.
- Assess when data is good or bad. Check if sensors measurements are correct.
- Analyse the data as soon as possible. Do not wait one year to realise it was not good enough.
- Measurements are important, but integration of these measurements into the monitoring system is not that straightforward. Prepare for failure of communication cables.
- Plan for the use of data. A huge amount of data is collected per day.

It is very important to consider marine operations and O&M in the design of the ocean energy device. Offshore operations introduce some requirements into the device design:

- Take into account available equipment and resources in the area.
- Design for availability, installability and maintenance; not just for efficiency and cost.

- Build some flexibility into the design of the prototype.
- Fouling in mooring lines is not normally taken into account when calculating mooring forces on the device. Besides, marine fouling is very difficult to predict.
- Scaling up the device can make impossible to use the same solution either technically (high loads) or economically (O&G technologies or vessels).
- Plan for WEC accessibility due to resonance in some sea states.

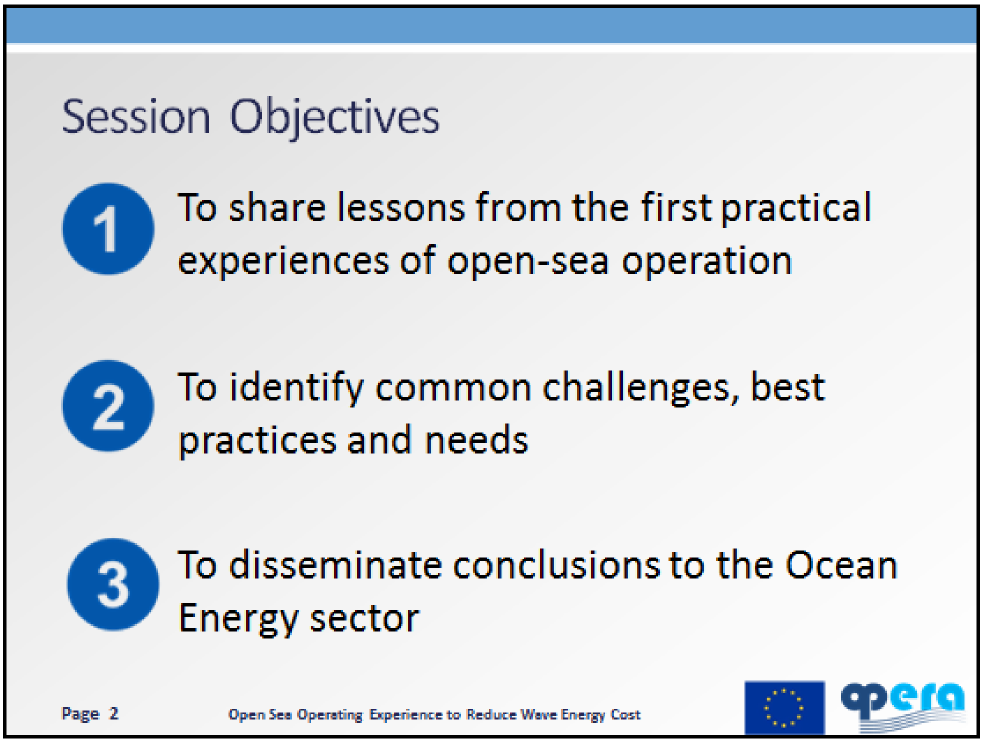
Regarding ecologist concerns the panellists highlighted:

- Early consultation with locals.
- Carry out environmental impact studies.
- Monitor deployment to gain more information.
- In regions without much industry these projects can attract international interest, which is great for the economy.

A final set of various recommendations was commented by panellists:

- Perform a staged testing programme.
- Document everything. Changes to the prototype should be logged very carefully using any kind of media such as videos and photos, because one year later you will not remember the change made.
- If no regulation exists, do not to take O&G regulations as baseline since they are based on very different requirements.
- Allow for mistakes since mistakes most certainly will happen and have sufficient resources to deal with problems.

ANNEX I: INTRODUCTION TO THE WORKSHOP




Why to run this session?
Those who fail to learn from history are doomed to repeat it
Winston Churchill
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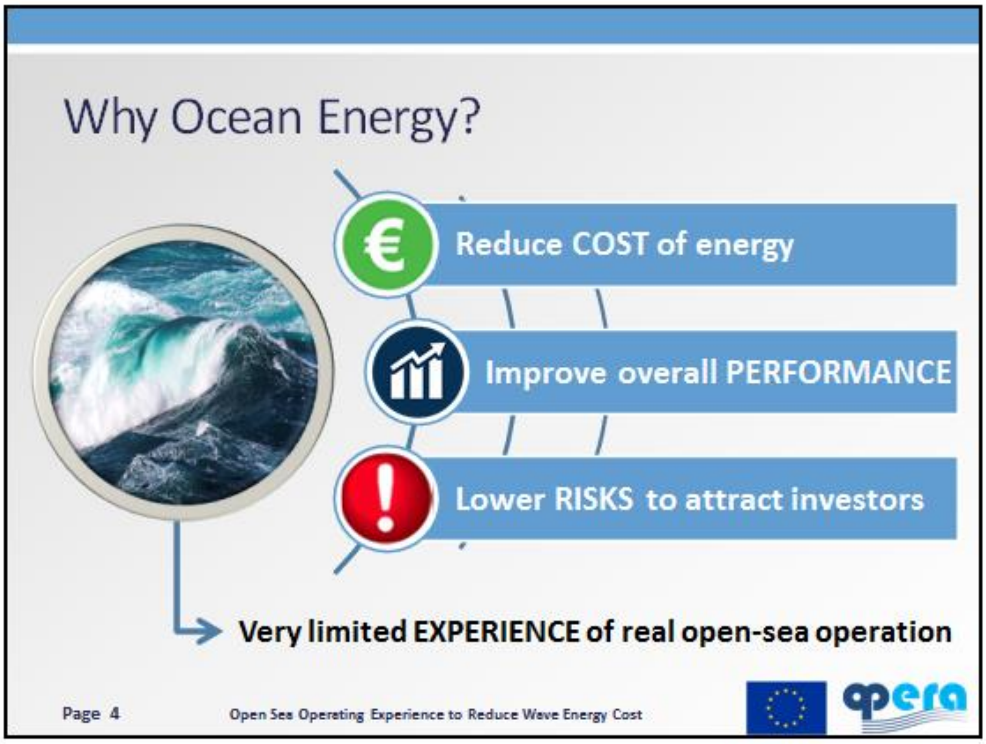
Why Ocean Energy?
Reduce COST of energy
Improve overall PERFORMANCE
Lower RISKS to attract investors
Very limited EXPERIENCE of real open-sea operation
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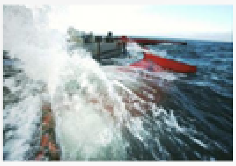
Why Ocean Energy?

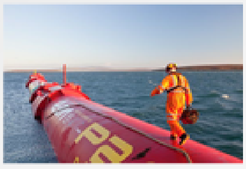
Proven off-the-self components fail early in the sea environment

Corroded connectors - Aquamarine

Uncertainties on the structural device performance under extreme events

Wave Dragon – Mooring failure





Safety issues and limited access during device O&M

Pelamis P2

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OPERA Project Contribution

Collect, analyse and share for the first time high-quality **open-sea operating data and experience**

Validate & de-risk **4 industrial innovations** for wave energy

Innovation	Target	LCOE impact
Novel biradial air turbine	50% higher annual efficiency compared to Wells turbine	33%
Advanced control strategies	30% increase in energy production	23%
Elastomeric mooring tether	Reduce peak loads by 70%	7-10%
Shared mooring configuration	50% reduction in overall mooring costs in arrays	5-8%

Reduce the **cost of wave energy** by 50% in the long term

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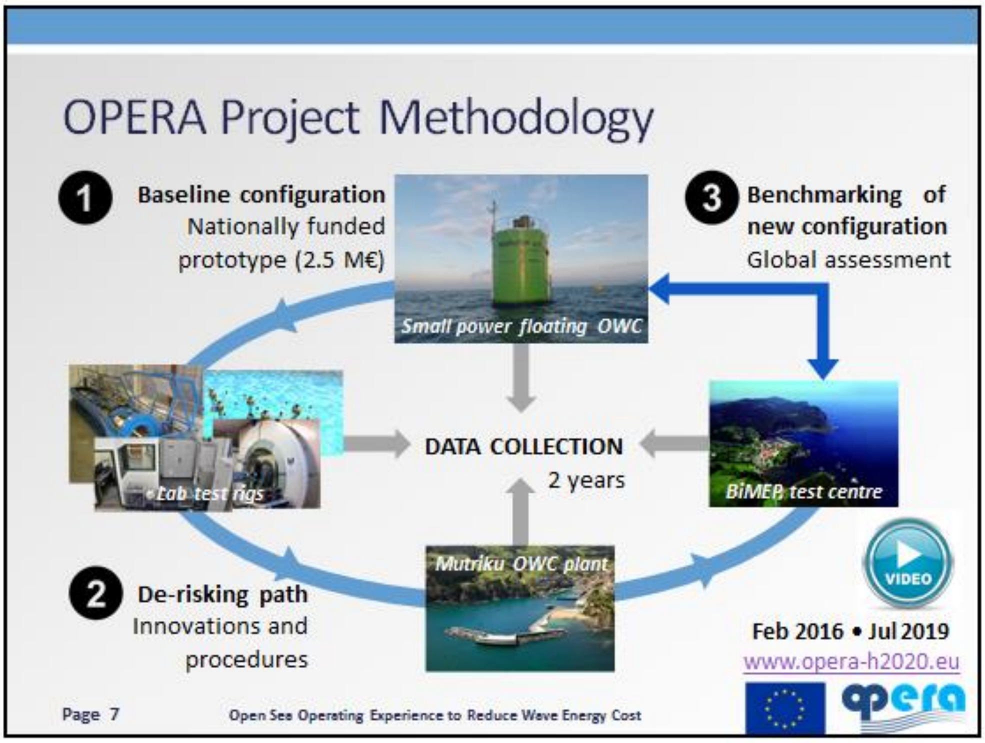
OPERA Project Methodology
1 Baseline configuration
Nationally funded prototype (2.5 M€)
Small power floating OWC
3 Benchmarking of new configuration
Global assessment
Lab test rigs
DATA COLLECTION
2 years
BiMEP test centre
Mutriku OWC plant
VIDEO
2 De-risking path
Innovations and procedures
Feb 2016 • Jul 2019
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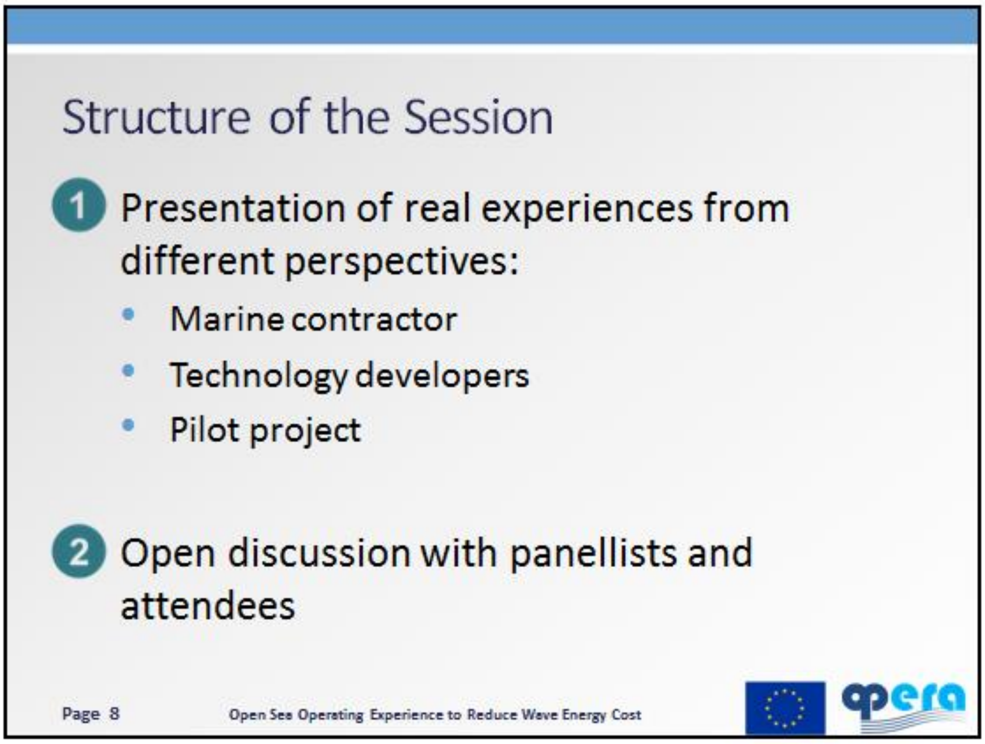
Structure of the Session
1 Presentation of real experiences from different perspectives:
• Marine contractor
• Technology developers
• Pilot project
2 Open discussion with panellists and attendees
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Presentation of real experiences
CoreMarine
Mr. Carlos López Pavón,
Project Manager
OCEANENERGY
A WORLD OF POWER
Prof. Tony Lewis,
Chief Technical Officer
OCEANTEC
Mr. Borja de Miguel Para,
R&D Engineer
FLOATING POWER PLANT
Dr. Sarah Thomas,
Head of R&D
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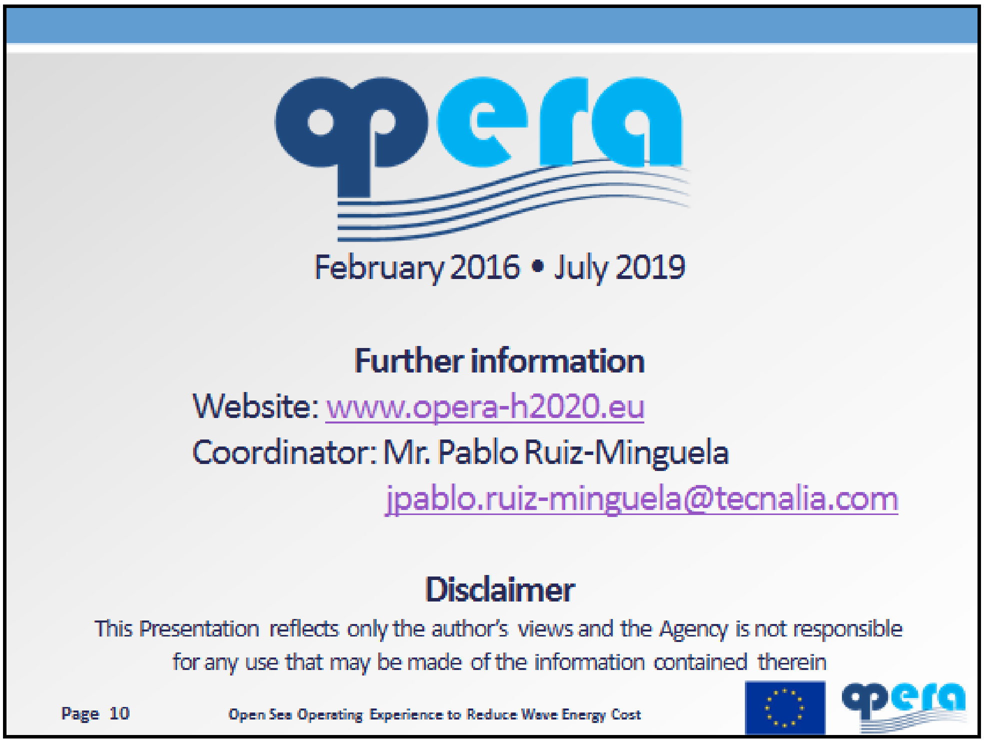
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February 2016 • July 2019
Further information
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