Advances in Renewable Energies Offshore – Guedes Soares (Ed.)

Site selection process for floating offshore wind farms in Madeira Islands

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ABSTRACT: This work develops and implements a methodology for comprehensive evaluation of feasible areas for floating offshore wind farms, useful to support the strategic spatial planning around the islands. The site selection criteria are classified into five categories: metocean data, proximity to facilities, marine environment, techno-economic data and viability. The basic tool used to achieve the study's goals is the marine spatial techniques based on geographic information systems and the investigated resources and criteria available in the country. The main output of this study is the provision of an objective and realistic overview of offshore wind farm siting considering the reduction of the environmental impacts and to reduce the social conflicts between stakeholders.

1 INTRODUCTION

The efficient exploitation of local offshore wind potential is directly linked to energy strategies and policies of the European Union (EU) towards energy economic blue growth and CO2 emissions reduction (European Commission, 2017; Wind Europe, 2018). As a result, in recent years the European offshore wind energy sector on North Sea has been rapidly developed and this fact has meant a large-scale commercial deployment of offshore wind farms in Europe. The projection of new offshore wind farms (OWFs) in 2030 are mostly located in the Nordic and Baltic Seas with respectively 45 GW and 8 GW of total installed capacity (EWEA, 2015).

However, the limited availability of shallow water areas has initiated the necessity for deploying wind turbines in deeper waters, where, additionally, stronger and more consistent winds exist (Bilgili et al., 2011). As a result, in recent years the European offshore wind energy sector on the North Sea has been rapidly developed and also has promoted offshore wind deep water research in Europe Atlantic Regions, with various floating concepts under study, WindFloat (Roddier et al., 2010), Hywind (Skaare, et al. 2015) and FLOATGEN (Beyer et al., 2015).

This new technological and economical challenges should be adequately addressed towards the sustainable and cost-efficient realization of offshore wind energy projects.

The objective of the floating offshore wind energy sector is to overcome critical technological barriers to achieve safety, durability in harsh sea environmental conditions, energy effectiveness, cost efficiency and, therefore, competitiveness with other renewable energy sources.

The present paper contributes to the field of renewable energy resources with an approach to select feasible areas for development. The related studies for OWFs have been applied either to coastal regions of countries or to islands (Vagiona & Karanikolas, 2012; Kim et al., 2016). This study is performed in the Autonomous Region of Madeira, Portugal, which is divided into three major islands, which are Madeira, to the west; Porto Santo in the North; and Desertas to the south. This study focuses on a regional application. It should be noted that islands present sustainable-energy growth challenges for numerous reasons such as remoteness, limited energy resources, vulnerability to external events as the fluctuations in the price of hydrocarbons and strong dependence on international trade agreements (AREAM, 2012).

With regard to the determination of suitable marine areas for deploying floating offshore wind farms (FOWFs), a site selection methodology addressing this objective has been developed by taking into account a variety of siting criteria, such as available wind resource and water depth, a geographic information system (GIS)-based platform was developed. This platform in combination with the multiple-attribute value theory for multicriteria analysis will be applied for the site selection of offshore wind technologies in a large geographic region (European Atlantic Coast).

A methodological framework for identifying the most appropriate marine areas in the Madeira Islands to deploy the wind farms is developed and presented. The methodology followed includes three phases: data collection, exclusion criteria and evaluation criteria.

The rest of this paper is organized as follows: Section 2, a brief description state of art; Section 3 describes the methodological framework developed, as well as the exclusion and evaluation criteria used in the analysis; and Section 4 provides the main conclusions of the present study.

2 STATE-OF-THE-ART

In the international literature several tools exist to analyse the sustainable siting of OWFs taking into account area or the capacity constraints (Mekonnen & Gorsevski, 2015). They have put emphasis on the potential environmental effects and socio-economic impacts.

Kim et al. (2016) suggest strategies for conducting an offshore wind farm site selection and evaluates feasible offshore wind farm sites in the coastal areas of Jeju Island, South Korea. They used as criteria: energy resources and economics, conservation areas and landscape protection, human activities, and the marine environment and marine ecology. Then, a GIS method was employed to evaluate the available areas in the region.

Another selection method of OWF siting shown in Salvador et al. (2018), based on a methodology of legal restrictions—applied in Galicia, Spain. The legal restrictions derived from the protection of other interests that converge in the marine environment (such as fishing, navigation, and biodiversity conservation) must be considered, along with technical limitations resulting from water depth. This study analysed legal restrictions on the installation of OWFs in Galician waters and at identifying those zones of less conflict where the wind power density is greater and the depths and distances from the coast are technically feasible given the current status of technology in Europe.

Finally, Vagiona & Kamilakis (2018) developed an integrated methodology for the evaluation and prioritization of appropriate sites for sustainable offshore wind-farm development at South Aegean, Greece. The methodological framework includes the application of several siting criteria (technical, spatial, economic, social and environmental) proposed either by the national legislative framework (Specific Plan for Spatial Planning and Sustainable Development for Renewable Energy) and international literature with the combined use of geographic information systems.

The current methodology exploits most of the advantages of the previous studies, but also integrates the following important issues:

i. The recent revised Maritime Space Situation Plan (PSOEM) utilizes the main outputs and concept to identify the proper siting for OWF on the islands.
ii. It includes also a uniform digital background of the island in the form of dynamic data, easily to be updated and derived from a large number of state and European entities related to the sea and its uses.
iii. The floating offshore wind structures aspects had been taking into account as site selection parameters.
iv. It puts emphasis on the marine and coastal ecosystems and biodiversity taking into account the most recent findings.
v. The selected open source software is widely spread in the public and private sector facilitating the use of the created database.

3 MATERIALS AND METHODS

3.1 *Study area*

Madeira is an autonomous region of Portugal. It is an archipelago composed of volcanic islands in the North Atlantic Ocean about 400 km north of Tenerife, Canary Islands, Spain. The islands extend to an area of a little more than 740 km^2, while its permanent population according to the last 2016 official population census corresponds to almost 289.000 people. The extended marine area in Madeira enables the continuous implementation of various relative activities, such as tourism, shipping, fishing, military activities etc. The study area of the present investigation as defined by the coastline and the rest geographical boundaries of the archipelago marine area, taken into account in this study, is shown in Figure 1.

Finally, it is worth to note that currently in Portugal investments have been made towards the exploitation of any kind of offshore renewable energy source. Even in the case of the immature offshore floating wind energy sector, there is commercial deployment of offshore wind farms today in the Portuguese continental marine environment. This can be mainly attributed to the existence of establish licensing procedure, to the maturity of the investment plans, as well as to reduction of social constraints (Carvalho Moreira & Sousa Almeida, 2011).

3.2 *Methodology*

The process of identifying the optimum locations for wind farms in a geographical region includes

Figure 1. Location of the Madeira Archipelago in Portugal.

various stages. In the present paper, a combination of applied methodologies is used and integrated with the criteria found in the legislative framework of the Maritime Space Situation Plan (PSOEM) (Assembleia da República, 2014) and in the international literature. More specifically, the proposed methodology is divided into three stages. The first stage is the data collection phase, which includes the creation of a GIS database as well as the depiction of information in different thematic layers.

The application was performed using the digital platform of Python and some of its libraries. The second stage, which is the exclusion phase, consists of two distinct steps, which involve the exclusion of incompatible areas according to exclusion criteria and the application of surface restrictions.

Finally, there is a transition to the evaluation stage, where areas deemed to be suitable in the previous stage are further evaluated according to a set of criteria (wind resource, water depth, etc.). It is important to note that some of the exclusion

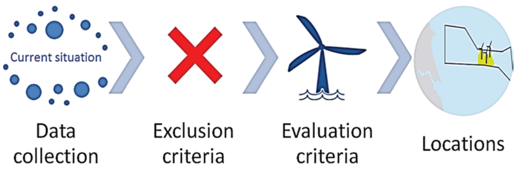

Figure 2. Methodology.

criteria are also used as evaluation criteria, mainly due to their nature. Figure 2 shows the described process steps.

3.3 *Data collection – current situation*

The adopted methodology, initially, analyses the current status, tracing all data affecting the siting of floating wind farms, in order to create a framework for knowledge sharing and to address possible scenarios of development and deployment of FOWFs.

Gathered information not only concerns offshore resources (wind statistics, wave spectra, ocean currents, temperatures, etc.), but also bathymetry, seabed morphology, existing and planned uses, marine spatial planning, existing and planned renewable energy plants, environmental conditions (marine life, migratory paths, habitats, ecosystems), networks of technical structure and facilities, military areas, other competing uses such as navigation routes, fisheries, aquaculture and the regulatory and legislative framework. All marine areas within the Territorial sea and contiguous zone are considered and information is collected at different scales (European, national regional and local).

Such data range from GIS layers used for planning "pre-selection" process to retain only valid and feasible sites to wind speed data and main criteria to evaluate sites performances. GIS data are ideally processed taking into consideration a preferably small variations level specifically for wind speed vectors (historical data) that are converted and adjusted to the intended height of exploitation.

3.4 *Exclusion criteria*

For determining the unsuitable areas for the siting of floating wind turbines (second stage of the proposed framework) a set of exclusion criteria was taken into account. These criteria describe utilization restrictions as well as economic, technical and social constraints that restrict the deployment of floating platforms. Utilization restrictions are imposed by the various human activities existing in the marine environment and/or by environmental requirements related to the conservation and the protection of marine areas of recognized natural and ecological value.

The rest of constraints are mainly driven by economic viability and technical feasibility factors as well as by social implications. It should be mentioned that all exclusion criteria have been defined considering the available literature (Fetanat & Khorasaninejad, 2015; Ziemba et al., 2017; Bagocius et al., 2014), the main characteristics of the examined Portuguese marine environment that can have an impact on the decision upon the implementation or not of a floating wind project, as well as the availability of data required for the formation of the relevant thematic maps in the GIS database. Based on the above, ten exclusion criteria were selected, as shown as shown in Table 1.

The first seven exclusion criteria (Ex1-Ex7) are related to utilization restrictions. More specifically, the following marine areas are excluded for further analysis:

Table 1. Exclusion criteria.

No.	Criteria	Unsuitable areas
Ex1	Military areas	All
Ex2	Hydrocarbons and minerals	All
Ex3	Marine renewable energies pilot zones	All
Ex4	Environmental protected areas	All
Ex5	Underwater lines and pipelines	<500 m
Ex6	Maritime traffic	<500 m
Ex7	Heritage areas	All
Ex8	Wind Velocity	<4 m/s
Ex9	Water Depth	>1000 m
Ex10	Distance from Shore	>44.4 Km

Military areas (Ex1): Areas for military activities (exercises and manoeuvres). These marine areas are considered unsuitable for the floating wind farm siting, since they are utilized for the implementation of periodical and special military operations. Figure 3 shows the military areas for the Madeira Islands.

Exploration and exploitation of hydrocarbons and/or minerals (Ex2): The areas for the public tender of marine areas cannot be considered eligible for the deployment of floating farms.

Marine renewable energies pilot zones (Ex3): These marine areas have to be considered unsuitable for the implementation of new projects, since they have been already taken into account for the realization of other offshore renewable energy pilot or pre-commercial projects (wave farms, tidal farms, offshore wind farms, etc.).

Environmental protected areas (Ex4): The protected areas correspond to zones of recognized ecological and natural value, where the viability and maintenance of the biodiversity is ensured through regional, national or European legislation. In the present paper, the National Network of Protected Areas (RNAP), National Information System of the Sea (SNIMar) and Natura2000 network has been used in order to define the protected areas in the Madeira marine environment.

Underwater lines and pipelines (Ex5): The underwater network is selected as an exclusion criterion due to the regulatory framework that protects these installations. The minimum distances from underwater lines and/or pipelines according to the following categories are: (i) all undersea pipelines and power cables have safety zones extending 500 metres on each side. Within such a zone, no other seabed activities are permitted. Similarly, (ii) all active telecommunications cables have maintenance zones of 750 metres on each side (The Ministry of Infrastructure and the Environment, 2014) (see Figure 3).

Maritime traffic (Ex6): The revised maps show the shipping lanes, anchoring areas, precautionary areas and clearways. The wind energy area

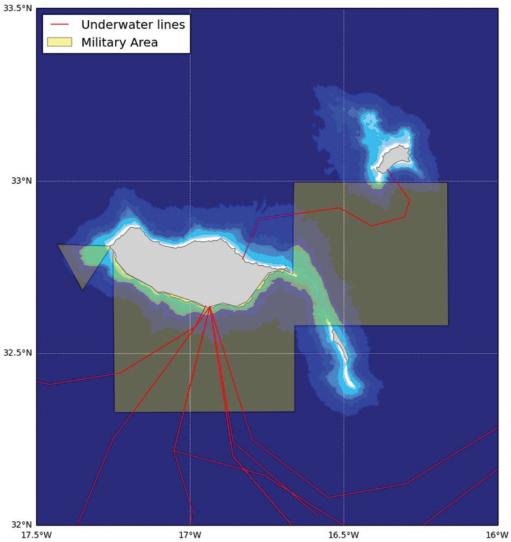

Figure 3. Military and underwater lines exclusion criteria for the Madeira Islands.

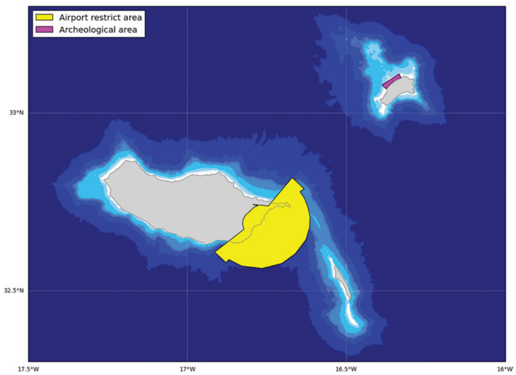

Figure 4. Archaeological and airport exclusion/evaluation criteria for the Madeira Islands.

designation should adhere to the principle that no permanent construction is permissible within two nautical miles of a shipping lane. At the detailed planning stage, the application of this requirement may be adapted to particular circumstances. However, according to UNCLOS a zone of 500 m should always be kept clear between a wind farm and a shipping lane.

Heritage areas (Ex7): The archaeological monuments and historical places located in the National Geographic Information System (SNIG) (Direção-Geral do Território) and PSOEM. These areas are excluded of any use licence and protected by national and regional Legislative Decrees. The Porto Santo Island has an archaeological park near its north shore that can be seen in Figure 4.

Continuing with the rest of exclusion criteria (Ex8-Ex10), the next two are related technical and economic constraints, while the last to social implications. These criteria are defined as follows:

Wind Velocity (Ex8): The wind velocity potential can be expressed quantitatively through the mean values of 10, 80 or 120 m.

Combining on all the above, marine areas with mean speed smaller than 4 m/s (average cut-in wind speed) (Energinet.dk, 2015)were considered unsuitable for the siting of floating wind farm and were excluded for further analysis.

Water Depth (Ex9): The bathymetry imposes significant spatial constraints on the site selection. These constraints depend upon the configuration of the support structure employed. In the case of floating wind turbines, they can be utilized in significantly larger water depths; however, there are still specific design challenges (efficient design of mooring lines and anchors for deep water floating structure) and cost related issues (installation, operational and maintenance cost), that limit their installation depth. In the research, the deployment of floating wind turbines is taken into account (Uzunoglu et al., 2016). Therefore, only an upper limit for the water depth is used in order to define marine areas unsuitable for the deployment of platforms. This limit has been selected equal to 1000 m, based on the current technology advances (Pacheco et al., 2017) and available areas.

Distance from Shore (Ex10): The installation of wind turbines close to the shore leads to negative environmental impacts, such as visual, noise impact and aesthetics impacts, and it may affect the safe and continuous operation of the various human activities (fishing, recreational activities, etc.) existing in the corresponding coastal areas. In this context and taking into account the Madeira Islands characteristics as well as the current legislation marine areas with smaller than 1.8 km are considered unsuitable for the siting of floating wind turbines and are excluded from further analysis.

In the Portuguese Specific Framework for the Maritime Spatial Planning, no explicit value for distance from shore is defined. On the contrary, 1.8 km limit for the distance is given, depending mainly upon the type of the existing human coastal activities and the existence of places with special cultural, physical or historical significance. On the other hand, the 44.4 km of the contiguous area was fixed as superior limit.

3.5 *Evaluation criteria*

The other kinds of criteria are called the evaluation criteria, whose value can be evaluated based on the investigation or analysis by the experts. Before the establishment of the evaluation criteria, the evaluation merits should be determined. Wind resource, economic factors, supporting conditions onshore are essential merits for floating wind farms site selection according to Latinopoulos & Kechagia (2015); and Cavallaro & Ciraolo (2005). Environment and society factors are considered as important merits for decision making in the current status of the study.

Last, but not least, since the construction, maintenance and legislative conditions of offshore wind farms are much more complicated and have more impacts on the plant benefits than onshore wind farm and fixed offshore wind farm counterparts, they are not was considered as the decisive factors for the location selection in the first stage of the analysis. Based on the above considerations, the list of the floating wind farm evaluation criteria of the current study includes wind resource, sea conditions, supporting conditions onshore, and environmental impacts (see Table 2).

The evaluation criteria are divided in five categories: metocean data (Ev1-Ev5), viability (Ev6-Ev7), proximity to facilities (Ev8-Ev15), marine environment (Ev16-Ev18) and techno-economic data (Ev19-Ev22).

Table 2. Evaluation criteria.

No.	Criteria	Objective
Ev1	Wind velocity	Maximize
Ev2	Water depth	Minimize
Ev3	Wave conditions	Minimize
Ev4	Marine currents	Minimize
Ev5	Temperature	Minimize
Ev6	Technical feasibility	Maximize
Ev7	Sufficient study times	Maximize
Ev8	Distance from shore	Minimize
Ev9	Distance to local electrical grid	Minimize
Ev10	Distance from coastal facilities	Minimize
Ev11	Distance from residential areas	Maximize
Ev12	Distance from the maritime routes	Maximize
Ev13	Distance from underwater lines	Maximize
Ev14	Distance to marine recreational activities	Maximize
Ev15	Distance from airport	Maximize
Ev16	Distance from protected areas	Maximize
Ev17	Proximity to migratory birds' paths	Maximize
Ev18	Proximity to migratory marine life paths	Maximize
Ev19	Area of the territory	Maximize
Ev20	Proximity to the area of electric demand	Maximize
Ev21	Population served	Maximize
Ev22	Multiple resources	Minimize

Wind velocity (Ev1): Refers to the speed of the wind at the height of 10 m, 80 m and 120 m, which meet the most used hub height requirements (m/s) (Salvação & Guedes Soares, 2018). This criterion is measured by the average speed during a full calendar year, and is amended according to the long-term representative wind speed series to decrease the influence of annual wind speed alterations, which represent long-term fluctuations.

Water depth (Ev2): In consideration of the complex conditions on the sea, it is important to analyse whether the identified sites bathymetry are suitable for floating wind farm construction and maintenance. An increase of water depth includes technical and economic conditions that will be reflect in the possible project implementation.

Wave conditions (Ev3): The waves characteristics need to be considered in the floating platforms design (Christiansen et al., 2013).

Marine currents (Ev4): Evaluate the marine currents velocity and its future planning meets the platforms and mooring systems requirements.

Temperature (Ev5): With temperature reduction the extractable turbine power and its useful life increase (Chamanehpour et al., 2017). Thus the locations having lower temperature are more suitable to installation.

Technical feasibility (Ev6): This criterion includes an evaluation, which is based on a qualitative comparison between the complexity of the considered technology, and the capacity of the local actors to ensure an appropriate operating support for installation and maintenance of technology.

Sufficient study times (Ev7): The number of times studied or tested successfully each location can be taken into account as a decision parameter.

Distance from shore (Ev8): The personal and equipment transport close to the coastline is more cost-effective.

Distance to local electrical grid (Ev9): This criterion evaluates the distance between the offshore wind farm and the power transmission grid. The locations closer to electrical grid are more economically suitable.

Distance from coastal facilities (Ev10): Facilities onshore refer to the favourable factors to facilitate the construction and O&M of the projects (harbours, shipyards, etc.).

Distance from residential areas (Ev11): The suitable distance from the population centres is of importance due to some reasons: (i) the noise pollution of wind turbines, (ii) visual impacts, and (iii) associated financial costs.

Distance from the maritime routes (Ev12): Keep enough distance with the maritime lines and ships main traffic can reduce the collision risk.

Distance from underwater lines (Ev13): A possible iteration of an offshore wind farm to the existing underwater cables could result in significant adverse effects on the telecommunications, electrical and hydrocarbons networks.

Distance to marine recreational activities (Ev14): Refers to the suitability of plant construction including maximum distance to beach areas, scuba diving areas, aquatic sports, etc.

Distance from airport (Ev15): The wind turbines can cause interference in the performance of control radars (see Figure 4). In radar system airplanes are recognized and tracked via return signal frequency change (Doppler Effect). Although the position of wind turbines due to the lack of change is not followed by Doppler Effect, but rotation and turning of turbine wings causes Doppler Effect wherein this issue causes interference in the tracking and disrupts identification of an airplane (de la Vega et al., 2013).

Distance from protected areas (Ev16): The wind power stations due to the changes of natural landscapes besides the creation of noise pollution have a negative impact on intrinsic property of these regions. For this reason wind turbines should be nestled in a suitable distance in relation to the protected areas.

Proximity to migratory birds' paths (Ev17): An appropriate distance and a minimum influence on the migratory paths is an optimal solution in order to preserve the biodiversity.

Proximity to migratory marine life paths (Ev18): Refers to the coordination degree with sea area planning for marine life, which is measured by the distance between turbines and migration paths (Kaimuddin et al., 2016).

Area of the territory (Ev19): The total area plays an important role in the wind farm capacity installed and in the economic potential.

Proximity to the area of electric demand (Ev20): It is defined as the distance between wind installation and the high-energy consumption locations in the electric network (big cities, factories, etc.).

Population served (Ev21): The number of people that could be potentially served by a floating wind project (especially in remote areas, such as islands) in terms of contributing to coverage of energy needs/demands is also important for the projects economic viability and its social acceptance.

Multiple resources (Ev22): This criterion indicates the potential disagreements between the various stakeholders (mainly fishing) in the selected marine area use. It is characterized by the amount of fisheries boats in the select area during a long-term period of time.

3.6 *Locations*

The set of eligible areas for the siting of floating offshore wind farm in Madeira region corresponds to the complement of the unsuitable Madeira marine areas' set. Therefore, based on the previous criteria, three eligible marine areas have been identified for evaluation (see Figure 5).

The areas were chosen based on the criteria previously defined. They avoid the restricted areas, such as military areas, and leave a 2 km space between them and the existing underwater lines.

The chosen areas are also located between the depths of 50 and 1000 meters, so that they are feasible for the floating wind structures.

Table 3 shows the characteristics for those locations (M1 and M2 close to the Madeira Island and PS1 close to Porto Santo Island).

The wind data was obtained from the ERA-Interim reanalysis data (Salvação et al., 2014), retrieved from the European Centre for Medium-Range Weather Forecasts (ECMWF), taking into account average wind speeds for the period between 1997 and 2017.

All three locations present approximate wind speeds, and are thus considered suitable for wind

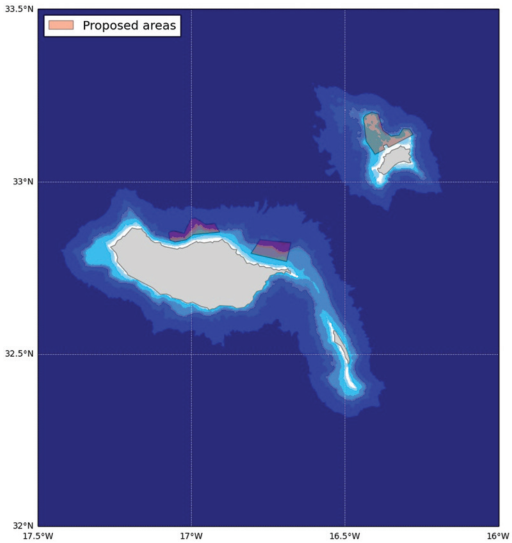

Figure 5. Proposed locations for the floating wind farm siting in the Madeira Islands.

Table 3. Locations main characteristics.

Criteria \ Locations	São Vicente M1	Porto da Cruz M2	Porto Santo PS1
Av. wind speed (10 m) (m/s)	6.49	6.52	6.53
Av. water depth (m)	500	400	70
Distance to shore (km)	1.8	2.8	1.0
Population served	262302	262302	5483
Area (km^2)	51	57.5	87

farm installation. There is a significant difference between the water depths of the locations of the two islands. In fact, location PS1 has water depths varying between 50 and 100 m, which could lead to a cheaper wind farm installation. Location PS1 is also the one with the largest area for the wind farm installation. It is, however, very close to the Porto Santo Island (1 km) and serves directly only 2% of the combined population of the islands. In case this area was chosen, this would mean an extra cost for underwater cables connecting the two islands.

4 CONCLUSIONS

In the present paper, a methodological framework, based on the combined use of criteria and GIS, for identifying the available marine areas in Madeira archipelago towards the siting of floating wind turbines has been developed. The main conclusions of this study are as follows:

- Three eligible marine areas (exclusion and evaluation alternatives) for the siting of wind farms in Madeira have been identified, located in the offshore areas North and East of Madeira Island, as well as in a lengthwise zone extended at North Porto Santo Island.
- The marine areas with very large water depths (> 1000 m) were excluded despite the vast wind energy potential.
- The offshore area, located North of Porto Santo (size equal to 87 km^2), presents the most adequate area for the siting of floating wind structures. This is mainly attributed to the simultaneous existence of the largest wind potential in this area, as well as to the greatest distance of this marine area to the coast with the respective reduction in visual impact.
- The offshore area located North-East of Madeira presents the first top choice, mainly due to the efficient satisfaction of economic/technical (proximity to local grid) and economic/socio-political (population served) factors.
- The present results illustrate the potential of deploying offshore wind turbines in Madeira Islands and they can serve as a basis for determining exact (pinpointing) relevant locations in the Portuguese marine environment.

The present investigation can be further extended, so that stakeholders, policy makers and/or locals contribute to the pairwise comparison of the evaluation criteria with respect to the goal according to their requirements (Multi-criteria Decision Making Methods). Their involvement facilitates the selection of marine areas by taking into account the social acceptance aspect, additionally, to the various technical, economic and environmental criteria. Considering the subjectivity and the complexity that characterize the social acceptance factor, public surveys among locals should be implemented to gauge public attitudes and perceptions regarding the realization of floating offshore wind farms in the Madeira marine environment.

Moreover, the proposed methodology can be easily applied to other marine areas outside Madeira Archipelago at regional and/or national level in order to support the site selection process of floating wind farms by appropriately modifying if necessary the sets of exclusion and/or evaluation criteria according to up-to-date conditions and needs, local marine characteristics, socio-political constraints, legislation limitations and/or data availability.

ACKNOWLEDGEMENTS

This work was conducted within the ARCWIND project—Adaptation and implementation of floating wind energy conversion technology for the Atlantic region (EAPA 344/2016), which is co-financed by the European Regional Development Fund through the Interreg Atlantic Area Programme.

REFERENCES

ARCWIND. Adaptation and implementation of floating wind energy conversion technology for the Atlantic region. www.arcwind.eu.

AREAM (2012). Sustainable energy action plan – Madeira Island. *Resolution no. 244/2012 of the Council of the Government of the Autonomous Region of Madeira, in plenary session, on March 29th 2012 (published in JORAM, I Série – Suplemento, nº 43, of April 5th 2012)*. 1–56.

Assembleia da República (2014). Lei 17/2014 Estabelece as Bases da Política de Ordenamento e de Gestão do Espaço Marítimo Nacional. *Diário da República, 1.ª série – N.º 71 – 10 de abril de 2014*, 2358–2362.

Bagocius, V., Zavadskas, E.K. & Turskis, Z. (2014). Sequence determining of construction of the offshore wind farm construction applying permutation method, *Ekonomika a management (17)*: 50–61.

Beyer, F., Choisnet, T., Kretschmer, M. & Cheng, P.W. (2015). Coupled MBS-CFD Simulation of the IDEOL Floating Offshore Wind Turbine Foundation Compared to Wave Tank Model Test Data. *Proceedings of 25th International Ocean and Polar Engineering Conference*. 367–374.

Bilgili, M., Yasar, A. & Simsek, E. (2011). Offshore wind power development in Europe and its comparison with onshore counterpart. *Renewable and Sustainable Energy Reviews 15(2)*: 905–915.

Carvalho Moreira, S.E. & Sousa Almeida, T.A. (2011). Potencial de produção de energia eólica em parques offshore. *Neutro à Terra – Revista Técnico-Científica Nº19 1º Semestre de 2017*. 1–6.

Cavallaro, F. & Ciraolo, L. (2005). A multicriteria approach to evaluate wind energy plants on an Italian island. *Energy Policy, 33(2)*: 235–244.
Chamanehpour, E., Ahmadizadeh & Akbarpour (2017). Site selection of wind power plant using multi-criteria decision-making methods in GIS: A case study. *Computational Ecology and Software 7(2)*: 49–64.
Christiansen, S., Bak, T. & Knudsen, T. (2013). Damping wind and wave loads on a floating wind turbine. *Energies 6(8)*: 4097–4116.
Direção-Geral do Território. Sistema Nacional de InformaçãoGeográfica.http://snig.dgterritorio.pt/portal/index.php.
Energinet.dk (2015). Technical Project Description for Offshore Wind Farms (200 MW). 1–73.
European Commission (2017). Report on the Blue Growth Strategy: Towards more sustainable growth and jobs in the blue economy, SWD/2017/128 final. 1–62.
EWEA (2015) Wind energy scenarios for 2030. 1–16.
Fetanat, A. & Khorasaninejad, E. (2015). A novel hybrid MCDM approach for offshore wind farm site selection: A case study of Iran. *Ocean and Coastal Management (109)*: 17–28.
Kaimuddin, A.H., Laë, R. & Tito De Morais, L. (2016). Fish Species in a Changing World: The Route and Timing of Species Migration between Tropical and Temperate Ecosystems in Eastern Atlantic. *Frontiers in Marine Science (3)*: 1–20.
Kim, T., Park, J. Il. & Maeng, J. (2016). Offshore wind farm site selection study around Jeju Island, South Korea. *Renewable Energy (94)*: 619–628.
de la Vega, D., Matthews, J., Norin, L. & Angulo, I. (2013). Mitigation Techniques to Reduce the Impact of Wind Turbines on Radar Services. *Energies 6(12)*: 2859–2873.
Latinopoulos, D. & Kechagia, K. (2015). A GIS-based multi-criteria evaluation for wind farm site selection. A regional scale application in Greece. *Renewable Energy (78)*: 550–560.
Mekonnen, A.D. & Gorsevski, P.V. (2015). A web-based participatory GIS (PGIS) for offshore wind farm suitability within Lake Erie, Ohio. *Renewable and Sustainable Energy Reviews. (41)*: 162–177.
Pacheco, A., Gorbeña, E., Sequeira, C. & Jerez, S. (2017). An evaluation of offshore wind power production by floatable systems: A case study from SW Portugal. *Energy (131)*: 239–250.
Roddier, D., Cermelli, C., Aubault, A. & Weinstein, A. (2010). WindFloat: A floating foundation for offshore wind turbines. *Journal of Renewable and Sustainable Energy, 2(3)*: 1–34.
Salvação, N., Bernardino, M. & Guedes Soares, C. (2014). Assessing mesoscale wind simulations in different environments. *Computers and Geosciences. Elsevier, (71)*: 28–36.
Salvação, N. & Guedes Soares, C. (2018). Wind resource assessment offshore the Atlantic Iberian coast with the WRF model. *Energy (145)*: 276–287.
Salvador, S., Costoya, X., Sanz-larruga, F.J. & Gimeno, L. (2018). Development of Offshore Wind Power : Contrasting Optimal Wind Sites with Legal Restrictions in Galicia, Spain. *Energies (11)*: 1–25.
Skaare, B., Nielsen, FG, Hanson, TD, Yttervik, R., Havmøller, O, Rekdal, A, 2015, Analysis of measurements and simulations from the Hywind Demo floating wind turbine, *Wind Energy,* 18, 1105–1122.
The Ministry of Infrastructure and the Environment (2014). White paper on Offshore Wind Energy. 1–72.
Uzunoglu, E., Karmakar, D. & Guedes Soares, C. (2016). Floating offshore wind platforms. *Floating Offshore Wind Farms,* Castro-Santos and Díaz-Casas (eds). Springer International Publishing: 53–76.
Vagiona, D.G. & Kamilakis, M. (2018). Sustainable site selection for offshore wind farms in the South Aegean-Greece. *Sustainability 10(3)*: 1–18.
Vagiona, D.G. & Karanikolas, N.M. (2012). A multicriteria approach to evaluate offshore wind farms siting in Greece. *Global Nest Journal 14(2)*: 235–243.
Wind Europe (2018). Offshore wind in Europe. Refocus. 1–37.
Ziemba, P., Wątróbski, J., Zioło, M. & Karczmarczyk, A. (2017). Using the PROSA method in offshore wind farm location problems. *Energies 10(11)*: 1–20.