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# Marine Spatial Planning-Based Siting Methodology for Co-Located Offshore Wind and Wave Energy

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## Abstract

This paper develops a marine spatial planning (MSP) methodology for strategic siting of co-located offshore wind and wave energy systems, demonstrated for Ireland's west coast. Although Ireland has exceptional wind and wave resources, objective spatial methods for assessing combined development potential remain limited. The proposed framework integrates a two-stage screening process comprising Boolean exclusion criteria and a weighted multi-criteria suitability index (SI) spanning technical, environmental, and socio-economic factors. The western Irish Exclusive Economic Zone is discretised into 189 grid cells, and site conditions are quantified using 20 years of ECMWF ERA5 metocean data (2002–2022) together with marine-use, environmental protection, and infrastructure datasets from Ireland's Marine Atlas and associated public sources. Three representative west-coast locations were evaluated in detail. Under the equal-weighting scenario, the site at 52.5° N, 10° W (approximately 40 km west of Moneypoint) achieved the lowest SI score (4.231) and was therefore ranked most suitable compared with 6.634 at 52° N, 11.5° W and 8.093 at 54° N, 10.5° W. The selected site combines comparatively low spatial constraints with favourable depth (−52.4 m) and moderate wind–wave correlation ($r = 0.4636$), while the resource assessment confirms strong west-coast conditions overall. The framework provides a transparent, transferable, and stakeholder-informed decision-support methodology for early-stage MSP and strategic siting of hybrid offshore renewable energy developments in Ireland and other maritime regions.

**Keywords:** offshore wind; wave energy; marine spatial planning; environmental planning; marine protected areas

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## 1. Introduction

### 1.1. Context and Research Motivation

Ireland possesses some of Europe's strongest offshore wind and wave resources, yet progress toward large-scale offshore renewable energy (ORE) development has been constrained by planning complexity, spatial conflict, and infrastructural limitations. While the technologies required to meet EU renewable energy targets are well established [1], their effective deployment depends on coherent marine policies and spatial planning frameworks. Ireland's intention to join the North Seas Energy Cooperation further heightens the urgency of developing structured, evidence-based approaches to offshore energy siting.

As Ireland remains heavily dependent on imported fossil fuels, offshore wind and wave installations offer a significant opportunity to enhance national energy security [2].

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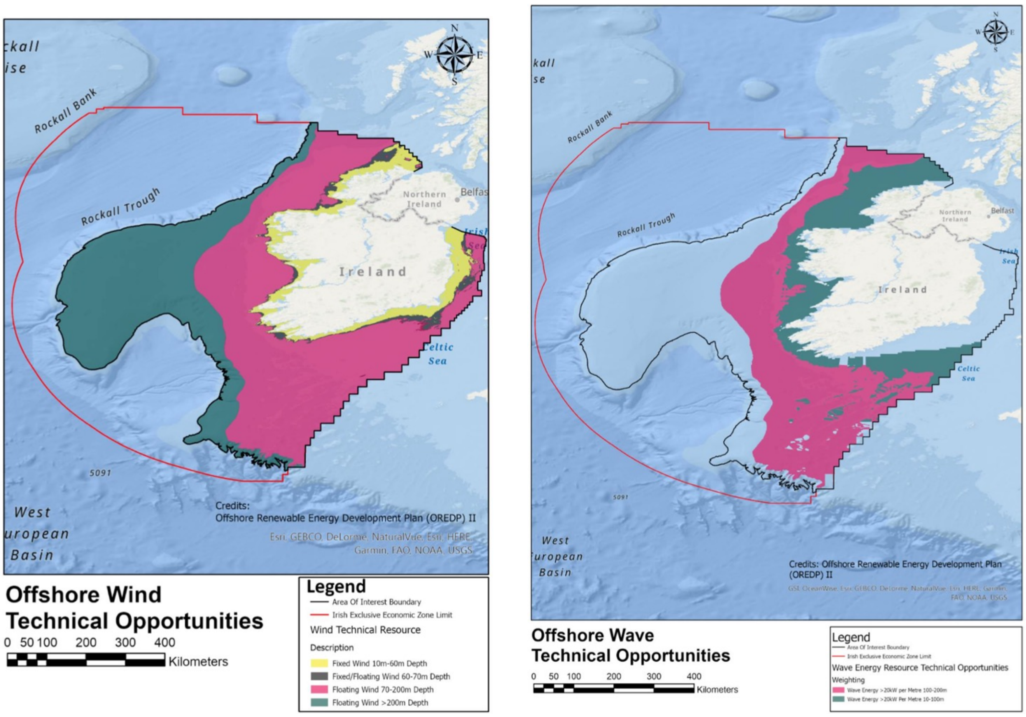
However, both resources are intermittent, and their temporal variability complicates production forecasting and grid integration [3,4]. Combining wind and wave technologies can reduce output variability and increase overall resource utilisation efficiency [5], particularly in regions such as the Irish Atlantic margin, where both resources are abundant (Figure 1).



(**a**) (**b**)

**Figure 1.** OREDP II offshore wind and wave technical opportunity areas within Ireland's EEZ. (**a**) Offshore wind technical opportunity areas; (**b**) offshore wave technical opportunity areas.

Marine spatial planning (MSP) provides a framework for organising competing marine uses, such as fishing, shipping, conservation, and energy production, while balancing technical, environmental, and socio-economic considerations [6,7]. Despite strong support for ORE expansion, concerns remain regarding the displacement of existing marine activities, interaction with marine protected areas (MPAs), and the need for transparent, stakeholder-informed planning processes. A structured MSP framework is therefore essential for identifying suitable development areas, mitigating spatial conflict, and supporting sustainable ORE deployment [8]. Yet for Ireland, objective and spatially explicit methods for assessing co-located wind–wave development suitability remain limited.

### *1.2. Scope and Research Objectives*

The goal of this study is to develop and demonstrate a marine spatial planning methodology that identifies suitable areas for the combined exploitation of offshore wind and wave energy along Ireland's west coast. The approach integrates technical resource assessments with environmental and socio-economic constraints to support sustainable, multi-use marine planning.

Building on national frameworks such as the National Marine Planning Framework (NMPF) and the Offshore Renewable Energy Development Plan (OREDP), the western EEZ is discretised into 189 grid cells using a spatial resolution of 0.5° × 0.5° (corresponding to a coarse regional grid spacing of approximately 30–35 km at Irish latitudes), within which exclusion criteria are applied to remove unsuitable sites. The remaining locations are evaluated using a weighted suitability index that incorporates met-ocean conditions, spatial constraints, logistical considerations, and environmental sensitivities.

Stakeholder insights drawn from developers, the transmission system operator, and environmental NGOs inform the definition and weighting of criteria to ensure that the approach reflects real-world planning needs. The resulting methodology is applied to three representative offshore locations to identify the most favourable site for combined offshore wind–wave development.

The potential of offshore renewable energy resources, including wind, wave, and tidal energy, is now well established, and substantial progress has been made in resource characterisation and site screening for individual technologies. Recent work by O'Connell et al. [9] highlights the persistent uncertainty in identifying economically viable wave energy locations and quantifies the spatial variability of development costs through a geospatial levelised cost of energy (LCOE) assessment for Irish and western UK waters. Their results identify the Atlantic margin off Ireland's west coast as a particularly promising region for wave energy deployment, thereby reinforcing the need for more detailed marine spatial planning (MSP)-oriented assessment in this area. This is especially relevant for studies considering co-located offshore renewable systems rather than single-technology deployment.

Recent GIS-based offshore wind siting studies have similarly advanced the state of practice in spatial screening. For example, Johnston et al. [10] applied a multi-criteria GIS framework to offshore wind development in Northern Ireland, integrating resource, bathymetric, and marine-use constraints to identify technically suitable zones. While this type of approach provides a strong foundation for strategic site screening, it also underscores an important limitation in much of the current literature, namely, that economic, environmental, and broader socio-spatial considerations are often not integrated in a transparent and transferable way within a single decision-support framework.

At the same time, the recent co-location literature has increasingly emphasised the importance of structured site-selection methods for combined offshore wind–wave systems. A systematic review by Hosseinzadeh et al. [11] noted growing use of GIS and multi-criteria decision-making for combined offshore wind–wave site selection while also identifying recurring gaps in the treatment of environmental constraints, seabed conditions, and reproducible decision logic. More recent studies have further expanded hybrid wind–wave assessment using resource complementarity and large-scale screening approaches, demonstrating the value of correlation-aware metrics and transparent screening workflows for identifying co-location potential across regions [12,13]. These developments motivate the need for MSP-compatible methodologies that move beyond resource mapping alone and support strategic, evidence-based siting decisions.

In this context, the present study develops a high-level, multi-faceted MSP methodology for co-located offshore wind and wave energy siting and applies it to the Irish west coast. The proposed framework combines exclusion mapping with a weighted multi-criteria suitability index to evaluate candidate areas across technical, environmental, economic, and social dimensions. In doing so, the study addresses a key gap between resource-focused assessments and practical MSP decision-support tools for early-stage planning of hybrid offshore renewable energy developments.

### 1.3. Contribution and Novelty

This study makes three contributions to the emerging field of combined resource development of offshore renewable energy. First, it introduces a unified and MSP-compatible suitability index specifically designed for co-located offshore wind–wave systems. Existing spatial planning tools typically assess wind and wave resources independently; the proposed framework integrates exclusion layers with dynamically weighted technical, environmental, and socio-economic criteria to provide a transparent and reproducible structure for early-stage site screening.

Second, the methodology is applied to the Irish Atlantic margin using multi-decadal ERA5 metocean data and publicly accessible spatial layers (Figure 1), producing the first spatially explicit assessment of combined wind–wave opportunities on Ireland's west coast within an operational MSP context.

Third, the criteria and weighting scheme are informed by structured engagement with developers, NGOs, and policy actors, addressing a recognised gap between technical analyses and real planning and governance constraints. Collectively, these contributions position the work as a methodological advance that can support ongoing strategic processes such as DMAPs and OREDP II.

Beyond its national application, the methodology offers a transferable framework that can be adapted to other maritime regions undergoing offshore renewable energy expansion. Because the suitability index integrates universally relevant dimensions—metocean resource characterisation, exclusion logic, weighted multi-criteria evaluation, and stakeholder-aligned prioritisation—it provides a replicable approach for early-stage screening across diverse regulatory, ecological and infrastructural settings. The structured yet flexible design means that alternative datasets, regional planning frameworks, or distinct stakeholder priorities can be incorporated without altering the core logic of the method. In this sense, the paper proposes not only a case study for Ireland, but a generalisable MSP-based methodology that can support strategic planning for hybrid offshore energy systems in coastal regions worldwide.

The remainder of this paper is organised as follows. Section 2 describes the study area, datasets, and the marine spatial planning framework adopted in this work, including the exclusion criteria and weighted multi-criteria suitability assessment. Section 3 presents the application of the methodology to the Irish west coast and reports the results for the candidate co-located offshore wind–wave sites. Section 4 discusses the principal findings, limitations of the current framework, and implications for future marine spatial planning and offshore renewable energy development. Finally, Section 5 summarises the main conclusions and outlines directions for further work.

## 2. Literature Review

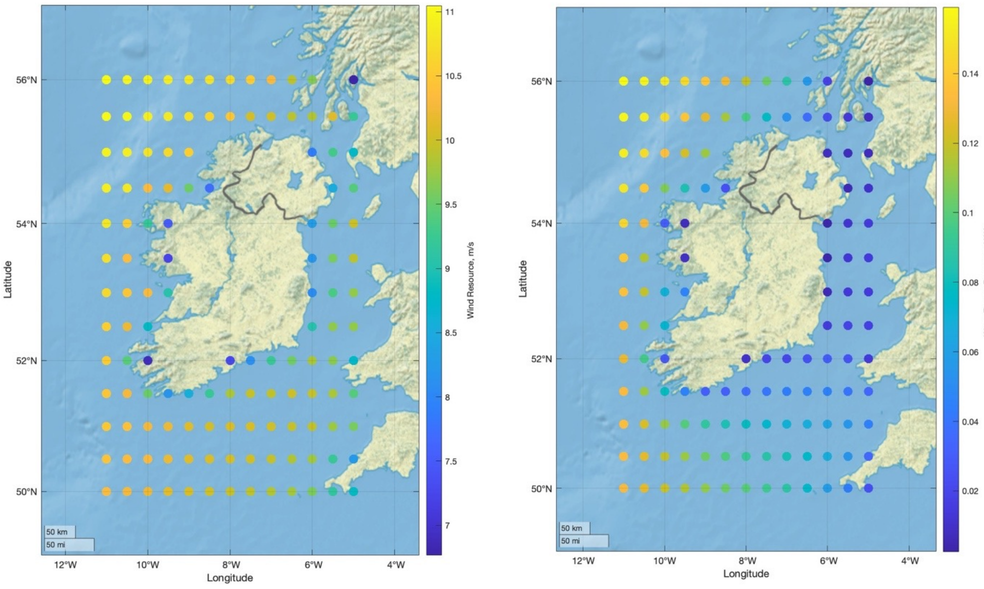
### 2.1. Offshore Wind and Wave Resources in Ireland and Combined Exploitation

Ireland's position on the eastern North Atlantic provides exceptional offshore wind and wave resources that can be harnessed through large-scale wind farms and wave energy parks [14,15]. Figure 2 illustrates the spatial distribution of long-term mean offshore wind and wave resources around Ireland, showing consistently high wind speeds and energetic wave conditions along the western Atlantic margin compared with more moderate resource levels on the east coast. Offshore renewable energy (ORE) offers higher and more reliable energy yields than onshore generation [16,17], and multiple pathways exist for Ireland to move towards a predominantly renewable energy system [1]. Policy targets under the Paris Agreement and Ireland's Climate Action Plan 2023 require approximately 80% renewable electricity by 2030, with at least 30 GW of offshore wind potential identified off the west coast [16]. Combined exploitation of wind and wave energy has been proposed as a means to reduce intermittency, improve capacity credit and lower levelised cost of energy (LCoE) by sharing infrastructure and grid connections [16,18].

In practice, there are two broad pathways for exploiting offshore wind and wave energy from dual sources: (i) hybrid systems, in which wind and wave devices are integrated on a shared platform or support structure, and (ii) combined renewable energy parks, in which wind and wave technologies are co-located within the same marine area while sharing selected infrastructure and spatial planning functions [19,20]. The latter may include shared anchors/moorings, electrical infrastructure (e.g., inverters, export cables, and inter-connectors), installation logistics, and maintenance access while retaining separate energy-conversion devices. By contrast, hybrid concepts typically involve tighter physical and functional integration, with wave energy converters incorporated into fixed-bottom or floating wind-turbine support platforms. Reviews by Wang et al. [21] and Lee and Ong [22] provide overviews of current hybrid wind–wave technologies and the associated numerical and experimental modelling approaches.

The maturity, complexity, and risk profile of these integration pathways differ significantly. Co-located or shared-infrastructure concepts are generally more suitable for near-term deployment because they can leverage existing offshore wind development practice while improving space utilisation and potentially reducing balance-of-plant costs. More tightly integrated hybrid concepts may offer greater long-term synergies, but they introduce additional engineering challenges related to coupled hydrodynamic–aerodynamic–structural response, control coordination, survivability, and whole-life reliability. As discussed by Wan et al. [19], a major barrier to wider deployment of combined wind–wave infrastructure is the complexity arising from system dynamics, structural diversity, and the wide range of possible technology-combination patterns. These challenges motivate the high-level MSP approach adopted in the present study, which focuses on strategic siting and suitability screening prior to project-specific technology selection and detailed engineering design.

Studies of the Irish Atlantic margin show strong wind and energetic wave climates with favourable low to moderate wind–wave correlation, driven by long-fetch Atlantic swells and time lags between wind and wave peaks [14,15,23]. Such conditions are well suited to hybrid or co-located wind–wave schemes that smooth power output and expand weather windows for operation and maintenance [23,24]. Veigas and Iglesias [18] and others demonstrate that combined systems around Ireland and the Atlantic arc can deliver substantial annual energy production and attractive LCoE. However, these studies focus primarily on resource characterisation or techno-economic performance and do not integrate technical, environmental and socio-economic factors within a marine spatial planning (MSP) suitability framework.



(**a**) (**b**)

**Figure 2.** Offshore wind and wave resource maps for Irish waters. (**a**) Offshore wind resource distribution; (**b**) offshore wave resource distribution.

### 2.2. Environmental and MSP Considerations

Offshore renewable energy developments interact with marine ecosystems across their life cycle, from site investigation and construction through operation and decommissioning [17,25]. Key pressures include underwater noise (especially from pile driving), changes to hydrodynamics and sediment dynamics, habitat disturbance, risks of collision or entanglement for marine fauna, and cumulative impacts with other maritime activities such as fisheries and shipping [26–28]. Floating offshore wind turbines (FOWTs) and many wave energy converters (WECs) avoid some of the most damaging construction processes but introduce mooring and cable interactions, local habitat changes and potential alterations in wave and current regimes [17,29]. At the same time, ORE structures can act as artificial reefs or fish aggregation devices, contributing locally to biodiversity when appropriately sited [29,30]. As multiple stressors often act simultaneously, cumulative impact assessment through Strategic Environmental Assessment, Environmental Impact Assessment or related tools is essential to support precautionary but enabling decision making [30,31].

These environmental considerations sit within a rapidly evolving protection framework. Ireland is committed to expanding its network of marine protected areas (MPAs), special areas of conservation (SACs) and special protection areas (SPAs) within the Natura 2000 framework and the “30 × 30” goal of protecting 30% of marine waters by 2030 [32]. Fair Seas’ systematic conservation planning identifies priority areas for biodiversity protection, illustrating the potential spatial tension between future ORE zones and ecological sensitivities. MSP offers the main process for resolving these tensions. As an ecosystem-based, cross-sectoral and adaptive framework, MSP relies on high-quality spatial data and strong stakeholder engagement [33–35]. While the NMPF and OREDP provide policy direction, they do not yet supply operational spatial tools that integrate resource mapping with environmental and socio-economic constraints for co-located wind–wave development [34,36].

### 2.3. Site Selection and Suitability Indices

Site selection for offshore renewables combines considerations of resource strength, water depth, seabed type, distance to ports and grid, navigation routes, fishing effort, environmental sensitivities and existing infrastructure [14,16,37]. A range of spatial and multi-criteria decision frameworks have been used internationally to manage these factors. Galparsoro et al. developed a suitability index for wave energy by aggregating environmental, technical and socio-economic layers [27]. Davies et al. proposed a constraint-based planning framework for Scottish waters that applies weighted scenarios to environmental and industry themes [35]. Sweden’s Symphony tool integrates ecosystem components, pressures and expert-elicited sensitivity scores into a matrix framework for estimating cumulative impacts [31]. Dimensionality-reduction methods such as PCA and K-means clustering have also been used to identify coherent development zones for ORE along the Irish Atlantic margin [5,15].

These spatial methodologies are frequently combined with multi-criteria decision-making (MCDM) tools such as WASPAS, ARAS or TOPSIS to rank candidate sites with conflicting objectives [38]. While previous Irish studies have mapped resources or estimated LCoE, there remains limited integration of quantitative suitability indices with cumulative impact considerations and MSP requirements [14,34,36]. The present study advances the literature by defining a transparent, MSP-compatible suitability index for combined wind–wave exploitation that integrates Boolean exclusion layers with dynamically weighted technical, environmental and socio-economic evaluation criteria.

### *2.4. Limitations of Existing Approaches to Hybrid Offshore Renewable Energy Siting*

Despite the maturity of spatial and multi-criteria approaches for offshore wind or wave developments considered separately, there remains a noticeable gap in the literature regarding integrated, MSP-compatible frameworks for co-located wind–wave systems. Existing studies tend to prioritise either resource characterisation, techno-economic performance, or single-sector suitability, and few combine exclusion constraints, weighted evaluation criteria and stakeholder-informed prioritisation into a reproducible spatial methodology. Moreover, although several tools (e.g., Galparsoro's suitability index, Davies' constraint-based framework, Sweden's Symphony) demonstrate strong single-sector or environmental capabilities, none have yet been adapted to identify and compare hybrid wind–wave opportunities. This gap underscores the need for a transparent, transferable methodology that links long-term met-ocean analysis with environmental and socio-economic constraints in a form that can support early-stage MSP screening for combined offshore renewable energy developments.

## 3. Methodology

In this section we develop a marine spatial planning (MSP) framework to identify suitable areas for the combined exploitation of offshore wind and wave energy along Ireland's west coast. The approach integrates met-ocean resource assessment, technical and environmental constraints, and socio-economic considerations into a two-stage suitability index. First, exclusion criteria are used to remove clearly infeasible locations. Second, the remaining grid points are ranked using a weighted multi-criteria evaluation that can be tuned to different stakeholder priorities. The overall structure of the methodology is summarised in Figure 3.

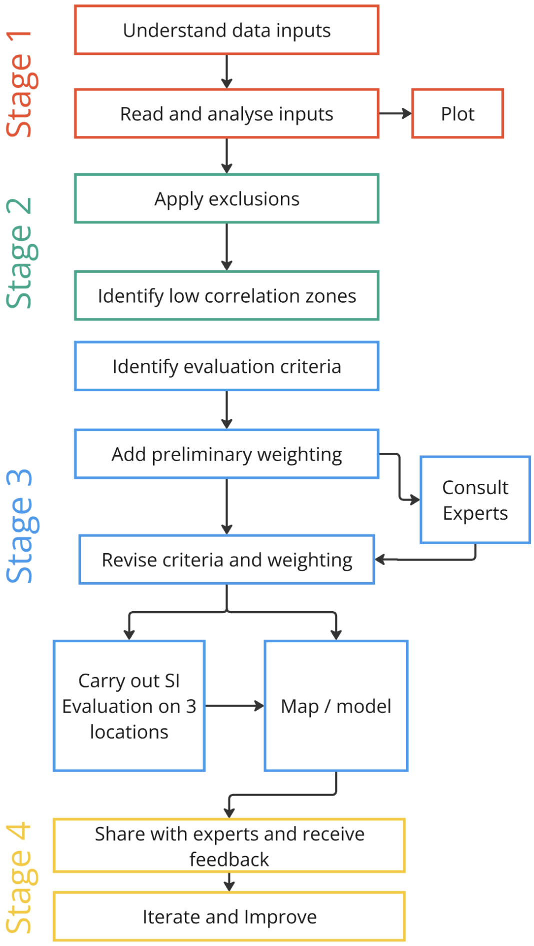


**Figure 3.** Overview of the four-stage methodology used to identify suitable areas for combined offshore wind–wave development.

### 3.1. Study Area

Ireland's marine space is approximately ten times its land area, with an Exclusive Economic Zone (EEZ) of about 880,000 km$^2$ [39]. In this paper, the focus is on the western EEZ, where prevailing south-westerly to westerly winds and long Atlantic fetch generate high-quality wind and wave resources. Previous studies have consistently highlighted the west coast as favourable for offshore wind and wave exploitation [14,15,34].

The study area is defined as the OREDP II technical opportunity region on the Atlantic coast and extends to the EEZ boundary. In geographic terms, the analysed western EEZ domain spans approximately 50° N to 55° N and covers the offshore Atlantic waters west of Ireland (see Figure 1). Figure 1 shows the OREDP II technical opportunity areas for offshore wind and wave within Ireland's EEZ. For computational tractability, the domain is discretised into 189 grid cells, represented by their centres, with a resolution of $0.5^\circ \times 0.5^\circ$. This grid resolution was selected to support a regional-scale screening assessment of the western Irish EEZ, consistent with the early-stage marine spatial planning objective of the study. In this context, the aim is to identify and rank broad candidate areas for co-located offshore wind–wave development rather than to optimise project-scale layouts. The adopted $0.5^\circ \times 0.5^\circ$ discretisation also aligns with the spatial scale of the ERA5 metocean dataset used to derive wind and wave resource and correlation metrics, making it suitable for comparative high-level assessment across the domain. Once priority areas are identified, the framework can be refined using higher-resolution spatial grids and project-specific datasets to support local-scale site assessment. The same methodology can be applied at higher spatial resolution or to other regions of Ireland's EEZ when more detailed data or project-specific surveys become available. A formal grid-sensitivity (grid-independence) analysis is recommended as a further step in future work, particularly when applying the methodology at finer spatial resolution.

The same methodology can be applied at higher spatial resolution or to other regions of Ireland's EEZ when more detailed data or project-specific surveys become available. More broadly, while the overall screening methodology is transferable, its application to other jurisdictions would require adaptation of the exclusion criteria, weighting structure, and input datasets to reflect local regulatory frameworks, ecological sensitivities, marine-use patterns, and infrastructure constraints.

### 3.2. Data and Processing

The methodology relies on publicly available, quality-controlled datasets covering met-ocean conditions, seabed characteristics, existing marine uses and environmental protection areas. These datasets are sufficient for a regional-scale MSP screening; higher-resolution proprietary datasets would only be required at later project stages once a site has obtained Maritime Area Consent (MAC).

#### 3.2.1. Met-Ocean Resource Data

Wind and wave conditions are taken from the ERA5 reanalysis dataset provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) [40]. For each grid point in the study area, 20 years of data (2002–2022) are extracted at six-hourly resolution. The following variables are used:

- Zonal and meridional wind components at 100 m, $u$ and $v$ (m/s);
- Significant wave height, $H_s$ (m);
- Mean wave period, $T$ (s);
- Mean wave direction (degrees).

Wind speed is computed as

$$U_{\mathrm{w}} = \sqrt{u^2 + v^2}. \tag{1}$$

Wind power density is then estimated as

$$\mathrm{Wind}_{\mathrm{power\_density}} = \frac{1}{2}\rho_{\mathrm{air}}\,U_{\mathrm{w}}^3, \tag{2}$$

where $\rho_{\mathrm{air}} = 1.225\ \mathrm{kg/m^3}$.

Wave energy density in deep water is computed using [39,41]

$$\mathrm{Wave}_{\mathrm{energy\_density}} = \frac{\rho_{\mathrm{sea\ water}}\, g^2\, H_{\mathrm{s}}^2\, T}{64\pi}, \tag{3}$$

with $\rho_{\mathrm{sea\ water}} = 1020\ \mathrm{kg/m^3}$ and $g = 9.81\ \mathrm{m/s^2}$.

For each grid point, long-term mean wind and wave energy densities are calculated, and the Pearson correlation coefficient between wind and wave power time series is evaluated using

$$\rho_{X,Y} = \frac{n\sum_{i=1}^{n} x_i y_i - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{\sqrt{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}\sqrt{n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} y_i\right)^2}}, \tag{4}$$

where $X$ and $Y$ denote the wind and wave power density series respectively and $n$ is the number of time steps. Low correlation values are favourable for combined exploitation because they imply reduced variability in the joint power output [14,15,23].

### 3.2.2. Marine Uses, Seabed and Environmental Data

Spatial data for existing marine uses and constraints are compiled from:

- Ireland's Marine Atlas and EMODnet, providing vessel density, navigation routes, fishing activity and marine boundaries;
- INFOMAR and GEBCO bathymetry products, used to determine water depth and broad seabed morphology;
- National Parks and Wildlife Service (NPWS) datasets for existing and proposed Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and other designated sites;
- FairSeas proposed Marine Protected Area (MPA) network for anticipated conservation constraints.

Environmental protection areas from these datasets are illustrated in Figure 4, which shows existing SACs and SPAs and highlights the relatively small fraction of currently designated areas compared with anticipated targets for the "30 × 30" goal.

Bathymetry is used to distinguish regions suitable for bottom-fixed versus floating foundations, e.g., with fixed-bottom offshore wind typically preferred in shallower waters (commonly up to approximately 50–60 m, depending on foundation type and seabed conditions), while floating offshore wind is generally considered for deeper sites from around 50 m onward [42,43]. Environmental layers identify current and future conservation priorities, and marine use layers capture potential conflicts with shipping, fishing and other activities.

**Figure 4.** Existing SACs and SPAs in Irish waters used as environmental protection area layers in the exclusion and evaluation criteria.

### 3.2.3. Pre-Processing

ERA5 data are obtained in NetCDF format and converted to comma-separated values (CSV) for analysis in MATLAB (Version: R2024b). Basic pre-processing includes removal of missing values, consistency checks and aggregation to long-term statistics at grid-point level. Mapping and spatial analysis are performed in MATLAB using the Mapping Toolbox, which allows the met-ocean resource, bathymetry and constraint layers to be collocated on the same grid.

## *3.3. Suitability Index Framework*

The suitability assessment proceeds in two stages. First, exclusion criteria are applied using Boolean logic to remove grid points that are clearly incompatible with combined offshore wind and wave developments. Second, the remaining candidates are scored against a set of evaluation criteria encompassing technical, environmental and socio-economic dimensions. Scores are combined through a weighted multi-criteria analysis to yield a dimensionless suitability index for each grid point. Conceptually, the suitability index nests evaluation criteria within an overarching exclusion layer, as illustrated in Figure 5, while the detailed workflow is summarised in Figure 6. A breakdown of the criteria structure is shown in Figure 7.

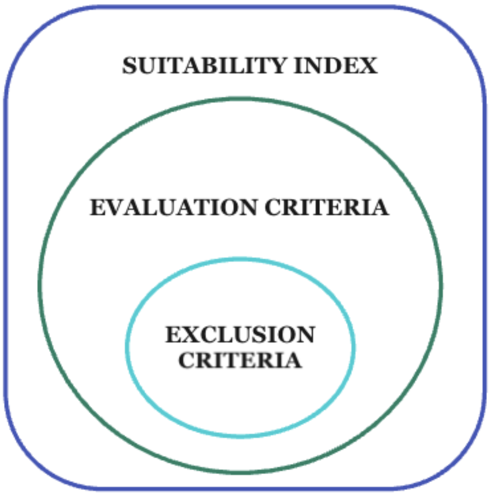


**Figure 5.** Conceptual structure of the suitability index, with exclusion criteria forming the outer envelope and evaluation criteria nested within.

**Figure 6.** Flow chart of the suitability index methodology, showing exclusion screening followed by multi-criteria evaluation.

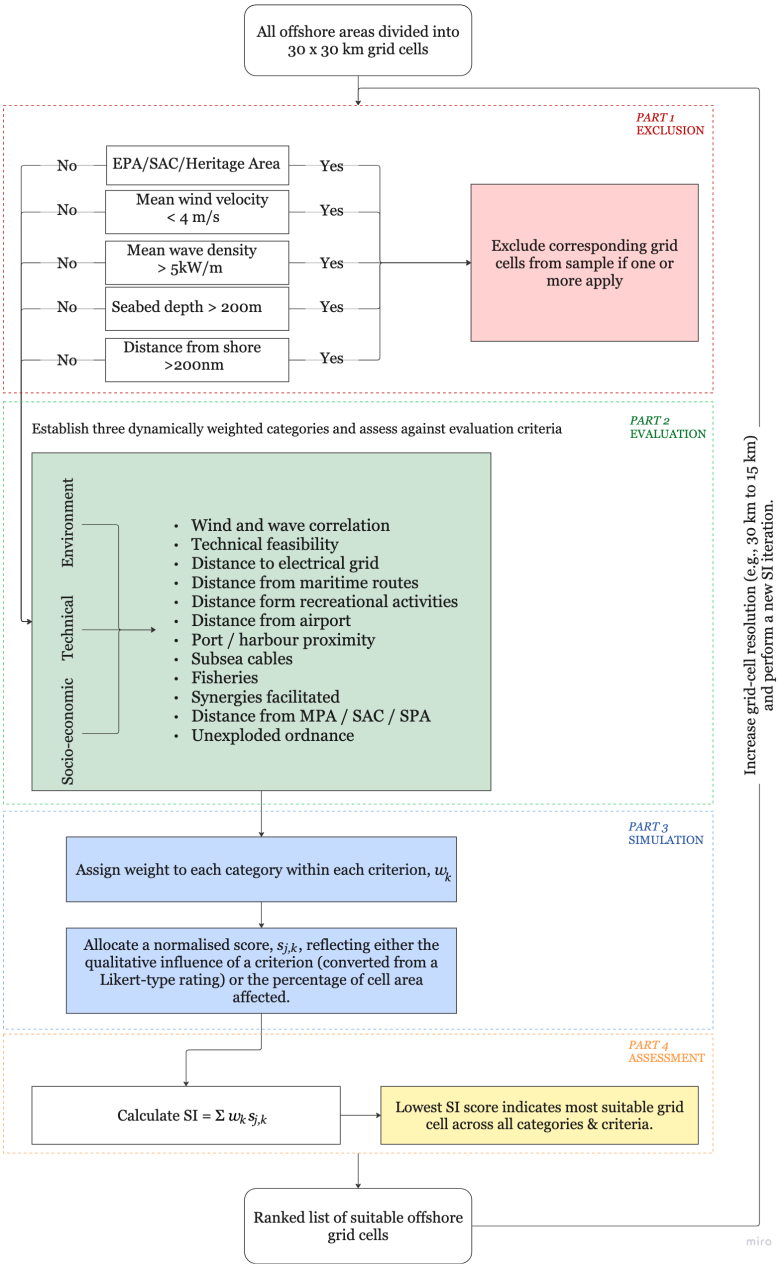


**Figure 7.** Hierarchical breakdown of the suitability index criteria into technical, environmental and socio-economic components.

### 3.3.1. Exclusion Criteria

Exclusion criteria are defined to capture non-negotiable constraints and hard feasibility limits. Building on the methodology employed by Vasileiou et al. [37], a grid point is excluded if any of the following conditions apply (full list given in Table 1):

- Located within existing or proposed conservation areas where large-scale ORE is incompatible (selected SACs, SPAs, MPAs);

- Located within main shipping lanes or high-density vessel traffic corridors, including safety buffers [14,27];
- Outside the depth range considered viable for offshore wind and wave developments (e.g., depths shallower than the minimum required for navigation or deeper than the assumed practical limit for floating arrays);
- Insufficient wind or wave resource, based on minimum thresholds for long-term mean power density [37];
- Other hard constraints identified in stakeholder discussions (e.g., proximity to existing subsea cables where co-location is not feasible).

**Table 1.** Exclusion criteria and associated constraint type.

| No. | Criteria | Criteria Type/Constraint and Source |
|---|---|---|
| 1 | MPAs/EPAs/SACs/SPAs, etc. | Environmental [37] |
| 2 | Heritage area | Socio-economic [37,44] |
| 3 | Maritime traffic | Socio-economic [6] |
| 4 | Wind and wave correlation | Technical [23] |
| 5 | 4 m/s $<$ Wind velocity $<$ 25 m/s | Technical [37] |
| 6 | Wave energy potential $<$ 5 kW/m | Technical [6,37] |
| 7 | Distance from shore $>$ 200 nm (i.e., EEZ) | Technical [27,37,44] |
| 8 | Military training zones | Socio-economic [11] |

This Boolean screening yields a reduced set of candidate grid points for detailed evaluation.

### 3.3.2. Evaluation Criteria

For each remaining grid point, a set of evaluation criteria is defined under three main categories, informed by previous MSP and suitability studies [27,32,35]:

- **Technical**: wind and wave energy density, wind–wave correlation, water depth, distance to shore, distance to suitable port facilities, seabed conditions and existing grid infrastructure.
- **Environmental**: overlap with or proximity to sensitive habitats, cumulative footprint relative to conservation and fisheries, and exposure to future MPA designations.
- **Socio-economic**: fishing intensity, shipping and navigation uses, proximity to population centres and tourism areas, and potential conflicts with existing marine activities.

Each criterion $k$ is assigned a normalised score $s_{j,k}$ for grid point $j$, derived either from a qualitative Likert-type rating or from the proportion of the grid cell affected by the activity. Higher scores indicate greater constraint or lower suitability, and the normalisation ensures that qualitative judgements and area-based measures are handled consistently within the calculation.

### 3.3.3. Weighting and Aggregation

To reflect different planning priorities, the criteria are grouped by category and combined using a dynamic weighting scheme adapted from [35]. Let $w_k$ denote the weight assigned to criterion $k$ and $s_{j,k}$ the corresponding score at grid point $j$. The suitability index $\mathrm{SI}_j$ is defined as

$$\mathrm{SI}_j = \sum_{k=1}^{N} w_k \, s_{j,k}, \tag{5}$$

where $N$ is the total number of evaluation criteria. A lower value of $\mathrm{SI}_j$ corresponds to a more suitable location for combined wind–wave exploitation. Weights are normalised such that $\sum_{k=1}^{N} w_k = 1$.

Weights are constructed at two levels. First, category weights (environmental, technical, socio-economic) are chosen to reflect the overall planning emphasis (e.g., equal weighting, environment-favoured, technical-favoured or socio-economic-favoured), as illustrated in Table 2.

**Table 2.** Applied dynamic weighting values for environmental, technical and socio-economic categories.

| | **Equal** | **Tech Favoured** | **Env Favoured** | **Socio Favoured** |
|---|---|---|---|---|
| Environmental | 0.33 | 0.25 | 0.50 | 0.25 |
| Technical | 0.33 | 0.50 | 0.25 | 0.25 |
| Socio-economic | 0.33 | 0.25 | 0.25 | 0.50 |

The suitability of each grid cell was evaluated using a weighted multi-criteria assessment. Each criterion was first assigned a baseline relevance score on a 1–5 Likert scale to reflect its relative importance within the technical, environmental, or socio-economic category. This baseline score was then multiplied by the scenario-specific category weighting factor given in Table 2 to obtain the final weighting used in the suitability index:

$$\mathrm{FinalWeight}_{i,s} = \mathrm{LikertScore}_i \times \mathrm{CategoryWeightFactor}_s,$$

where $i$ denotes the criterion and $s$ denotes the weighting scenario.

For each grid cell, the value of each criterion (expressed either as a Likert rating or as the proportion of the cell affected, depending on the criterion) was multiplied by its final weighting to produce a weighted criterion score:

$$\mathrm{CriterionScore}_{i,\mathrm{cell},s} = \mathrm{Value}_{i,\mathrm{cell}} \times \mathrm{FinalWeight}_{i,s}.$$

The weighted criterion scores were then aggregated to obtain the overall suitability index for each grid cell in each scenario. For transparency, Table 3 presents the baseline Likert scores and resulting criterion-level weights for all criteria. A worked example of the SI calculation for one representative site is provided in Appendix A.

Second, within each category, individual criteria are assigned relative weights based on the literature, data analysis and stakeholder input. Stakeholder workshops and targeted discussions with developers, NGOs and the transmission system operator were used to benchmark these weights and to check that the scoring and aggregation are consistent with perceived risks and priorities in Irish waters.

Stakeholder engagement (including developers, NGOs, and the transmission system operator) was used to inform the distinction between binary exclusion constraints and weighted evaluation criteria and to benchmark the relative importance of planning factors in the Irish MSP context; these inputs were used to structure the suitability framework rather than as independent validation of the results.

The scenario-specific weights were defined as simple sensitivity-testing cases rather than as fixed industry-standard values or technology-maturity-based coefficients. In each "favoured" scenario, a 0.5:0.25:0.25 split was adopted to apply a clear but moderate emphasis to one category (technical, environmental, or socio-economic) while retaining balanced contributions from the remaining two categories, thereby enabling transparent comparison with the equal-weighting case. The resulting suitability index provides a transparent, flexible and repeatable metric that can be used to rank candidate sites and to explore how different weighting schemes influence site preference. In this study, the framework is applied to three representative locations along the west coast with low wind–wave correlation, identified from the ERA5 resource analysis.

**Table 3.** Weighted evaluation criteria with notes column.

| Evaluation Criteria | Category | Weight | Notes |
|---|---|---|---|
| Wind and wave correlation | Environmental | 3 | Strong environmental relevance due to natural resource alignment. |
| | Technical | 4 | High technical importance for optimal energy capture. |
| | Socio-economic | 2 | Moderate socio-economic influence. |
| Technical feasibility: seabed type and water depth | Environmental | 4 | Seabed type and topology affects ecological disturbance. |
| | Technical | 3 | Seabed type and topology affects technical deployment challenges. |
| | Socio-economic | 4 | Cheaper installation in favourable topologies. |
| Distance to electrical grid | Environmental | 3 | Grid proximity reduces environmental disturbance during cabling. |
| | Technical | 3 | Important for efficient and reliable transmission and maintenance operations. |
| | Socio-economic | 3 | Environmental and logistical implications influence cost. |
| Distance from maritime routes | Environmental | 1 | Minimal direct environmental concern. |
| | Technical | 2 | Low technical relevance. |
| | Socio-economic | 3 | Reduces risk of conflict with commercial activities, e.g., shipping. |
| Distance from recreational activities | Environmental | 1 | Minimal direct environmental concern. |
| | Technical | 1 | Low technical relevance. |
| | Socio-economic | 3 | Tourism and local use impacts due to restricted usage and landscape disturbances. |
| Distance from airport | Environmental | 2 | Proximity affects wind patterns and turbulence. |
| | Technical | 3 | May impact turbine performance reliability. |
| | Socio-economic | 3 | Safety and noise conflicts with air travel. |
| Adequate port/harbour proximity | Environmental | 3 | Closer ports reduce vessel-related emissions. |
| | Technical | 4 | Critical for maintenance and installation logistics. |
| | Socio-economic | 4 | Reduces operational costs significantly. |
| Subsea cables (oil/gas/communications) | Environmental | 4 | Avoids damaging crucial subsea infrastructure. |
| | Technical | 4 | High technical risk if located too close. |
| | Socio-economic | 4 | Damage could incur major economic and service impacts. |
| Fisheries | Environmental | 2 | Low impact on local fishing, positive impacts due to deterring industrial fishing which has negative impacts on maritime biodiversity. |
| | Technical | 2 | Low technical relevance. |
| | Socio-economic | 3 | Strong socio-economic relevance due to local livelihoods and food supplies. |
| Multiple resources/synergies | Environmental | 3 | Potential over-exploitation but also increased utility of space. |
| | Technical | 2 | Technology still developing; can be reinstated post-use, (e.g., aquaculture). |
| | Socio-economic | 4 | Maximises space use and enhances economic output. |
| Distance from MPA/SAC/SPA | Environmental | 4 | High environmental protection priority which would be negatively affected. |
| | Technical | 3 | Identifying areas of low environmental significance is critical; most of the seabed is made of rock and mud substrate, which is not of environmental significance. |
| | Socio-economic | 2 | Impacts socio-economic benefits garnered from supporting and protecting maritime ecosystems. |
| Unexploded ordnance (UXO) | Environmental | 2 | No impact if undisturbed. |
| | Technical | 4 | Significant technical hazard if not monitored properly. |
| | Socio-economic | 3 | Costly to assess, avoid and manage safety concerns. |

# 4. Results and Discussion

## *4.1. Resource Characterisation and Site Selection*

Figure 8 illustrates Ireland's maritime limits, including the NMPF area, the Exclusive Economic Zone (EEZ), and the OREDP technical opportunity regions. The figure also marks candidate ports previously identified as suitable for supporting offshore renewable energy (ORE) developments, including Killybegs, Rossaveel, Moneypoint and Castletownbere [45,46]. These ports influence logistical feasibility in the suitability index through their distance to each site and the level of existing infrastructure.

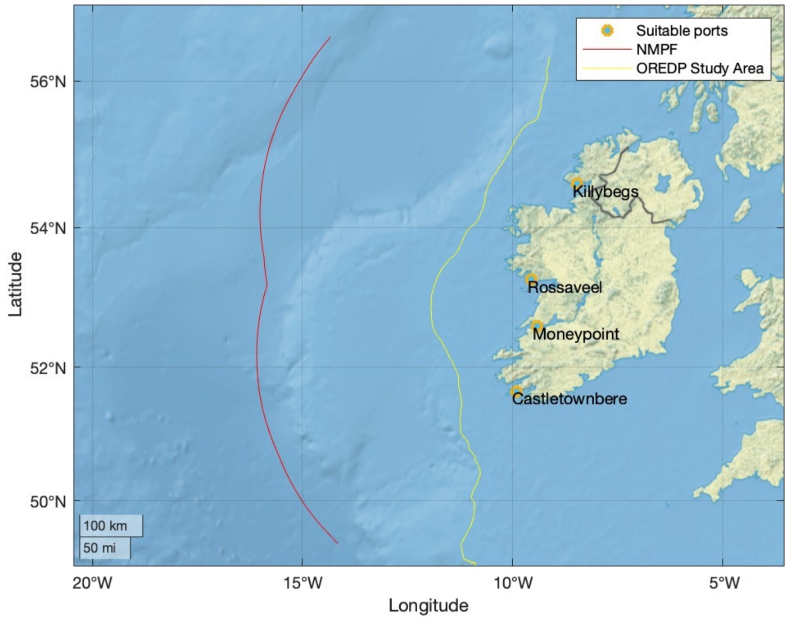


**Figure 8.** Ireland's NMPF area, EEZ boundary, and OREDP technical opportunity regions, including candidate ports relevant for offshore renewable energy logistics.

The spatial distribution of long-term mean wind speed and wave power density over Irish waters is presented in Figure 9. The west and north-west coasts show the strongest wind and wave climates, with 100 m wind speeds typically in the range 10–11 m/s and wave power densities significantly higher than along the east coast. These results are consistent with previous assessments [14,15].

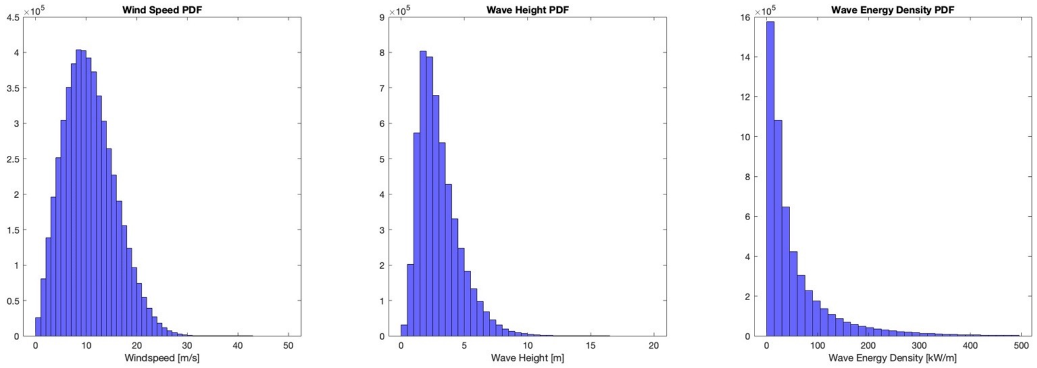


**Figure 9.** Spatial distribution of long-term mean wind speed and wave power density over Irish waters, based on 20 years of ERA5 data (2002–2022).

The gridded resource assessment is illustrated in Figures 10 and 11, which shows wind and wave energy densities at each grid point across the western EEZ. Both wind and wave resources increase offshore, with peak values occurring towards the mid-Atlantic boundary. It should be noted that the resource maps presented here are based on long-term mean values (2002–2022) because the objective of this study is regional-scale MSP screening and comparative identification of broad candidate areas. Seasonal variability and more detailed extreme-value statistics (e.g., seasonal resource distributions and design-condition extremes) are important for subsequent site-level assessment and technology design but are beyond the scope of the present high-level suitability screening framework.

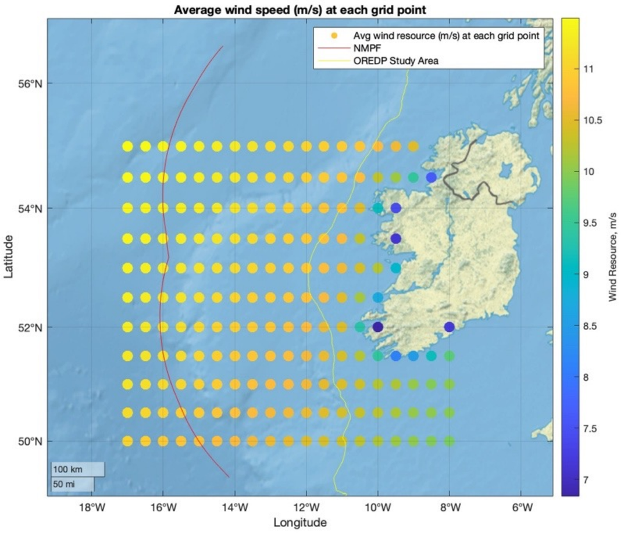


**Figure 10.** Wind resource distribution at each grid point within the study area.

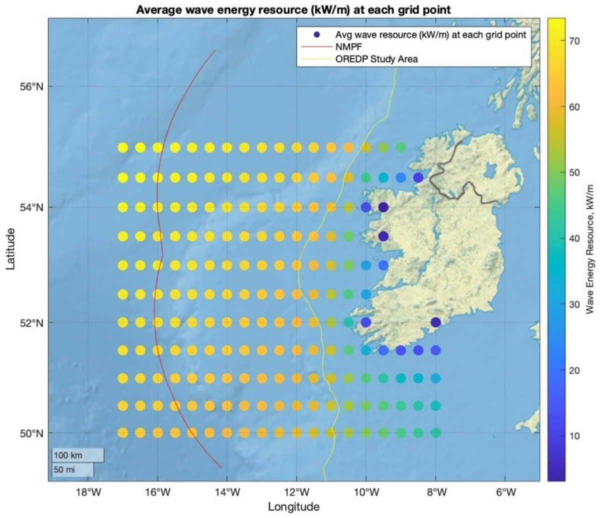


**Figure 11.** Wave resource distribution at each grid point within the study area.

Three-dimensional surfaces of wind and wave energy density are shown in Figures 12 and 13. These plots highlight persistent high-energy conditions along the Atlantic margin, with clearly defined zones of elevated wind and wave energy.

The correlation between wind and wave power was determined for all grid points, using Pearson's coefficient for time steps where wave power exceeded 30 kW/m and wind speeds exceeded 9 m/s. The thresholds of mean wind speed $> 9$ m/s and wave power $> 30$ kW/m were adopted as indicative regional screening criteria to identify locations with consistently strong offshore wind and wave resource potential. A mean wind-speed threshold of 9 m/s was adopted as an indicative screening benchmark for a strong offshore wind resource, consistent with reported offshore site mean wind-speed ranges at high-performing locations, while recognising that turbine performance and energy yield depend on the specific turbine model, hub height, and site-specific wind regime [47,48]. The 30 kW/m threshold was selected as a practical screening benchmark for a strong wave energy resource, consistent with reported resource-class ranges and with the energetic Atlantic conditions typically considered favourable for offshore wave development [49], while noting that technology-specific viability depends on converter type and project economics. These values are used here for comparative suitability screening at MSP scale, rather than as project-specific design thresholds, and are intended to filter for sites with resource levels broadly aligned with early-stage offshore wind and wave development interest.

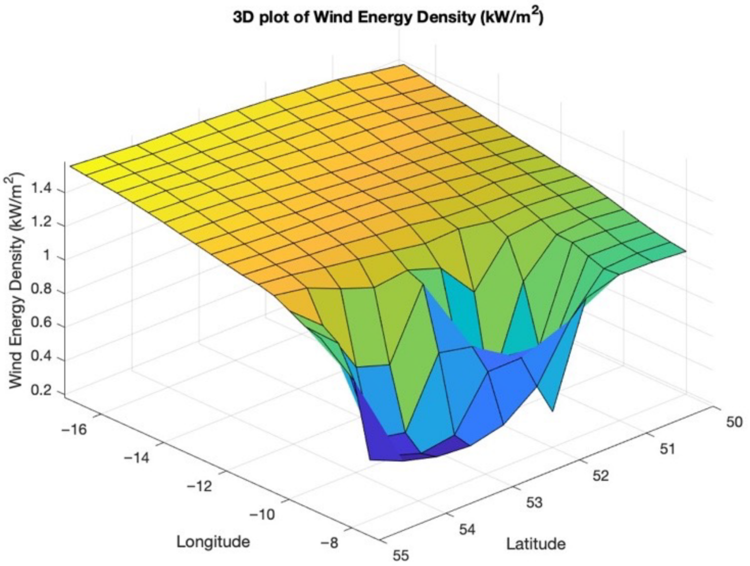


**Figure 12.** Three-dimensional visualisation of mean wind energy density across the western EEZ.

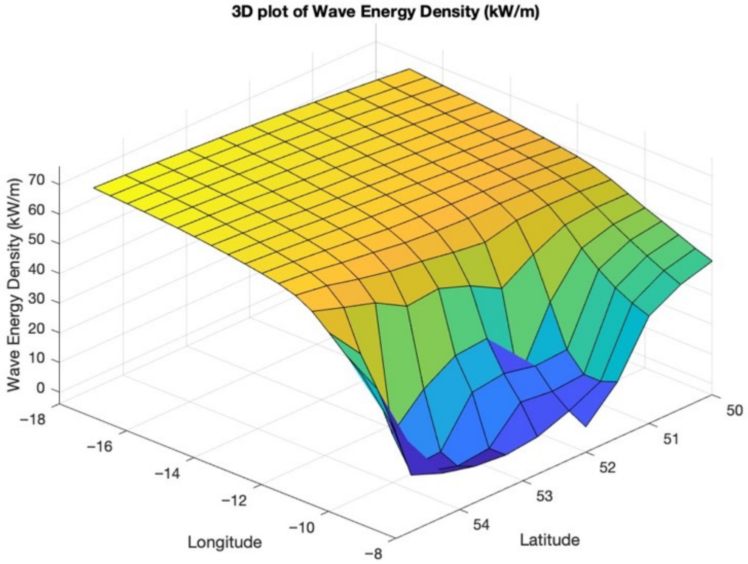


**Figure 13.** Three-dimensional visualisation of wave energy density across the western EEZ.

Table 4 lists the correlation scale used. The resulting correlation field is shown in Figure 14, indicating predominantly moderate positive correlation ($r \approx 0.5$), which is favourable for combined exploitation.

**Table 4.** Correlation scale used for interpreting wind–wave resource complementarity.

| Pearson's Correlation Coefficient | Representation |
|---|---|
| $0 < r \leq 0.19$ | Very low correlation |
| $0.2 \leq r \leq 0.39$ | Low correlation |
| $0.4 \leq r \leq 0.59$ | Moderate correlation |
| $0.6 \leq r \leq 0.79$ | High correlation |
| $0.8 \leq r \leq 1.0$ | Very high correlation |

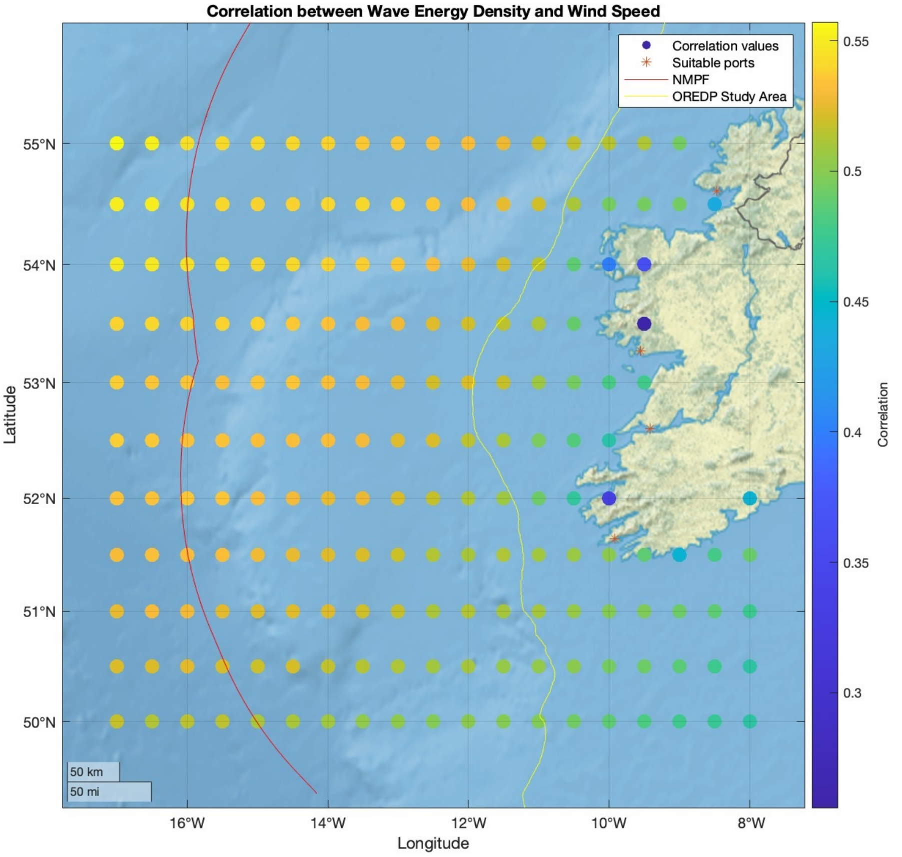


**Figure 14.** Pearson correlation between wind and wave power density for all grid points considered, with OREDP west-coast area outlined in yellow.

Within the OREDP west-coast boundary, three representative locations were selected for detailed suitability evaluation. Their coordinates and metocean characteristics are summarised in Table 5, with wind and wave energy densities shown in Table 6. The three sites considered in detail were selected as representative case-study locations to illustrate application of the framework in candidate west-coast areas with favourable resource conditions and relatively low-to-moderate wind–wave correlation; they are not intended to represent the only suitable cells within the study domain.

**Table 5.** Location characteristics at selected study locations.

| Latitude | Longitude | Mean Wave Data | | | Mean Wind Data | | Correlation | Depth, m | Max. $H_s$ (m) |
|---|---|---|---|---|---|---|---|---|---|
| | | $H_s$ (m) | $T_p$ (s) | $\theta_m$ (°) | $U_w$ (m/s) | $\Phi$ (°) | | | |
| 54 N | 10.5 W | 2.89 | 16.56 | 263.83 | 10.49 | 191.86 | 0.4870 | −121.48 | 12.93 |
| 52.5 N | 10 W | 2.13 | 16.50 | 274.45 | 8.71 | 192.32 | 0.4636 | −52.41 | 11.45 |
| 52 N | 11.5 W | 3.06 | 16.04 | 261.17 | 10.59 | 189.16 | 0.5069 | −253.37 | 15.05 |

**Table 6.** Wind and wave energy densities at each location.

| Latitude | Longitude | Mean Wind Energy Density (kW/m$^2$) | Mean Wave Energy Density (kW/m) |
|---|---|---|---|
| 54° N | 10°30′ W | 1.2336 | 54.4935 |
| 52°30′ N | 10° W | 0.71191 | 30.2878 |
| 52° N | 11°30′ W | 1.255 | 59.2086 |

These metocean characteristics also indicate strong potential for combined wind–wave exploitation at the selected sites. The resource assessment highlights the importance of the Atlantic wave climate alongside favourable offshore wind conditions, suggesting that both resources could make a meaningful contribution in future co-located offshore renewable energy developments at these west-coast locations. Consistent with earlier studies [18,23], the low-to-moderate wind–wave correlation values reported in Table 4 also indicate potential for smoothing of aggregated output, which is favourable from a variability and predictability perspective. This reinforces the suitability of the selected west-coast candidate areas for subsequent multi-criteria evaluation.

### 4.2. Suitability Index Outcomes

The suitability index (SI) defined in Section 3.3 was applied to each of the three sample sites in the equal-weighting scenario and three alternative weighting schemes (technical-favoured, environmental-favoured and socio-economic-favoured). The resulting SI values are shown in Figure 15.

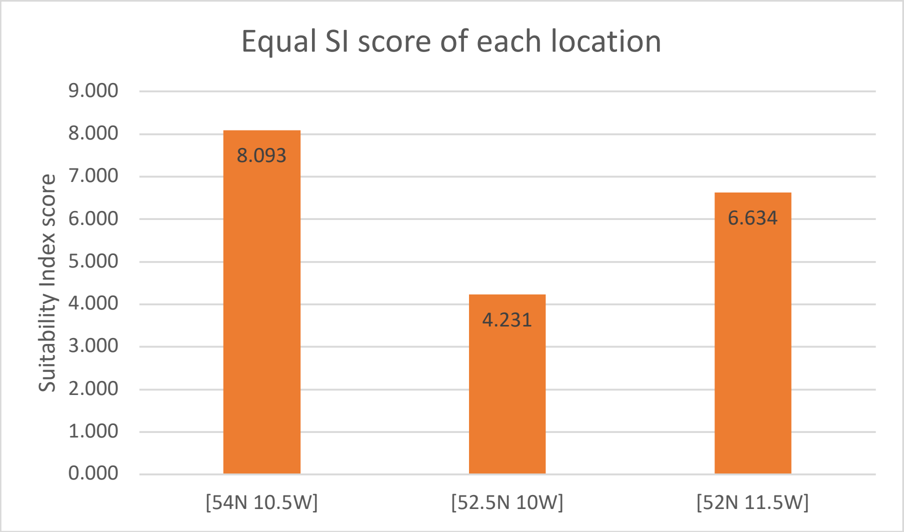


**Figure 15.** Suitability index values for the three sample sites in the equal-weighting scenario. Lower values indicate more suitable locations.

Figure 16 presents the criterion-level breakdown of the suitability index for the three representative sites in each of the four weighting scenarios. The stacked bars show how the overall SI score at each location is composed from the individual technical, environmental, and socio-economic criteria, allowing both within-site and between-site comparison. Across all scenarios, the site at 52.5° N, 10° W consistently exhibits the lowest overall SI score, indicating the most favourable combined suitability, while the site at 54° N, 10.5° W yields the highest scores, reflecting less favourable conditions within the present framework. The figure also highlights how the relative importance of specific criteria changes under the different weighting assumptions. In particular, criteria related to technical feasibility, infrastructure access, and spatial constraints make a substantial contribution to the final scores, and the bar-chart format makes these differences more transparent than the original pie-chart presentation. Figure 16 also provides insight into the dominant constraints shaping each SI value, illustrating that

- The northern site ([54° N, 10.5° W]) is penalised by distance from ports and grid infrastructure despite excellent resources.
- The southern site ([52.5° N, 10° W]) is most suitable overall, with manageable environmental and socio-economic constraints.
- The mid-southern site ([52° N, 11.5° W]) is moderately constrained but could become suitable with targeted infrastructure upgrades.

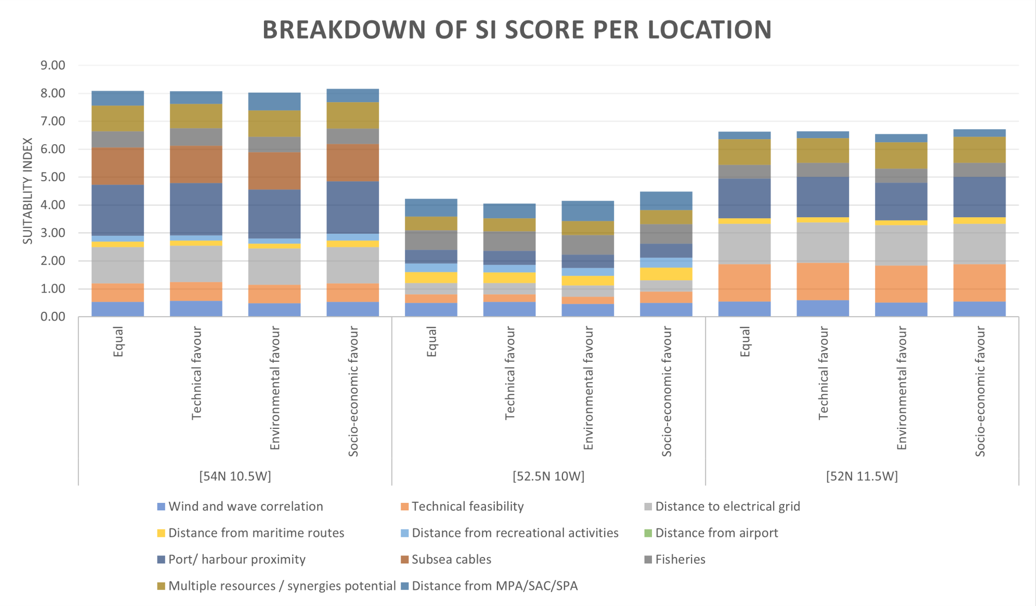


**Figure 16.** Breakdown of the suitability index (SI) for the three representative sites in the four weighting scenarios.

The SI results point to several wider implications for marine spatial planning. They show that even among uniformly energetic areas on the west coast, sites can be differentiated clearly once logistical distance, environmental sensitivities and socio-economic activity are taken into account. They also reveal how strongly port and grid infrastructure shape feasibility: improvements at Moneypoint, Killybegs or Castletownbere would materially shift suitability toward deeper offshore regions that currently carry higher logistical penalties. At the same time, the approach demonstrates that environmental designations can be incorporated in a structured and transparent manner through explicit scoring and weighting, helping to align offshore renewable deployment with Natura 2000 obligations and emerging 30 × 30 conservation targets. The suitability-index results are also consistent with stakeholder priorities identified during development of the framework, particularly in relation to practical deployment constraints in Irish waters. In particular, the influence of infrastructure-related criteria (e.g., proximity to ports and grid connection opportunities) and spatial constraints in the site rankings highlights the importance of distinguishing between hard exclusions and criteria that may be manageable through project design or phased development. In this context, the stakeholder-informed weighting framework is used to support transparent interpretation of the screening outcomes at MSP scale, while recognising that final site selection requires subsequent project-specific engineering, environmental, and consenting assessments.

The principal limitations of the present framework and recommended directions for future development are discussed in the Section 5, together with a summary of the main findings and implications for MSP-based offshore renewable energy siting.

## 5. Conclusions

This paper has proposed and implemented a marine spatial planning methodology for the combined exploitation of offshore wind and wave energy in the Irish seas, with a focus on the west coast. A suitability index (SI) framework was developed that integrates technical, environmental and socio-economic criteria through a two-stage process of exclusion and weighted evaluation. Using long-term ERA5 metocean data and publicly available spatial datasets, the method was applied to three representative offshore locations within the OREDP study area. Among these, the site located approximately 40 km west of Moneypoint was identified as the most suitable for combined wind–wave developments owing to its strong resources, favourable depth, and comparatively advantageous proximity to grid and port infrastructure. The methodology provides a transparent, traceable decision-support tool that can inform policymakers, developers and NGOs in the early-stage screening of areas for combined offshore renewable energy.

While the analysis focuses on strategic-scale planning, several scope boundaries should be recognised. The spatial resolution, based on a $0.5° \times 0.5°$ grid and ERA5 metocean data at comparable scale, is appropriate for regional screening and provides a coherent overview of broad spatial patterns across the west coast, though it is not intended to replace the finer-resolution surveys and site-specific assessments required at later project stages. The detailed evaluation of three representative sites offers a comparative insight into contrasting resource, environmental and infrastructural contexts, rather than a full optimisation across the entire Irish EEZ; this approach aligns with the study's objective of demonstrating and validating the methodology. The SI framework makes use of consistent, long-term reanalysis datasets and publicly available spatial layers, which ensures transparency and reproducibility, even if highly localised engineering or cost data fall outside the present scope. Similarly, the weighting structure benefits from stakeholder input and reflects realistic planning considerations while leaving room for future refinement through formal uncertainty analysis or expanded cumulative impact assessment.

More broadly, the work contributes to the growing international literature on marine spatial planning for hybrid offshore renewables by demonstrating a methodology that is both structured and transferable. Although the case study centres on Ireland's west coast, the two-stage suitability index, the integration of exclusion and weighted evaluation criteria, and the use of publicly available metocean and spatial layers are not location-specific. The framework can be adapted to other national EEZs simply by substituting local datasets, adjusting constraints and weights to reflect regional governance and ecological conditions, and re-calibrating the scoring to stakeholder priorities. As such, the study provides a generalisable template for early-stage screening of co-located wind–wave developments that complements existing MSP practice and can support strategic planning in a wide range of maritime regions.

This study is subject to several limitations that should be considered when interpreting the results. First, the suitability framework is intended for regional-scale strategic screening and therefore relies on relatively coarse spatial resolution and publicly available datasets, which are appropriate for MSP-level assessment but not for project-scale design or consenting. Second, the weighting of criteria, while informed by stakeholder engagement and literature review, remains sensitive to planning priorities. To examine the influence of weighting subjectivity on the results, a one-at-a-time sensitivity analysis was carried out on the category weights. In this analysis, the relative emphasis assigned to the technical, environmental, and socio-economic categories was varied individually while the remaining weights were held constant, in order to assess the stability of the resulting site rankings. The analysis showed that, although the absolute suitability index values changed under different weighting assumptions, no significant changes were observed in the ranking of the highest-performing cells. In particular, the top candidate locations remained stable across the tested variations, indicating that the identification of the most suitable areas is reasonably robust to moderate changes in category weighting. This provides additional confidence that the main conclusions of the screening exercise are not unduly dependent on any single weighting scenario. Third, the present framework does not explicitly include all potentially relevant socio-cultural or market factors, which may become increasingly important as MSP practice evolves. Future work should therefore focus on higher-resolution local application of the framework, grid-sensitivity and weighting-sensitivity analysis, and the integration of additional environmental, socio-economic, and infrastructure datasets. In addition, seasonal variability and extreme-condition metrics should be incorporated in subsequent site-level studies to support technology selection, detailed engineering design, and project feasibility assessment.

As offshore renewable deployment accelerates worldwide, particularly in regions seeking to balance ambitious climate targets with increasingly contested marine space, the demand for clear, adaptable MSP tools tailored to hybrid wind–wave systems will only grow, positioning frameworks such as the one developed here as an important foundation for the next generation of integrated ocean energy planning.

**Author Contributions:** Conceptualization, E.C. and B.F.; Methodology, E.C. and B.F.; Software, E.C.; Formal analysis, E.C. and B.F.; Investigation, E.C.; Data curation, E.C.; Writing—original draft, E.C.; Writing—review and editing, B.F. All authors have read and agreed to the published version of the manuscript.

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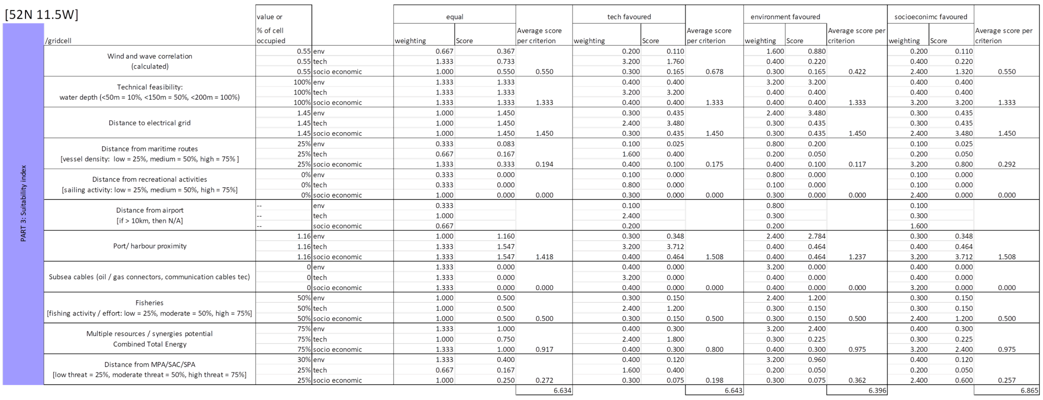
**Conflicts of Interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Worked Example of Suitability Index Calculation for a Representative Site

To improve transparency of the weighting and scoring procedure, this appendix presents a worked example of the suitability index (SI) calculation for the representative site located at 52° N, 11.5° W. The example illustrates how the raw criterion values for a single grid cell are combined with the baseline Likert scores and the scenario-specific weighting factors to produce the final SI score.

Figure A1 presents the calculation framework used for this representative site. For each evaluation criterion, the underlying site value (expressed either as a percentage of the grid cell affected or as a criterion-specific rating) is first combined with the corresponding criterion weight. The criterion weights are obtained by multiplying the baseline relevance score assigned to that criterion by the category weighting factor associated with the selected scenario. The resulting weighted criterion scores are then aggregated across all criteria to obtain the final SI value for the site.

This worked example is included for illustration of the calculation procedure only. The same methodology is applied consistently across all 189 grid cells and for each of the four weighting scenarios considered in the main analysis.



[52N 11.5W]

PART 3: Suitability index

| /gridcell | value or % of cell occupied | | equal | | | tech favoured | | | environment favoured | | | socioeconimc favoured | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | weighting | Score | Average score per criterion | weighting | Score | Average score per criterion | weighting | Score | Average score per criterion | weighting | Score | Average score per criterion |
| Wind and wave correlation (calculated) | 0.55 | env | 0.667 | 0.367 | | 0.200 | 0.110 | | 1.600 | 0.880 | | 0.200 | 0.110 | |
| | 0.55 | tech | 1.333 | 0.733 | | 3.200 | 1.760 | | 0.400 | 0.220 | | 0.400 | 0.220 | |
| | 0.55 | socio economic | 1.000 | 0.550 | 0.550 | 0.300 | 0.165 | 0.678 | 0.300 | 0.165 | 0.422 | 2.400 | 1.320 | 0.550 |
| Technical feasibility: water depth (<50m = 10%, <150m = 50%, <200m = 100%) | 100% | env | 1.333 | 1.333 | | 0.400 | 0.400 | | 3.200 | 3.200 | | 0.400 | 0.400 | |
| | 100% | tech | 1.333 | 1.333 | | 3.200 | 3.200 | | 0.400 | 0.400 | | 0.400 | 0.400 | |
| | 100% | socio economic | 1.333 | 1.333 | 1.333 | 0.400 | 0.400 | 1.333 | 0.400 | 0.400 | 1.333 | 3.200 | 3.200 | 1.333 |
| Distance to electrical grid | 1.45 | env | 1.000 | 1.450 | | 0.300 | 0.435 | | 2.400 | 3.480 | | 0.300 | 0.435 | |
| | 1.45 | tech | 1.000 | 1.450 | | 2.400 | 3.480 | | 0.300 | 0.435 | | 0.300 | 0.435 | |
| | 1.45 | socio economic | 1.000 | 1.450 | 1.450 | 0.300 | 0.435 | 1.450 | 0.300 | 0.435 | 1.450 | 2.400 | 3.480 | 1.450 |
| Distance from maritime routes [vessel density: low = 25%, medium = 50%, high = 75% ] | 25% | env | 0.333 | 0.083 | | 0.100 | 0.025 | | 0.800 | 0.200 | | 0.100 | 0.025 | |
| | 25% | tech | 0.667 | 0.167 | | 1.600 | 0.400 | | 0.200 | 0.050 | | 0.200 | 0.050 | |
| | 25% | socio economic | 1.333 | 0.333 | 0.194 | 0.400 | 0.100 | 0.175 | 0.400 | 0.100 | 0.117 | 3.200 | 0.800 | 0.292 |
| Distance from recreational activities [sailing activity: low = 25%, medium = 50%, high = 75%] | 0% | env | 0.333 | 0.000 | | 0.100 | 0.000 | | 0.800 | 0.000 | | 0.100 | 0.000 | |
| | 0% | tech | 0.333 | 0.000 | | 0.800 | 0.000 | | 0.100 | 0.000 | | 0.100 | 0.000 | |
| | 0% | socio economic | 1.000 | 0.000 | 0.000 | 0.300 | 0.000 | 0.000 | 0.300 | 0.000 | 0.000 | 2.400 | 0.000 | 0.000 |
| Distance from airport [if > 10km, then N/A] | -- | env | 0.333 | | | 0.100 | | | 0.800 | | | 0.100 | | |
| | -- | tech | 1.000 | | | 2.400 | | | 0.300 | | | 0.300 | | |
| | -- | socio economic | 0.667 | | | 0.200 | | | 0.200 | | | 1.600 | | |
| Port/ harbour proximity | 1.16 | env | 1.000 | 1.160 | | 0.300 | 0.348 | | 2.400 | 2.784 | | 0.300 | 0.348 | |
| | 1.16 | tech | 1.333 | 1.547 | | 3.200 | 3.712 | | 0.400 | 0.464 | | 0.400 | 0.464 | |
| | 1.16 | socio economic | 1.333 | 1.547 | 1.418 | 0.400 | 0.464 | 1.508 | 0.400 | 0.464 | 1.237 | 3.200 | 3.712 | 1.508 |
| Subsea cables (oil / gas connectors, communication cables tec) | 0 | env | 1.333 | 0.000 | | 0.400 | 0.000 | | 3.200 | 0.000 | | 0.400 | 0.000 | |
| | 0 | tech | 1.333 | 0.000 | | 3.200 | 0.000 | | 0.400 | 0.000 | | 0.400 | 0.000 | |
| | 0 | socio economic | 1.333 | 0.000 | 0.000 | 0.400 | 0.000 | 0.000 | 0.400 | 0.000 | 0.000 | 3.200 | 0.000 | 0.000 |
| Fisheries [fishing activity / effort: low = 25%, moderate = 50%, high = 75%] | 50% | env | 1.000 | 0.500 | | 0.300 | 0.150 | | 2.400 | 1.200 | | 0.300 | 0.150 | |
| | 50% | tech | 1.000 | 0.500 | | 2.400 | 1.200 | | 0.300 | 0.150 | | 0.300 | 0.150 | |
| | 50% | socio economic | 1.000 | 0.500 | 0.500 | 0.300 | 0.150 | 0.500 | 0.300 | 0.150 | 0.500 | 2.400 | 1.200 | 0.500 |
| Multiple resources / synergies potential Combined Total Energy | 75% | env | 1.333 | 1.000 | | 0.400 | 0.300 | | 3.200 | 2.400 | | 0.400 | 0.300 | |
| | 75% | tech | 1.000 | 0.750 | | 2.400 | 1.800 | | 0.300 | 0.225 | | 0.300 | 0.225 | |
| | 75% | socio economic | 1.333 | 1.000 | 0.917 | 0.400 | 0.300 | 0.800 | 0.400 | 0.300 | 0.975 | 3.200 | 2.400 | 0.975 |
| Distance from MPA/SAC/SPA [low threat = 25%, moderate threat = 50%, high threat = 75%] | 30% | env | 1.333 | 0.400 | | 0.400 | 0.120 | | 3.200 | 0.960 | | 0.400 | 0.120 | |
| | 25% | tech | 0.667 | 0.167 | | 1.600 | 0.400 | | 0.200 | 0.050 | | 0.200 | 0.050 | |
| | 25% | socio economic | 1.000 | 0.250 | 0.272 | 0.300 | 0.075 | 0.198 | 0.300 | 0.075 | 0.362 | 2.400 | 0.600 | 0.257 |
| | | | | | 6.634 | | | 6.643 | | | 6.396 | | | 6.865 |

**Figure A1.** Suitability index for 52 N 11.5 W.

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