

TD2

TurboWave Challenge Descriptive Document

TURBOWAVE PROJECT

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1 The TurboWave challenge

1.1 Background

The Mutriku Wave Power Plant was commissioned in 2011 as part of the Nereida MOWC project partly funded by the European Commission through the 6th Framework Programme (FP6). The project was promoted by the Ente Vasco de la Energía (EVE), taking advantage of the construction works of the new breakwater in the town of Mutriku (Basque Country). The main objective of those works was to protect the inner harbour and enable the passage of vessels.

In this context, the project was designed to demonstrate the technical feasibility of the construction and operation of a wave energy plant located in the breakwater of a sea wall, being the first wave energy project in Europe and one of the first worldwide, thus demonstrating its viability for future commercial projects.

The operation of the plant is based on a technology known as Oscillating Water Column (OWC), whereby a hollow structure built as a chamber and open at the bottom is used to compress and decompress the air inside caused by the movement of the waves back and forth. The turbine is located in a small hole at the top of the chamber. Due to the compression and decompression of the air inside the chamber, an upward and downward flow of air is generated, respectively, which turns the turbine and in turn moves the generator, thus producing electricity.

The Mutriku Wave Power Plant (hereinafter, MWPP) consists of 16 OWC chambers distributed along the 100 metres of breakwater that the plant occupies. Each chamber is equipped with a dual-stage Wells turbine coupled to an 18.5 kW generator, which together make up a total of 296 kW of installed power. It should be mentioned that the plant is connected to the local grid, so the power generated is supplied directly to it. Over its 11 years of operation, the plant has produced just over 2.6 GWh of power, which is without doubt a milestone as it is the plant that has produced the most wave power and which, to date, has been in operation the longest.

In 2020, the management of the plant passed into the hands of the Biscay Marine Energy Platform (hereinafter, BiMEP), in order to combine all marine energy related projects in the Basque Country under a single organisation. Today, the MWPP is not only a power generation plant but also serves as a test infrastructure where new turbine concepts, equipment and auxiliary systems and/or control systems can be tested and validated.

1.2 Motivation

The Energy Transition and Climate Change Plan 2021-2024 (hereinafter, ETCCP 2021-2024) is one of the main tools for delivering the objectives set at the Basque Country level. In this sense, the Basque Country is committed to complying with the internationally agreed objectives to try to reduce the speed at which the climate is changing and increase the capacity to respond to its effects.

One of the objectives of the ETCCP 2021-2024 is to position the Basque Country as an international benchmark in the field of ocean energies (Initiative 2) and to position the industry at the forefront of technological development.

The Basque Country Energy Strategy 2030 (3E2030) is one of the commitments taken on by the Basque Government, and has been drawn up in line with the main international and national trends and guidelines. The strategy itself defines a series of priority areas for action in the field of energy, also included in the EnergiBasque strategy, including the use of marine energy and, in particular, wave energy. Taking into account the state of the art of the two technologies, the aim is to give a boost to their development by making the BiMEP and Mutriku test areas available to technologists and researchers.

Specifically, one of the objectives is to increase the use of renewable energies to account for 21% of final energy consumption. In the case of marine energy, the target set for 2030 is 50 MW of installed offshore wind power and 10 MW of ocean energy.

In this context, the MWPP has been in continuous operation since 2011. The turbines are exposed to a marine environment with a high degree of humidity and salinity, which means that their useful life is limited and that they need to be replaced once they have exceeded a certain number of

operating hours. In addition, the turbines are subject to high axial loads, causing other components such as bearings to suffer increased wear. In the 11 years of operation, all the turbines have already been replaced, and it is expected that in the next few years the existing turbines will have to be replaced by newer ones.

The Wells turbines currently installed at the MWPP are considered first generation, since their design dates from over 10 years ago. The industry has moved on considerably since then and we firmly believe that, as a result of these new developments, there is sufficient capacity to design more efficient, robust and reliable turbines.

This initiative has not been conceived solely with a view to potentially improving the MWPP. Indeed, the main objective is to provide the market with new, more efficient and robust turbines so that the different developers specialising in Oscillating Water Columns can have a wider range of designs at their disposal when choosing the collection system that best suits their device.

1.3 Mutriku wave power plant

1.3.1 Location

The Mutriku wave power plant is located at the mouth of the port of Mutriku (Basque Country, Spain), within the new outer breakwater (43.31° N, 2.38° W). The plant occupies about 100 metres of the central part of the breakwater, which slightly overhangs it to minimise the influence of the rockfill on the windward side of the breakwater. Figure 1 of Annex I shows an aerial view of the plant.

At the foot of the plant the depth is 4 metres, with a platform at 6-7 metres depth extending for about 200 metres in front of the plant. Figure 2 of Annex I shows a bathymetric map of the area.

1.3.2 Dimensions of the plant

The structure of the plant consists of a vertical 'L' shaped chamber built as a caisson. The chamber is 4.5 metres wide, 3.1 metres long and 9.7 metres high from the

Mean Low Water Springs (hereinafter, MLWS) level. The wall thickness on the seaward side is 6.65 meters (1.65 meters wall + 5 meters reinforcement).

The lower opening of the chamber on the seaward side is 2.8 metres high and 4.5 metres wide. The top of the chamber is -0.60 metres below the MLWS.

Centred on the top of the chamber is a circular orifice, or hole, of 0.75 meters in diameter where the turbine will be located.

A circular orifice, or hole, with a diameter of 0.75 metres can be found at the centre of the top of the chamber. The designed system may occupy a maximum space of 2 metres in diameter around this hole, measured from the central point.

Figure 3 of Annex I shows the plan of the floor in more detail that includes a lateral view and the elevation of the chamber.

1.3.3 Marine climate

At the time of writing this document, there are no real data available on ground swell.

However, a preliminary numerical study of the wave climate near the plant based on models has been performed based on the following information:

- Bathymetry of the area, bathymetric mapping of the Basque continental shelf up to 100 meters of depth represented by isobaths with a distance of 1 meter (<https://datos.gob.es/en/catalogo/a16003011-batimetrias-marinas-pais-vasco-ano-20091>), EMODnet topobathymetry (2020) and plant and breakwater layouts.
- Wave buoy data available from different sources: the Bilbao-Bizkaia buoy from the Network of External Buoys (REDEXT) and the BiMEP's WAVESCAN buoy.
- Satellite altimetry database integrating intercalibrated measurements from ten altimeters: Topex-Poseidon, Jason-1, Jason-2, Jason-3, ERS-1, ERS-2, GFO, Envisat, CryoSat-2 and SARAL.

- Seawind wind database developed by IHCantabria.
- GOT (Global Ocean Tides) database to characterise the astronomical tide and GOS (Global Ocean Surges) weather tide database to simulate the wave in Mutriku.
- Wave information from GOW2 (Global Ocean Waves) database.

The methodology used for the characterisation of the wave climate at the foot of the breakwater is based on the regionalisation of the sea wave dynamics. This regionalisation has been carried out by dynamic downscaling (using numerical models) in two numeric domains, one outer with a spatial resolution of 500 meters and a coastal one of 25 meters.

All numerical wave simulations have been performed using the SWAN model.

The applied methodologies of dynamic downscaling have been validated comparing the results obtained during the simulated historical period with the observed period from instrumental measurements of both available buoys and satellite information mentioned above.

Basic statistical information for this phase is shown in Annex I. More specifically, Figure 4 shows the joint distribution of peak period and significant height at the foot of the power plant. Graphs of probability of non-exceedance in average regime of significant wave height (Figure 5) and peak period (Figure 6) are also included.

Figure 7 shows return periods where the continuous black line shows the extreme scalar regime and the dashed line shows the 95% confidence band intervals. The parameters estimated in the fitting of extremes are included in Table 1 where u is the threshold (m), λ the Poisson parameter, σ the parameter of the Pareto scale, and μ , ψ and ξ are the localisation, scale and distribution shape parameters, respectively.

The generated wave hindcast covers the period from January 1990 to March 2021.

This information may be expanded with information regarding time series of sea state parameters and wave spectra once participation within the TurboWave program has been confirmed.

For further information, the SIMAR database (description in Spanish) (https://bancodatos.puertos.es/BD/informes/INT_8.pdf) is available on the website of the Spanish State Ports Authority (<https://www.puertos.es/es-es/oceanografia/Paginas/portus.aspx>). These are historical wave data obtained through numerical modelling. The closest SIMAR point is SIMAR 3171032 (43.33° N, 2.38° W), located approximately one nautical mila north of the plant.

1.4 The TurboWave challenge

The aim of the TurboWave challenge is to accelerate the development of air turbine technologies that are tailored to the needs of the wave energy sector in general and the specific technical requirements of the MWPP in particular, with the ultimate goal of building confidence in the wave energy sector and its ability to play a role as a competitive renewable energy source in the future energy mix on a regional and global scale.

The aim of the TurboWave project is to gain knowledge on technologically innovative solutions for air turbine concepts. The challenge encompasses the design, development and demonstration of a cost-efficient, reliable and safe two-directional air turbine system for power production at the MWPP.

The main technical challenges to be addressed are as follows:

- Performance: to obtain quantitative evidence of adequate energy conversion capability and increase confidence in performance predictions from numerical model simulations.
- Controllability: to demonstrate that the turbine has the necessary characteristics and elements to enable optimal energy capture and conversion over a wide range of operating states.
- Reliability: to demonstrate adequate levels of availability through reliable and robust prototype operation over a representative test period (12 months).

- **Maintainability:** to demonstrate that preventive or corrective maintenance, including modifications, adjustment, repair or replacement, can be performed with reasonable means and with minimum system downtime.
- **Affordability:** to increase confidence in the estimation of technology costs (capital and operational) for wave energy air turbines.

It is planned to have air turbine prototypes installed and fully operational at the MWPP during a significant period (around 12 months) to provide a solution to the challenge set out above.

2 TurboWave Program Requirements

2.1 Level of Technological Development

Programme constraints (time and budget) require that the proposed conceptual designs have reached a minimum state of development prior to programme entry.

The minimum required state of pre-development is completion of TRL2. The set of engineering activities related to each of the TRLs is outlined in Annex II.

As a fundamental part of the wave energy collection system (OWC), some of the areas of assessment of the IEA-OES Framework are relevant for the purpose of identifying engineering tasks and operational planning.

Successful completion of the TurboWave PCP programme corresponds to reaching TRL7.

2.2 Innovation

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

Innovations within the TurboWave PCP can be new designs that will enable progress beyond the current state of the art.

Where the proposed conceptual design can be perceived as having already reached or exceeded the stage of development envisaged in the final phase of the TurboWave PCP, the innovative aspect(s) should represent a significant adaptation to the current design.

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

2.3 Phase III testing campaign

In Phase III of the TurboWave PCP, full-scale prototypes of two designs will be installed and commissioned at the MWPP for a 12-month demonstration and operational testing programme.

The proposed designs must be adaptable to the environmental conditions and be capable of operating (and surviving) across all operational circumstances foreseen during the test period.

The objective of the Phase III test programme is to demonstrate that the proposed technology meets the functional requirements set out in Section 3 Functional Requirements.

Practical information on the MWPP has been included as part of the documentation for this tender so that technologists can take this into account when preparing their proposals. The bidder is encouraged to liaise directly with BiMEP when further information is required to inform the preparation of their bid.

2.4 Future opportunities

The objective of EVE and BiMEP is to have efficient, robust and affordable alternatives available in a possible future tender for the partial or total replacement of existing systems.

The administrative procedure, scope, budget and timeframe of such a possible future tender will be determined by EVE/BiMEP according to the current legal framework for procurement.

EVE may use the information generated as part of the contracts assigned in TurboWave for the design of such a possible future tender, respecting at all times the clauses regulated under the Framework Agreements with the TurboWave programme participants.

Participation in TurboWave will in no way confer any advantage on companies participating in such a possible future tender.

2.5 Compliance with standards

The development of the engineering design for the wave energy conversion system, the experimental test campaigns and ultimately the installation and operation of the Phase III

prototypes at the MWPP facility must comply with relevant and recognised standards, guidelines and recommended practices, such as IEC, DNV, etc.

2.6 Technological Qualification Plan

Projects must propose and follow a technological qualification plan, which will guide the engineering activities to be conducted in each of the phases. In this sense, the use of recognised practices or standards to guide this process is recommended.

It is advisable, though not essential, that the technological qualification process be checked with organisations of recognised solvency and experience in guiding technological qualification processes.

2.7 Technological and Commercial Development

Projects must propose and comply with a roadmap for the ongoing technology during the three phases of the TurboWave PCP.

A short to medium term plan will be developed, setting out the steps to be taken to further develop the proposed system design towards a commercial application after the completion of the TurboWave PCP programme.

The proposed plan should include, in increasing detail at each stage:

- A technology development roadmap to bring the system to the target market successfully, indicating the technical, human and financial resources needed to achieve this.
- The strategy for the protection of the results generated (IIPR), both during the execution of the contract and at the end of it.
- The marketing strategy pursued, e.g. directly or indirectly (through transfer or licensing to third parties, etc.).
- Evidence that the above are supported by contact/dialogue with the market, potential customers, stakeholders, etc.

3 Functional requirements

The table below summarises the functional requirements to be met by the proposed TurboWave Phase III solution.

Criterion	ID	Requirement	Indicator	
			Current situation	Target value/ Improvement Objective
Performance	P01	To convert pneumatic power of the OWC chamber into electrical power, in line with the particular characteristics of the MWPP	Average annual pneumatic to electric conversion efficiency of 30%	Average annual pneumatic to electric conversion efficiency of 50%
Performance	P02	To provide improvements over currently deployed systems in terms of Annual Energy Produced per air chamber.	Average annual electric power per chamber: 20 MWh	Average annual electric power per chamber: 28 MWh
Performance	P03	To be scalable and replicable in the 16 OWC chambers that make up the plant.	N/A	N/A
Controllability	C01	To be able to maintain an autonomous operation under the expected average conditions in MWPP.	The proposed solution must be able to remain operational in the operational range between $0.5 \leq H_s \leq 4.0$ [m]	
Controllability	C02	To be able to stop its operation to a mode of low consumption in conditions of insufficient swell. Also capable of restarting the operation autonomously when the standard operating conditions (C01) are recovered.	N/A	N/A

Criterion	ID	Requirement	Indicator	
			Current situation	Target value/ Improvement Objective
Controllability	C03	To be able to stop its operation in a “safe mode” under swell conditions above the operational limit. Also capable of restarting the operation autonomously when the standard operating conditions (C01) are recovered.	N/A	N/A
Controllability	C04	To be able to record key parameter data to demonstrate the main characteristics of the technology, as well as exchange this information in real time with the MWPP monitoring and registration system.	N/A	N/A
Controllability	C05	To have a monitoring and operating system that allows operators to perform routine tasks (boot, stop...) as well as monitor the operational status of the machine and the main process values.	N/A	N/A
Reliability	F01	To maintain the integrity of the system during survival events and under the environmental conditions expected at any time throughout the year.	The design life of the proposed solution (the Phase III prototype) is 5 years. This requirement extends to both structural loads derived from extreme events and fatigue loads, as well as corrosion protection and other aspects.	

Criterion	ID	Requirement	Indicator	
			Current situation	Target value/ Improvement Objective
Reliability	F02	That the control hardware, instrumentation and other systems associated with the solution are adequately protected and sufficiently reliable against moisture and corrosion in their operating conditions.	The MWPP turbine room has seawater condensation as a result of existing systems exhaling into it.	
Reliability	F03	That the proposed system is inherently secure in the event of a one-off or sustained power failure.	The Phase III prototype should incorporate safety mechanism to stop its operation in a controlled manner.	
Reliability	F04	That the components/systems are designed for safe and efficient operation and maintenance.	N/A	N/A
Maintainability	M01	That the system can be installed and de-installed by reasonable means and within reasonable time limits, and in safe conditions for personnel and equipment.	The installation process of the solution requires a maximum of 3 hours, with appropriate means.	
Maintainability	M02	The system includes items of hardware or software that enable plant operators to perform the main monitoring and maintenance tasks.	The main preventive maintenance tasks require a maximum of 30 hours per year.	
Affordability	A01	The proposed system is attractive and affordable in its target market.	The solution is adaptable, through reasonably feasible modifications, to other OWC systems including: - Other infrastructures similar to MWPP, or wave harnessing systems that may be attached to existing port infrastructures, and in particular those intended to operate in less energetic marine climates than MWPP. - Floating OWC systems	

4 Programme

Details of the objectives, anticipated tasks and activities, target outcomes and deliverables for each phase of the TurboWave CPP are outlined below.

4.1 Phase I (Concept Development)

Phase I enables the selected R&D providers to address the conceptual engineering tasks and implement the numerical and physical models necessary to establish the fundamental characteristics of the technology (e.g. performance, survivability, etc.).

4.1.1 Objectives

The main objectives for Phase I of the TurboWave PCP are to:

- Develop the conceptual engineering design for TurboWave requirements.
- Set benchmark performance values.
- Calculate the energy throughput capacity of Phase III.
- Demonstrate that the proposed system will be able to provide an attractive final solution in its target market.

4.1.2 Reference Activities

Tasks and activities should be appropriate to deliver the objectives and be aimed at mitigating the main risks of the proposed system.

A Phase I project is expected to cover conceptual design of the complete system.

Examples of development tasks and reference activities are provided in the tables below for guidance. Not all activities listed in these tables may be appropriate for every project, and additional development tasks may also be required. Projects should consider the need and justification for the constituent activities proposed for Phase I, with respect to the key technical challenges and risks particular to each technology.

Design	• To develop the bases for design specific to the features of the MWPP. • To complete previous conceptual development activities, identifying associated technological challenges and subsystem integration. • To define the key design parameters, subsystem interfaces and system requirements for the Phase III prototype design. • To develop a survivability strategy to ensure suitability for Phase III deployment. Refine the conceptual design to optimise performance, installation, maintainability, survivability and affordability. • To develop an overall conceptual design for the Phase III prototype system, with credible strategies for meeting the functional requirements of the TurboWave challenge and the constituent subsystems. • To develop and deploy a technology qualification plan to ensure the necessary qualification activities are performed during the future phases of the TurboWave programme.
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Modelling	- To create and refine numerical models to obtain information on device performance, loads and behaviour. - To explore the effect of key conceptual design aspects on performance, such as main dimensions and proportions, to inform all other engineering activities. - To analyse and interpret modelling results to inform conceptual design development. - To produce a power matrix and model the efficiency of the concept against the reference conditions of the target commercial site.
Installation, Operation and Maintenance	- To develop an initial approach for the installation, operation and maintenance processes of the proposed system. - To identify the requirements and features needed for maintenance during the Phase III test campaign.
Marketing Plan	- To apply learning from conceptual design and modelling activities to develop a breakdown of expected system costs for the Phase III prototype and final commercial product. - To develop and refine the set of costs to be used for financial modelling, based on the performance, controllability, reliability, maintainability and cost profile results of the design and modelling activities. - To identify enabling innovations that will sustain progression towards cost reduction. - To draw up cost projections appropriate to the business opportunities identified with the proposed technology, using suitable modelling tools and documenting assumptions and simplifications.

4.1.3 Target Outcomes

Once Phase I is completed, projects are expected to be able to:

- Demonstrate that the proposed system is conceptually suitable for the deployment of Phase III in the MWPP operational environment.
- Estimate device performance at Phase III test sites using robust and recognised numerical modelling practices.
- Provide clarity on progress with respect to the state of the art offered by the proposed system.
- Identify the key risks associated with the deployment of Phase III, and support these with credible mitigation proposals.
- Demonstrate that the overall feasibility and technical/commercial opportunity associated with the proposed design requires continued R&D activities through the TurboWave PCP.

4.1.4 Deliverables and Milestones

As a minimum, Phase I must comprise the following list of deliverables and technical milestones:

Deliverable	Title	Description	Date (Reference)
E0	Public Summary	Project sheet, based on template provided, summarizing the proposed technology and an image of the conceptual design.	Month 1
E01	Technological and Commercial Development Plan	Report containing the actions carried out during the Phase to advance the implementation of the Technological and Commercial Development Plan, including the planned short and medium term actions to protect and exploit the IIPRs generated.	Month 6
E02	End of Phase Deliverable	Final report containing the studies carried out, conclusions drawn from them and sufficient design information on the ability of the proposed solution to meet the functional requirements established.	Month 6

Milestone	Associated Deliverables	Description	% of contract value associated for payment
H01	E01,E02	Phase Completion Milestone	70

4.2 Phase II (Laboratory testing and detailed modelling)

Phase II will provide the selected contractors with the opportunity to address the numerical model refinement and physical demonstration tasks necessary to demonstrate that the proposed solution will meet the functional requirements.

4.2.1 Phase II Objectives

The main objectives for Phase II of the TurboWave PCP are to:

- Improve the accuracy of numerical models to capture the characteristics of the proposed technology.
- Test the proposed system in a controller environment (laboratory/wind tunnel) at a representative and appropriate scale.

- Conduct a critical analysis of the experimental results obtained, validating the numerical models developed.
- Demonstrate, on the basis of trials and refined efficiency and cost models, that the proposed system is on track to provide an attractive commercial offer.

4.2.2 Reference activities

Tasks and activities should be appropriate to deliver the objectives and demonstrate actions to mitigate the main risks of the proposed system.

A Phase II project is expected to involve detailed modelling and experimental testing of the proposed solutions.

Examples of development tasks and reference activities are provided in the tables below for guidance. Not all activities listed in these tables may be appropriate for every project, and additional development tasks may also be required. Projects should consider the need and justification for the constituent activities proposed for Phase II, with respect to the key technical challenges and risks particular to each technology.

Design	• To draw up a preliminary design of the solution, including subsystems, taking into consideration the design bases drawn up during Phase I. • To complete previous conceptual development activities, identifying associated technological challenges and subsystem integration. • To design key design parameters, subsystem interfaces and system requirements for the Phase III prototype design. • To refine the conceptual design to optimise performance, controllability, maintainability, and reliability. • To demonstrate compliance and progress in the roll-out of the technological qualification plan drawn up in Phase I.
Modelling	• To create and refine detailed numerical models to obtain information on device performance, loads and behaviour. • To explore the effect of key conceptual design aspects on performance, such as main dimensions and proportions, to inform the rest of the engineering activities. • To critically analyse and interpret modelling results to inform conceptual design development. • To produce a power matrix of the proposed solution against MWPP reference conditions.
Testing	• To design and conduct an appropriately sized and scaled test plan of the proposed solution (or its key elements), following recognised practices and standards.
Installation, Operation and Maintenance	• To storyboard the processes of installing and uninstalling systems. • To identify the main operation and maintenance tasks of the proposed system, as well as their frequency and the material and personnel means required to perform them. • To identify the requirements and features required for the installation, maintenance and proper operation of the prototype to be tested during the Phase III test campaign.
Marketing Plan	• To apply learning from design and modelling activities to refine the breakdown of expected system costs for the Phase III prototype and final commercial product.

	- To develop and refine the set of costs to be used for financial modelling, based on the performance, controllability, reliability, maintainability, and cost profile results of the design and modelling activities. - To identify enabling innovations to sustain progression towards cost reduction. - To draw up cost projections that are appropriate to the business opportunities identified with the proposed technology, using suitable modelling tools and documenting assumptions and simplifications.
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4.2.3 Target Outcomes

Once Phase II is completed, projects are expected to be able to:

- Have a solution for the specific characteristics and requirements of the design presented by the MWPP.
- Propose quantitative targets for Phase III, relating to the evaluation metrics considered, informed by Design, Test and Simulation activities.
- Provide attractive and credible estimates of the long-term CAPEX and OPEX that the proposed system can deliver.
- Identify the Phase III trial plan and expected results.
- Demonstrate that the overall feasibility and technical/commercial opportunity associated with the proposed design requires continued R&D activities through the TurboWave PCP.

4.2.4 Deliverables and Milestones

As a minimum, Phase II must comprise the following list of deliverables and technical milestones:

Deliverable	Title	Description	Date (Reference)
E0	Public Summary	Project sheet, based on template provided, summarising the proposed technology and an image of the conceptual design, scale, simplifications made and practical aspects of test specimen design and construction.	Month 1
E01	Test Plan	Summary document outlining the proposed physical test plan, including identification of the main features of the test infrastructure, as well as the scale, simplifications made and practical aspects of the design and construction of the test specimens.	Month 2 – Month 3

Deliverable	Title	Description	Date (Reference)
E0	Public Summary	Project sheet, based on template provided, summarising the proposed technology and an image of the conceptual design, scale, simplifications made and practical aspects of test specimen design and construction.	Month 1
E02	Test Report	Summary report of the tests conducted, including a description of the methodology used, analysis of uncertainties, critical analysis of the results obtained and their relationship with the metrics for evaluating the success of the solutions.	Month 7 – Month 8
E03	Technological and Commercial Development Plan	Report containing the actions carried out during the Phase to advance the implementation of the Technological and Commercial Development Plan, including the planned short and medium term actions to protect and exploit the IIPRs generated.	Month 9
E04	Final Phase Report	Final report containing the studies conducted, conclusions drawn from them and sufficient design information on the ability of the proposed solution to meet the functional requirements established.	Month 9

Technical Milestones	Associated Deliverables	Description	% of contract value associated for payment
H1	E01	Test plan and design of the completed physical model	20
H2	E02	Laboratory tests conducted and report submitted	25
H3	E03,E04	Phase Completion Milestone	25

4.3 Phase III (Construction and testing at the MWPP)

The selected R&D providers will finalise the design of their system before proceeding with the manufacturing, installation and commissioning at the MWPP. The prototype will be operated for a period of time expected to be not less than 12 months (including time for inspections, maintenance, etc.). After the test phase, an evaluation, interpretation and critical analysis of the results obtained will be conducted.

4.3.1 Phase III Objectives

The main objectives for Phase III of the TurboWave CPP are to:

- Validate the proposed approach for a commercial-scale system through manufacturing, commissioning, installation and subsequent testing at MWPP.
- Identify opportunities to reduce the risk to the manufacturability of the proposed system at commercial scale.
- Demonstrate sustained power production during trials through the reliable and robust operation of the Phase III prototype.
- Successfully demonstrate the survival strategies elements to be used in the future commercial-scale system.
- Successfully demonstrate the planned operation and maintenance plans for the Phase III prototype, and gather applicable learning to guide the strategies to be used for the future commercial product.
- Successfully uninstall the Phase III prototype, and all associated equipment, at the conclusion of the test programme.
- Demonstrate that the power performance is in line with the estimates made using the testing and modelling results in previous phases.
- Establish a commercialisation strategy, including financial capability and capacity to bring the technology to market, and that identifies funding and/or investment opportunities for further technological and commercial development.

4.3.2 Reference Activities

Tasks and activities should be appropriate to deliver the objectives and demonstrate actions to mitigate the main risks of the proposed system.

A Phase III project is expected to involve detailed modelling and experimental testing of the proposed solutions.

Examples of development tasks and reference activities are provided in the tables below for guidance. Not all activities listed in these tables may be appropriate for every project, and additional development tasks may also be required. Projects should consider the need and justification for the

constituent activities proposed for Phase II, with respect to the key technical challenges and risks particular to each technology.

Design	- To draw up a final design of the solution, including subsystems. - To complete previous development activities, identifying the associated technological risks and the integration of subsystems with the rest of the MWPP. - To demonstrate compliance and progress in the roll-out of the technological qualification plan drawn up in Phase II.
Modelling	- To create and refine detailed numerical models to obtain information on the performance, loads and behaviour of the device to be tested during Phase III. - To critically analyse and interpret the results of the experimental testing campaign of the Phase III prototype to validate the reporting models to the cost models. - To compare the modelled and experimentally obtained power matrices, making a critical analysis of the results.
Construction	- To manufacture, assemble and commission the prototype to be deployed in the MWPP. - To identify the lessons learned during manufacturing, assembly and commissioning to optimise future similar processes linked to the commercial solution based on the prototype to be tested.
Testing	To design and conduct a test plan of the proposed solution at full scale and size, following recognised practices and standards.
Installation, Operation and Maintenance	- To perform and record the main operation and maintenance tasks of the proposed system, as well as their frequency and the material and personnel means required to perform them. - To revise installation, operation and maintenance strategies if necessary, taking note of lessons learned during the testing phase.
Marketing Plan	- To apply learning from the trial period to refine the breakdown of expected costs of the final commercial product. - To draw up cost projections that are appropriate to the business opportunities identified with the proposed technology, using suitable modelling tools and documenting assumptions and simplifications.

On a preliminary basis, each project is expected to complete the following tasks:

- Detailed design of the Phase III prototype and its constituent subsystems
- Manufacture of the Phase III prototype and its constituent subsystems.
- Obtain the necessary marine licences to cover the deployment period.
- MWPP testing of the Phase III prototype for a period of not less than 12 months.
- Business plan development and refinement.
- Broader commitment to identify opportunities for continued development after TurboWave.

4.3.3 Target Outcomes

Once Phase III is completed, projects are expected to be able to:

- Demonstrate compliance with the functional requirements described in the TurboWave Challenge, through a rigorous programme of testing and operation under real MWPP conditions.
- Demonstrate continuous power conversion, controllability and reliability, as well as validation of strategies for the installation, maintenance, survivability and de-installation of the commercial system.
- Have validated numerical tools to predict device performance, supported by performance data recorded over the test period in a real operating environment.
- Meet the quantitative performance and reliability requirements indicated by the purchaser group.
- Demonstrate the validity and robustness of the proposed strategies for the survival, installation, operation and maintenance of the commercial-scale development of the Phase III prototype system.
- Identify and propose strategies to mitigate key failure modes of the overall system.
- Identify the main cost elements and sensitivity of the final cost to them, with a view to optimising them in future developments.
- Identify business opportunities and engage with potential customers and partners

4.3.4 Deliverables and Milestones

As a minimum, Phase III must comprise the following list of deliverables and technical milestones:

Deliverable	Title	Description	Date (Reference)
E0	Public Summary	Project sheet, based on template provided, summarising the proposed technology and an image of the preliminary design.	Month 1
E01	Detail Design	Design report of the prototype to be tested in the MWPP, including: • The main dimensions and characteristics. • A breakdown of subsystems that make up the prototype. • A justification of how the results of the phase II tests and modelling tasks have influenced the design.	Month 2– Month 3
E02	Test Plan	Summary document outlining the proposed test plan, and the practical aspects of the construction of the prototype to be tested and its integration with the existing MWPP infrastructure.	Month 5– Month 6

Deliverable	Title	Description	Date (Reference)
E0	Public Summary	Project sheet, based on template provided, summarising the proposed technology and an image of the preliminary design.	Month 1
E03	Test Report	Summary report of the tests conducted, including a description of the methodology used, analysis of uncertainties, critical analysis of the results obtained and their relationship with the metrics for evaluating the success of the solutions.	Month 18
E04	Technological and Commercial Development Plan	Report containing the actions carried out during the Phase to advance the implementation of the Technological and Commercial Development Plan, and the commercial exploitation plan for the 4 years following the conclusion of the TurboWave PPP programme, identifying strategy, planned actions and monitoring indicators.	18 th month
E05	Final Phase Report	Final report, which, complementing the Test Report, includes the studies conducted, the conclusions derived from them as well as sufficient detailed design information to demonstrate the capacity of the proposed solution to comply with the established functional requirements.	Month 18

Technical Milestones	Associated Deliverables	Description	% of contract value associated for payment
H1	E01	Detailed design completed	20
H2	E02	Test plan and design of the completed physical model	20
H3	E03,E04,E05	Completion of Trials and End of Phase	30

Annex I: Information for design bases in MWPP



Figure 1. Aerial view of the Mutriku Wave Power Plant.

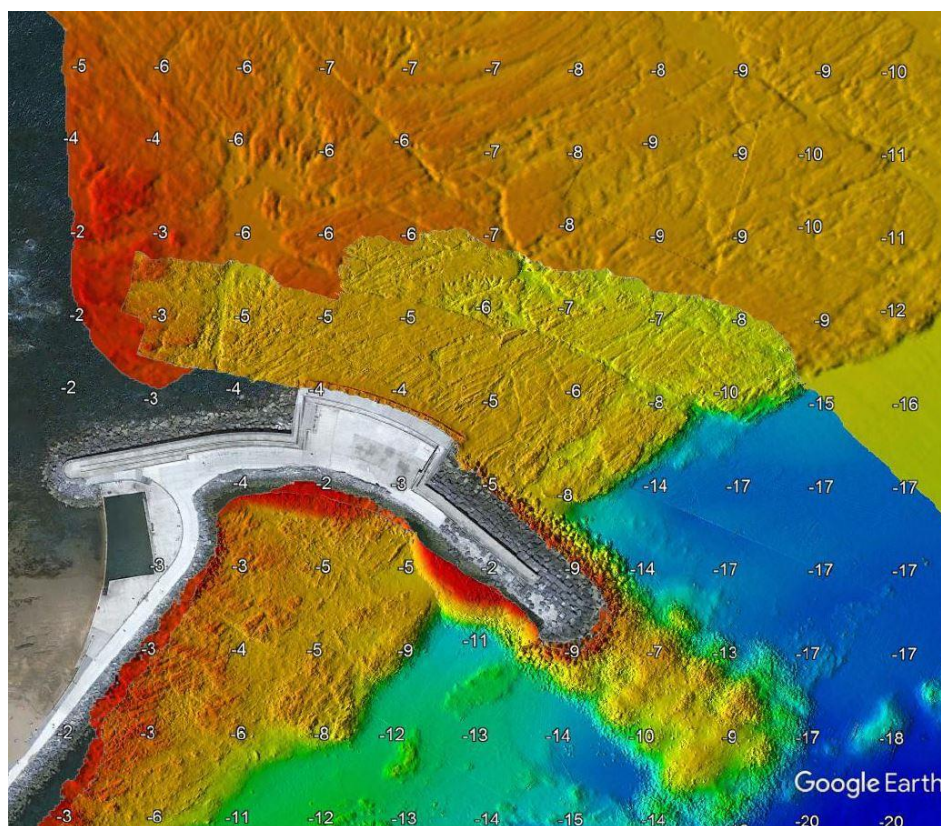


Figure 2. Bathymetric map in front of the Mutriku Wave Plant.

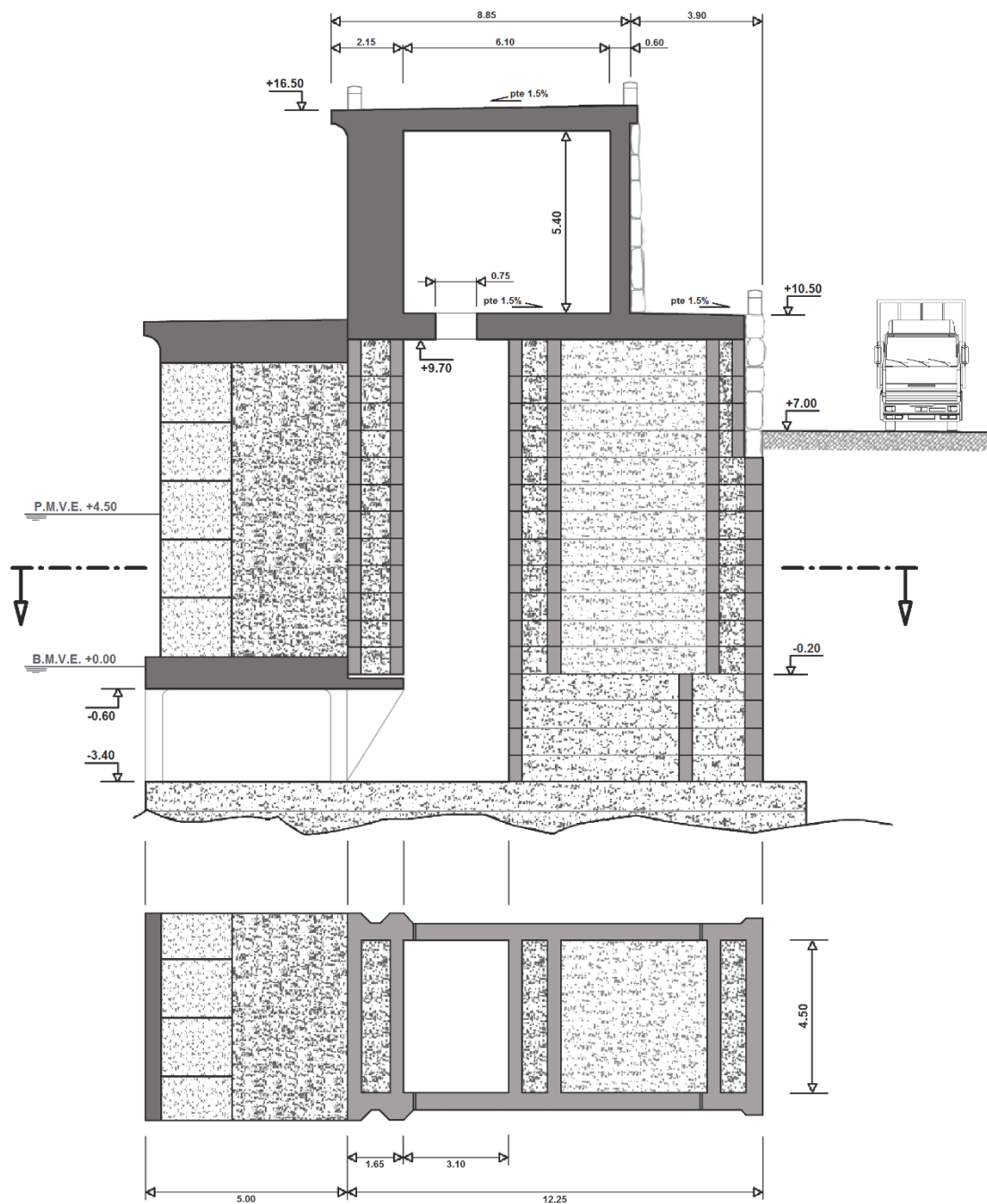


Figure 3. Chamber dimensions. Side view (above) and elevation (below).

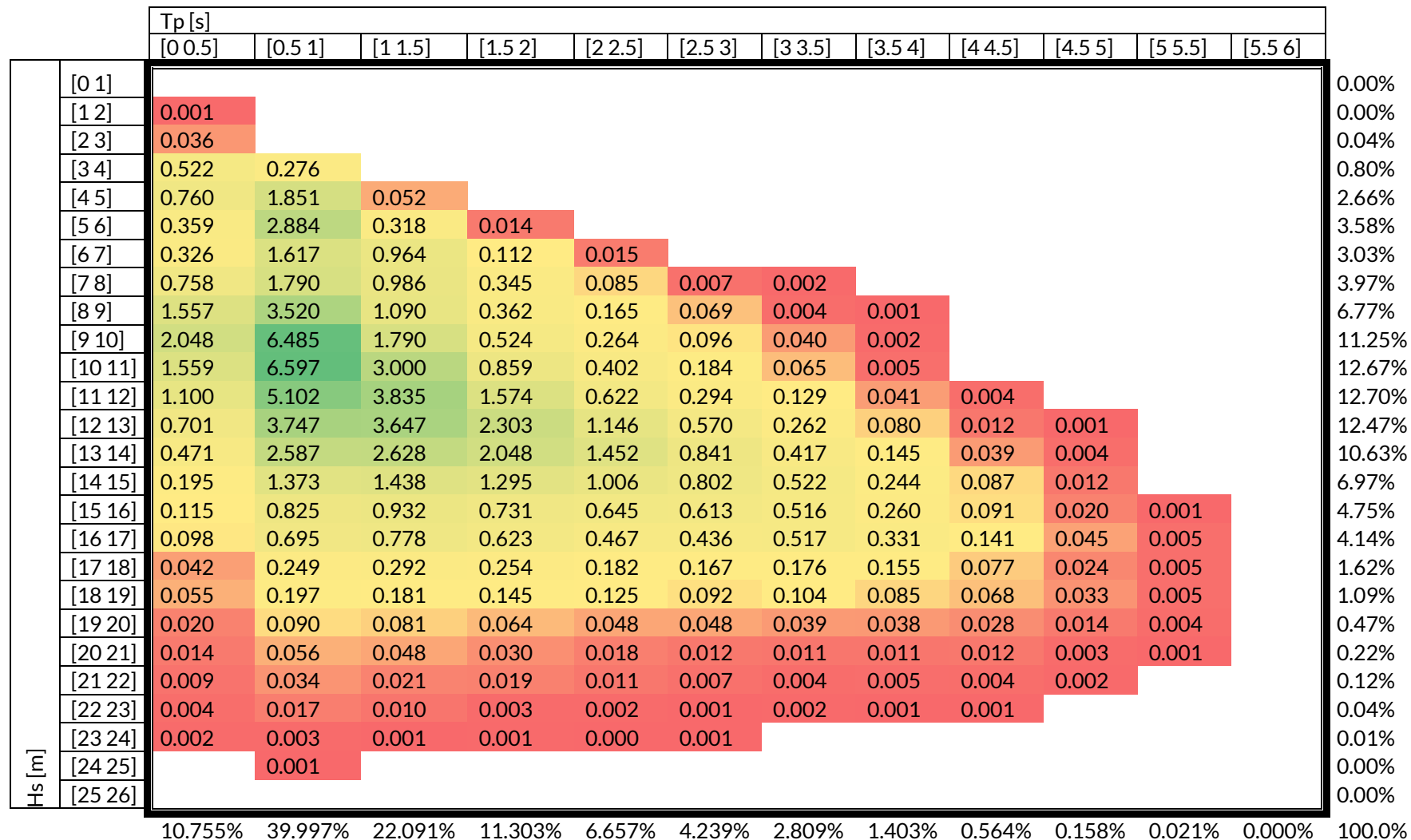


Figure 4. Joint distribution of peak period and significant height.

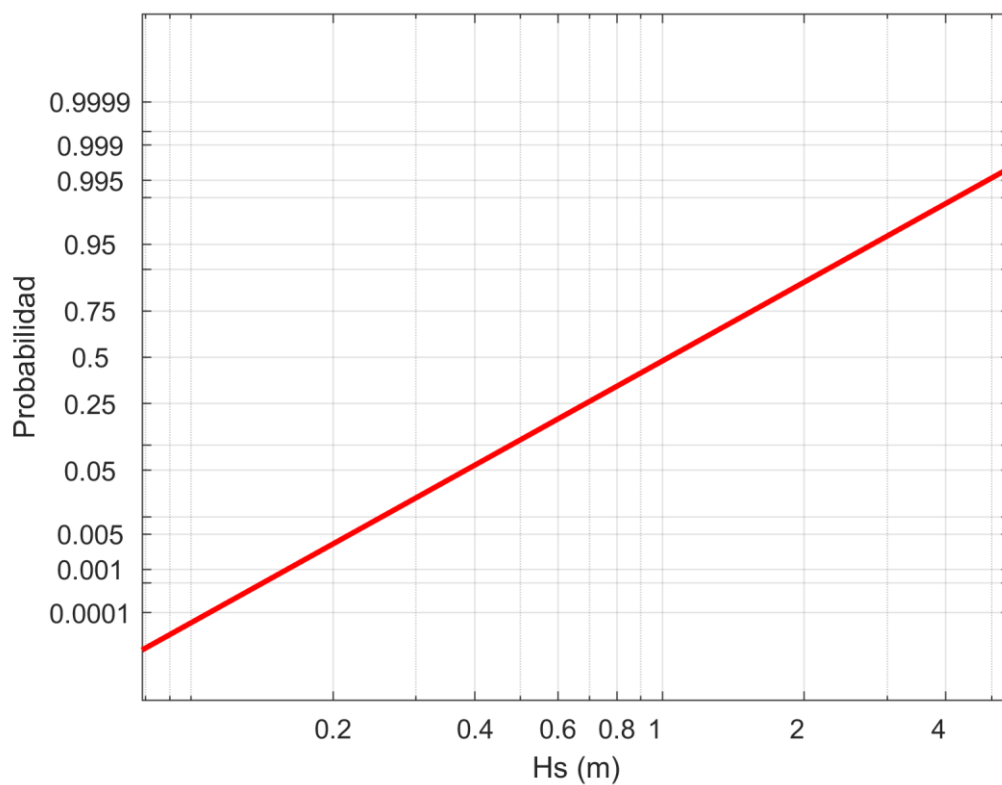


Figure 5. Mean significant height regime.

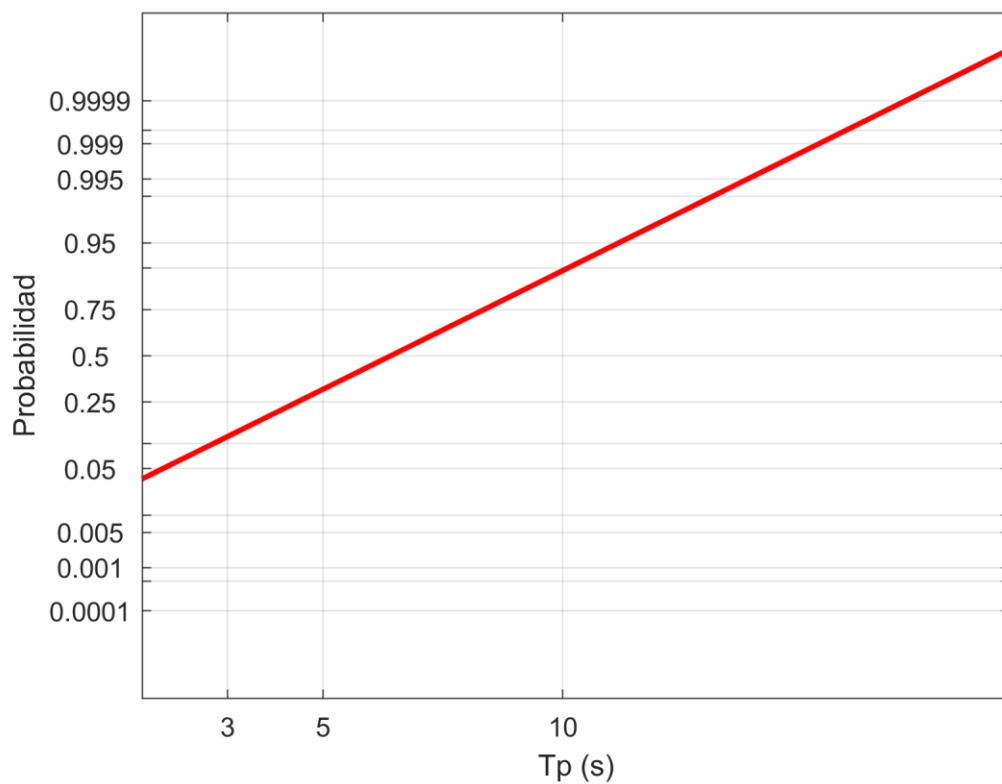


Figure 6. Mean peak period regimen.

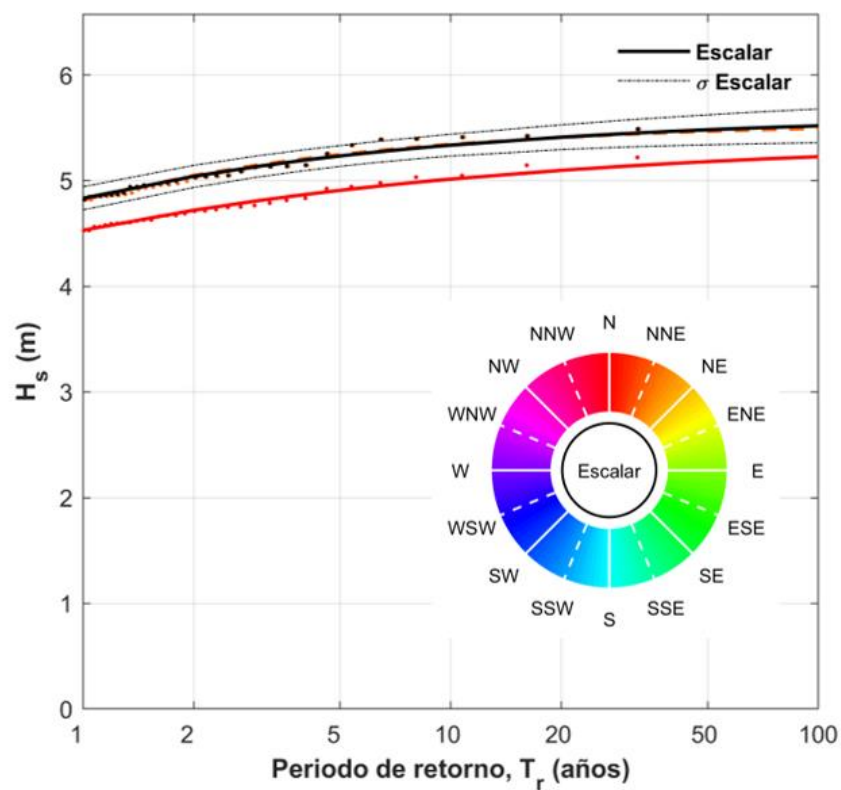


Figure 7. Extreme regime.

Annex II: Summary table TRL (Technology Readiness Levels)

Level	Real-world technology situation	Status of testing and validation technology	Situation of technology with regard to the classic R&D&I scheme (detailed)	Situation of technology with regard to the classic R&D&I scheme
TRL 9	System tested successfully in real environment.	Successful tests in real environment.	Deployment.	Innovation.
TRL 8	Complete and certified system through tests and demonstrations.	Full validation and certification in a real environment.	Marketable product or service. Specific test certifications.	
TRL 7	Demonstration of system or prototype in a real environment.	System validation in a real environment.	Prototype/ Demonstrator. Technological development.	
TRL 6	System or subsystem model or demonstration of prototype in a relevant environment.	Validation of system or subsystem in a relevant environment.		Development.
TRL 5	Component validation and/or their arrangement in a relevant environment.	Component level validation in a relevant environment.		
TRL 4	Component validation and/or their arrangement in the laboratory environment.	Component level validation in the laboratory.		
TRL 3	Analytical and experimental critical function and/or proof of characteristic concept.	Proof of concept.	Proof of concept. Industrial research.	Research.
TRL 2	Concept and/or formulated technological application.	Formulated concept or technology.		
TRL 1	Basic principles observed and reported.	Basic idea.		