WESE

WAVE ENERGY IN SOUTHERN EUROPE

DELIVERABLE 5.3

Creation of suitability maps for wave energy projects in the context of Maritime Spatial Planning

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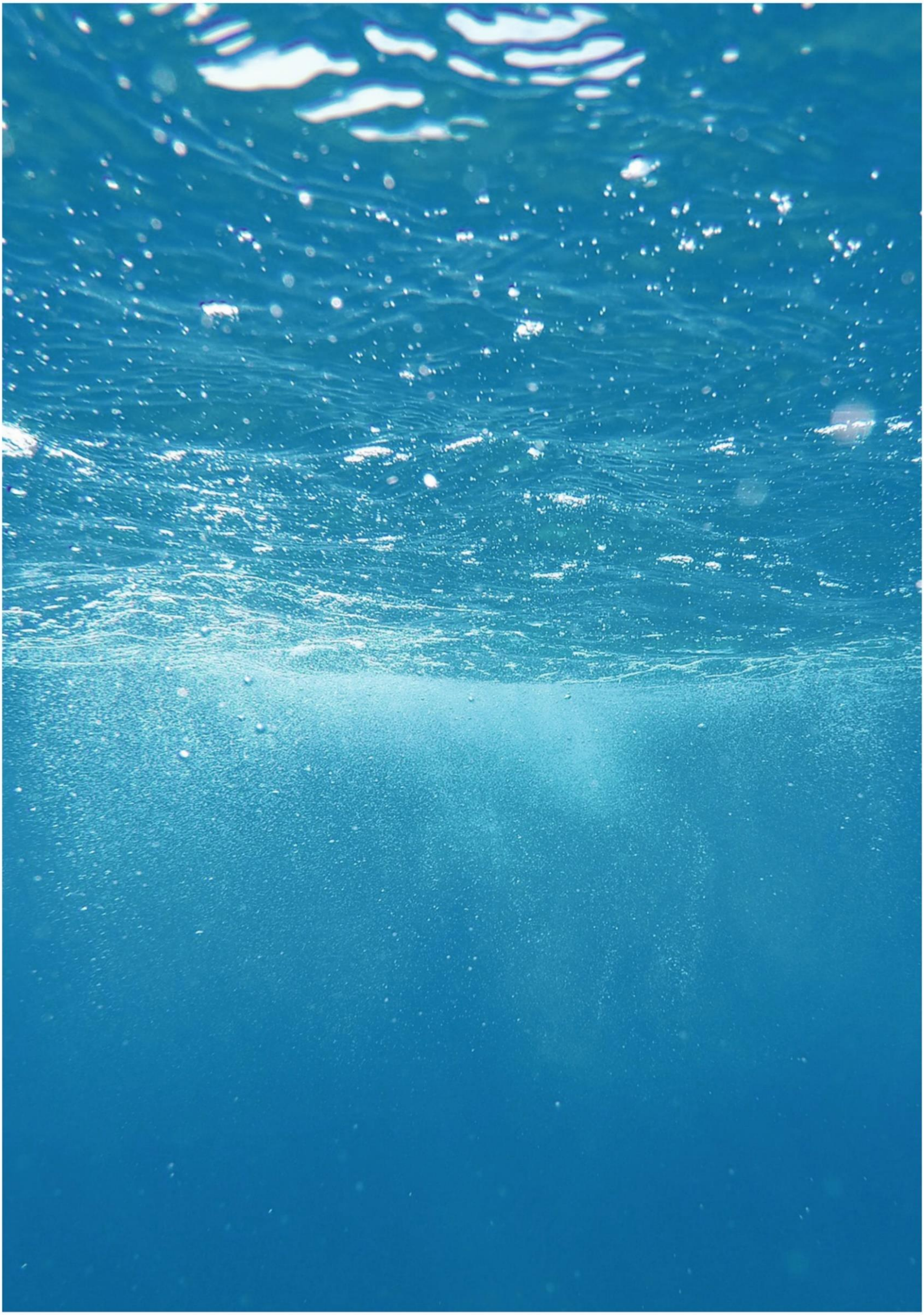

WP 5

DELIVERABLE 5.3. Creation of suitability maps for wave energy projects in the context of Maritime Spatial Planning

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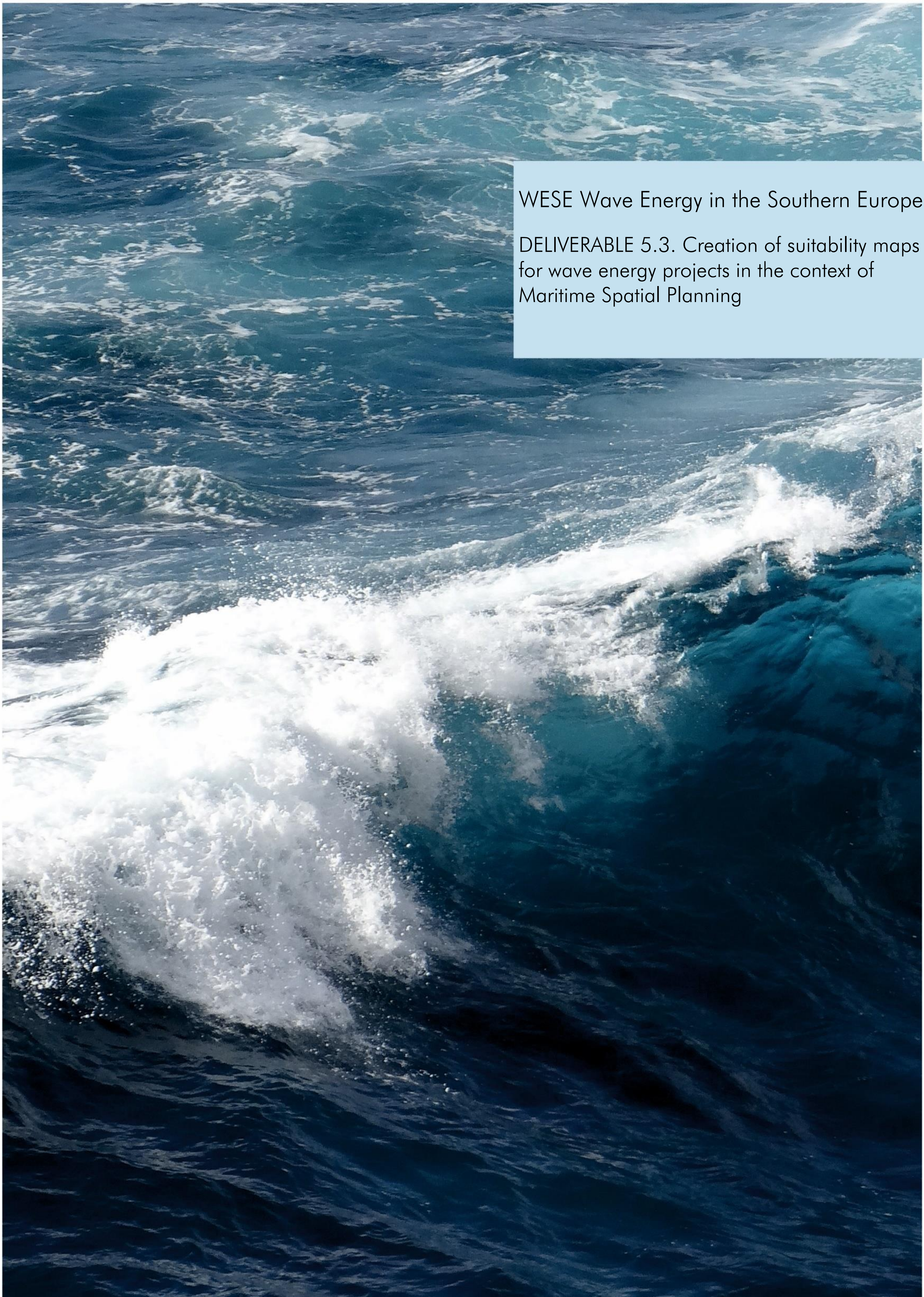

WESE Wave Energy in the Southern Europe

DELIVERABLE 5.3. Creation of suitability maps for wave energy projects in the context of Maritime Spatial Planning

CONTENTS

1. WESE project synopsis

The Atlantic seaboard offers a vast marine renewable energy (MRE) resource which is still far from being fully exploited. These resources include offshore wind, wave, and tidal energies. This industrial activity holds considerable potential for enhancing the diversity of energy sources, reducing greenhouse gas emissions, and stimulating and diversifying the economies of coastal communities. Therefore, the ocean energy development is one of the main pillars of the EU Blue Growth strategy. While the technological development of devices is growing fast, their potential environmental effects are not well-known. In a new industry like MRE, and in the Wave Energy (WE) sector, in particular, there may be interactions between devices and marine organisms or habitats, that regulators or stakeholders perceive as risky. In many instances, this perception of risk is due to the high degree of uncertainty that results from a paucity of data collected in the ocean. However, the possibility of real risk to marine organisms or habitats cannot be ignored; the lack of data continues to confound our ability to differentiate between real and perceived risks. Due to the present and future demand for renewable energy, marine resources and space, human activities in the marine environment are expected to increase, which will produce higher pressures on marine ecosystems, as well as competition and conflicts among marine users. This scenario poses several challenges to permitting/consenting of commercial-scale development of these activities. Time-consuming procedures linked to uncertainty about project environmental impacts, the need to consult with numerous stakeholders and potential conflicts with other marine users appear to be the main obstacles to consenting WE projects. These are considered as non-technological barriers that could hinder the future development of WE in EU. This is the case of Spain and Portugal were, for instance, consenting approaches remain fragmented and sequential. Consequently, and in accordance with the Ocean Energy Strategic Roadmap, published in November 2016, the main aim of WESE project consists of overcoming these non-technological barriers through the following specific objectives:

- Development of environmental monitoring around wave energy converters (WECs) operating at sea, to analyse, share and improve the knowledge of the positive and negative environmental pressures and impacts of these technologies and consequently a better knowledge of real risks.
- The resulting data collection will be used to apply and improve existing modelling tools and contribute to the overall understanding of potential cumulative pressures and impacts of larger scale, and future, wave energy deployments.

- Development of efficient guidance for planning and consenting procedures in Spain and Portugal for WE projects, to better inform decision-makers and managers on environmental real risks and reduce environmental consenting uncertainty of ocean WE, introducing the Risk Based Approach suggested by RiCORE, a Horizon 2020 project, which underlines the difficulties for developers with an existing fragmented and sequential consenting approach in these countries;
- Development and implementation of innovative 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, as well as to support decision makers and developers during the licensing process. These DSTs will consider previous findings (both environmental and legal, found in RiCORE) and the new knowledge acquired in WESE in order to support the development of the risk-based approach mentioned in the previous bullet point);
- Development of a Data Sharing Platform to be used by data providers, developers, and regulators. This includes the partners of the project. WESE Data Platform will be made of a number of 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 (iv) synchronized biological data and environmental parameters in order to feed models automatically.

2. Executive summary

The main objective of WP5 is the identification of the most suitable areas for the development and deploying of wave energy projects in the Portuguese and Spanish Atlantic area. Suitability maps contribute to a more efficient planning of future wave energy deployments. For that purpose, in a first phase publicly available information that could be of relevance for the assessment of suitable areas for the establishment of wave energy convertors facilities was identified (Galparsoro *et al.*, 2019). In a second phase, a conceptual framework which considers the main environmental, technical, and socio-economic factors that could influence the suitability for the establishment of wave energy projects was developed. Afterwards, the conceptual framework was operationalised into a Bayesian Belief Networks (BBNs) model, able to create suitability maps, meanwhile GIS tools were used for input data preparation. Finally, the model was implemented into a Decision Support Tool (DST) to assist in the process of production of suitability maps and the creation of management scenarios (Galparsoro *et al.*, 2020).

The present report corresponds to Deliverable 5.3. dedicated to the creation of suitability maps for wave energy projects in the context of Maritime Spatial Planning. The maps have been produced using the site identification Bayesian Belief model implemented into the VAPEM tool (https://aztidata.es/vapem/) which was developed in Task 5.2 of the WESE project and it is described in detail in Galparsoro *et al.* (2020).

A set of 24 maps are presented in the present deliverable, which are showing the spatial distribution of technical suitability, environmental risks and potential conflicts with other uses and activities in relation to offshore wave energy sector in the Portuguese and Spanish Exclusive Economic Zones. The maps are presented for six regions (i.e., Azores, Madeira and Canary Islands, Portugal mainland and southern Spanish coast, northern Spanish Atlantic coast, and Spanish Mediterranean region).

In the Portuguese and Spanish, 17% of the total area has been identified as suitable for the development of wave energy projects, while the highly suitable areas, go down up to just 0.2% of the area. Still almost half of the region is not suitable due to technical restrictions (45.9%). This is because the large extent of deep areas, limited number of good weather windows for maintenance operations in the Atlantic area together with the distance to electric substations for the evacuation of the produced electricity. 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 are 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 type of restrictions are identified for 4.7% of the study area.

The maps representing the distribution of suitability areas for the development of wave energy projects are intended to be easily understood and interpreted by different kind of stakeholders. It is especially useful for managers and decision makers, but also for the industry or other kind of stakeholders, to inform about different options of development of wave energy projects under Maritime Spatial Planning context. The model and resulting maps could still be improved based on the comments and inputs that might be received when presenting the results to different end-users. It could be expected that the wave energy projects to be developed in the suitable areas identified by these decision support tools of MSP under this risk-based approach will suffer a more straightforward consenting procedure (Apolonia *et al.*, 2021), this is, during the Strategic Environmental Assessment and Environmental Impact Assessment, the environmental risks assessment will be easier identified, facilitating the decision taken by managers and policy makers.

3. Introduction

The European Green Deal (European Commission, 2019) aims EU to be climate-neutral by 2050, with a share of marine renewables of at least 32% of the EU's gross final energy consumption by 2030 (European Commission, 2020b), making ocean energy a pillar of both the Green Deal and the Sustainable Blue Economy (European Commission, 2021). The European Commission adopted the European offshore renewable energy strategy (European Commission, 2020a) to give a strategic direction for the ambitious development and integration of this type of energy by 2030 and 2050. According to the offshore renewable energy strategy the achievement of the ocean energy production objectives will require a scale up of the offshore wind industry, which is estimated to require less than 3% of the European maritime space (European Commission, 2020a). No estimation is provided for wave energy or other sources due to their incipient stage of development and associated uncertainties.

When identifying suitable areas for the development and deploying WEC projects, it is important to balance the WEC siting requirements together with other environmental and socio economic factors (Azzellino et al., 2013; Galparsoro et al., 2012; Quero García et al., 2020), to avoid environmental risks (Galparsoro *et al.*, 2021) and potential conflicts with other maritime uses and sectors. That requires the analysis and organisation of human activities in marine areas; i.e. Maritime Spatial Plans (Directive 2014/89/EU). For that purpose models and tools support and inform decision makers and industry in the process of allocating marine activities (Pınarbaşı *et al.*, 2019; Pınarbaşı *et al.*, 2017). One of the main strength of models and tools is their capacity of integrating spatially and temporally explicit data of the environmental, and socioeconomic factors needed to be considered when managing new strategic activities in the context of the existing activities.

One of the main outputs of such models and tools are maps. The maps are the graphical representation of information and can be easily understood and interpreted by different profiles of stakeholders. In the context of Maritime Spatial Planning they are used to represent the spatial distribution of existing uses or the spatial distribution of sensitive species and habitats that should be avoided when allocating marine uses. Maps can be also used to delineate preferential locations for a certain sector development according to a number of criteria. This is the case for wave energy sector, for which maps can be produced by the implementation of models that consider the most relevant factors influencing suitability for wave energy deployment.

4. Objectives

The main objective of the present deliverable is the provision of suitability maps for wave energy projects in the context of Maritime Spatial Planning in the Portuguese and Spanish Atlantic area.

For that purpose, specific objectives were defined:

1. Use the Bayesian Belief model implemented in the VAPEM tool (https://aztidata.es/vapem/) which was developed in Task 5.2 for the production of maps.

2. Definition of six regions in the Portuguese and Spanish Exclusive Economic Zones: Azores, Madeira and Canary Islands, Portugal mainland and southern Spanish coast, northern Spanish Atlantic coast, and Spanish Mediterranean region.

3. Production of maps representing the technical suitability, environmental risks, conflicts with other uses and activities and integrated suitability.

5. Suitability maps for wave energy projects in the context of Maritime Spatial Planning

The maps that are presented in this section have been produced using the wave energy project suitability model implemented in the VAPEM tool (https://aztidata.es/vapem/) (Figure 1) which was developed in Task 5.2 of the WESE project and it is described in detail in Galparsoro *et al.* (2020).

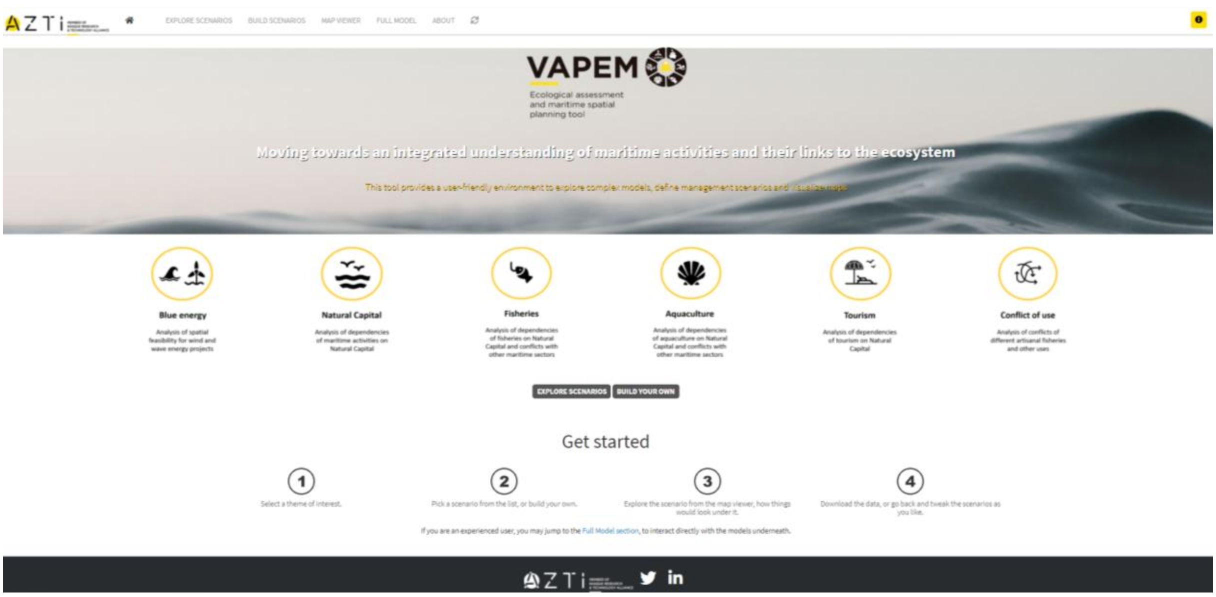

Figure 1. Landing page of the VAPEM tool where the user can select the marine sector or the model that wants to run (https://aztidata.es/vapem/).

When the integrated wave energy suitability model and the current status scenario is selected the model is run and the resulting map is presented in the Map Viewer screen (Figure 2). The user can interactively visualise and navigate within the integrated suitability map. The map allows zoom in, zoom out or moving around for a detailed view of an area of interest. The resulting map is provided at 1 km^2 resolution, which is more than enough for a first area identification. The user can also see the geographical coordinates of the cursor when moving in the map. When clicking in a certain location, specific information of that location is provided below the map.

The suitability map appearance can be customized and can be downloaded as a georeferenced raster (geoTIFF format) for its detailed analysis or integration with other information layers in desktop GIS.

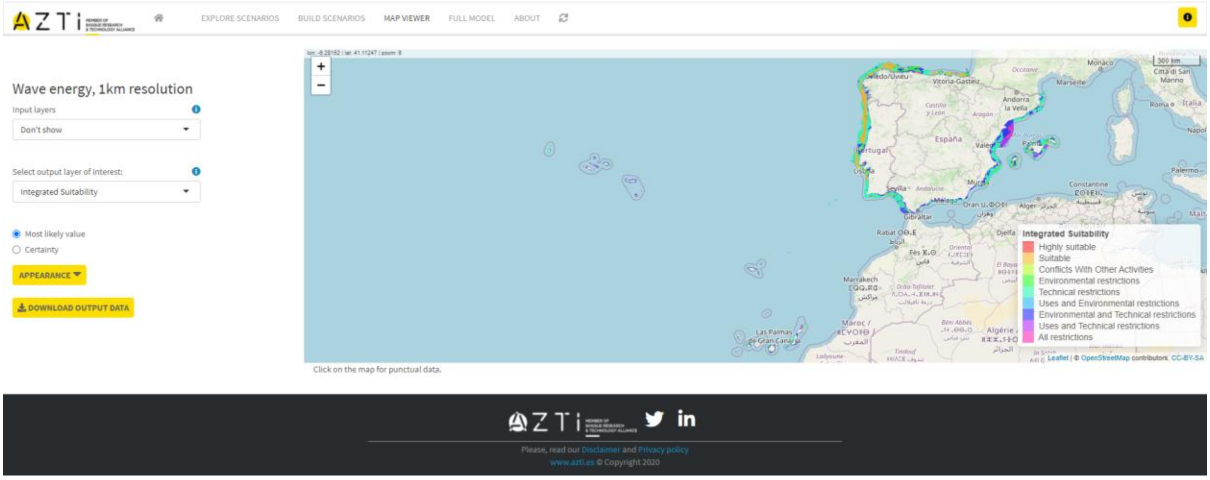

Figure 2. Map viewer page of VAPEM tool where the user can interactively visualise and navigate within the integrated suitability map. The map appearance can be customized and can be downloaded. Screenshot obtained from VAPEM tool (https://aztidata.es/vapem/).

The suitability maps provided in the subsequent sections are corresponding to an offshore oscillating point absorber device, while the ecological risk has been assessed for the operational phase (Galparsoro *et al.*, 2021).

5.1 Technical suitability

Figure 3 to Figure 8 show the spatial distribution of technical suitability for an offshore oscillating water column point absorber device within the six regions of Portuguese and Spanish Exclusive Economic Zones.

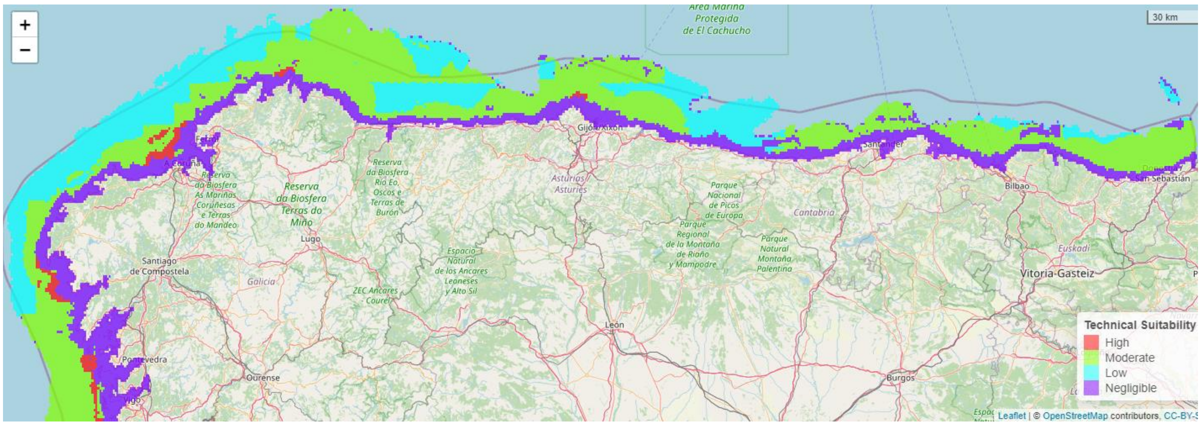

Figure 3. Technical suitability distribution for wave energy projects in the northern Spanish coast.

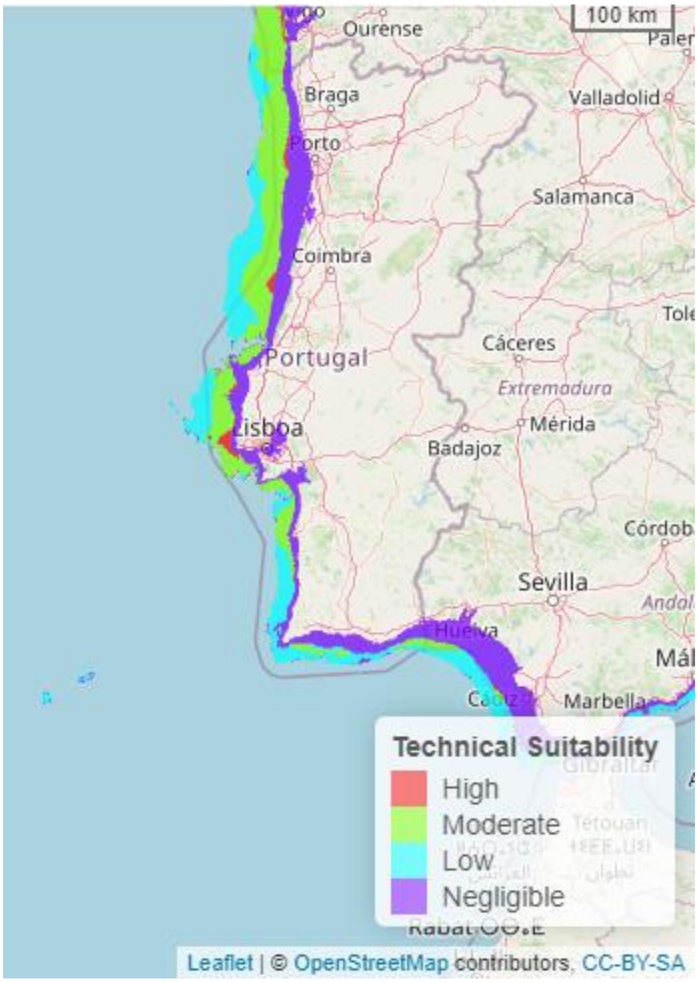

Figure 4. Technical suitability distribution for wave energy projects in the Portuguese mainland coast and southern Spanish Atlantic coast.

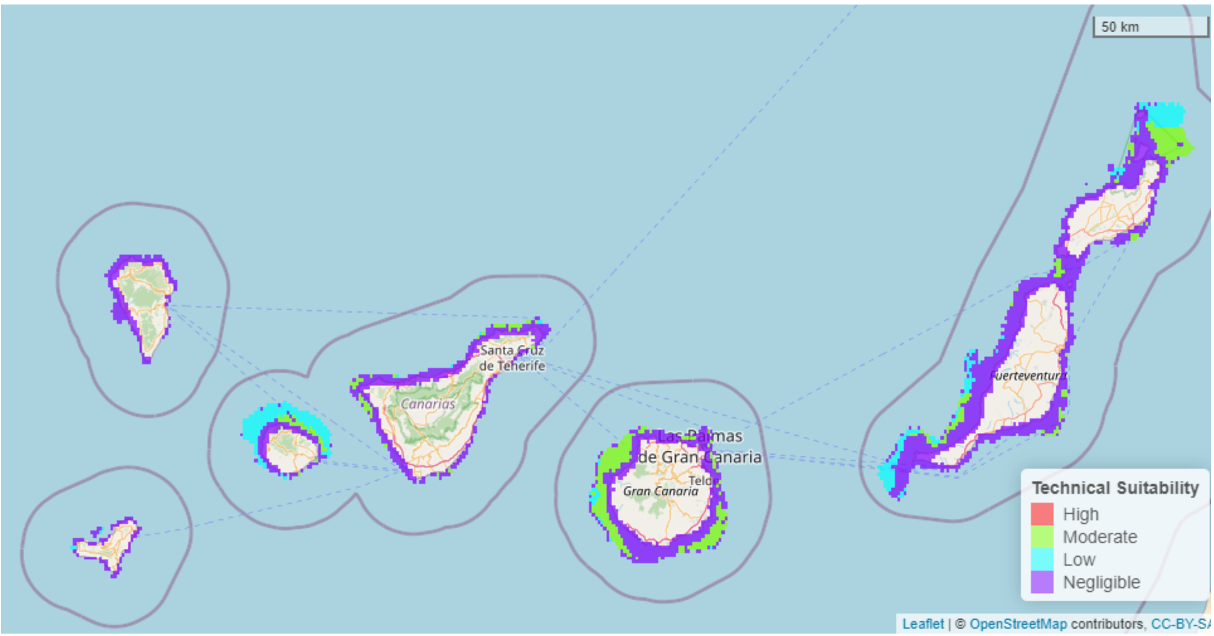

Figure 5. Technical suitability distribution for wave energy projects in the Canary Islands.

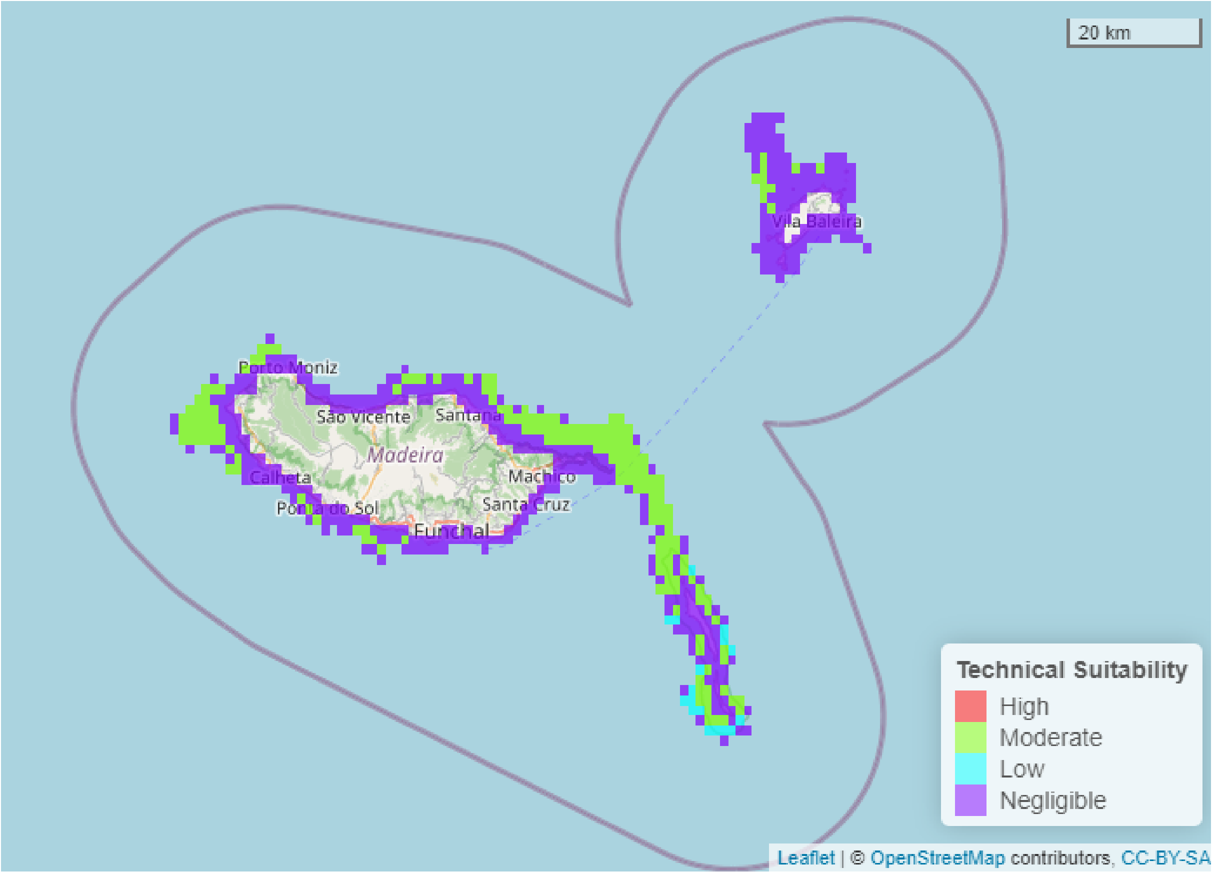

Figure 6. Technical suitability distribution for wave energy projects in Madeira.

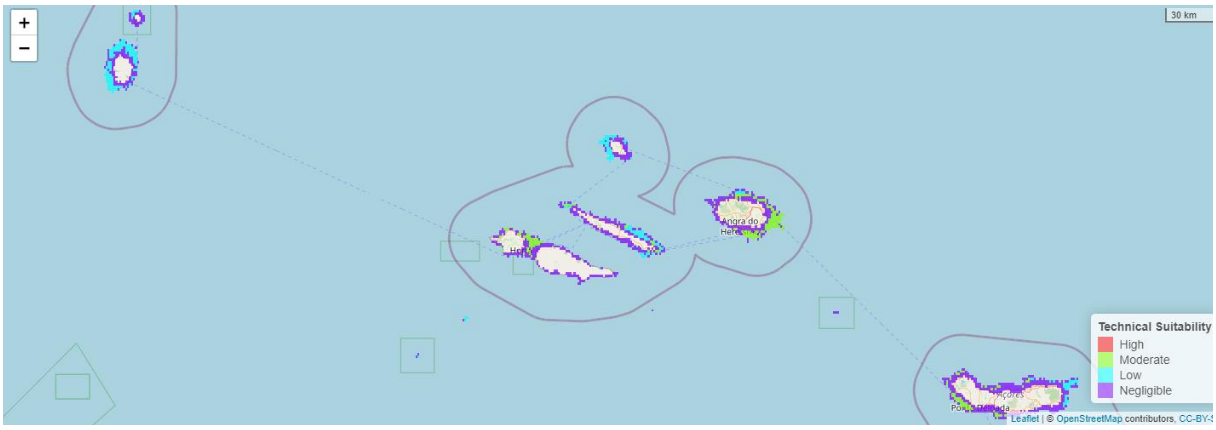

Figure 7. Technical suitability distribution for wave energy projects in Azores.

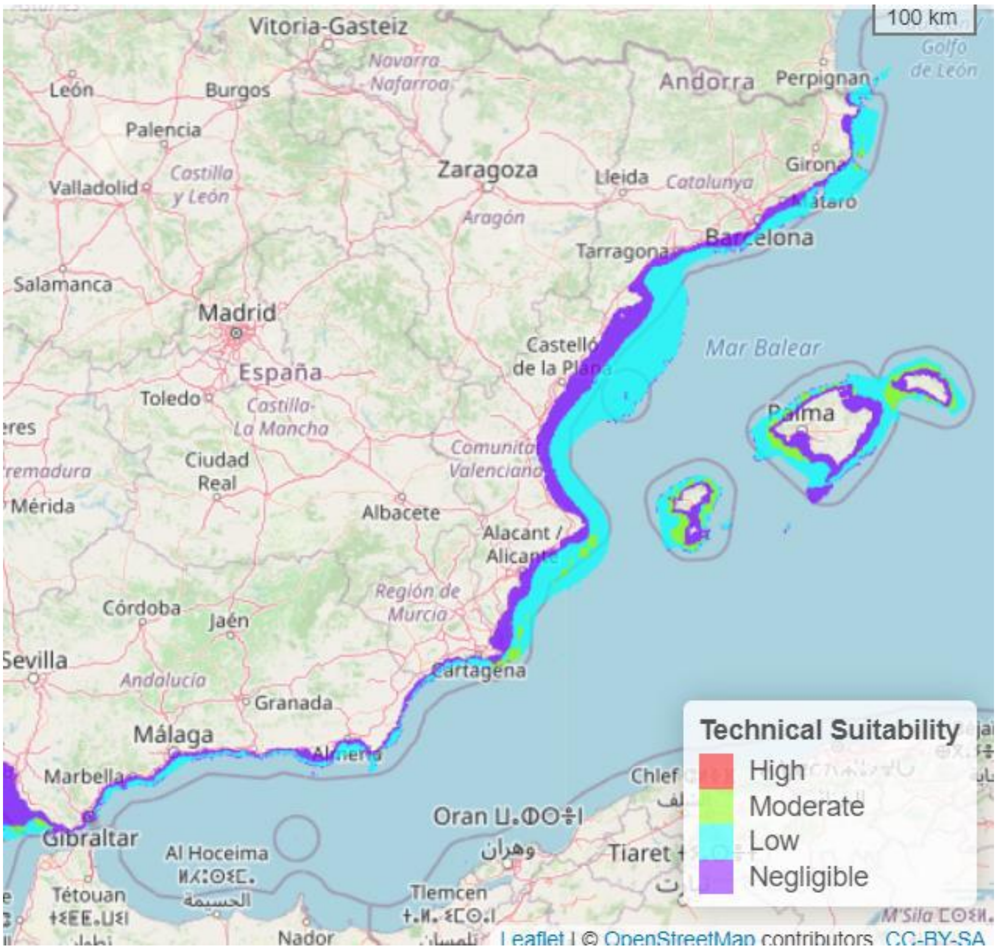

Figure 8. Technical suitability distribution for wave energy projects in the Spanish Mediterranean coast.

5.2 Environmental risks assessment

The spatial distribution of the environmental risk associated to an offshore oscillating water column point absorber during its operational phase, are shown in Figure 9 to Figure 14.

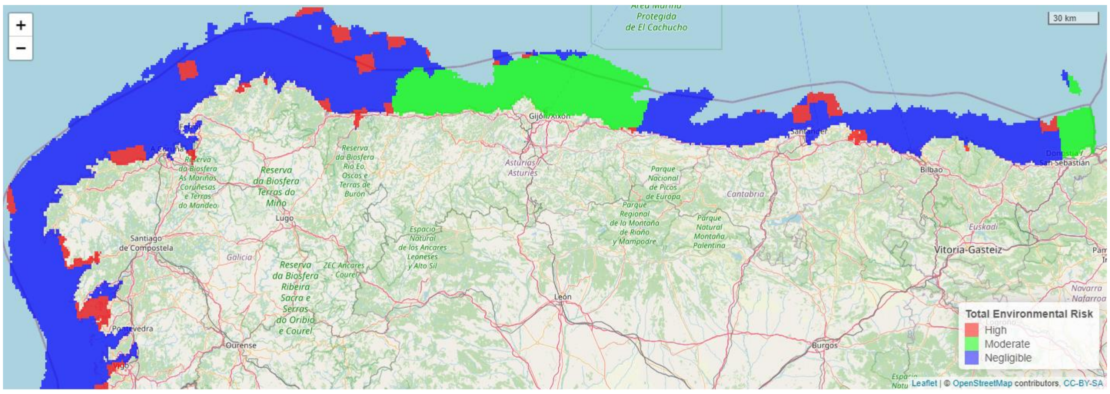

Figure 9. Environmental risk assessment distribution for wave energy projects in the northern Spanish coast.

Figure 10. Environmental risk assessment map for wave energy projects in the Portuguese mainland coasts.

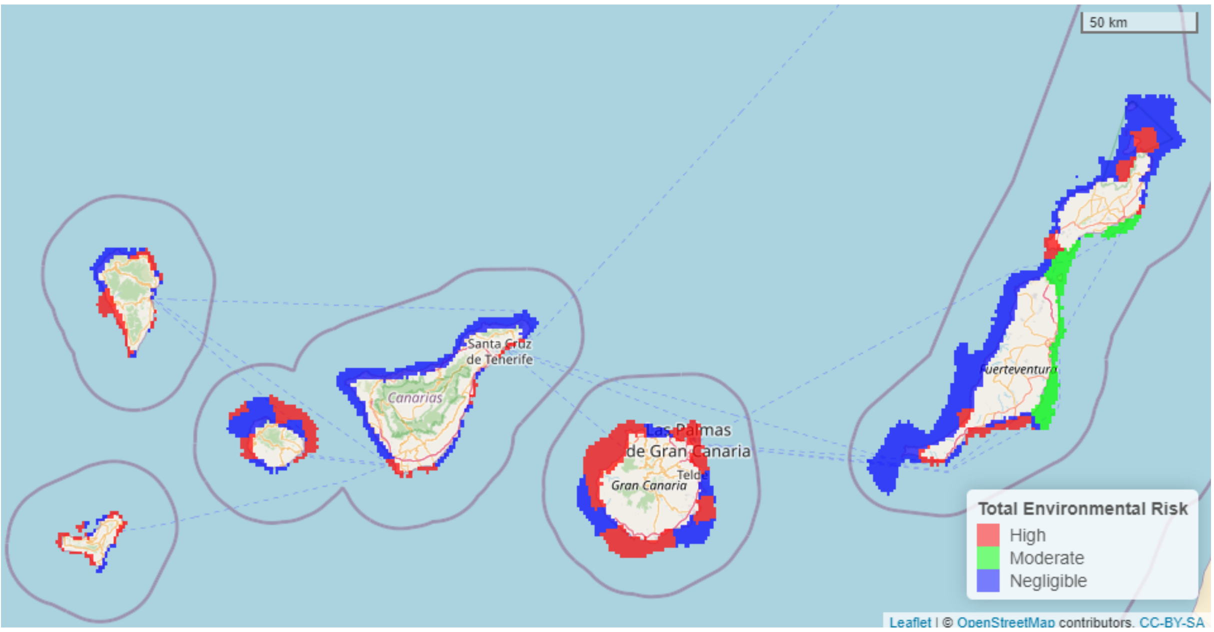

Figure 11. Environmental risk assessment map for wave energy projects in the Canary islands.

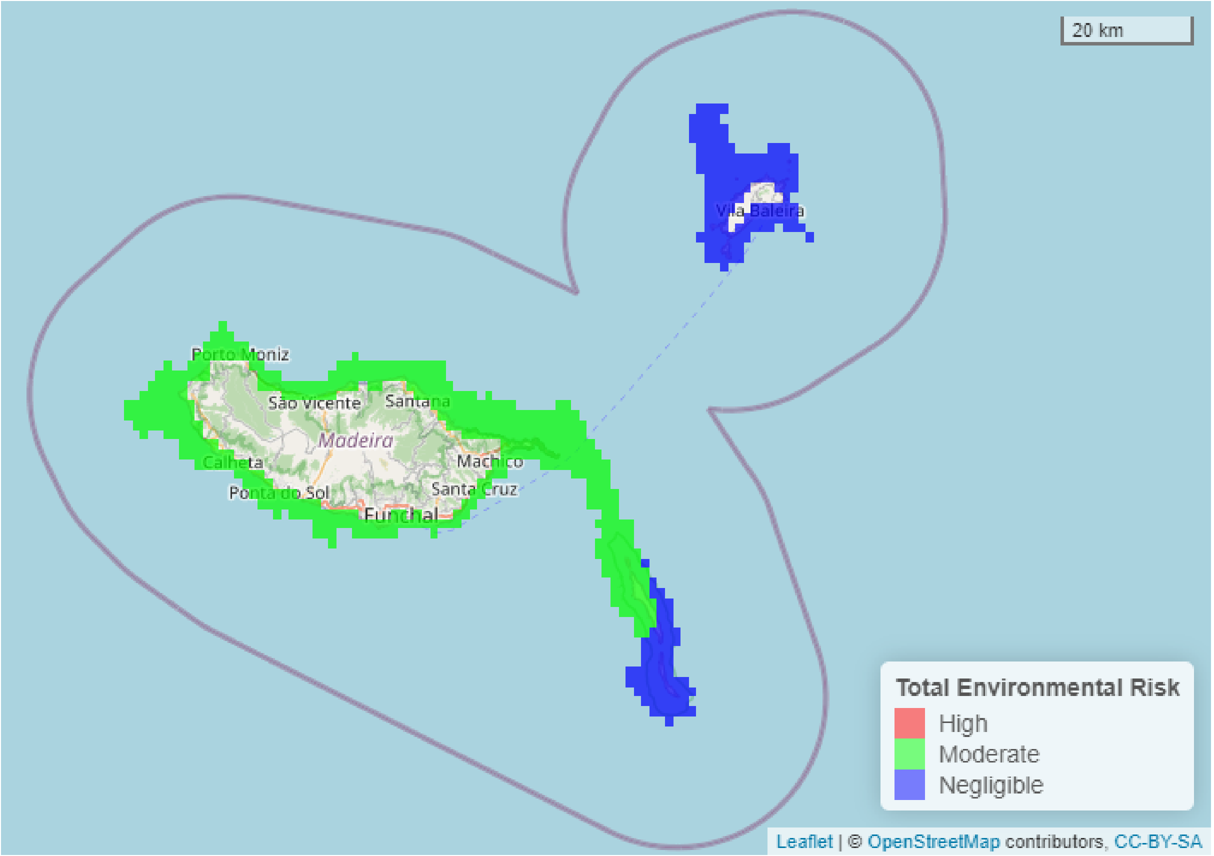

Figure 12. Environmental risk assessment map for wave energy projects in Madeira.

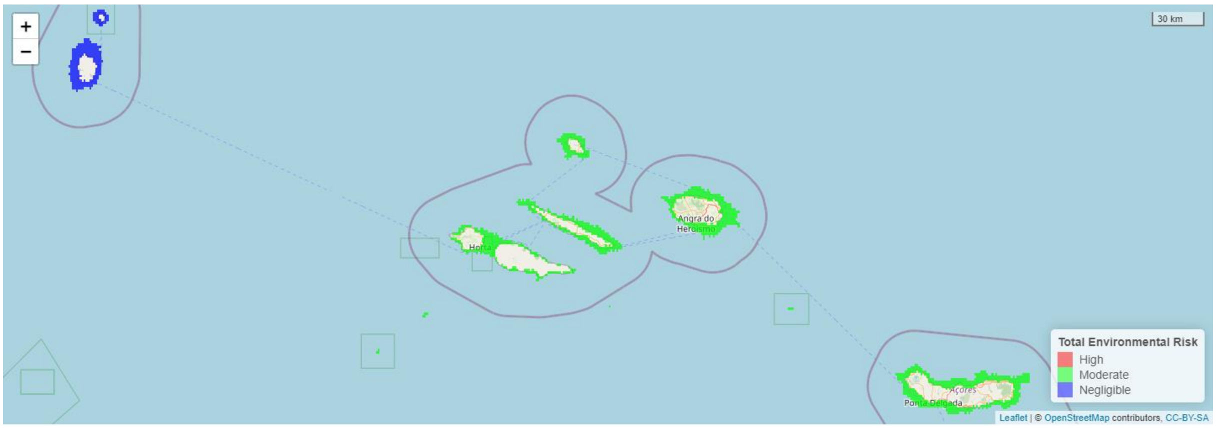

Figure 13. Environmental risk assessment map for wave energy projects in Azores.

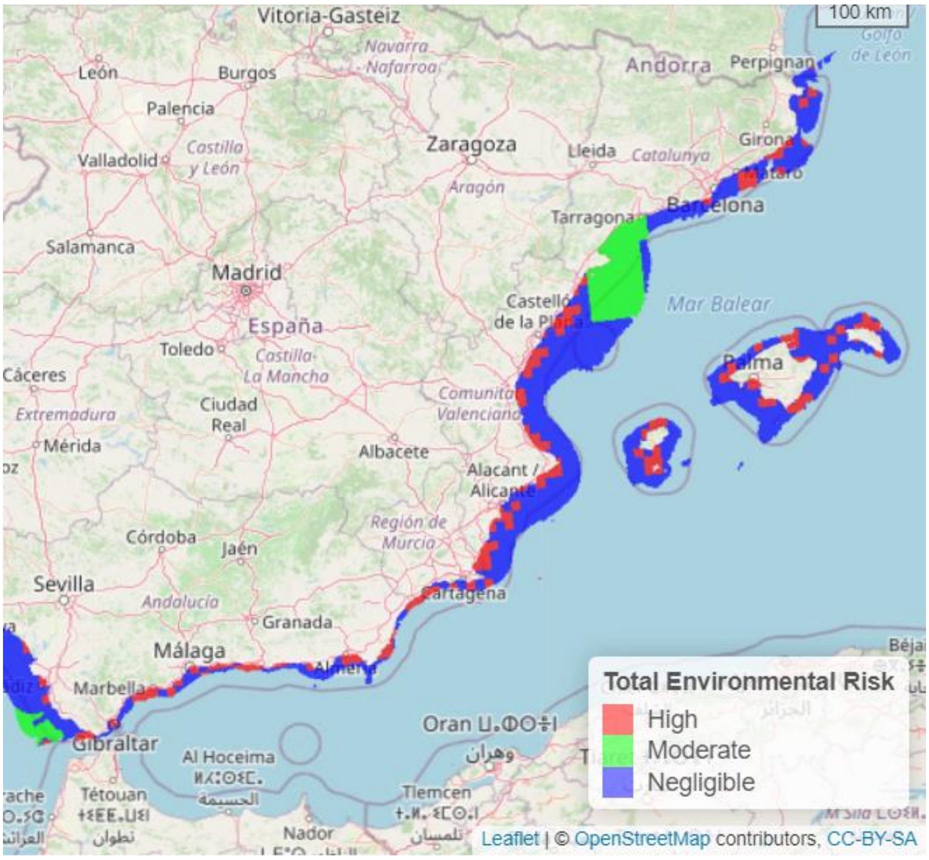

Figure 14. Environmental risk assessment map for wave energy projects in the Spanish Mediterranean coast.

5.3 Conflicts with other uses and activities

Figure 15 to Figure 20 show the integrated assessment of all activities or uses that might conflict or represent excluding factor (i.e., underwater infrastructures, cables, pipelines, etc.) for the development of wave energy projects.

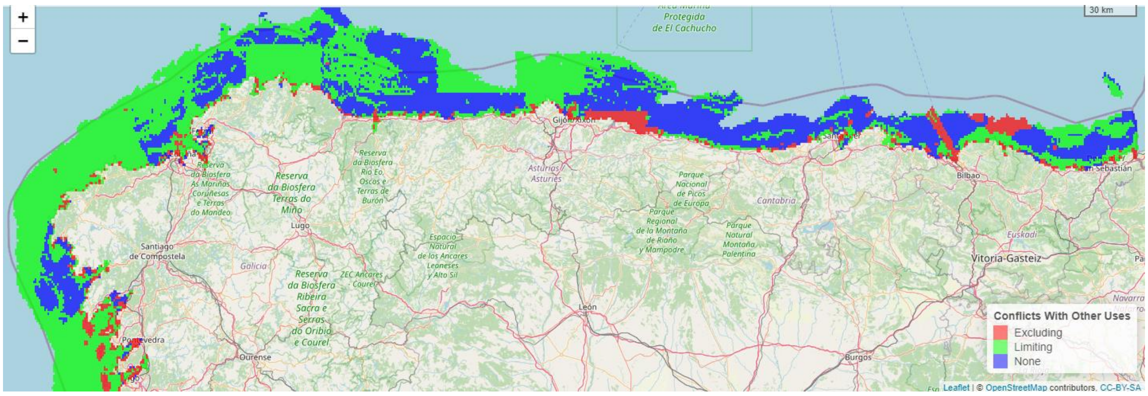

Figure 15. Conflicts with other uses and activities distribution for wave energy projects in the northern Spanish coast.

Figure 16. Conflicts with other uses and activities distribution for wave energy projects in the Portuguese mainland coasts.

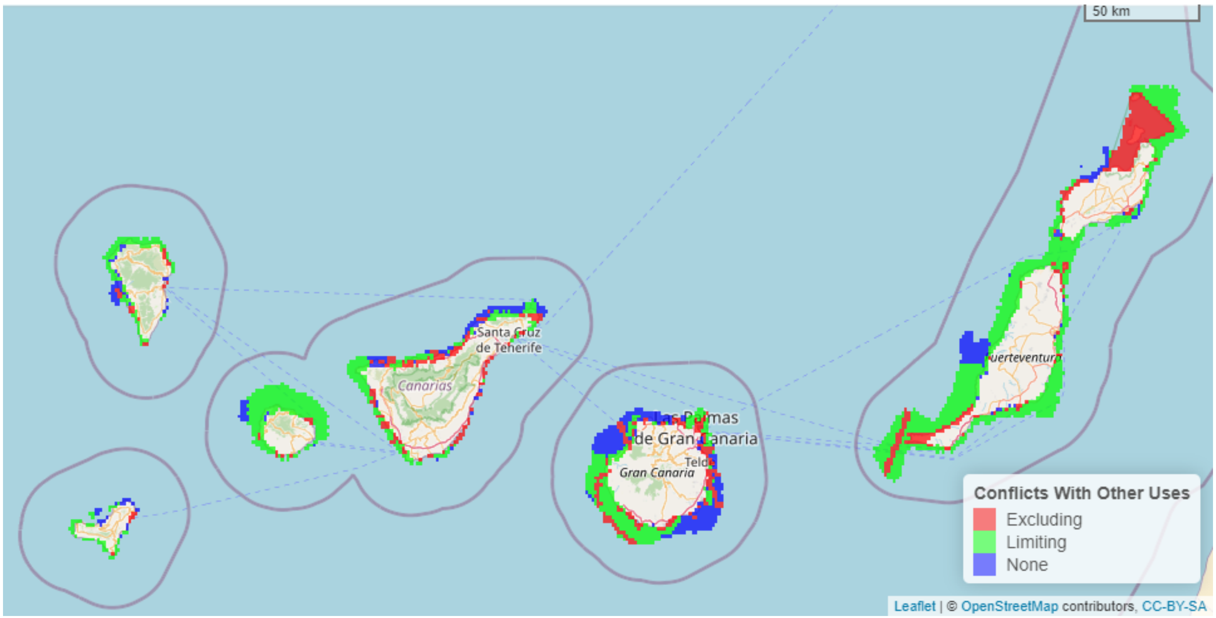

Figure 17. Conflicts with other uses and activities distribution for wave energy projects in the Canary Islands.

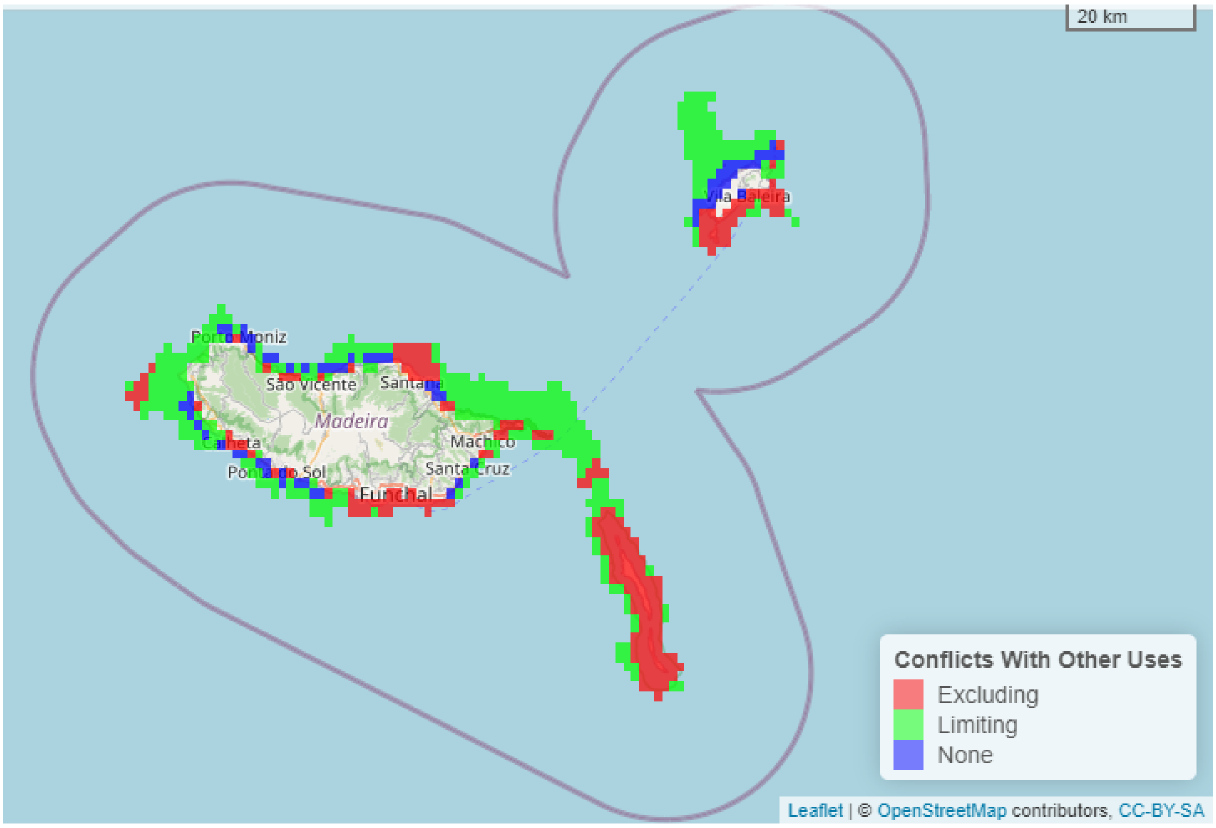

Figure 18. Conflicts with other uses and activities distribution for wave energy projects in Madeira.

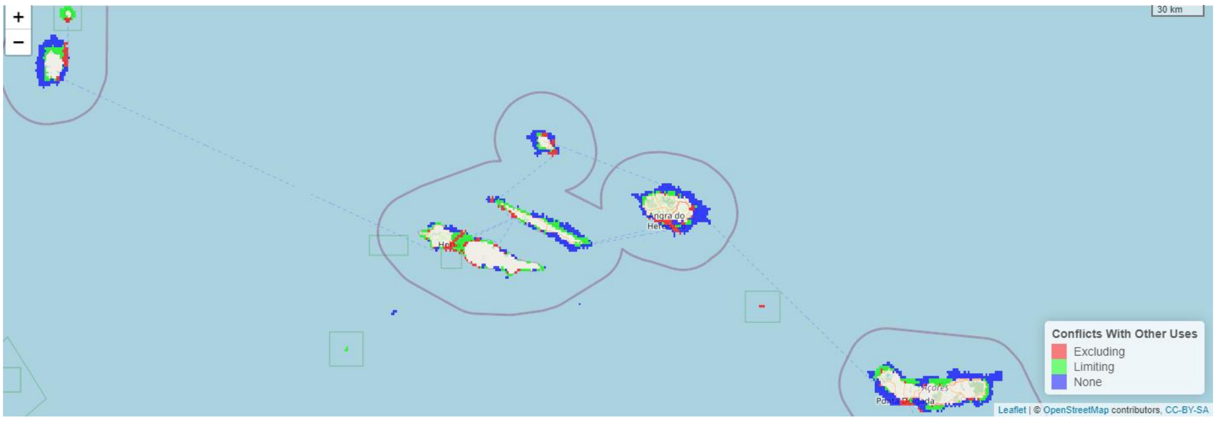

Figure 19. Conflicts with other uses and activities distribution for wave energy projects in Azores.

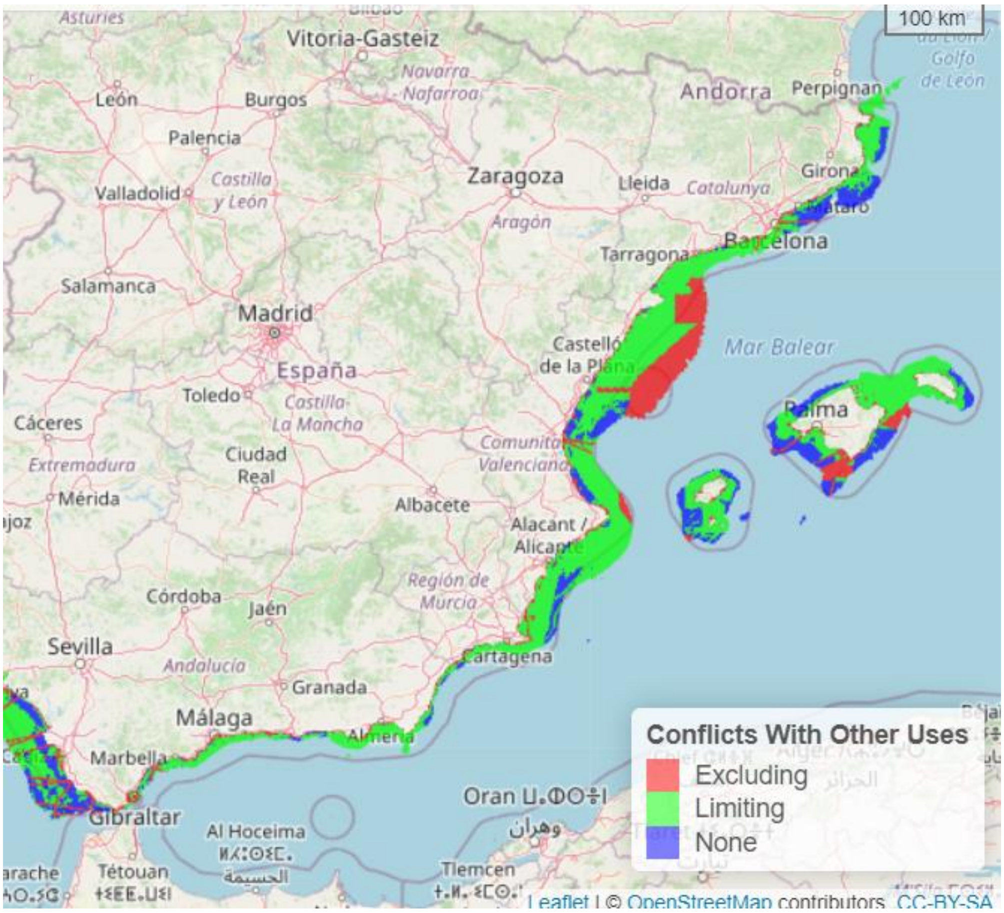

Figure 20. Conflicts with other uses and activities distribution for wave energy projects in the Spanish Mediterranean coast.

5.4 Integrated suitability

Integrated suitability maps for the development of wave energy projects are provided in Figure 21 to Figure 27.

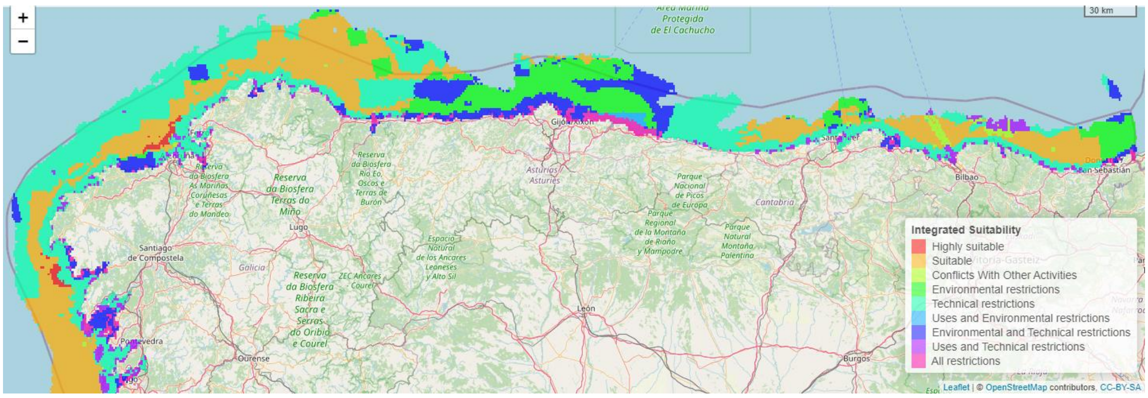

Figure 21. Integrated suitability distribution for wave energy projects in the northern Spanish coast.

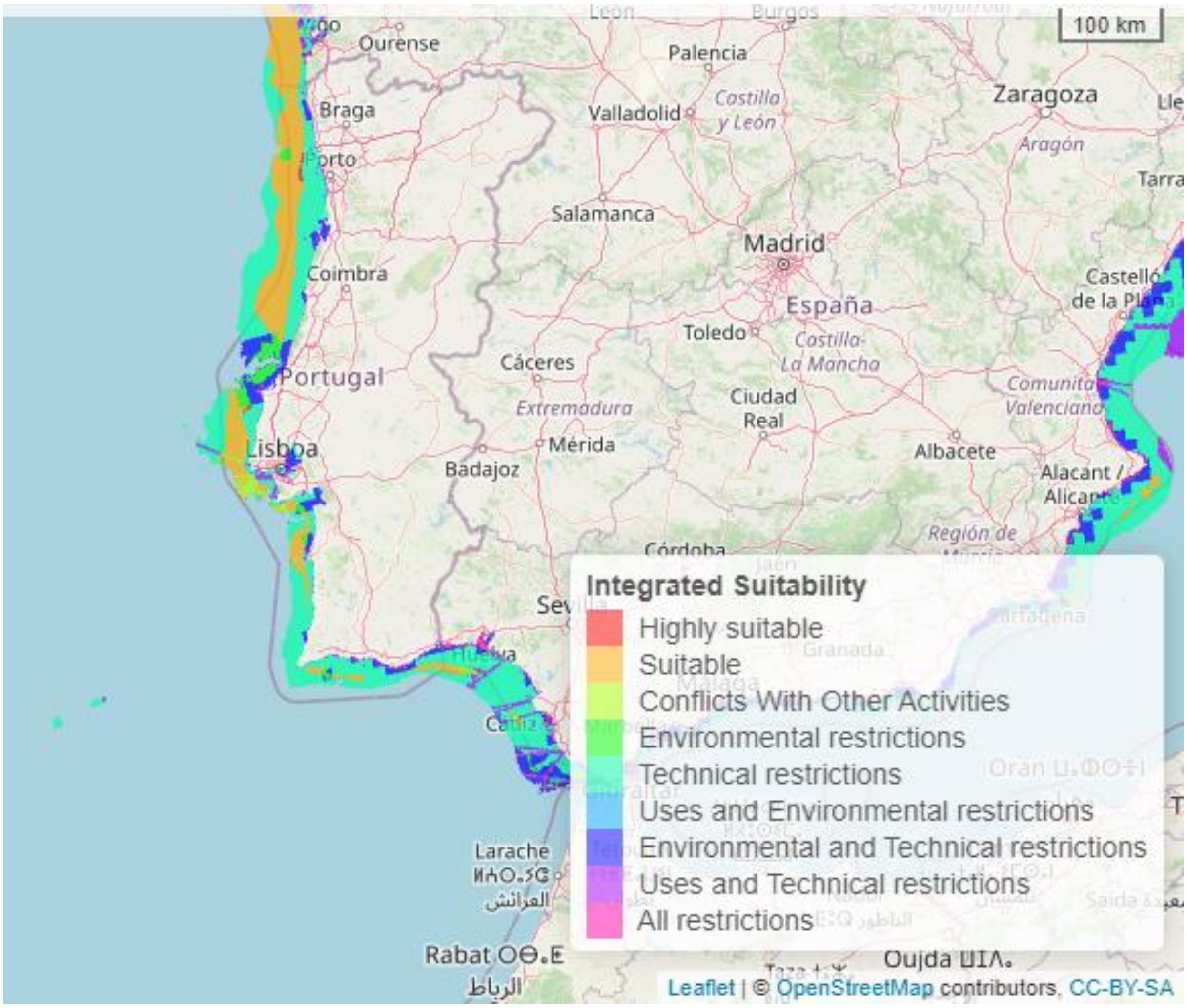

Figure 22. Integrated suitability distribution for wave energy projects in the Portuguese mainland coasts.

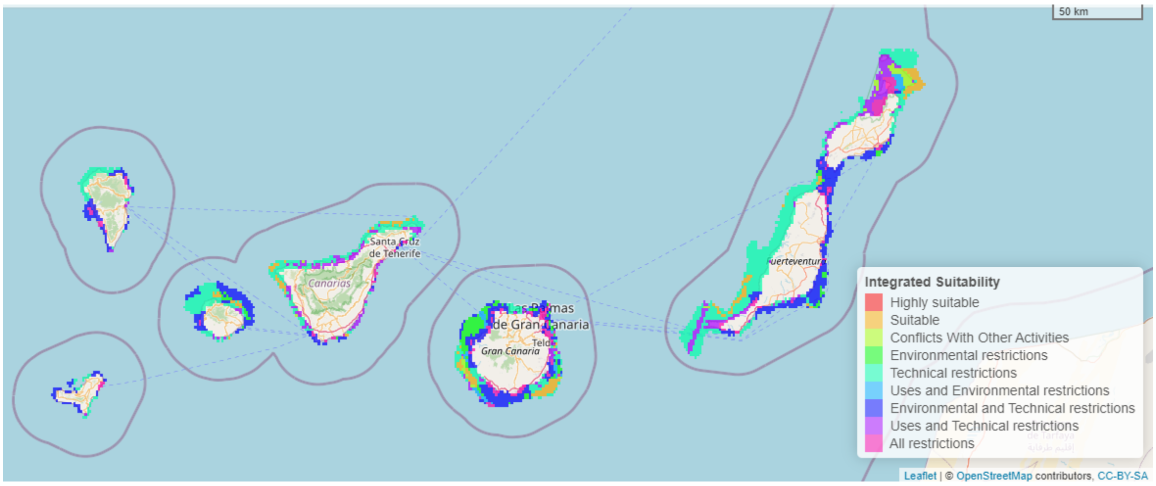

Figure 23. Integrated suitability distribution for wave energy projects in the Canary Islands.

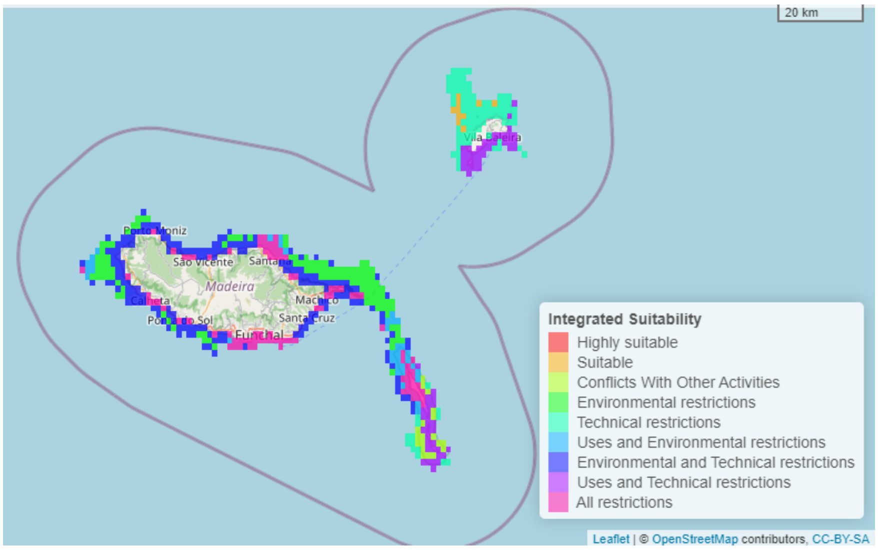

Figure 24. Integrated suitability distribution for wave energy projects in Madeira.

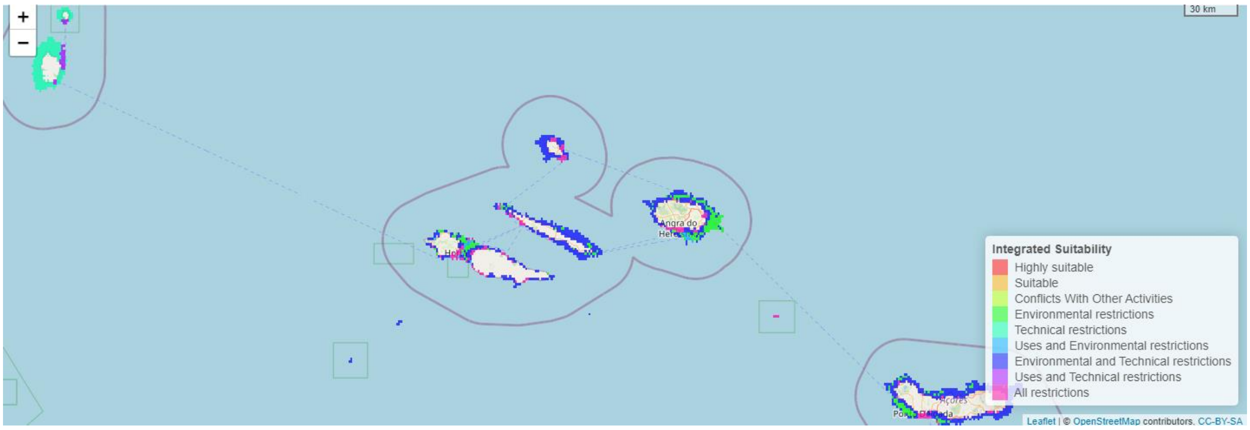

Figure 25. Integrated suitability distribution for wave energy projects in Azores.

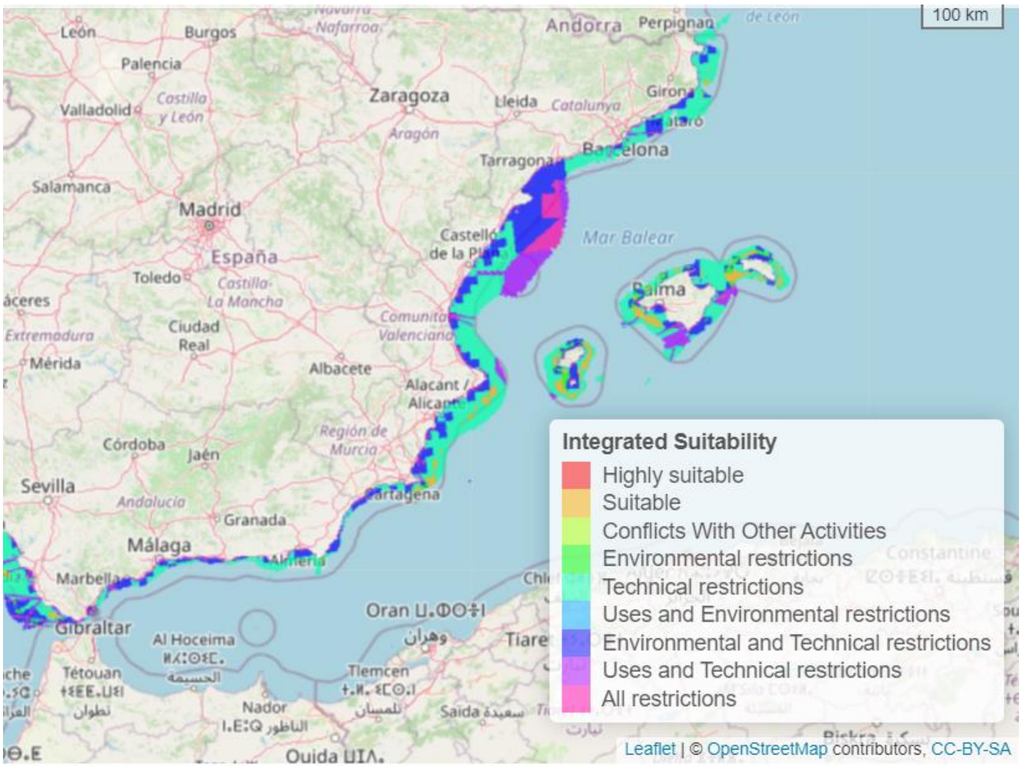

Figure 26. Integrated suitability distribution for wave energy projects in the Spanish Mediterranean coast.

6. Synthesis and interpretation of results

6.1 Geographical distribution of suitable areas for the development of wave energy projects

A suitability map for wave energy projects development in the Portuguese and Spanish Exclusive Economic Zones has been produced. To reach to that final result, a conceptual model considering all the most relevant technical, environmental and conflicts with other uses factors was elaborated, which was then operationalised into a Bayesian Belief model and implemented into a Decision Support Tool called VAPEM tool (https://aztidata.es/vapem/) which was developed in Task 5.2 and it is described in detail in Galparsoro *et al.* (2020). The model was then fed with the publicly available and self-produced information layers (Task 5.1 and corresponding technical report (Galparsoro *et al.*, 2019)). Adopting the European Environment Agency reference grid[1], a 1km^2 resolution suitability map has been produced.

The final suitability map is presented in this report as a set of 24 maps that show the spatial distribution of technical suitability, environmental risks and potential conflicts with other uses and activities in relation to offshore wave energy sector in the Portuguese and Spanish Exclusive Economic Zones.

Approximately 17% of the total area has been identified as suitable for the development of offshore wave energy projects, while the highly suitable areas, go down up to just 0.2% of the area (Figure 27). Even if those values could be seen as being low, it should be considered that it reaches almost 19,000 km^2 of the Portuguese and Spanish (EEZs), which would mean that there would not be space restrictions for the development of wave energy sector (Table 1).

Still almost half of the region is not suitable due to technical restrictions (45.9%). Main spatial limitation is related to depth. It should be highlighted that the depth ranges considered as suitable for offshore WECs has been defined between 60 m and 200 m depth. Apart from depth, other relevant factors are related to the distribution of areas with limited number of good weather windows for maintenance operations in the Atlantic area together with the distance to electric substations for the evacuation of the produced electricity. The technically suitable area would be increased by adopting strategic measures that could reduce installation and maintenance costs as well as technical developments to install wave energy devices at deeper zones.

[1] https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2

The areas limited by environmental risks are representing 5.3% of the study area. This result is obtained by the application of a new framework for ecological risk assessment of wave energy converters projects (Galparsoro *et al.*, 2021) and the publicly available information layers of the most sensitive ecosystem components distribution layers. According to this results, environmental aspects would not pose a big limitation in terms of space availability, but special care should be taken with the representativity, precision and resolution of the publicly available information at a such broad scale of analysis. Thus, as well as for the rest of factors, detailed studies would be required when development of new wave energy projects and their corresponding consenting processes (Machado *et al.*, 2021).

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. This does not mean, that potential conflicts would raise with existing activities such as artisanal fisheries, which should be considered into a more detailed analysis.

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 are 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. And finally, all type of restrictions are identified for 4.7% of the study area (Figure 27 and Table 1).

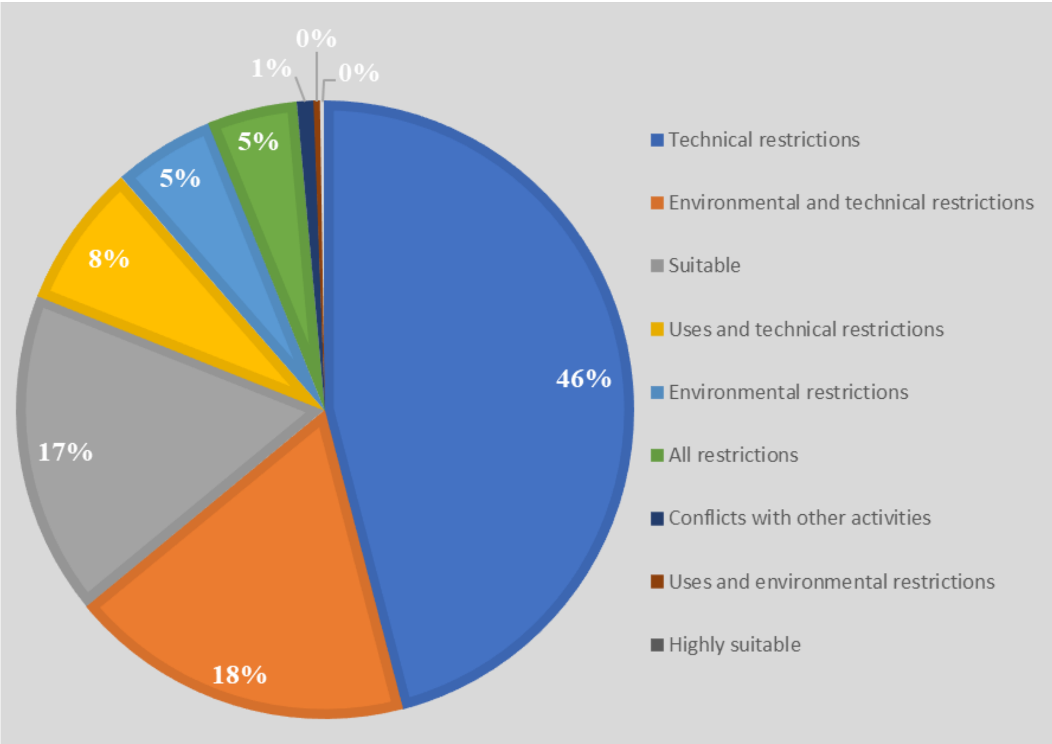

Figure 27. Integrated suitability map for wave energy projects in Azores.

Table 1. Total area and percentage of the total area for each wave energy projects development suitability class in Portuguese and Spanish Exclusive Economic Zones.

Suitability	Area (km^2)	% of the total area
Technical restrictions	49,979	45.9
Environmental and technical restrictions	19,711	18.1
Suitable	18,492	17.0
Uses and technical restrictions	8,201	7.5
Environmental restrictions	5,781	5.3
All restrictions	5,093	4.7
Conflicts with other activities	973	0.9
Uses and environmental restrictions	340	0.3
Highly suitable	256	0.2
TOTAL	**108,826**	

6.2 Underlying assumptions when developing a wave energy suitability model and producing maps

When interpreting the results it should be taken into consideration that we are providing very general information regarding to the potential suitability, but more detailed analysis would be still required when a site is selected for the development of a wave energy farm.

This happens for all the factors considered in our approach. For example, detailed information should be acquired regarding to the oceanographic conditions referring to the wave climatology in terms of the potential resource as well as regarding to extreme events and good weather windows needed for the construction and operational phase of wave farms. Still refined assessments of available resource and expected generated power to optimize devices designs and locations are required (Guillou *et al.*, 2020). For example, even if the most recurrent test environment is the North Atlantic Ocean, which possesses high energy potential, the Mediterranean Sea is less energetic, but also possesses less dangerous extreme conditions (Mattiazzo, 2019). This can be observed for certain coastal areas of the Spanish coast and islands that have been identified as being technically suitable according to our results (Figure 8). The incorporation of the Levelized Cost of Energy (LCOE) (Castro-Santos *et al.*, 2015) into the model would be also of high interest.

Regarding to environmental risks, this is defined by the potential pressures that an offshore oscillating water column point absorber device would produce during its operation phase and the spatial location of the most sensitive ecosystem components (i.e., species and habitats) (Galparsoro *et al.*, 2021). For the present work, we have used general data sources providing information of the potential distribution of such ecosystem components (e.g., EMODnet[2], Aquamaps[3], etc.). Special care should be taken with this information, because they are very general maps derived from modelling approaches. The approach presented here, is not considering the particular sensitivity of specific species to the pressures derived from WECs, but we have integrated all the species for which we do have information and we have used such information to estimate the potential spatial distribution of potentially sensitive species in all the analysis region. Thus, when selecting areas for the development of projects, detailed information regarding to the distribution of sensitive and vulnerable habitats and species should be collated or surveys should be conducted, as required by the consenting processes (Bald *et al.*, 2020).

If wave energy sector is going to be implemented, as well as for other offshore energy sources, it will require marine space and potentially, conflicts with other uses and activities might raise. Apart from the main excluding factors (such underwater infrastructures), that might be quite well represented in our approach, special care should be taken with other conflicting activities that might pose a limitation to the development of wave farms. This is the case for fishing sector. In our approach we have included general information on fishing activity which is derived from publicly available information layers derived from AIS data[4]. But, according to our interpretation of those maps, they are representing the industrial fishing fleet and mainly for bottom trawling fleet. In considering that offshore wave farms should be installed at a shorter distance from the coast, the space occupied by the farms, might conflict with artisanal fisheries. And this is the fleet for which there is quite limited information, specially, when considering broad maps. Thus, when selecting sites for the development of wave projects, more detailed data and information would be required to understand and estimate the socioeconomic impact and consequences.

In terms of the socioeconomic aspects, the model could also be improved by incorporating other aspects of social acceptance or any other relevant information dealing with this aspect.

The analysis resolution could be also improved. At the moment, the model runs at 1 km^2 which is quite a high resolution at the geographical extent for which it has been developed, but the spatial resolution could be improved reducing the geographical extent of the analysis and with the input of background information layers of higher resolution and precision.

6.3 Potential improvements

The scope of the model developed here and the maps produced are intended to show the general picture of the potential sites in which wave energy projects could be developed. But

[2] https://www.emodnet-seabedhabitats.eu/
[3] https://www.aquamaps.org/
[4] https://data.jrc.ec.europa.eu/dataset/jrc-fad-ais1415

more importantly, it stablishes a framework and approach to conduct risks analysis and site suitability analysis based on an integrated approach. The approach presented here, could be modified according to inputs from users of the model and tool, the model could be improved if more detailed is used to feed it. The model is flexible enough to incorporate new nodes that represent additional factors that are not considered in the present version but that could be suggested by the end users. This can be for the incorporation of additional technical factors that are relevant when identifying suitable areas. Improvements will continue to be implemented to make the tool fit to purpose for the end users.

The maps presented here might still change as it is a work in progress. As it is running in a server property of AZTI, it is guaranteed that the VAPEM tool will continue to work after the end of the project.

We have produced maps for the Spanish and Portuguese ZEEs, which was the objective established for WESE project, but further work is ongoing to extend the geographical scope of the model to France, UK and Ireland. This would mean that the whole European Atlantic region will be analysed.

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