EUROPEWAVE

Bridging the Gap to Commercialization of Wave Energy Technology using Pre-commercial Procurement

by Peter Dennis

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Introduction

Against a backdrop of energy security concerns, net-zero goals, and economic instability, governments worldwide are making bold policy decisions relating to green technologies, including renewable energy sources. In Europe, the EU's ambitious climate targets and policy initiatives have encouraged individual countries to set their own ambitious national targets in relation to renewables. It is perhaps natural that the Atlantic-facing regions and those bordering the North Sea, with an exposure to a significant wave energy resource, view the wave energy sector as being of strategic importance in meeting these targets.

The ambitions and priorities for the wave energy sector in these countries are expressed in high-level terms: providing support for industrial and academic ocean energy research and development and investment (R&D&I); supporting testing infrastructure that nascent ocean energy technology would be reasonably expected to require; encouraging diversification in existing supply chains; and developing financial policies to support deployments.

The priorities emerging from recent technology roadmaps and strategic research agendas, which focus on technological aspects, are perhaps best summarized as "learning by doing at a meaningful scale." This priority is compatible with the high-level national and regional priorities.

The European Technology and Innovation Platform for Ocean Energy's 2019 summary of the state-of-the-art for ocean energy technologies highlighted the need to "pull" the most promising wave energy technologies forward to a Technology Readiness Level (TRL) 6-8 and thus bridge the gap between publicly funded R&D&I and commercial investment. To achieve this requires the deployment of prototype "whole-systems" of a substantial scale in representative and operational wave climates.

The European Commission's Strategic Energy Technology Plan has set ambitious targets for ocean energy technologies targeting the electricity utility market, challenging the wave energy sector to reduce its levelized cost of energy (LCOE) to at least the equivalent of C$0.30 (20 c€)/kWh by 2025, $0.22 (15 c€)/kWh by 2030, and $0.15 (10 c€)/kWh by 2035.

While producing power at the utility scale is a focus for many wave developers, and has a bigger impact on high-level targets, the emerging Blue Economy offers an alternative route to market. Technological innovation is fuelling high-growth maritime industries, including marine aquaculture, ocean observation, marine robotics, biofuels, and seawater mineral extraction. Wave energy technology can play a unique role in these sectors, providing power at sea in off-grid and offshore locations, untethered from land-based power grids.

What is Wave Energy?

Wave energy technologies capture the movement of surface waves and swell, and use it to create energy – usually electricity. The amount of energy created depends on the speed, height, and frequency of the wave, as well as the water density.

Wave energy can provide utility-scale power production and works very well in tandem with other renewables such as wind power. It is also a clean, infinitely available alternative to polluting and expensive diesel for remote islands and offshore industries.

Today, scaled and full-size wave energy prototypes are being tested at sea. The most advanced device developers are planning and building the first multi-device wave energy farms around Europe, most notably in the U.K., Portugal, Spain, and Italy. Once built, these pilot farms will serve as a basis for commercializing wave energy technology and building a new European industry.

What is EuropeWave?

EuropeWave is an R&D&I program to advance the most promising designs for wave energy converter systems to the point where they can be commercially exploited through other national/regional programs and/or private sector investment. These designs will have been validated through testing in multiple program phases, progressing from physical modelling at small scale in a test tank through to deployment of prototypes of a substantial scale and size at the open-water test facilities of the Biscay Marine Energy Platform (BiMEP) in the Basque Country and the European Marine Energy Centre (EMEC) in Scotland.

The EuropeWave program is a C$28.9 (€19.6) million cross-border joint pre-commercial procurement of R&D&I services. Wave Energy Scotland (WES) and the Basque Energy Agency have joined forces to form a "buyers group" that shares a common ambition and pooling national funding to undertake a single joint procurement process. The program's budget is co-funded through the European Union's Horizon 2020 research and innovation program under grant agreement no. 883751.

The program is run in collaboration with Ocean Energy Europe, which provides expertise and guidance in the dissemination of project outputs and a direct link with the wider ocean energy sector.

The motivation for the buyers group is to support renewable energy policy objectives and to deliver economic benefits in the supply chains and economically fragile coastal/island communities. The buyers group is committed to procuring the best solutions from anywhere in Europe with a proviso that the physical demonstrations are carried out in Scotland and the Basque Country.

These regions are well placed to reap the potential environmental, economic, and social benefits of a maturing wave energy sector. Both regions boast a number of strategic advantages, namely:

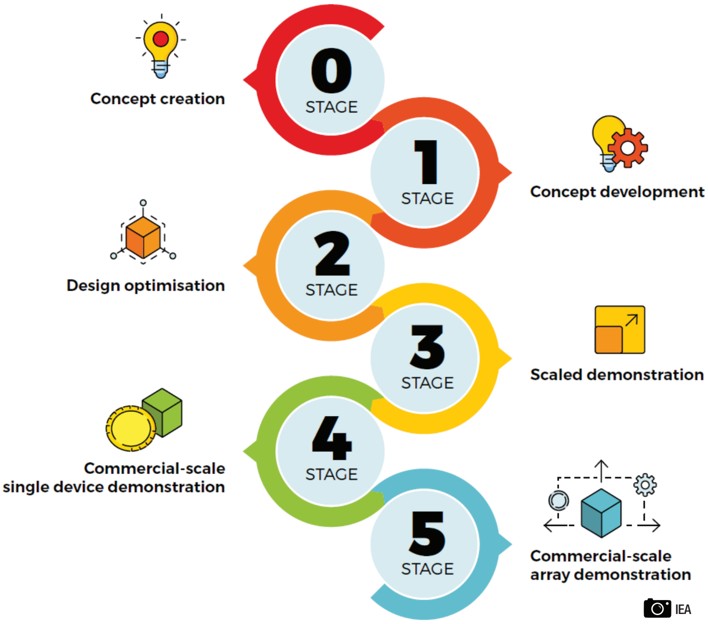
- Significant exploitable wave resource
- Indigenous R&D&I capability
- Indigenous wave energy technology developers
- Supply-chain opportunities

The main technical challenges to be addressed by the wave energy technology designs being developed through EuropeWave may be expressed in terms of:

- Performance – addressed by obtaining quantitative evidence of appropriate power capture and conversion capability, and an associated increase in confidence in yield predictions from numerical model simulations.
- Survivability – addressed by demonstrating effective strategies for survival in survival events.
- Availability – addressed by demonstrating levels of availability through reliable prototype operation.
- Affordability – addressed by increasing confidence in the estimation of the technology costs (capital and operational) and determining a route to cost reduction to achieve a competitive LCOE.

The International Energy Agency's (IEA) International Evaluation and Guidance Framework for Ocean Energy Technology presents a framework for technology evaluation and guidance of engineering activity throughout the technology development process. The Framework is built upon an international consensus on the evaluation of ocean energy technology and is intended to support decision-making associated with technology evaluation and funding allocation, ensuring decision-makers have consistent information available to them.

The EuropeWave pre-commercial procurement (PCP) is using the IEA Framework as the basis for its technology development program. The IEA Framework breaks the technology development process into six stages, from concept creation to commercialization (Figure 1). The three



IEA

Figure 1: The International Energy Agency (IEA) Framework's six-stage technology development process, and how it relates to EuropeWave.

phases of the EuropeWave PCP cover Stage 2 and Stage 3 of the IEA Framework.

At each stage, a collection of technical activities is proposed, focused on the Framework's nine key evaluation areas (Figure 2).

What is Pre-Commercial Procurement?
Pre-commercial procurement (PCP) is a form of public sector innovation procurement. A procurer identifies a need for which no commercially-proven, or near-to-the-market, solution exists and new R&D&I is required to create a solution. PCP is a specific approach to procure the necessary R&D&I services. PCP allows the procurer to compare the pros and cons of alternative competing solutions.

This industrial development process creates a "funnel" via a multi-phase funding program.

At the start, developers can apply for support via an open call. In the subsequent phase, the most promising projects are selected through a competitive process to continue into the next phase, concentrating the remaining funding on the best-performing technologies (Figure 3). Technologies that progress to the final phase will be demonstrated in Basque and Scottish open waters at the end of the program.

This model, first implemented in Scotland by WES, is an alternative approach to conventional R&D&I funding. It optimizes public spending on wave energy innovation by providing up to 100% funding in priority areas that need improved solutions. In EuropeWave, the focus is on demonstration of appropriately scaled prototypes in an operational environment.

The process creates market pull for the most promising technologies (through an open competition) and its "phase-gate" converging process then concentrates funding on the most successful projects. Projects that successfully complete all phases of the PCP program will have demonstrated that their technology has the performance and reliability required to proceed to system qualification and early commercialization.

The Attraction of PCP for EuropeWave
PCP is a staged procurement process that

Figure 2: The International Energy Agency (IEA) Framework's nine evaluation areas.

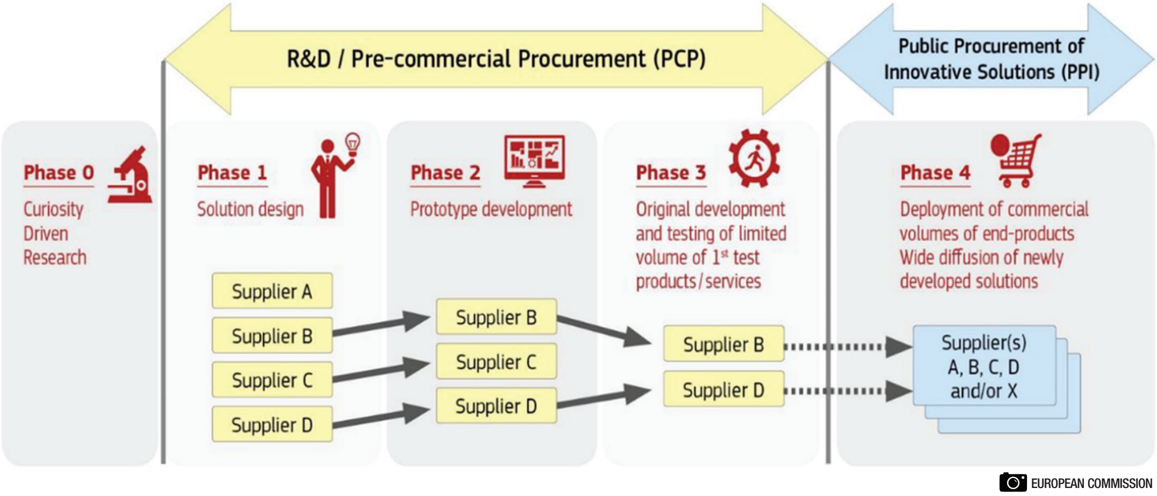


Figure 3: Competitive development phases of the pre-commercial procurement process.

can be mapped onto the staged development process for wave energy technology (i.e., the aforementioned IEA Framework).

The PCP model was an attractive option for EuropeWave for several reasons. As an approach to purchasing the R&D&I activities necessary to progress technology development, PCP facilitates the participation of small companies and there is no obligation for technology developers to match fund, meaning that a broad range of participants and associated technologies are brought forward for assessment. The R&D&I services are purchased at a market rate. The multi-contract phased approach maintains a competitive environment during the program and avoids being locked-in with a single provider.

For technology developers, PCP brings the benefit of a level of continuity in funding, and promising technologies can expect

Figure 4: EuropeWave program timeline.

to progress. The aforementioned fact that no match funding is required is also very attractive for developers.

On the downside, there is undoubtedly an administrative burden for the procurers running the PCP. It must be an intelligent client, with a strong understanding of its requirements and a robust entry and phase gate assessment process. Independent experts can be used during application assessments to augment internal expertise and to help reinforce a principle of openness.

Program Overview

The EuropeWave PCP program consists of three phases, as shown in Figure 4.

Phase 1

A total of 35 compliant applications were received for the EuropeWave program and after the assessment process seven contractors were accepted into Phase 1 of the PCP. This first phase allowed the selected R&D&I providers to progress their concept engineering designs and undertake such physical and numerical modelling as required to establish the technology's characteristics (e.g., performance, survivability, etc.). Small-scale tank testing campaigns under defined environmental conditions were completed to allow the buyers group to understand the performance potential of the wave energy converter (WEC) systems.

The core objectives for Phase 1 of the EuropeWave PCP were to:

- Optimize the concept engineering design for the EuropeWave requirements.
- Benchmark performance.
- Estimate the Phase 3 power performance capability.
- Evidence that the WEC system is on track to provide an attractive commercial offering.

The tasks and activities proposed for Phase 1 had to be appropriate to address the objectives and demonstrate relevant mitigations for critical system challenges. All Phase 1 projects were expected to complete a number of mandatory development tasks, consisting of:

- Conceptual design development of the complete system that will be tested in an open water environment during Phase 3.
- Physical testing of a small-scale model in a set of mandatory test conditions relevant to the Phase 3 test sites and defined by the buyers group.
- Independent review of tank testing activities, commenting on compliance with the technical specifications published by the IEC.
- Preliminary design review of the conceptual design for the Phase 3 prototype, highlighting the development progress made during Phase 1.

Phase 2

Five providers were selected to progress to Phase 2. They are currently completing this phase by continuing design development work

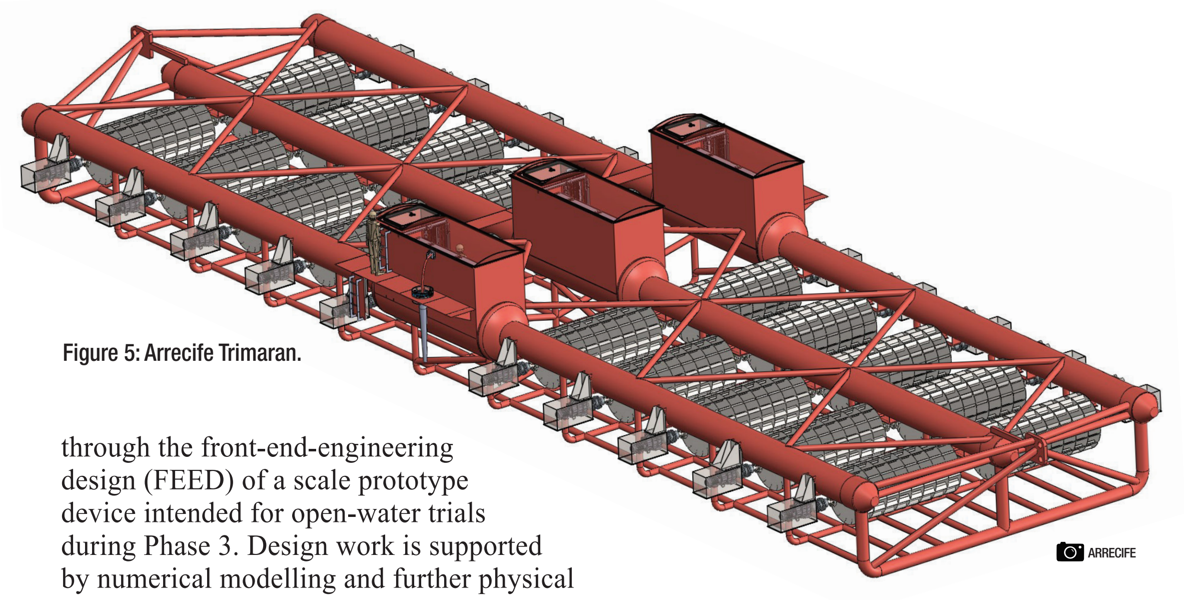


Figure 5: Arrecife Trimaran.

through the front-end-engineering design (FEED) of a scale prototype device intended for open-water trials during Phase 3. Design work is supported by numerical modelling and further physical test campaigns of the complete WEC and constituent subsystems. Some information on each of the five technologies in Phase 2 is provided below.

The Arrecife Trimaran (Figure 5) is a floating platform with a modular and scalable turbine system, where multiple turbines, each of which is connected to an electrical generator, are used to capture wave energy and produce electricity. The turbine design is intended to mimic the behaviour of coral reefs, by breaking the waves and extracting the energy. The future aim for this WEC technology is to develop 0.3 MW units, multiples of which can be installed in an array for mass electrical energy production connected to the electrical grid.

The AMOG SeaSaw WEC (Figure 6) technology involves a dual hinged, twin hull, combined surge and pitch device with two rolling mass power take-offs (PTOs) on curved tracks. The hinge-linked hulls, with their independent PTOs and the resulting induced “SeaSaw” motion, are designed to enhance power production and widen the range of suitable operational conditions. The fundamental design aims and principles of the WEC technology are to avoid contact between moving parts and seawater, use commercially available subsystems proven in other industries, ensure ease of installation through use of conventional catenary mooring lines and anchors, and ease of operations by allowing a single vessel to complete maintenance of the PTO while the WEC remains on its mooring.

The ACHIEVE project intends to deliver a design of the CETO WEC technology (Figure 7), which is a submerged buoy tethered to the seabed. The project integrates new innovations, collaborates with experienced partners, and focuses on optimizing performance and cost while leveraging learnings from prior design and deployments. This should provide step change improvements to the CETO technology while retaining compelling features, such as fully submerged operation, which minimizes visual impact and offers inherent protection from breaking waves and storms. The new CETO design developed in EuropeWave is estimated to capture nearly twice as much energy as previously deployed CETO systems, due to an enhanced mooring, a new fully electric rotary PTO design, and an advanced control strategy that optimizes capture from every wave and can modify the position in the water column for both enhanced energy capture and survivability.

IDOM’s wave energy harvesting technology is a point absorber based on the oscillating water column working principle called MARMOK (Figure 8). The basic device concept can be described as a spar element holding a cylindrical water column inside. During operation, due to wave excitation, a relative

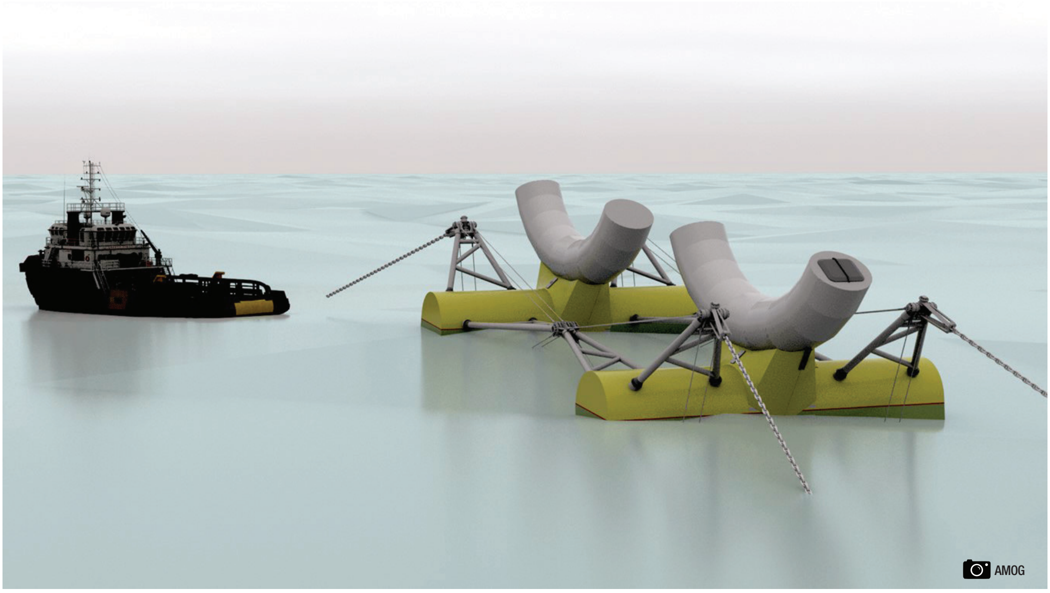


Figure 6: AMOG SeaSaw.

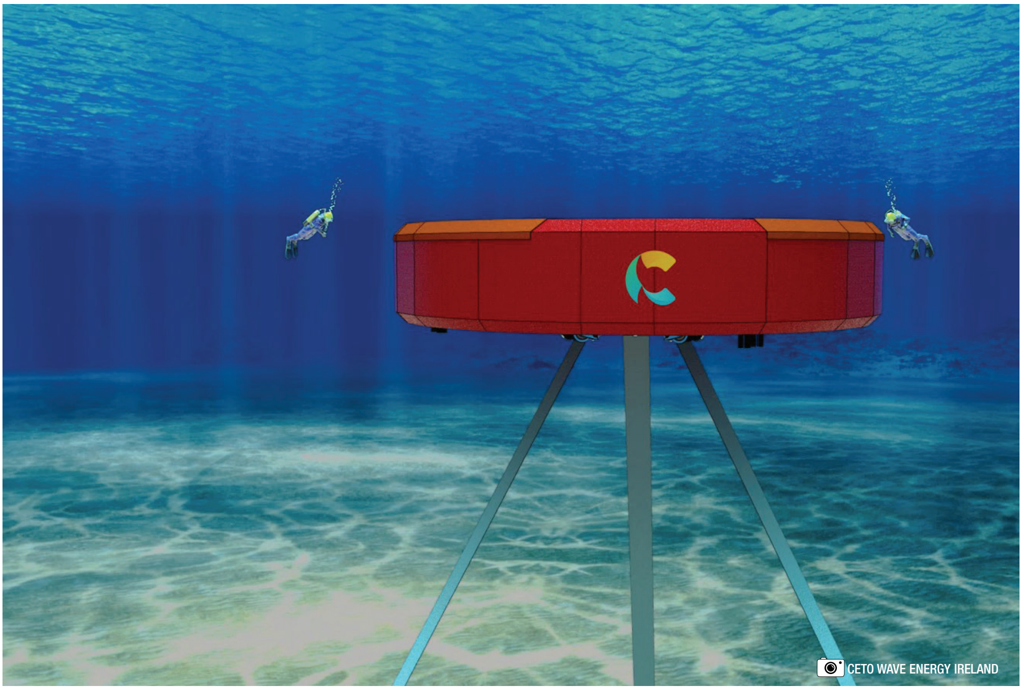


Figure 7: CETO WEC.


CONSULTING ENGINEERING

Figure 8: IDOM MARMOK.

movement between inner water column and buoy is produced. This makes the water column act like a piston that compresses and expands the air chamber in the upper section of the buoy, generating a reciprocating airflow that is then converted into electric power by passing through an air turbine.

Mocean Energy is developing the Blue Horizon 250 (Figure 9), which is the latest embodiment of its recognizable WEC architecture and builds on the successes and lessons learned at smaller scale with the BlueX architecture in the WES program. The WEC features a hinged raft with forward and aft wave channels that are geometrically optimized using Mocean's inhouse expertise, and a direct-drive electric Vernier hybrid machine PTO. Within EuropeWave, Mocean proposes to build a first-of-a-kind version of a 250 kW WEC product, bringing in additional funding as required to support manufacture and operations. This ambitious target serves to maximize the benefits of the program, and crucially to accelerate the technology towards commercialization. The commercial applications for a 250 kW Blue Horizon device include offshore oil and gas, islands and remote communities, and early grid projects, where nearer to longer term value propositions have been identified.

The core objectives for the five contractors in Phase 2 are to complete a FEED for a prototype device to be constructed and tested in Phase 3. The phase will close with each technology undergoing a critical design review of its complete proposed system, to review readiness for progression and to enable contractors to begin to work with fabrication providers to obtain detailed quotations for the build in Phase 3. In addition, Phase 2 work will progress numerical simulations, financial modelling, and will develop operational plans for the Phase 3 deployment. The FEED design, along with installation and operation and maintenance plans, will be reviewed by an independent third party, to give the buyers group confidence on the quality and veracity of the technology proposals. The anticipated outcome of Phase 2 correlates to Stage 2 of the IEA Framework.

Phase 3

In Phase 3 of the EuropeWave PCP, prototype representations of three designs will be deployed at the open-water test facilities of either BiMEP in the Basque Country or at EMEC in Scotland for a demonstration and operational testing program of at least 12 months in duration. The initial phase of testing is anticipated to include a work-up program to commission the system and subsystems, prior

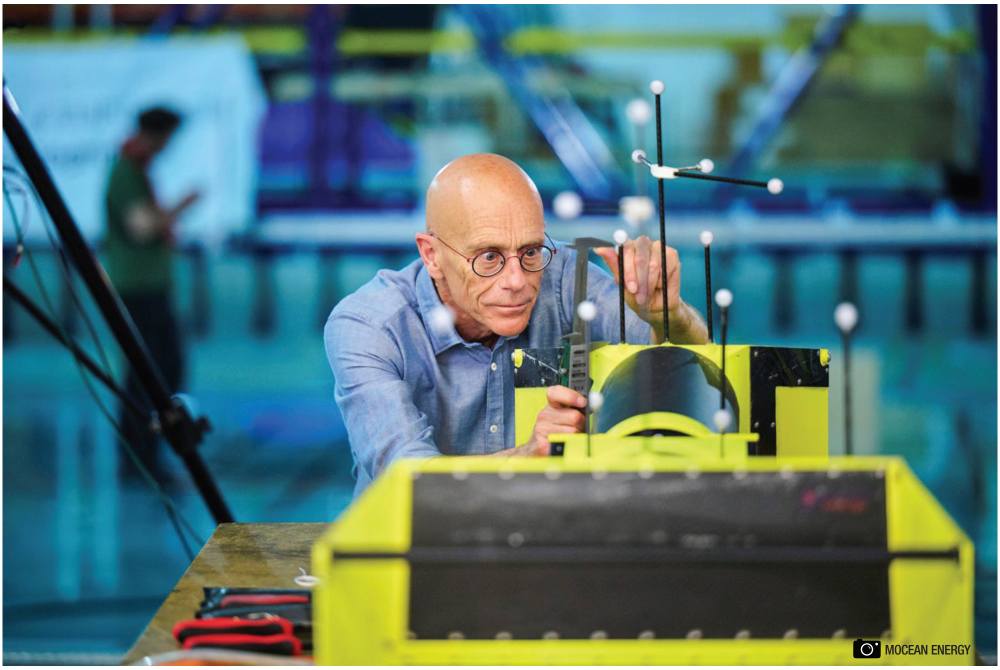


Figure 9: Chris Retzler with a model of the Mocean Blue Horizon 250.

to demonstrating sustained periods of operation to deliver electricity and survival in extreme environmental conditions.

The main objectives of the Phase 3 testing program are:

- To validate the design's power capture and conversion capability through operational data recorded during sustained periods of operation in the energy producing sea states.
- To demonstrate the effectiveness of survival strategies.
- To demonstrate approaches that will enable commercial levels of availability in the future.

Successful completion of the EuropeWave PCP program corresponds to the substantial completion of Stage 3 of the IEA Framework; the equivalent of achieving TRL 6.

Conclusion

The EuropeWave program brings together experience from Ocean Energy Europe and the partners in the buyers group to implement a PCP-based procurement for the development of wave energy technology. By using PCP, the procurers were able to draw in many potential technologies to be investigated, and the phase-gate process enables the selection of the best performers to be progressed towards commercialization.

Since this route to commercialization is a key aim of EuropeWave, contractors within the program are required to develop and maintain plans that set out the measures that will be undertaken to continue the development of the design of the WEC system towards a commercial application after the conclusion of the EuropeWave PCP. As a minimum, these plans identify a technology development roadmap to successfully deliver the WEC system to market, and demonstrate how the financial capability and capacity for doing so will be established during the PCP.

The success to date of using the PCP model for wave energy development, through the EuropeWave and Wave Energy Scotland programs, has led to initial discussions regarding the possibility of a follow-on program. This would provide an opportunity for a wider selection of national and regional partners to take part, and open up access to a greater variety of devices and test locations.

Wave energy is a key part of addressing the twin challenges of climate change and energy security – so it is crucial to get machines in the water and clean power into the European grid without delay. Models such as the PCP open up new ways of thinking about the procurement of energy technologies and, fundamentally, can provide a springboard to get more renewable sources onto the grid. ~

Dr. Peter Dennis has been a project manager with Wave Energy Scotland (WES) since 2005. He has managed WES's oversight of different projects within the program, including the development of the AWS Ocean Energy WaveSwing. Prior to this, Dr. Dennis has experience of renewable energy and project management in the public, private, and academic sectors. He has a degree and PhD in civil and structural engineering.

This project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement 883751.