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Tender Document TD02: Specification – PCP Challenge

This document, designated as tender document TD02, should be read in conjunction its annexes

Annex A: Phase 1 Testing

Annex B: Phase 3 Test Site Fact Sheet

and with other documents related to this Pre-Commercial Procurement (PCP), listed hereunder:

Tender document TD01: Request for Tenders

Tender document TD03: Terms and Conditions – Framework Agreement

Tender document TD04: Terms and Conditions – Phase Call-off Contract (Phase 1) (including Annexes)

Tender document TD05: Technical Offer (including Annexes)

Tender document TD06: Financial Offer and Cost Breakdown

Tender document TD07: Tender Forms

Tender document TD08: Market Consultation – Questions and Answers

Tender document TD09: Documentation Checklist

All documents are available from the Public Contracts Scotland portal (www.publiccontractsscotland.gov.uk**).**

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1 The Challenge

1.1 EuropeWave PCP background

In response to the EU's policies on climate and energy and the associated targets, Member States and Regions have set their own ambitious policy targets in relation to renewable energy generation. It is perhaps natural that the Atlantic-facing Member States and Regions and those bordering the North Sea, with an exposure to the significant wave energy resource, view the wave energy sector as being of strategic importance in these policy targets.

The ambitions and priorities for the wave energy sector in these Member States / Regions are expressed in high-level terms: providing support for industrial and academic ocean energy 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 early deployments.

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

ETIP Ocean'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 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.

1.2 EuropeWave PCP motivation

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 the Member States/regions of the buyers group.

It is perhaps natural that the Atlantic-facing Member States and Regions and those bordering the North Sea, with an exposure to the significant wave energy resource, view the wave energy sector as being of strategic importance and have been most active in supporting the research and development of wave energy technology. These Member States and Regions are well placed to reap the potential environmental, economic and social benefits of a maturing wave energy sector. The importance has several stimuli:

- Significant exploitable natural resources;
- Indigenous R&D&I capability;
- Indigenous wave energy technology developers;
- Supply-chain opportunities.

The European Commission's Strategic Energy Technology Plan (SET Plan) has set ambitious targets for ocean energy technologies targeting the electricity utility market, challenging the wave energy sector to reduce its levelised cost of energy (LCOE) over the next fifteen years to at least 20 c€/kWh (2025), 15 c€/kWh (2030) and 10 c€/kWh (2035).

The emerging "blue economy" provides an alternative market for wave energy [1]. Technology innovation is fuelling high-growth industries including marine aquaculture, ocean observation, marine robotics,

[1] Powering the Blue Economy; Exploring Opportunities for Marine Renewable Energy in Maritime Markets. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Washington, D.C. (2019).

biofuels, and seawater mineral extraction. Wave energy can play a unique role in these sectors, providing power at sea in off-grid and offshore locations, untethered from land-based power grids.

1.3 EuropeWave PCP challenge

This procurement is for R&D services to develop and test solutions that address the following overarching challenge: the design, development, and demonstration of cost-effective wave energy converter (WEC) systems for electrical power production that can survive in the harsh and unpredictable ocean environment.

Within this overarching challenge, the EuropeWave PCP challenge is to advance the most promising designs for wave energy converter systems to a level from which they can be developed to be commercially exploited through other national/regional programmes and/or private sector investment. These designs will have been validated through physical model testing at small scale, and through deployment of scaled prototypes at the open-water facilities of the Biscay Marine Energy Platform (BiMEP) in the Basque Country and the European Marine Energy Centre (EMEC) in Scotland.

The main technical challenges to be addressed may be expressed in terms of

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

This is a common challenge shared by all members of the buyers group.

1.4 Technology development stages

The International Energy Agency's "International Evaluation and Guidance Framework for Ocean Energy Technology" [2] 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 PCP is using the IEA Framework as the basis for its technology development programme.

The IEA Framework breaks the technology development process into six stages, from concept creation to commercialisation (Figure 1). The three phases of the EuropeWave PCP will cover Stage 2 and Stage 3 of the IEA Framework.

[2] International Evaluation and Guidance Framework for Ocean Energy Technology. Published January 2021 [https://www.ocean-energy-systems.org/publications/oes-documents/]

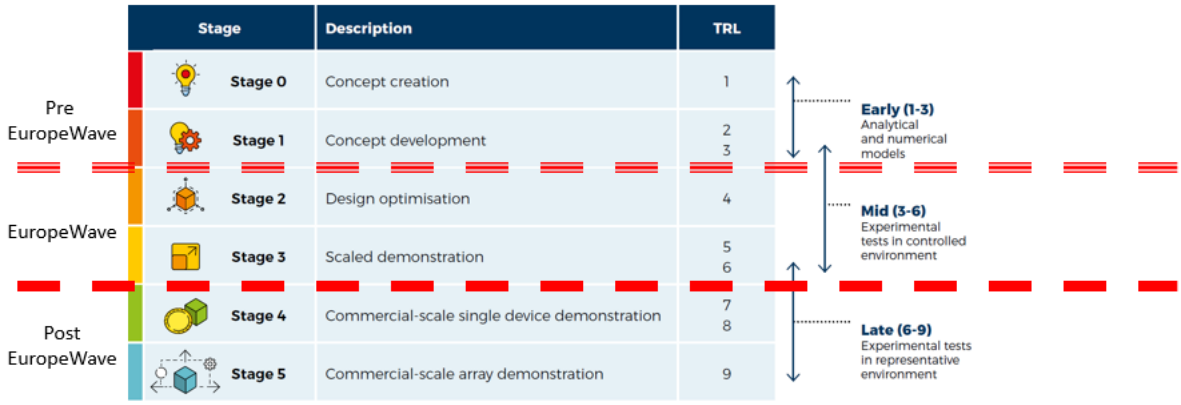

Figure 1: The IEA Framework's six-stage technology development process, and how it relates to EuropeWave.

At each stage, a collection of technical activities is proposed, focussed on the Framework's nine key evaluation areas (Figure 2). The tenderer should familiarise themselves with these activities.

Figure 2: The IEA Framework's nine evaluation areas.

2 Programme requirements

The EuropeWave PCP programme will develop designs for wave energy converter (WEC) systems, culminating in the demonstration of device performance, survivability, reliability and cost through testing of prototype representations of these designs at the open-water facilities of the Biscay Marine Energy Platform (BiMEP) in the Basque Country and the European Marine Energy Centre (EMEC) in Scotland. The prototype (henceforth referred to as the Phase 3 prototype) shall be of a substantial scale and size and shall incorporate fully functional subsystems representative of the anticipated commercial-scale device.

2.1 At programme entry

2.1.1 Prior development

Programme constraints (time and budget) require proposed concept designs to have achieved a minimum state of development prior to programme entry.

The required minimum state of prior development corresponds to the completion of the IEA Framework's Stage 1 activities for the nine evaluation areas. The tenderer should familiarise itself with these activities.

A key purpose of the Framework's Stage 1 is to explore and investigate several device configurations to identify the characteristics of a preferred concept design, and to obtain an estimation of power performance though initial physical model testing.

At programme entry, the EuropeWave PCP is placing greater emphasis on certain evaluation areas which are associated with the fundamental characteristics of the technology (power performance, survivability and affordability), but all evaluation areas remain relevant.

2.1.2 Innovation

It is a requirement of the EuropeWave PCP that proposed innovations justify research and development activities to establish their potential.

Innovations within the EuropeWave PCP may be new designs that will enable progress beyond the current state-of-the-art, or significant adaptations to existing designs.

Where the proposed concept design could be perceived as having already achieved or exceeded the state of development anticipated in the final phase of the EuropeWave PCP (see §2.2), the innovative aspect(s) must represent a significant adaptation to the current design.

A significant adaptation is one that addresses shortcomings in the existing design, which has the potential to provide a significant improvement, and which requires R&D activities at the concept development stage to confirm.

2.2 At programme completion

Successful completion of the EuropeWave PCP programme corresponds to the substantial completion of Stage 3 of the IEA Framework; the equivalent of achieving technology readiness level (TRL) 6.

2.3 Laboratory testing

Scaled physical model testing of the design for the wave energy converter system during Phase 1 and Phase 2 must be undertaken at the wave basin facilities at IHCantabria in Spain or FloWave in Scotland.

A tenderer should contract with the test facility directly and should record it as a subcontractor in the tender response. The test facility should not be a party to a group (or consortium) submitting a joint

tender.

Subsystem testing during all phases must be undertaken at technically appropriate facilities in Spain or Scotland.

2.3.1 Mandatory testing

In Phase 1, projects are required to test a scaled physical model of the wave energy converter system in a set of mandatory wave conditions, covering regular waves and defined long-crested and short-crested sea-states, in a tank testing programme to evaluate performance characteristics. The mandatory wave conditions are estimated to occupy between 1-2 days of the overall test programme.

Details of the wave conditions and the requirements for conducting the mandatory tests are provided in [TD02_ PCP_Challenge_AnnexA_Phase1Testing].

2.3.2 Phase 1 independent review

Phase 1 performance testing will be validated by an independent and accredited third party, to be organised by the tenderer. This activity may be provided by the wave basin facility within their scope of services.

The scope of the independent review activities should include the preparation of a report providing an objective assessment of the test campaign, covering the quality of the model and measured data, the uncertainties in the measured data, and the compliance of the test methodology relative to recognised guidelines. Further details are provided in [TD02_PCP_Challenge_AnnexA_Phase1Testing].

2.4 Open-water deployments

In Phase 3 of the EuropeWave PCP, prototype representations of three designs will be deployed at the open-water facilities of BiMEP in the Basque Country and EMEC in Scotland for a demonstration and operational testing programme of 12-month duration.

The proposed concept designs must be suited to the environmental conditions and be capable of operating (and surviving) in all seasons at the BiMEP and EMEC test sites.

The duration of the testing programme includes an initial work-up programme to commission the system and subsystems, prior to delivering sustained periods of operation.

The main objectives of the Phase 3 testing programme 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 achievable levels of availability.

Key information about the test facilities at BiMEP and EMEC is provided in Annex B to this document [TD02_PCP_Challenge_AnnexB_TestSiteFactSheet].

The site environmental conditions and water depths should be considered when determining the size of the Phase 3 prototype.

BiMEP and EMEC have access to long-term historical wave climate data at their test sites, and additional environmental data will be supplied to the successful tenderers at the start of Phase 1 to support engineering design activities.

Both BiMEP and EMEC are fully consented test sites that can provide berths with or without grid-connections. While grid-connected deployments are desirable it is not an essential requirement and alternative energy delivery strategies are acceptable.

The tenderer is encouraged to engage with both Phase 3 test sites directly where further information is required to inform the preparation of their tender.

2.4.1 Phase 3 allocation

Two prototypes will be deployed at BiMEP and one prototype will be deployed at EMEC.

The allocation of deployment location will take place following completion of the call-off competition (phase gate) for entry to Phase 3.

It is anticipated that the allocation will be based on the outcome of the phase gate evaluation process, i.e. the agreed ranking of the offers for Phase 3, and the contractors' stated preferred locations.

The highest ranked contractor will be offered their preferred location. The second ranked contractor will then be offered their preferred location (if available) or the alternative. Finally, the third ranked contractor will be offered the remaining location.

This process may result in the both the second and third ranked contractor being allocated a non-preferred location.

2.4.2 Environmental impact

The open-water testing campaign provides the opportunity to undertake environmental monitoring activities to increase the sector's understanding of the impact of the deployment of wave energy converter systems. The contractor should utilise opportunities, where possible, to enhance any mandatory environmental monitoring activities imposed as part of the regulatory licensing conditions. or required as part of any Environmental Impact Assessment (EIA) studies.

This is in addition to any Environmental Impact Assessment (EIA) studies required as part of the consenting process.

2.5 Multiple energy source applications

It is a requirement that the concept design for the wave energy system must be capable of operation as an independent (standalone) system (i.e. all inherent functionality must be provided by the concept design). Any R&D service contract issued through the EuropeWave PCP will relate only to development activities associated with the design for the wave energy system.

Where the concept design is *conceived* as an auxiliary system in a multiple energy source application and relies on elements of the principal system to provide essential functionality, such elements must be incorporated into the demonstration and financial projections.

Performance metrics, and energy production thresholds, for the Phase 3 demonstration and operational testing programme shall only relate to the wave energy system. However, synergies and potential cost reductions arising from the colocation with other renewable energy sources may be considered in technology development and commercialisation plans.

2.6 Design process requirements

2.6.1 Adherence to Standards

The development of the engineering design for the wave energy converter system, experimental testing campaigns, and, ultimately the installation and operation of the Phase 3 prototypes at the open-water test facilities are required to follow relevant and recognised standards, guidelines and recommended practices, such as IEC, DNV, etc.

2.6.2 Certification plan

A credible strategy indicating the requirements for future certification of the WEC product shall be developed and complied with during the EuropeWave PCP. This will require engagement from recognised and appropriate classification bodies during all three phases to increase fidelity of the

strategy and endorse maintained compliance.

2.6.3 Sustainable design

The development of the design for the wave energy converter system must follow recognised principles of sustainable design including, but not limited to conservation of materials and resources and minimisation of carbon footprint.

2.6.4 Design reviews

It is a requirement that a robust design review process is adhered to during the three phases of the EuropeWave PCP. To maintain compliance with this, several mandatory design reviews are indicated:

- Preliminary Design Review (PDR) – for the conceptual design developed in Phase 1
- Critical Design Review (CDR) – for the Front-End Engineering Design (FEED) developed in Phase 2
- System Integration Review (SIR) – to review fabrication progress during Phase 3 and to review commissioning plans
- Operational Readiness Review (ORR) – to sign off the pre-installation commissioning work completed, and give the go-ahead for the Phase 3 deployment

Reviews are intended to be primarily for the benefit of the project team. Representatives of the buyers group shall attend on the review panel, as may independent third-party reviewer(s) where appropriate. Documentation shall be made available to the review panel an appropriate time in advance of the review. The location of the reviews will be selected by the project team.

Additional or subsequent reviews may be required depending on the technology, its subsystems, or where there have been substantial deviations following the original review. These can be proposed in the scope of work, as required.

2.7 Commercial requirements

Projects should adhere to and comply with an ongoing technology exploitation plan during all three phases of the EuropeWave PCP.

A short to mid-term plan shall be developed, setting out the measures that will be undertaken to continue the development of the design of the wave energy converter system towards a commercial application after the conclusion of the EuropeWave PCP. As a minimum, the plan shall detail with increasing clarity at each phase:

- the technology development roadmap to deliver the wave energy converter system to market successfully;
- how the financial capability and capacity for doing so will be established during the PCP;
- the commercialisation strategy being pursued, e.g. direct or indirect (through transfer or licensing); and,
- end-user engagement.

2.8 Health, safety and environmental requirements

A high standard of health, safety and environmental (HSE) management is required to be maintained at every phase of the EuropeWave PCP.

The health, safety and environmental risks become increasingly significant as projects proceed though the phases, with the greatest risks associated with Phase 3 and particularly the open-water deployment. Accordingly, the health, safety and environmental management is expected to become increasingly sophisticated as the programme progresses.

3 Functional requirements

The design for the wave energy converter system, and for the Phase 3 prototype representation of that design, must satisfy a number of functionalities, informed by the requirements of the EuropeWave PCP and the IEA Framework's Evaluation Areas. Definitions for the Evaluation Areas are provided in the IEA Framework document.

Table 1 – EuropeWave PCP functionalities

Evaluation Area	ID	Requirement
Performance	P01	Extract energy from the available wave resource.
Performance	P02	Produce an electrical power output.
Performance	P03	Incorporate fully functioning sub-systems (including but not limited to power take-off, control system, mooring / foundation, energy storage, etc.)
Performance	P04	Be an appropriate size and rating to perform reliably in the environmental conditions at the BiMEP and EMEC test sites.
Performance	P05	Be capable of sustained operation in the environmental conditions at any time during the full year at the BiMEP and EMEC test sites.
Performance	P06	Be capable of recording key, meaningful parameter data.
Performance	P07	Exhibit consistent behavioural characteristics (in terms of control response, degrees of freedom, etc.) with those anticipated on the proposed commercial-scale development of this design.
Performance	P08	Possess the capability to simulate the performance of the design in its Phase 3 prototype and proposed commercial-scale forms.
Survivability	S01	Maintain system integrity during survival events and in environmental conditions anticipated at any time during the full year at the BiMEP and EMEC test sites.
Survivability	S02	Be designed to survive under extreme conditions as represented by the 50-year return period sea states[3].
Survivability	S03	Be inherently survivable while in a dark state or unpowered (i.e. not dependent on powered or operational subsystems), until such time that a suitable weather window for recovery may occur.
Survivability	S04	Be capable of autonomous restart into a generating, or ready to generate, state following a survival event (i.e. without necessitating full recovery of the device).
Availability	OM01	Components/systems are designed for safe and efficient operation and maintenance.
Availability	OM02	Achieve acceptable levels of reliability, for an R&D prototype[4], to maximise opportunities to capture performance and operational data.
Installability	I01	Safe installation and recovery, in an acceptable range of environmental conditions and completed within an acceptable duration.
Installability	I02	Weather windows for installation and recovery are possible during all seasons at the BiMEP and EMEC test sites.
Installability	I03	Design enables safe site maintenance and towing operations

[3] Initial information regarding the 50-year return period extremes at the BiMEP and EMEC sites is provided in Annex B to this document [TD02_ PCP_Challenge_AnnexB_TestSiteFactSheet].

[4] It is acknowledged that the WEC devices tested during Phase 3 will be R&D prototypes, and so commercial levels of reliability are unlikely to be achieved.

Affordability	A01	Whole-system design is affordable in its intended market.

3.1 Targets

Specific measurable targets for the Phase 3 deployment are expected to be set at Phase 2 entry. These will include targets for energy production (e.g. a global target for AEP, or yearly MWh) and availability (e.g. % of time available to generate in operational sea conditions, durations of sustained operation, etc.).

4 Programme overview

Details of the objectives, anticipated tasks and activities, target outcomes, and mandatory outputs for each phase of the EuropeWave PCP are presented. The details for Phases 2 and 3 are indicative and are subject to change. Any change will be communicated at the relevant phase call-off.

4.1 Phase 1 (Concept development)

Phase 1 permits the selected R&D 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 will be completed to allow the buyers group to understand the performance potential of the WEC systems.

Completion of Phase 1 of the EuropeWave PCP represents the partial completion of Stage 2 of the IEA Framework.

4.1.1 Phase 1 objectives

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

- Optimise 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.

4.1.2 Phase 1 main activities

The tasks and activities should be appropriate to address the objectives and demonstrate relevant mitigations for critical system challenges.

As a minimum, a Phase 1 project is expected to complete the following *"mandatory"* development tasks:

- Conceptual design development of the complete system which will be tested during Phase 3.
- Physical testing of a small-scale model in the mandatory test conditions.
- Independent review of tank testing activities.
- Preliminary Design Review of the conceptual design for the Phase 3 prototype.

Examples of development tasks and their constituent activities, which may be required to mitigate the critical elements, are given in the tables below. Not all the activities indicated in these tables may be appropriate for every project, and additional development tasks may also be required. Projects should consider the necessity and justification of the constituent activities proposed for Phase 1.

4.1.2.1 Engineering Development (Design, Testing and Simulation)

Design	• Develop the Basis of Design, specific to the EuropeWave Phase 3 deployment sites. • Consolidate prior conceptual development activities, identifying outstanding technology challenges associated with the prime mover and subsystem integration. • Define key design parameters, subsystem interfaces, and system requirements for the Phase 3 prototype design. • Adapt the survival strategy to ensure suitability for Phase 3 deployment. • Refine the conceptual design to optimise for performance, installability, maintainability, survivability and affordability.

	• Commence engagement with sub-system suppliers who can support development and subsequent implementation in Phase 3. • Produce an overall concept design for the Phase 3 prototype system, which presents credible strategies to address the global functional requirements for the EuropeWave PCP, and the constituent subsystems (including but not limited to, structure, moorings/foundation, PTO, installation, maintainability, etc.). • Provide all necessary reporting and design documentation, including drawings, calculations, etc. to facilitate a Preliminary Design Review – Phase 1 (PDR-P1) at the close of the project. • Develop, and seek input to inform, a qualification plan which will ensure compliance with necessary qualification activities during future phases of the EuropeWave PCP.
Testing	• Engage with the wave basin facilities to agree a testing strategy for Phase 1. • Engage an independent and accredited third-party to review the Phase 1 tank testing activities and related outputs. • Design and build the tank testing physical model(s) at an appropriate size to incorporate requirements for scaled similitude (dimensions, mass and buoyancy distribution, etc.). • Design and commission a representative PTO, with appropriate control sophistication and the ability to mimic proposed full-scale device behaviour, for integration into the tank testing physical model(s). • Test the physical model in a range of defined conditions (still water decay, regular and irregular waves), necessary to validate the outputs of the numerical modelling and appreciate the device hydrodynamic response. • Test in the mandatory performance sea-states. • Interpret outputs from physical model testing, including device loads, motions, and the influence of control upon performance, and use to inform optimisations within the conceptual design. • Identify and develop a plan (objectives, requirements (locations, hardware, data sources and calibration) and anticipated outcomes) for any testing required within Phase 2. Phase 2 testing may include, but is not limited to, additional small-scale tank testing, subsystem reliability and survivability testing, etc.
Simulation	• Creation and refinement of numerical models to gain insights into device performance, loading and behaviour[5]. • Explore the effect of key conceptual design criteria on performance, such as leading dimensions and ratios, to inform and influence engineering activities. • Analyse tank testing performance data to validate and improve numerical modelling. • Analyse and interpret modelling outputs to inform conceptual design development.

[5] Numerical modelling should follow current, accepted and relevant industry best practice. The tenderer should identify the most relevant codes and/or industry best practice suitable for their current state of development.

	• Produce a power matrix and model the efficiency of the concept against the reference conditions of the target commercial site.

4.1.2.2 Operational Planning

Installation and Decommissioning	• Review existing installation and recovery plans and adapt for the design approach proposed under EuropeWave. • Develop an initial storyboard of the Phase 3 installation and recovery processes, identifying key HSE risks, expected limitations, etc.
Operations and Maintenance	• Review existing operational plans and adapt for the design approach proposed under EuropeWave. • Identify the requirements and characteristics necessary for maintenance during the Phase 3 deployment.

4.1.2.3 Financial

Financial	• Apply learning from conceptual design and modelling activities to refine and reduce uncertainty in the breakdown of expected system costs for the Phase 3 prototype. • Develop and refine a set of inputs to be used for financial modelling, based on the performance, reliability, survivability and cost profile outcomes from Design, Testing and Simulation activities. • Recognise enabling innovations that will maintain progression towards cost reduction. • Produce LCOE projections which are suitable for the commercial opportunities identified with the proposed technology, using appropriate modelling tools, and documenting the assumptions and simplifications.

4.1.3 Phase 1 target outcomes

Upon completion of Phase 1, projects are expected to be able to:

- Evidence that the proposed WEC system is conceptually suitable for the Phase 3 deployment in the operational environment(s) at BiMEP and EMEC.
- Pass the PDR-P1 with a conceptual design for the fundamental systems of the Phase 3 prototype.
- Estimate the device performance at the Phase 3 test sites using physical modelling data obtained from testing campaigns and numerical simulations validated against physical modelling data.
- Provide clarity on the long-term impacts that the proposed WEC system offers.
- Identify key risks associated with the Phase 3 deployment, and support these with credible mitigation proposals.
- Evidence that the overall feasibility and technical/commercial opportunity associated with the proposed WEC design supports continued R&D through the EuropeWave PCP.

4.1.4 Design reviews

An informal design review is anticipated to be completed during the course Phase 1.

Table 2 – Phase 1 design reviews

Review	Purpose	
Preliminary Design Review – Phase 1 (PDR-P1)	The PDR-P1 provides an opportunity for the project team to review the overall system and its progression during Phase 1. It acts as a precursor to both the Phase Gate 1-2, and a more formal review of the optimised conceptual design early in Phase 2. *Within the EuropeWave programme, PDR-P1 is expected to be completed by the close of Phase 1.*	The PDR-P1 will demonstrates that the preliminary design activities completed in Phase 1 are compatible with system and EuropeWave programme requirements with acceptable risk, within the cost and schedule constraints. It should consider the fundamental design principles, the proposals for major subsystems of the Phase 3 prototype, and the Phase 1 project achievements. Successful completion of the PDR-P1 will inform the development requirements and activities for Phase 2.

4.1.5 Phase 1 outputs, milestones and payments

4.1.5.1 Mandatory outputs

The tenderer is required to define a set of project outputs for Phase 1 that will be submitted to the buyers group (the "deliverables"). These enable reporting of the technical progress, dissemination of the project findings, and the demonstration of project target outcomes.

Amongst the project outputs in Phase 1 will be a number of mandatory outputs, as summarised below:

- A comprehensive suite of engineering and design information to facilitate the required PDR-P1 and demonstration of readiness for progress to Phase 2;
- A comprehensive set of reporting covering the Phase 1 testing, including but not limited to the test plan, testing methodology, outcomes, mandatory test data, analysis and critical interpretation of results, and a review of outcomes and compliance to best practice by an independent (of the developer), accredited third-party;
- Updated technology risk register, indicating progress on mitigation actions during Phase 1;
- A confidential, technical report summarising how the project met its target outcomes;
- End-of-phase deliverable (based on an H2020 template), including details of the IPR measures taken by the contractor to protect the results and the identity and location of personnel that carried out the R&D activities. Collection

4.1.5.2 Milestones

Milestones correspond to the completion of key activities in the technology's technical development and implementation. An appropriate collection of deliverables shall be used to evidence the achievement of each of the project's milestones.

Three milestones have been identified within Phase 1 (Table 3), all of which are technical in nature.

Table 3 – Phase 1 milestones

Milestone ID	Definition	Supporting evidence	To be delivered by…
M01	Internal review for tank testing planning and model design	Project outputs, relevant to defined milestone	Month 4
M02	Tank testing at wave basin complete		Month 6
M03	Acceptance of baseline conceptual design		Month 7

4.1.5.3 Payments

Each payment in Phase 1 will be linked to a milestone from Table 3, and shall be based on the principle of payment in arrears. Deliverables shall be provided as evidence for payments by either demonstrating completion of a milestone or providing timely reporting on the progress of additional technical and commercial activities unrelated to the specific defined milestone.

4.2 Phase 2 (FEED and modelling)

Selected R&D providers will continue design development work through the front-end-engineering design (FEED) of a scale prototype device intended for open-water trials during Phase 3.

Design work will be supported by numerical and further physical test campaigns of the complete WEC and constituent subsystems at facilities in the Member States (e.g. IHCantabria in Spain, FloWave in Scotland for tank testing).

4.2.1 Phase 2 objectives

The core objectives for Phase 2 of the EuropeWave PCP are to:

- Complete FEED of the Phase 3 prototype;
- Pass Critical Design Review (CDR) to begin meaningful engagement with fabrication providers;
- Improve fidelity of simulation and financial modelling;
- Develop and evidence appropriate planning for Phase 3 deployment;
- Achieve completion of Stage 2 of the IEA Framework.

4.2.2 Phase 2 main activities

Tasks and activities should be appropriate to address the objectives and demonstrate relevant mitigations for critical system challenges.

As a minimum, a Phase 2 project is expected to complete the following *"mandatory"* development tasks:

- Preliminary Design Review – Phase 2 (PDR-P2) of the optimised conceptual design for the Phase 3 prototype
- FEED development of the complete system which will be tested during Phase 3
- Independent verification of design, and installation and O&M plans
- CDR of the FEED

Projects should consider the necessity and justification of the constituent activities proposed within the Phase.

4.2.3 Phase 2 target outcomes

Upon completion of Phase 2, projects are expected to be able to:

- Understand, and have solutions for, the specific design implications associated with maintaining suitability to test in either Phase 3 test site.
- Pass the CDR with a FEED for the Phase 3 prototype that will be built and tested.
- Have received third party review feedback of well-considered and appropriately detailed installation and O&M proposals for Phase 3 testing.
- Engage with fabrication partners to order materials and long-lead items at the commencement of Phase 3.
- Propose metrics within the IEA Evaluation Areas, informed by Design, Testing and Simulation activities, to assess the success of the Phase 3 deployment.
- Provide clarity on the long-term CAPEX and OPEX that the proposed WEC can deliver.
- Provide clarity on the Phase 3 test plan, and the expected outcomes and achievements.
- Evidence completion of Stage 2 of the IEA Framework.
- Evidence that the overall feasibility and technical/commercial opportunity associated with the proposed WEC design supports continued R&D funding through the EuropeWave PCP.

4.2.4 Design reviews

Two formal reviews are anticipated during Phase 2.

Table 4 – Phase 2 design review

Review	**Purpose**	
Preliminary Design Review – Phase 2 (PDR-P2)	The PDR-P2 should present the optimised conceptual design for the Phase 3 prototype, and proposed resolutions to critical, system issues. *Within the EuropeWave programme, PDR-P2 is expected to be held shortly after the commencement of Phase 2.*	The PDR-P2 reinforces that the preliminary (conceptual) design meets the system and programme requirements with acceptable risk, within the cost and schedule constraints. It shows that suitable design options have been selected, key interfaces are identified, outcomes from testing and modelling have been incorporated, and design verification methods are understood. This in turn establishes the basis for proceeding with detailed design. As a result of successful completion of the PDR-P2, the conceptual design and its approach are approved, so that work can begin on front-end engineering design (FEED).
Critical Design Review (CDR)	The CDR consists of the final subsystem design reviews prior to detailed design, procurement, fabrication and assembly. *Within the EuropeWave programme, this is expected to be at the close of Stage 2.*	The review (or each review as part of a staged process, if multiple subsystems are considered critical) must cover the definition of the design solution, and this shall be achieved by principally focusing on: • Engineering of the FEED for the Phase 3 prototype; • Other outputs which influence design, including but not limited to testing plans, FMECA, and the output of the HIRA; • How success of design criteria will be determined.

4.2.5 Phase 2 mandatory outputs

R&D providers will be expected to define a set of project outputs for Phase 2 that are submitted to the buyers group (the "deliverables"). These enable reporting of the technical progress, dissemination of the project findings, and the demonstration of project target outcomes.

Amongst the project outputs in Phase 2 will be a number of mandatory outputs, as summarised below:

- A comprehensive suite of engineering and design information to facilitate the required CDR review of the FEED, and demonstration of readiness for progress to Phase 3;
- A comprehensive set of reporting covering the testing activities during Phase 2, including but not limited to the test plans, testing methodology, outcomes, analysis and critical interpretation of results;
- Report by an accredited, independent third-party providing assessment of the FEED, and corroboration of its suitability for all-season deployment at the Phase 3 test sites;
- Report by an accredited, independent third-party providing assessment and feedback on the approach for the installation and O&M strategies;
- Updated and comprehensive technology risk register, indicating progress on mitigation actions during Phase 2;
- A confidential, technical report summarising how the project met its target outcomes;
- End-of-phase deliverable (based on H2020 template), including details of the IPR measures taken by the contractor to protect the results and the identity and location of personnel that carried out the R&D activities.

The mandatory outputs for Phase 2 are indicative and are subject to change. Any change will be communicated at the relevant phase call-off.

Details of the Phase 2 milestones and payment schedule will be communicated at the phase call-off.

4.3 Phase 3 (Open-water deployment)

Selected R&D providers will finalise the design of their WEC system, before proceeding to fabrication, assembly, commissioning and installation at the open-water test sites of either BiMEP or EMEC. The prototype will be operated over a period of time expected to be no less than 12 months (including time for inspections, maintenance, etc.). Phase 3 will conclude with recovery of the prototype systems to the quayside, and assessment, interpretation and reporting of the outcomes and learning.

4.3.1 Phase 3 objectives

The core objectives for Phase 3 of the EuropeWave PCP are to:

- Validate the proposed approach to a commercial-scale system through the fabrication, commissioning, installation and subsequent open-water trials of the Phase 3 prototype;
- Identify opportunities to de-risk the manufacturability of the proposed commercial-scale system;
- Obtain necessary consenting and insurances, as appropriate and required by the test site;
- Maintain environmental monitoring during the open-water deployment and demonstrate no adverse effects on local ecosystems;
- Evidence sustained electrical output during open-water trials through reliable operation of the Phase 3 prototype;
- Successfully demonstrate survival strategies and approaches that will be used on the future commercial-scale system;
- Successfully demonstrate planned O&M for the Phase 3 prototype, and gather learning applicable to guide the strategies that will be used for a commercial-scale array;
- Recover the Phase 3 prototype, and all associated infrastructure, at the conclusion of the test programme;
- Demonstrate power performance is in line with estimates made using Testing and Simulation outputs in prior phases;
- Achieve completion of Stage 3 of the IEA Framework;

- Confirm the technology development roadmap to continue the technology development into Stage 4 of the IEA Framework and beyond.
- Establish a commercialisation strategy, including the financial capability and capacity to deliver the technology to market.
- Identify funding and/or investment opportunities to continue the technology development into Stage 4 of the IEA Framework.

4.3.2 Phase 3 main activities

The tasks and activities of Phase 3 should be appropriate to address the technical objectives of the EuropeWave PCP, and to demonstrate risk reduction of critical system elements.

Critical elements of the system which will require de-risking should be identified using the project's technology risk register, and the proposed risk mitigations for these will inform the activities to be carried out alongside the open-water testing during Phase 3. When developing and refining scopes for Phase 3, project teams should consider the necessity and justification of the proposed activities.

As a minimum, each project is expected to complete the following tasks:

- Detailed design of the Phase 3 prototype and its constituent subsystems
- Manufacture of the Phase 3 prototype and its constituent subsystems
- Obtain necessary marine licencing to cover the deployment period
- Open-water testing of the Phase 3 prototype over a period of no less than 12 months
- Business plan development and refinement
- Wider engagement to identify opportunities for continued development following EuropeWave

4.3.3 Phase 3 target outcomes

Upon completion of Phase 3, projects are expected to be able to:

- Have experience of completing a successful design and build of a WEC device, and of complying with relevant licence, HSE, and stakeholder requirements to deliver a successful open-water deployment programme;
- Evidence continuous energy conversion, reliability, and effective strategies for installation, maintenance, survivability, and decommissioning on a large-scale WEC device;
- Predict device performance, using simulation modelling validated against performance data recorded across all seasons in an uncontrolled, open-water environment;
- Satisfy the performance and reliability requirements indicated by the buyers group;
- Evidence that the open-water deployment has no adverse effects on the environment and local ecosystems;
- Have confidence in the reliability and dependability of the proposed strategies for survival, installation, operation and maintenance on a commercial-scale development of the Phase 3 prototype system;
- Appreciate, and have strategies to mitigate, the key failure modes of the overall system;
- Understand the cost drivers for the WEC and supporting subsystems and their influences, such that they can be optimised in future developments;
- Identify commercial opportunities and engage with potential customers and partners;
- Evidence completion of Stage 3 of the IEA Framework.

4.3.4 Design reviews

Two formal reviews are anticipated during Phase 3:

Table 5 – Phase 3 design reviews

Review	Purpose	
System Integration Review (SIR)	Update on the fabrication progress of the Phase 3 prototype's components and subsystems. *Within EuropeWave, this is expected to be approx. 6 months before deployment.*	The review must update on the integration activities and initial outputs of fabrication. This shall be supported by presenting: • Progress relative to original fabrication timescales; • Challenges that have been identified and mitigations to address these; • Confirmation that plans, personnel and facilities are in place to ensure delivery of the completed assembly on schedule. The review is expected to take place at the fabrication location.
Operational Readiness Review (ORR)	Final review prior to installation and operational testing. *Within EuropeWave, this is expected to be following dry commissioning, and just before deployment.*	The review must cover the preliminary outputs of commissioning and any dry/onshore testing, approved operational plans and procedures, and confirmation of the proposed decommissioning/disposal plans. This shall be achieved by presenting: • Confirmation that all hardware and software has been commissioned and is ready for operation; • Reviewed and approved system procedures; • Reviewed and approved operational strategies for installation and O&M. To facilitate the review, evidence should be supplied to support claims of readiness.

Safety-critical and specialist aspects (HIRA, marine operations planning, mooring design, etc.) should be reviewed by appropriate independent third parties.

In addition to the planned formal reviews, preliminary reviews of other project documentation may be organised prior to key project decisions.

4.3.5 Phase 3 mandatory outputs

R&D providers will be expected to define a set of project outputs for Phase 3 that are submitted to the buyers group (the "deliverables"). These enable reporting of the technical progress, dissemination of the project findings, and the demonstration of project target outcomes.

Amongst the project outputs in Phase 3 will be a number of mandatory outputs, as summarised below:

- A comprehensive suite of updated design documentation and requirements, including the Phase 3 prototype as-built designs, bill of materials, etc.;
- Report by an accredited, independent third-party providing assessment of the critical aspects for obtaining a marine licence and insurance, including but not limited to installation, station-keeping, recovery, decommissioning, etc.;
- Fabrication progress update, to support the System Integration Review (SIR), consisting of an update on fabrication progress and the plans for system and hardware integration and commissioning;
- A test-plan for the open-water deployment (including objectives, target conditions, proposed activities, and how data and progress will be recorded and reported);

- A suite of the FAT and commissioning records, system procedures and independently reviewed operational strategies to facilitate the Operational Readiness Review (ORR) and evidence preparedness for open-water testing;
- Open-water testing covering a 12-month period;
- A comprehensive set of reporting covering the outcomes from the testing activities during Phase 3, including but not limited to the testing methodology, data recorded, analysis and critical interpretation of results;
- Power matrix for the Phase 3 prototype;
- An updated Basis of Design for a commercial-scale WEC design, incorporating learning outcomes and any design changes identified during the EuropeWave PCP programme, which can be addressed in future deployments;
- Technical development roadmaps identifying the outstanding technical challenges to be addressed, their mitigations, and anticipated timescales;
- An updated, comprehensive technology risk register;
- A commercial exploitation plan which describes the measures to be undertaken after the completion of the Phase 3 project and presents a commercial development roadmap identifying the anticipated route to market;
- An IP register which records the IP and patent applications generated during the EuropeWave PCP programme;
- A confidential, technical report summarising the project and its achievements against the project target outcomes;
- A report capturing the lessons learnt during the Phase 3 project;
- End-of-phase deliverable (based on H2020 template), including details of the IPR measures taken by the contractor to protect the results and the identity and location of personnel that carried out the R&D activities.

The mandatory outputs for Phase 3 are indicative and are subject to change. Any change will be communicated at the relevant phase call-off.

Details of the Phase 3 milestones and payment schedule will be communicated at the phase call-off.