Project summary of outcomes and results of Wave Energy in Southern Europe (WESE) project

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WAVE ENERGY IN SOUTHERN EUROPE

PROJECT SUMMARY OF OUTCOMES AND RESULT

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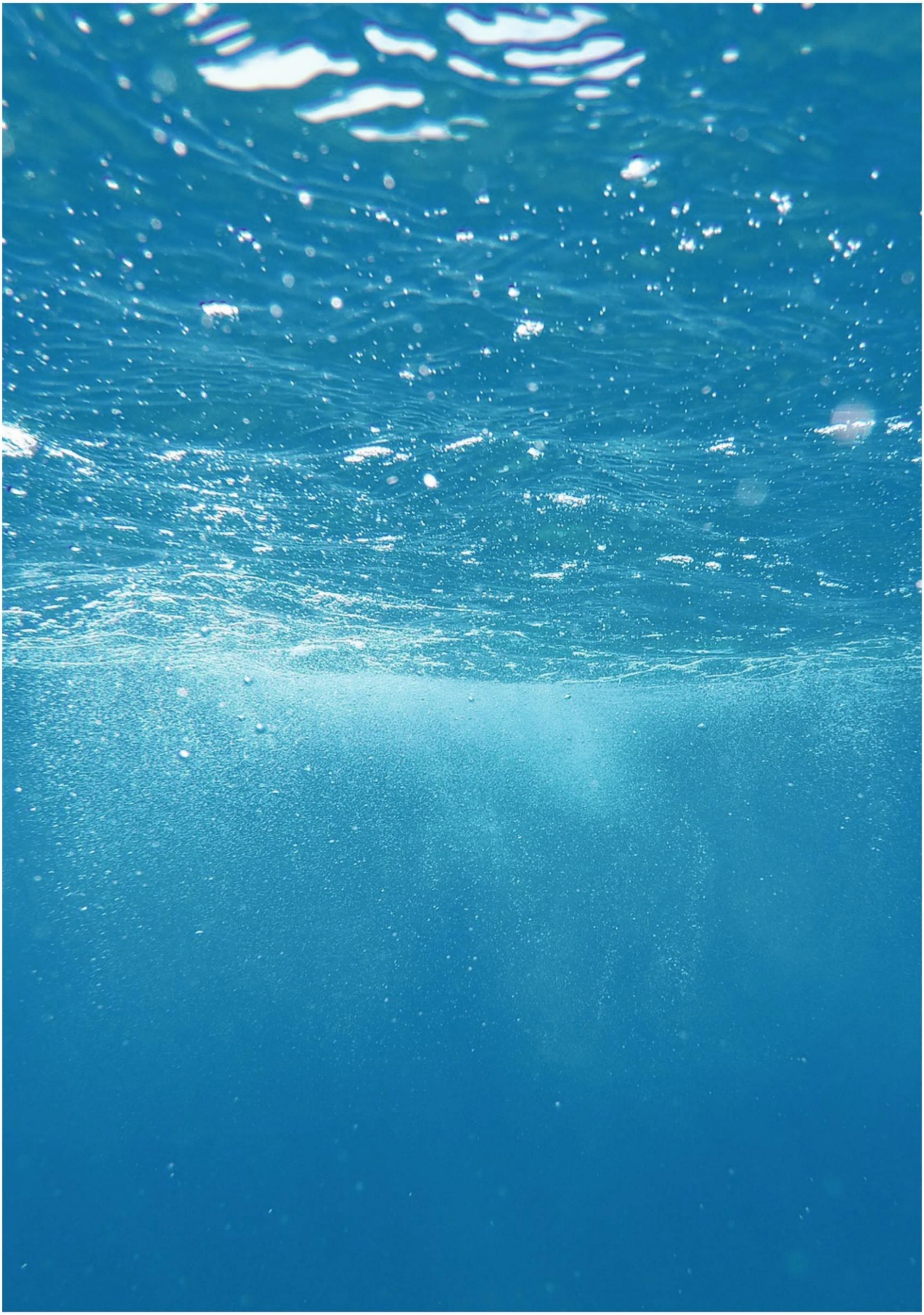

PROJECT SUMMARY OF OUTCOMES AND RESULTS OF THE WAVE ENERGY IN THE SOUTHERN EUROPE (WESE) PROJECT

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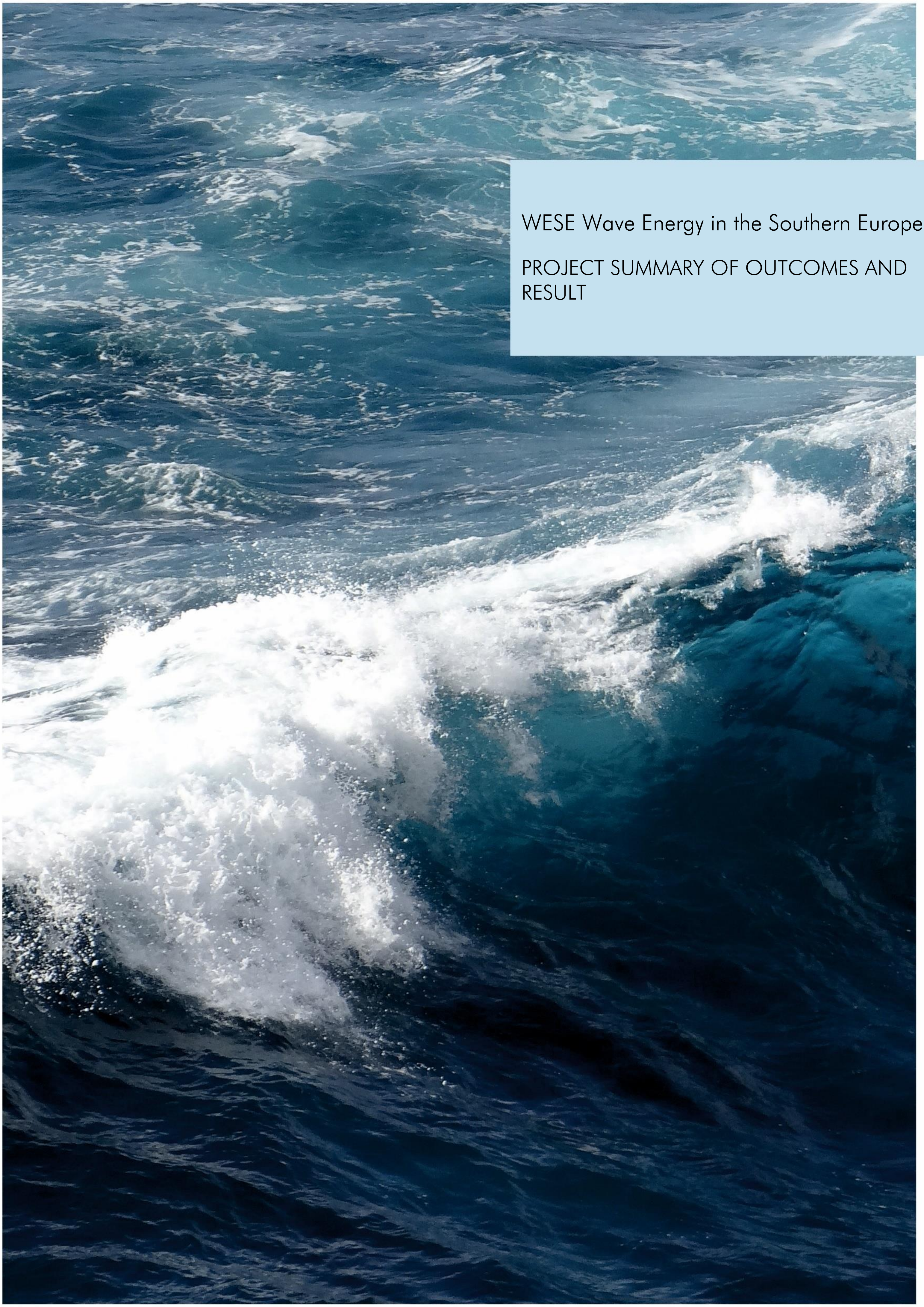

WESE Wave Energy in the Southern Europe

PROJECT SUMMARY OF OUTCOMES AND RESULT

CONTENTS

1. WESE project synopsis

The emerging marine renewable energy (MRE) industry, also known as ocean energy (mostly wave and tidal energy), yields many unknowns about its potential environmental pressures and impacts. Wave energy converters (WECs) are still perceived by regulators and other stakeholders as risky, particularly for some groups of species and habitats. In many cases, this perception of risk is due to the high degree of uncertainty that results from a scarcity of data collected in the ocean as well as lack of differentiating between real and perceived risks. The main non-technical obstacles in the MRE consenting process seem to be the time-consuming procedures linked to uncertainty about environmental impacts, the need to consult with numerous stakeholders, and potential conflicts with other marine users. De-risking environmental consenting (permitting) of wave energy projects has therefore been identified as a key challenge in the development of the MRE industry (Strategic Roadmap "Building Ocean Energy for Europe"). MRE stands as one of the main pillars of the European Union (EU) Blue Growth strategy which notes the need for studies, research, and actions on environmental consenting. In order to move beyond current consenting barriers, the European Commission has provided support to increase such research and reduce uncertainty around the potential environmental impacts of MRE development.

Launched in November 2018 and funded by the EU's European Maritime and Fisheries Fund (EMFF), the WESE project aims to improve the current knowledge on potential environmental effects and risks of wave energy, better inform decision-makers and managers on environmental risks, and reduce environmental consenting uncertainty. The WESE Consortium, led by the RD&I Basque center AZTI, has involved key MRE stakeholders from across Portugal and Spain to accomplish these goals. The multidisciplinary team includes test site owners (BiMEP) device developers (IDOM, AW-Energy), consultants, researchers (WavEC, CTN, AZTI), and data managers (Hidromod). The project finished in October 2021.

The workplan of the project was divided in different work packages devoted to:

1. Environmental monitoring (underwater acoustics, seabed integrity, and electromagnetic fields) around wave energy devices currently operating at sea:
   - Onshore: the Mutriku Oscillating Water Column plant, Basque Country, Spain;
   - Nearshore: the WaveRoller surge technology, under testing in Peniche, Portugal;
   - Offshore: the MARKMOK-A-5 of IDOM, OWC technology installed in BiMEP, Basque Country, Spain.

2. Modelling data for larger arrays (underwater sound propagation, electromagnetic fields, and coastal dynamics);
3. Review and implementation of a risk-based approach on the environmental consenting procedures;
4. Development of Maritime Spatial Planning tools for site selection under a risk-based approach; and
5. Development of a data sharing platform of the results obtained in the project (MARENDATA).

The main outcomes of the project have been the following:

1. A better knowledge of some of the pressures and impacts of wave energy converters through environmental monitoring and modelling;
2. Efficient guidance for environmental consenting procedures in Spain and Portugal;
3. Implementation of innovative Maritime Spatial Planning (MSP) Decision Support Tools (DST) for site selection and suitability maps for future wave energy developments in Portugal and Spain: (i) WEC-ERA tool (Wave Energy Converters Ecological Risk Assessment tool, https://aztidata.es/wec-era/) and VAPEM tool (Ecological Assessment and Marine Spatial Planning Tool, https://aztidata.es/vapem/)
4. A data sharing platform, MARENDATA (https://marendata.eu/) that will serve data providers, developers, and regulators.

2. Objectives

The nascent status of the Marine Renewable Energy (MRE) sector and Wave Energy (WE) in particular, yields many unknowns about its potential environmental pressures and impacts, some of them still far from being completely understood. Wave Energy Converters' (WECs) operation in the marine environment is still perceived by regulators or stakeholders as a risky activity, particularly for some groups of species and habitats. Therefore, de-risking environmental consenting of WE projects has been identified as a key challenge to foster the sector´s development (Ocean Energy Forum, 2016)[1]. Based on current knowledge gaps according to the most recent state of the art review developed by the Annex IV Initiative, under the Ocean Energy Systems (OES) (Copping et al., 2016)[2], corresponding to environmental effects assigning highest risks for the marine environment, different priority areas of research were identified to reduce pressures and impacts evaluation uncertainty. The main goal of the present project is to contribute to increase the current knowledge on these priority research areas to better inform decision-makers and managers on real environmental risks and reduce environmental consenting uncertainty of WE projects across Europe. This main goal was achieved through the following specific objectives:

1. **Work Package 2: Collection, processing, analysis and sharing of environmental data** around wave energy harnessing devices currently operating at sea, to increase the knowledge on positive, negative and negligible environmental impacts of the next priority research areas: (i) risk to marine animals from sound generated by wave devices; (ii) changes in physical systems (seabed integrity); (iii) effects of Electromagnetic Fields (EMF). Within this task we we have developed strategic research to address knowledge gaps regarding the priority research areas above mentioned.
2. **Work Package 3:** Resulting data collection where used to apply and improve existing **modelling tools** and contribute to the overall understanding of potential cumulative impacts of future large-scale wave energy deployments and to the development of mitigation measures;
3. **Work Package 4: Development of country-specific guidance on WE licensing processes**, including recommendations on good practices to streamline the procedures and

[1] Ocean Energy Forum (2016). Ocean Energy Strategic Roadmap 2016, building ocean energy for Europe.

[2] Copping, A., N. Sather, L. Hanna, J. Whiting, G. Zydlewsk, G. Staines, A. Gill, I. Hutchison, A. M. O'hagan, T. Simas, J. Bald, S. C., J. Wood and E. Masden, 2016. Annex IV 2016 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Pacific Northwest National Laboratory on behalf of the U.S. Department of Energy (the Annex IV Operating Agent). 224 pp.

identification of omissions and/or procedures that may require simplification to improve its management and integration. The application of an adaptive and risk-based approach to the consenting process of wave energy projects was studied. Reports that could support authorities' decision making on impacts evaluation, monitoring requirements and monitoring data analysis where produced. This work was carried out in close collaboration with regulators and key stakeholders in each country and with the developers that where part of the project Consortium.

4. **Work Package 5:** Development and implementation of **maritime spatial planning (MSP) Decision Support Tools (DSTs)** for Portugal and Spain for site selection of WE projects. The final objective of such tools will be the identification and selection of suitable areas for WE development for promoters and investors; as well as to support decision makers during the licensing process. These DSTs will consider the previous findings of the project described above (environmental and legal) and integrate the developed risk-based approach. The main output of this task will be to contribute to integrated and evidence-based decision making as an essential process for sustainable, effective and efficient maritime spatial planning (MSP).

5. **Work Package 6:** Development of a **Data Platform** that will serve data providers, developers and regulators. This includes the partners of the project. The WESE Data Platform was made of a number of Information and Communications Technology (ICT) services in order to have: (i) a single Web access point to relevant data (either produced within the project or by others); (ii) generation of Open Geospatial Consortium (OGC) compliant requests to access data via command line (advanced users); (iii) a dedicated cloud server to store frequently used data or data that may not fit in existing Data Portals; and synchronised biological data and environmental parameters in order to feed models automatically.

3. Work progress and achievements

3.1 Collection, processing, analysis and sharing of environmental data

In the WESE project scope, Work Package 2 aimed to collect, process, analyse and share environmental data collected in sites where WECs are operating in real sea conditions in Spanish and Portuguese coastal waters, representing different types of technology, sites and, therefore, types of marine environment (onshore, nearshore and offshore) that can potentially be affected by wave energy projects: (i) Idom-Oceantec MARMOK-A-5, installed in the Biscay Marine Energy Platform (BiMEP) in Spain; (ii) WaveRoller (AW-Energy), installed in Peniche (Portugal) and (iii) Mutriku Wave Power Plant, in operation in Spain.

Data were collected for three of the priority areas of research according to the monitoring plan described in Deliverable 2.1: 1) risk to marine animals from sound generated by wave devices, 2) changes in physical systems (seafloor integrity) and 3) effects of Electromagnetic Fields (EMF) emitted by the energy transfer cables.

- Vinagre P.A., Cruz E., Chainho P., Ruiz P., Felis I., Muxika I., Bald J., 2019. **Deliverable 2.1 Monitoring plans for Noise, Electromagnetic Fields and Seabed Integrity**. Corporate deliverable of the Wave Energy in the Southern Europe (WESE) Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 60 pp. http://dx.doi.org/10.13140/RG.2.2.17431.70562

3.1.1 Electromagnetic Fields (EMF)

For the MARMOK-A-5 device installed at BiMEP, a campaign was performed by MAPPEM Geophysics during the 20th and 21st of May 2019 according to the monitoring plan described in Deliverable 2.1.

In the case of the WaveRoller device in Peniche, Portugal, the installation of the device had started by the end of October 2019 and the monitoring campaigns were planned to be performed in spring-summer 2020 to allow enough deployment time to produce measurable/observable impacts. Due to the COVID outbreak, the expected maintenance works of AW-Energy device were postponed, and for security reasons electricity export from the device was stopped. Consequently, the acquisition of EMF data during the electricity export phase of the device was not possible.

Overall, no EMF signal could be identified as being originated from the MARMOK-A5 cable. The sea conditions were very calm during the survey, and reports from the WEC operation show the power output from the device was small (our estimates account for less than 6kW), with the low emissions possibly being masked by ambient EMF noise (e.g. swell, vessel generator).

- Chainho P., Bald J., 2020. **Deliverable 2.2 Monitoring of Electromagnetic fields**. Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 55 pp. http://dx.doi.org/10.13140/RG.2.2.27498.03526

3.1.2 Underwater Sound

For the MARMOK-A-5 device installed at BiMEP and the Mutriku Wave Power plant, vessel surveys were carried out on the 06-05-2019 and 07-05-2019 respectively according to the monitoring plan described in Deliverable 2.1. During these surveys noise was recorded in different locations during a short period of time (5 minutes). At the same time, a passive acoustic sensor was moored in a specific location for a long time, from the 7th of May of 2019 to the 18th of June of 2019 (that is, continuously for 42 days) in both sites. This way high temporal resolution was achieved and allowed registering variations due to environmental changes in different cycles of operation of the WEC.

In the case of the WaveRoller device, the acquisition of data during the operation phase of the device was not possible.

In general, the contribution of the devices' operation to the ambient soundscape is not very significant. Regarding the MARMOK-A-5 device, the most significant contribution to its surrounding soundscape appears between 40 and 120 Hz, with increments of 14 dB re µPa (H_w<1 m), 13 dB re µPa (1 m≤H_w<2 m) and 6 dB re µPa (H_w>2 m), even though the variability is quite relevant. Other sources of noise, most relevant with high wave heights, are the mooring chains, which can be perceived at frequencies beyond 2500 Hz, with SPL values approximately ranging from 90 (for lower wave heights) to 105 (higher wave heights) dB re 1 µPa. It should be noted that these metrics have been calculated at a distance of 90 m away from the converter.

Regarding the Mutriku Power Plant, there was no clear indication of an increase in the sound pressure levels when the plant is operating, at least at a distance of 1000 m from the plant. As it corresponds to a shallow water environment, the lower frequencies are shown to be filtered out, with higher frequencies being those with more acoustic energy. In any case, the highest difference (between background noise and the sound with the plant working) of sound pressure levels is just about 5 dB re 1 µPa, at 80 Hz, below typical deviations.

- Felis, I., Madrid, E., Álvarez-Castellanos, R., Bald, J., Uriarte, A., Cruz, E., 2020. **Deliverable 2.3 Acoustic Monitoring.** Corporate deliverable of the WESE Project funded

by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 85 pp. http://dx.doi.org/10.13140/RG.2.2.10406.24649

3.1.3 Seafloor integrity

Non-destructive methods were used for seafloor monitoring both in BiMEP and in Peniche: (i) a ROV was used to record videos of the seafloor in the vicinities of the MARMOK-A-5 moorings and chains (and also of the electric cable and the connector) on May 15th and 22th 2019, and at the WaveRoller area on October 17th 2020, including the foundation, the electrical cable, and mooring cables; (ii) in the BiMEP area, a side-scan sonar survey was also undertaken on May 14th 2019 to look for changes in the reflectivity of the seafloor close to the moorings.

For the case of MARMOK-A-5, considering the chains of the four mooring lines and the cable from the converter to the connector, it can be estimated that the area affected by the sections that are moving over the sediment could add up to roughly 250-300 m^2. Considering that the total area occupied by the device (polygon bound by the four anchors and the connector) is approximately 290,000 m^2, the affected area estimated relative to the total occupied area is 0.1%. Regarding the side-scan sonar survey, due to the rough sea conditions, the acquired data did not give a clear image of the seafloor and consequently it was not possible to collect useful data for the analysis of the impact associated to the anchors, mooring lines and umbilical cable. Hence, the assessment based on video recordings using the Remotely Operated Vehicle (ROV) could not be compared with the assessment using acoustic methods.

For the case of the WaveRoller device, according to the interpretation of the recorded videos, the WaveRoller unit seems not be impactful to the seafloor integrity. Three issues worthy to mention are: (i) the mooring and electrical cables were completely lying on the seafloor, the only exception being a small portion of a steel mooring that was found on a rocky substrate/outcrop near the foundation; (ii) also close to the foundation (~1 m from it), a small sand "dune" was found. The "dune" could have been formed by sediments depositing behind the device as a consequence of its presence; (iii) a piece of a synthetic strap found on the seafloor, although possibly insignificant with regards to impacts, it is evidence that wave energy projects as well as any anthropogenically driven activity at sea may represent some type of littering.

- Muxika I., Vinagre P., and Bald, J., 2020. **Deliverable 2.4 Monitoring of seafloor integrity.** Corporate deliverable of the WESE Project funded by the European

Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 59 pp. http://dx.doi.org/10.13140/RG.2.2.28792.52489

Once environmental data were acquired, analysed and processed, an understanding of how this data collection, processing, validation, and reporting to allow comparison among sites was undertaken in the Deliverable 2.6 setting the basis for the establishment of general guidelines for the development of future monitoring plans in Deliverable 2.7.

- Leitão, J.C., Basos, N., Rodrigues, J., Santos, H., 2019. **Deliverable 2.5 Data validation and reporting first upload to the data platform.** Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 19 pp.

- Vinagre P.A., Chainho P., Madrid E., Muxica I., Bald J., 2021. **Deliverable 2.6 Data results and analysis towards impacts evaluation and understanding.** Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 27 pp. http://dx.doi.org/10.13140/RG.2.2.34599.01447

- Bald., J., Vinagre P.A., Chainho P., Madrid E., Muxica I., 2021. **Deliverable 2.7 Guidelines on EMF, noise, and seabed integrity monitoring planning for wave energy devices**. Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 16 pp. http://dx.doi.org/10.13140/RG.2.2.14531.89122

One of the main conclusions is the need to minimise or avoid vessel surveys and to promote monitoring techniques based on autonomous remote sensing devices that are not dependant on sea conditions and are able to cover properly the temporal and spatial resolution of the expected environmental impacts coming from wave energy devices. Signals coming from WECs will be most probably detected when sea conditions are bad, which greatly limits the ability to monitor these with vessel surveys. For underwater acoustics, the mooring of more than one hydrophone in different locations for at least one month is one of the most promising methodologies. For seafloor integrity, visual inspections with ROV are a useful, non-destructive sampling technique but need to be complemented with side-scan sonar images acquired through autonomous and remote sensing devices such as AUVs, in order to avoid the limitations associated to sea conditions and be able to cover a larger area. For EMF, similar to seafloor integrity, remote sensing needs to be promoted through autonomous devices such as AUVs equipped with appropriate sensors. This would allow maintaining an appropriate proximity to cables and avoid the limitations associated to sea conditions.

3.2 Modelling

The aim of the modelling work package was to develop strategic research to address gaps in knowledge to improve modelling of potential cumulative pressures and environmental impacts of future wave energy deployments at larger scale coming from: (i) EMF emitted by subsea power cables; (ii) underwater acoustic fields radiated by the WECs and (iii) energy absorption and impact on marine dynamics.

3.2.1 Electromagnetic fields (EMF)

In general, both case studies, MARMOK-A- in BiMEP and WaveRoller in Peniche, showed small environmental impact derived from EMF. The BiMEP subsea cable serving IDOM device (operating at rated power) showed amplitudes of $|B|=0.40\mu T$ and $|E|=13\ \mu V.m^{-1}$ close to cable surface, with rapid decay to $|B|=0.008\mu T$ and $|E|=2\ \mu V.m^{-1}$ one meter away from the cable.

The Peniche subsea cable serving the Waveroller device (also operating at rated power) showed amplitudes of $|B|=7\mu T$ and $|E|=215\ \mu V.m$^(-1) close to cable surface, with rapid decay to $|B|=0.11\mu T$ and $|E|=29\ \mu V.m^{-1}$. The rather small EMF can be attributed to the small cable currents, or in other words, to the cables being oversized for the power capacity of the devices. Thus, to access the pressure of increasing the number of devices, the EMFs were also estimated for the maximum current capacity of both power cables.

The BiMEP subsea cable operating at its maximum current of 422A (corresponding to 9.6MVA), would produce an estimated EMF level rise up to $|B|=127\mu T$ and $4.2mV\cdot m^{-1}$ near the cable surface and $|B|=2.74\mu T$ and $675\mu V\cdot m^{-1}$ 1 m away from the cable. For the Peniche subsea cable operating at its maximum current of 125A (corresponding to 2.2MVA), the EMF levels would rise to $|B|=37.5\mu T$ and $|E|=1.1mV\cdot m^{-1}$, respectively; and $|B|=0.63\mu T$ and $|E|=150\mu V\cdot m^{-1}$ at a 1 m distance from the cable. The EMF shows an exponential decay with distance, with the computed amplitudes being reduced by at least one order of magnitude at a distance of 1 m from the cable source. Considering the EMF amplitude is linearly proportional to the electric current, the results can be extrapolated for any cable current.

- Chainho P. and Bald J., 2021. **Deliverable 3.1 EMF Modelling**. Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 30 pp. http://dx.doi.org/10.13140/RG.2.2.22464.87049

3.2.2 Underwater Sound

The aim of this task was to model the underwater acoustic fields radiated by the WECs with the support of the results from deliverable D2.3. To achieve this goal, a parabolic equation acoustic propagation model with full range dependence in environment variables (bathymetry, temperature, salinity, and seabed substrate elastic parameters) was implemented for three different frequencies (62.5, 125, and 1000 Hz), several depth levels, ranging from 5 m to 100 m, and different sea states (based on significant wave height).

In the case of the MARMOK-A-5, this device sound emission is most energetic in the 62.5 Hz band, although worse acoustic propagation conditions existed for this case in BiMEP, as the shallow water environment inhibits efficient sound transmission. When considering the depth in which greater overall values of SPL were found, the area of disturbance (for which $SPL_{on} > SPL_{off}$) obtained is 0.9 km^2 for such frequency and wave heights between 0 and 1 m, which is equivalent to a 0.28 km radius circle around the device. This can be viewed as an upper bound to the distance of disturbance around the device. When considering a swarm of 80 identic devices, differences up to a maximum of 50 dB re 1 μPa were found between this and the single device scenario (placed in the centre of the swarm), for the incoherent case. The radial distances (from the centre of the swarm) at which the sound pressure level fields are indistinguishable from the background noise levels are now much greater though, with maximum values for low wave heights (where there is less background noise) and frequencies around 3.4 km.

For the Mutriku wave power plant, the highest acoustic disturbances were found in the 1 kHz band, with maximum values SPL around 110 dB re μPa. When considering the depth in which greater values of SPL are found, the area of disturbance obtained is 15 km^2, for such frequency and wave heights greater than 2 m. In addition, for the depth-averaged SPL field, the maximum distance at which $SPL_{on} > SPL_{off}$ is satisfied is 2593.7 m from the plant. It must be noted (from D2.3) that the uncertainty in the Source Level values is around the calculated difference in SPL, but the analysis did not explicitly consider it; therefore, results for Mutriku are not conclusive.

- Felis, I., Madrid, E., Bald, J., 2021. **Deliverable 3.2 Acoustic Modelling**. Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 57 pp. http://dx.doi.org/10.13140/RG.2.2.11559.68001

3.2.3 Marine Dynamics modelling

In the present study the impact of WEC farms in nearshore morphodynamics was evaluated in two distinct case studies, BiMEP and Peniche. In the first case the hydrodynamics and beach shoreline evolution were studied by means of a probabilistic approach; and in the second case wave and morphodynamic evolution is analysed using a dynamic downscaling methodology. In the first case, the WEC farm studied is composed by 80 WECs deployed at 80m water depth at 4km from the coast in the BiMEP area. The P and Hs reduction produced by the WEC farm is limited and with little effect at the coastline. This is attributed to the long distance at which the WEC farm is located from the coastal zone, which is far enough to significantly reduce the wave shadowing effect that occurs in the vicinity of the WEC farm. The morphodynamic impact is quantified in the only beach of the study site (Bakio beach) where the hydrodynamic impact is limited. Both accretion and erosion magnitudes are considerably low, consequently it could be considered that the WEC farm does not provide any protective effect for the beach.

In the second case study, the impact of an array of 17 bottom-mount Waveroller devices was analysed in terms of energy removed from the system by the devices and its impact on the nearshore morphological evolution. Results show that the WEC array not only removes energy from the system but can also change the shape of the transmitted wave spectrum. Results also indicate that the WEC array offers little protection to extreme wave conditions due to the frequency operation limits of the Waveroller. No significant sediment exchange between long shore areas have been observed.

- De Santiago, I., Moura, T., Chambel, J., Liria, P., and Bald, J., 2020. **Deliverable 3.3 Marine dynamics modelling**. Deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 37 pp. http://dx.doi.org/10.13140/RG.2.2.24981.45283

3.2.4 Acquired knowledge

In Deliverable 3.4 a synthesis of the most significant acquired knowledge in all modelling activities (EMF, underwater acoustics, and marine dynamics) was presented.

- Madrid. E, de Santiago, I., Moura, T., Chainho, P. 2021. **Deliverable 3.4 Synthesis of knowledge acquired and gap analysis**. Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 28 pp.

3.3 Risk and adaptive based consenting for wave energy deployments

The WP4 of the WESE project aimed to develop guidelines for environmental consenting procedures in Spain and Portugal for ocean energy projects based on an environmental risk-based approach and adaptive management processes.

For this purpose, the first task consisted on the development of a database of key stakeholders (more details can be seen in Deliverable 4.1) such as project developers and promoters (license applicants and specialist consultants), policy makers and regulators, consenting and surveying service providers (including technology providers, Environment Impact assessment practitioners, consenting and surveying consultants), energy companies, academic experts (both in science and policy) and representatives of appropriate lobby and pressure groups. A total number of 310 stakeholders were identified belonging to 7 groups, 6 roles and 16 sectors.

- Galparsoro, I., I. Menchaca, M. Apolonia, D. Marina, P. Etxaniz, B. de Miguel and J. Bald, 2019. **Deliverable 4.1 Stakeholder database. Deliverable of the Wave Energy in Southern Europe (WESE) Project funded by the European Commission**. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 48 pp. http://dx.doi.org/10.13140/RG.2.2.18270.56647

The second task of WP4 was the review of national consenting processes in Spain and Portugal and undertaking an introduction to the general considerations of a risk-based approach and AM (more details can be seen in Deliverable 4.2).

- Bald, J., and Apolonia, M., 2020. **Deliverable 4.2 Review of consenting processes for wave energy in Spain and Portugal focusing on risk-based approach and Adaptive Management.** Deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 52 pp. http://dx.doi.org/10.13140/RG.2.2.16209.61281

Once this review was done, the following task was the study of the legal feasibility for the implementation of a risk-based approach and adaptive management (more details can be seen in Deliverable 4.3). For this purpose, two dedicated workshops were held with the Portuguese and Spanish stakeholders identified in the first task, on the 23rd and 24th of June 2020 respectively. Together with a review of the concepts of Adaptative Management, Risk Based approach and Legal and Institutional procedures in Spain and Portugal made in Deliverable 4.2, some conclusions and findings were made: (i) A risk-based approach to survey and consenting is an element of Adaptive Management (AM), which in turn is a structured process that enables learning by doing and adapting based on what is learned.

This is an important process to implement when environmental impact uncertainty exists, to better guide monitoring activities towards risk (and impacts) quantification; (ii) The results of the two workshops held with key stakeholders involved in the consenting process in both countries are presented to support this analysis. Outcomes show the implementation of a risk-based approach could be implemented on two levels: in the legal framework and in the licensing and post-installation operational procedures; (iii) Advancing the use of risk-based approaches for MRE will require the development of mechanisms that minimise financial risks for developers, while assuring adequate protection of the marine environment and receptors, which may require investments by governments to gather data that will assist with large-scale planning and management of marine resources. Additionally, the adoption of such approach requires long term commitment and relies on strong relationships and clear communication from all parties.

- Apolonia, M., Cruz, E., Simas, T., Menchaca, I., Uyarra, M.C. and Bald, J., 2021. **Deliverable 4.3 Feasibility for the implementation of wave energy licensing based on a risk-based approach and adaptive management in Spain and Portugal.** Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 67 pp. http://dx.doi.org/10.13140/RG.2.2.14915.12328

Finally, based on the results of the previous tasks, a guide was developed for Spain and Portugal (more details can be seen in Deliverable 4.4) aimed at describing the various steps of the licensing process of MRE projects to be located in the continental coast.

- Machado, I., Apolonia, M., Menchaca, I., Bald, J. 2021. **Deliverable 4.4. Guidance for a risk based and adaptive management consenting of wave energy projects in Spain and Portugal.** Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 49 pp. http://dx.doi.org/10.13140/RG.2.2.22920.49927

3.4 Development and implementation of maritime spatial planning (MSP) Decision Support Tools (DSTs)

The main objective of this work package was the identification of the most suitable areas for the development and deploying of MRE in the Portuguese and Spanish Atlantic area. For that purpose, dedicated DSTs were developed and implemented to assist in the process of data integration and modelling.

The first activity was to search for geographical information with coverage at a European level about different topics (maritime activities, technical aspects, environmental aspects and legal constrains) through publicly available data sources (EMODnet, Copernicus, DG-MARE's Atlas of the Sea and European Joint Research Centre). It should be noted that the process of generation of relevant information for site suitability has been a continuous process throughout the WESE project. More details can be seen in Deliverable 5.1.

- Galparsoro, I., M. Apolonia, I. Menchaca, O. Solaun, A. Uriarte and J. Bald, 2019. **DELIVERABLE 5.1. Report on available and gathered information**. Corporate deliverable of the Wave Energy in Southern Europe (WESE) Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 18 pp. http://dx.doi.org/10.13140/RG.2.2.10196.53128

In a second step, a Decision Support Tool (DST) for the identification of the most feasible areas for wave energy projects in the context of maritime spatial planning (MSP) was developed and implemented (more details can be seen in Deliverable 5.2).

- Galparsoro, I., A. D. Maldonado, Á. Borja and J. Bald, 2020. **Deliverable 5.2 Development and implementation of a decision support tool for wave energy development in the context of maritime spatial planning.** Corporate deliverable of the Wave Energy in Southern Europe (WESE) Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 43 pp. http://dx.doi.org/10.13140/RG.2.2.23618.30409

The DST is based on a conceptual model which considers the main environmental, technical, and socio-economic factors that could influence the suitability for the establishment of wave energy projects. The conceptual model has been developed considering the Marine Strategy Framework Directive (MSFD) for the integrated consideration of the 16 types of pressures and 27 ecosystem elements that could be affected by such technologies and has been operationalised using the Bayesian Belief Network (BBN) approach.

Two different but complementary tools have been developed. The first one, **WEC-ERA tool (Wave Energy Converters Ecological Risk Assessment tool)**, is an open access web-app that permits the user to assess the ecological risk of WECs: https://aztidata.es/wec-era/. The user can analyse the risks associated to three different wave energy technologies (i.e. OWC, OSWC and Wave Turbine) at their three life-cycle phases (i.e. construction, operation and decommissioning). The assessment is based on the integration of 16 pressure types and 27 ecosystem elements according to the MSFD. The second tool is the **VAPEM tool (Ecological Assessment and Marine Spatial Planning Tool)**. This is a DST which integrates the WEC-ERA information together with the technical and socio-ecological risks linked to wave energy projects, into a Bayesian model. The VAPEM tool is also an open access web-app: https://aztidata.es/vapem/. This tool permits the user to explore predefined scenarios or to generate their own. It provides information on the feasibility of wave energy projects under different technical, environmental, and socio-economic conditions. The outcome of the assessment is also provided as a spatially explicit feasibility map. This tool is described in detail in a dedicated paper:

- Galparsoro, I., M. Korta, I. Subirana, Á. Borja, I. Menchaca, O. Solaun, I. Muxika, G. Iglesias, J. Bald, 2021. **A new framework and tool for ecological risk assessment of wave energy converters projects**. Renewable and Sustainable Energy Reviews, 151: 111539. https://doi.org/10.1016/j.rser.2021.111539

Finally, with the developed tools, a set of 24 maps was created showing the spatial distribution of technical suitability, environmental risks and potential conflicts with other uses and activities in relation to the wave energy sector in the Portuguese and Spanish Exclusive Economic Zones (more details can be seen in Deliverable 5.3).

- Galparsoro, I., G. Mandiola, A. D. Maldonado, S. Pouso, I. de Santiago, R. Garnier, I. Menchaca and J. Bald, 2021. **Deliverable 5.3. Creation of suitability maps for wave energy projects in the context of Maritime Spatial Planning**. Corporate deliverable of the Wave Energy in Southern Europe (WESE) Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 35 pp. http://dx.doi.org/10.13140/RG.2.2.26210.40641

In Portugal and Spain, 17% of the total area was identified as suitable for the development of wave energy projects, while the highly suitable areas account for just 0.2% of the area. Almost half of the region is not suitable due to technical restrictions (45.9%). The areas limited by environmental risks are representing 5.3% of the study area, while the areas that would be excluded for the development of wave energy projects due to the presence of excluding human activities or underwater infrastructures are just 0.9% of the study area. The approach implemented also allows the identification of areas that are presenting combined restrictions for the development of wave energy projects. In that sense, the combination of environmental and technical restrictions is present in 18.1% of the area, uses and technical restrictions in 7.5%, and uses and environmental restrictions in 0.3% of the area. All types of restrictions are identified for 4.7% of the study area.

3.5 MARENDATA

Closely related with the tasks undertaken in WP2, a Data Platform for sharing all the environmental data acquired during the life of the project was developed. This data platform serves data providers, developers and regulators. The Data Platform´s name is MARENDATA (https://marendata.eu/) and it is made of a number of ICT services: (i) a single Web access point to relevant data based on Hidromod's AQUASAFE software; (ii) generation of requests to access data via command line (advanced users); (iii) a dedicated cloud server to store frequently used data or data that may not fit in existing Data Portals and (iv) synchronised collected data and modelled environmental parameters in order to feed EIA methodologies.

First, the concepts of data platform and data management were explored and explained in Deliverable 6.1. The second task was to understand and define: (i) the concept of metadata adopted by the WESE data platform, following the INSPIRE data specification template in its relevant parts, i.e., dataset-level, services metadata and data quality (Deliverable 6.2) and (ii) the types of secondary data (results, reports and post-processed primary data) and how they are to be generated and delivered to the user by the platform (Deliverable 6.3).

- Leitão, J.C., Santos, H., Galvão, P. and J. Bald, 2019. **Deliverable 6.1 Conceptual Data Platform**. Deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 24 pp. http://dx.doi.org/10.13140/RG.2.2.30329.19045

- Leitão, J.C., Santos, H., Galvão, P., and Bald, J., 2019. **Deliverable 6.2. Primary data structure**. Deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 17 pp. http://dx.doi.org/10.13140/RG.2.2.26973.74729

- Leitão, J.C., Moura, T., Leitão, P.C., Bald, J., Liria, P., Cruz, E., Vinagre, P., Felis, I., 2019. **Deliverable 6.3. Secondary data structure**. Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 35 pp. http://dx.doi.org/10.13140/RG.2.2.33684.63364

Then the design of the platform, how the user will interact with the platform and the services of the platform were developed in Deliverable 6.4. and 6.5 respectively.

- Leitão, J.C., Moitinho, L., Basos, N., Santos, H., 2019. **Deliverable 6.4 Design of the Data Platform.** Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 15 pp.

- Leitão, J.C., Moitinho, L., Basos, N., Santos, H., 2020. **Deliverable 6.5 Data Services.** Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 17 pp.

Finally, the developed MARENDATA data platform was updated and improved through the life of the project in successive moments (months 15, 24 and 36) incorporating new capabilities and services to the data platform (more details can be seen in Deliverable 6.6).

- Leitão, J.C., Moitinho, L., Basos, N., Santos, H., 2019. **Deliverable 6.6 Data Platform (month 15)**. Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 15 pp.

- Leitão, J.C., Moitinho, L., Cardoso, S., Santos, H., 2020. **Deliverable 6.6 Data Platform (month 24).** Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 22 pp.

- Leitão, J.C., Moitinho, L., Cardoso, S., Santos, H., 2021. **Deliverable 6.6 Data Platform (Month 36).** Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 33 pp

4. Dissemination and communication activities

4.1 Project Website and social media

The website of the project was launched in December 2018 at http://wese-project.eu/, and Twitter (https://twitter.com/WeseProject), LinkedIn (https://www.linkedin.com/groups/12192196/) and Research Gate (https://www.researchgate.net/project/Wave-Energy-in-the-Southern-Europe-WESE) accounts were launched to disseminate project milestones, announcements of project publications, participation in external events, dates of workshops and all other relevant news related with the project development.

4.2 Press releases

Four press releases have been made during the life of the project: (i) **Press release 1**: Distributed on 20th February 2019 to announce the project launch and website and present the objectives of the project throughout its duration (from November 2018 until October 2021); (ii) **Press release 2**: Distributed on 5th June 2019 to communicate another milestone of the project: the start of environmental monitoring activities around wave energy converters in BiMEP and Mutriku; (iii) **Press release 3**: Distributed on the 9th March 2020 to communicate the launch of the WESE & SEA Wave MARENDATA platform for ocean energy data sharing; (iv) **Press release 4**: Distributed on the 22nd December 2020 to announce the monitoring campaigns in Peniche, Portugal.

4.3 Other Media

During the life of the project different publications of the project findings have been made in different media such as the (i) European Commission Website; (ii) MarineEnergy.biz website[3,4]; (iii) SETIS Magazine of the European Commission; (iv) Renewable Energy Magazine[5]; (v) Maritime Journal[6]; (vi) Tethys Stories supported by the Annex IV of the International Energy Agency[7] (IEA) Ocean Energy Systems (OES).

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[3] https://www.offshore-energy.biz/wese-project-addresses-wave-energy-environmental-concerns/?uid=1982&emarkconv=997F94F1031F1432051016F1982F383719299F289626
[4] https://www.offshore-energy.biz/wese-project-completes-bimep-and-mutriku-sites-monitoring/
[5] https://www.renewableenergymagazine.com/ocean_energy/sea-wave-and-wese-launch-ocean-energy-20200309
[6] https://www.maritimejournal.com/eu-projects-tackle-barriers-to-wave-energy-development/1374146.article
[7] https://tethys.pnnl.gov/stories/european-unions-efforts-understanding-environmental-impacts-wave-energy-devices

4.4 Poster presentations

Nine poster presentations were done in different conferences in the V Marine Energy Conference on the 13th November 2018 in Bilbao (Spain), IV Marine Energy Week Congress on the 13th February 2019 in Bilbao (Spain) and EWTEC21 Conference, Plymouth (UK), 5-9 September 2021:

- Bald, J., Simas, T., Torre-Enciso, Y., Marina, D., Etxaniz, P., De Miguel, B., Mäki, T., Chambel, J.L., 2018. **Wave Energy in the Southern Europe (WESE)**. Poster presentation in the V Marine Energy Conference. November 13th Bilbao. 2018. http://dx.doi.org/10.13140/RG.2.2.27580.80006

- Bald, J., Simas, T., Torre-Enciso, Y., Marina, D., Etxaniz, P., De Miguel, B., Cervantes, P, Ruiz, P., Mäki, T., Chambel, J.L., 2019. **Wave Energy in the Southern Europe (WESE)**. Poster presentation in the IV Marine Energy Week. Bilbao, 12-14 February 2019. http://dx.doi.org/10.13140/RG.2.2.18341.35047

- Bald, J., Galparsoro, I., Menchaca, I., De Santiago, I., Uriarte, A., Uyarra, M.C., Pouso, S., Muxika, I.,Cruz, E., Apolonia, M., Vinagre, P., Chainho, P., Machado, I., Torre-Enciso, Y., Marina, D., Etxaniz, P., De Miguel, B., Felis, I., Madrid, E., P., Leitao, J.C., Cardoso, S., Moitinho, L., Santos, E., Bartolomeu, S., Moura, T., 2021. **Wave Energy in the Southern Europe (WESE)**. Poster presentation in the EWTEC21 Conference, Plymouth (UK), 5-9 September 2021. http://dx.doi.org/10.13140/RG.2.2.32111.76960

- Vinagre, P., Cruz, E., Chainho, P., Madrid, E., Felis, I., Muxika., I. and Bald, J., 2021. **WP2: Environmental Monitoring**. Poster presentation in the EWTEC21 Conference, Plymouth (UK), 5-9 September 2021. http://dx.doi.org/10.13140/RG.2.2.27917.46569

- Madrid, E., Felis, I., Bald, J., de Santiago, I., Liria, P., Chainho, P., Moura, T., Chambel Leitao, J., 2021. **WP3 - Environmental modelling**. Poster presentation in the EWTEC21 Conference, Plymouth (UK), 5-9 September 2021. http://dx.doi.org/10.13140/RG.2.2.34628.35203

- Apolonia, M., Menchaca, I., Cruz, E., Machado, I., Uyarra, M.C., Bald, J., 2021. **WP4. CONSENTING PROCESSES OF MRE PROJECTS**. Poster presentation in the EWTEC21 Conference, Plymouth (UK), 5-9 September 2021. http://dx.doi.org/10.13140/RG.2.2.19528.85765

- Galparsoro, I., M. Korta, I. Subirana, Á. Borja, I. Menchaca, O. Solaun, I. Muxika, G. Iglesias and J. Bald, 2021. **A new framework and tool for ecological risk assessment of wave energy converters projects**. Poster presentation in the EWTEC21 Conference, Plymouth (UK), 5-9 September 2021. http://dx.doi.org/10.13140/RG.2.2.15422.61762

- Galparsoro, I., A.D. Maldonado, I. de Santiago, R. Garnier, G. Mandiola, S. Pouso and J. Bald, 2021. **Offshore wave energy farms site identification in the framework of ecosystem-based marine spatial planning**. Poster presentation in the EWTEC21 Conference, Plymouth (UK), 5-9 September 2021. http://dx.doi.org/10.13140/RG.2.2.20455.78249

- Leitao, J.C., Cardoso, S., Moitinho, L., Santos, E., Bald, J., Galparsoro, I., Menchaca, I., De Santiago, I., Uriarte, A., Uyarra, M.C., Pouso, S., Muxika, I., Cruz, E., Apolonia, M., Vinagre, P., Chainho, P., Machado, I., Torre-Enciso, Y., Marina, D., Etxaniz, P., De Miguel, B., Felis, I., Madrid, E., P., 2021. WP6 – Data Platform - MARENDATA. Poster presentation in the EWTEC21 Conference, Plymouth (UK), 5-9 September 2021. http://dx.doi.org/10.13140/RG.2.2.22884.30081

4.5 Oral presentations

Oral presentations about the WESE project and results of different WPs were done in: (i) OES-Environmental & ORJIP International Forum #3: Updates on Monitoring and Research Around Wave Devices celebrated on the 23rd April 2020; (ii) Sectoral Forum on Wave Energy of the Basque Energy Cluster on the 5th November 2020; (iii) Understanding the Environment" organised by the Faculties of Science, and Economics and Business Administration of the University of Navarra in Pamplona (Spain); (iv) Sea Journeys II", a marine biology congress organised by the AEICBAS (Student Association of Abel Salazar Biomedical Science Institute, University of Porto); (v) webinar of ETIP Ocean 2 project about environmental monitoring solutions for ocean energy, on the 19th of May of 2020; (vi) webinar of ETIP Ocean 2 project about Best consenting practices for ocean energy, on the15th December 2020; (vii) webinar of ETIP Ocean 2 project about Environmental Toolkits for Consenting Ocean Energy, on the 13th December 2021; (viii) Ocean Energy Europe on the 7th December 2021.

- Bald, J., Simas, T., Felis, I., Cruz, E., 2020. **Environmental Monitoring of underwater noise around wave devices in the framework of the WESE project**. OES-Environmental & ORJIP International Forum #3: Updates on Monitoring and Research Around Wave

Devices celebrated on the 23rd April 2020[8]. http://dx.doi.org/10.13140/RG.2.2.10078.56649

- Bald, J., Galparsoro, I., Menchaca, I., De Santiago, I., 1Uriarte, A. Cruz, E., Torre-Enciso, Y., Marina, D., Etxaniz, P., De Miguel, B., Felis, I., Madrid, E., P., Leitao, J.C., 2020. **Esfuerzos de la UE para comprender los impactos ambientales de los dispositivos de energía de las olas Proyecto WESE.** Sectoral Forum on Wave Energy of the Basque Energy Cluster on the 5th November 2020. http://dx.doi.org/10.13140/RG.2.2.36764.82569

- Menchaca, I., Bald., J., Cruz, E. and Apolonia, M., 2020. Is it possible to incorporate Adaptive Management based on risk analysis in the approval procedures of marine renewable energy projects? Webinar of ETIP Ocean 2 project about Best consenting practices for ocean energy, on the 15th December 2020. http://dx.doi.org/10.13140/RG.2.2.33409.38240

- Bald., 2021. **NUEVOS DESARROLLOS EN EL MEDIO MARINO ENERGÍAS RENOVABLES MARINAS.** Course "Understanding the Environment" organized by the Faculties of Science, and Economics and Business Administration of the University of Navarra in Pamplona (Spain). http://dx.doi.org/10.13140/RG.2.2.23497.21602.

- Vinagre, P., 2021. **Environmental monitoring in the context of MRE projects in Portugal**. Sea Journeys II", a marine biology congress organized by the AEICBAS (Student Association of Abel Salazar Biomedical Science Institute, University of Porto).

- Galparsoro, I. and Bald., J., 2021. **Development of models and tools for the identification of the most suitable areas for the development and deploying of wave energy projects**. Webinar of ETIP Ocean 2 project about Environmental Toolkits for Consenting Ocean Energy, on the 13th December 2021. http://dx.doi.org/10.13140/RG.2.2.11753.16480

- Bald, J., Galparsoro, I., Menchaca, I., De Santiago, I., Uriarte, A., M.C. Uyarra, S. Pouso, I. Muxika, Cruz, E., Torre-Enciso, Y., Marina, D., Etxaniz, P., De Miguel, B., Felis, I., Madrid, E., P., Leitao, J.C., Pech, M., Nyman, N.J.C., 2021. **Environmental Monitoring.** Ocean Energy Europe on the 7th December 2021. http://dx.doi.org/10.13140/RG.2.2.33566.66885

[8] https://tethys.pnnl.gov/events/oes-environmental-orjip-international-forum-3-updates-monitoring-research-around-wave-energy

4.6 Final Event

The final event of the project aimed at sharing and discussing the results of the projects with key relevant stakeholders in the field of wave energies, specifically scientists, developers, and policy and decision makers.

To this end, two events were organised:

a) The first event was organised in the context of the EWTEC conference (European Wave and Tidal Energy Conference), in Plymouth (UK) between the 6 and 10 of September 2021. The participation was mainly from researchers/academia and developers, who attended both physically and online.

b) The second event was celebrated on the on the 28th of October 2021 fully online and attendees were again mainly developers, researchers/academia, but also policy/decision makers, NGOs and consultants attended.

It is considered that the two complementary Final events allowed for a good participation of relevant stakeholders and, therefore, dissemination of the results of WESE project and gathering important feedback that will be considered in the ongoing EU funded project SafeWAVE and other projects.

In total, 50 and 71 people registered for the hybrid and online events, of which 26 and 36 attended each event (excluding the people from the project), respectively. Therefore, approximately 50% of those showing interest in attending have joined the event. Attendees to the online event (this information was not available for the hybrid event) were from 11 European countries (e.g., Spain, Greece, Italy, Belgium, UK, Norway). People registered from other countries, such as USA, Canada, Vietnam, and Singapore, but did not join the event, possibly due to time differences. The attendees were from different professional sectors, having a higher representation of industry/developers (43%) and research/academia (37%), followed by policy makers/advisory public bodies (13%), NGOs (3%), and consultancy (3%).

- Uyarra, M.C, Menchaca, I., Pouso, S., Bald, J., Uriarte, A., Galparsoro, I., de Santiago, I., Madrid, E., Vinagre, P., Machado, I., Apolonia, M., Chambel, J. 2021. Deliverable 7.5 Project final event. Corporate deliverable of the WESE Project funded by the European Commission. Agreement number EASME/EMFF/2017/1.2.1.1/02/SI2.787640. 28 pp + Appendixes. http://dx.doi.org/10.13140/RG.2.2.16144.07689

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