Global Offshore Wind Farm Site Selection Methodologies And Untapped Regional Potential: A Systematic Review

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Abstract
Offshore wind farms (OWFs) are vital to the low-carbon energy transition, yet their success depends on selecting sites that balance energy potential, environmental sustainability, maritime safety, and economic feasibility. Despite expanding research, methodological inconsistencies and the underrepresentation of high-potential regions such as the Red Sea and Arabian maritime zones remain major gaps. This review addresses (1) the inconsistent representation of decision-making frameworks in OWF site selection literature, and (2) the limited development in resource-rich maritime zones despite favourable wind regimes. Ninety-seven peer-reviewed papers (2015–present) were collected, and metadata were manually extracted from full texts. Although OpenAlex was initially used for retrieval, its metadata often failed to capture the full and precise scope, and inconsistent terminology—such as multiple labels for the same concept—risked misleading analysis. Standardization, splitting of compound terms, and manual tagging of unlisted methodologies enabled accurate classification by decision framework and turbine type. The analysis revealed that MCDA was the most common framework (56 papers), with AHP leading within this category (18). Fuzzy logic appeared in 15 studies, and hybrid approaches—especially MCDA combined with fuzzy methods—were frequent. Research on floating turbines has increased sharply since 2020. In deployment, Northern European countries lead in offshore wind production per capita, Brazil and China dominate in total capacity, while the Red Sea and Arabian maritime zones host only one recorded project, currently in pre-construction in Egypt.

Keywords: Systematic review; Bibliometric analysis; Offshore wind farm site selection; GIS; Decision-making frameworks; Spatial distribution of offshore wind farms.

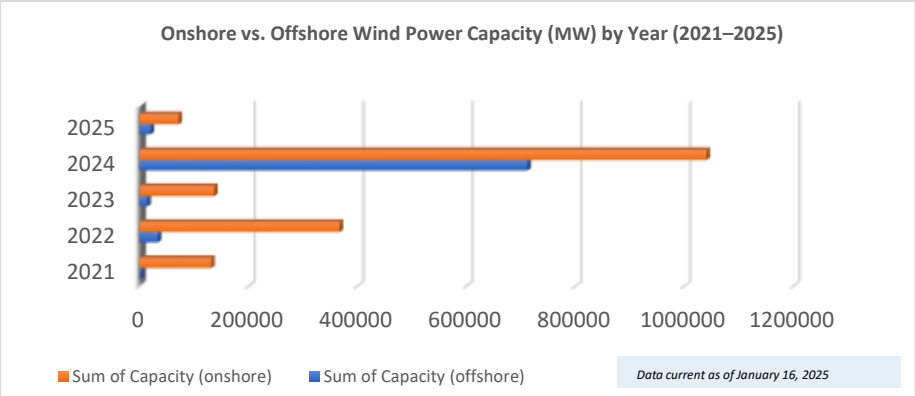
1. Introduction

Offshore wind energy (OWE) has emerged as a transformative solution in the global shift toward renewable energy, driven by the urgency of decarbonizing energy systems, enhancing energy security, and capitalizing on maturing wind technologies. Since 2010, global offshore capacity has expanded rapidly from approximately 3 GW to more than 117 GW by 2020 and is projected to reach between 400 and 600 GW by 2040 [1]. As this path continues, offshore wind is expected to play a central role in meeting both climate commitments and energy diversification goals.

Offshore wind farms offer a range of technical, environmental, and social advantages over their onshore counterparts. They benefit from stronger and more stable wind conditions, allowing the deployment of larger turbines with higher rated capacities and improved energy yields. These turbines routinely achieve higher capacity factors typically around 38%, compared to 24% for onshore systems [2]. Furthermore, the remote siting of OWFs mitigates many of the challenges associated with land-based projects, including noise pollution, visual disruption, land-use conflicts, and public opposition. In contrast, onshore wind, though generally more cost-efficient to deploy, is associated with environmental and social trade-offs such as land value depreciation, bird collisions, noise sensitivity, and in some cases, shadow flicker effects that may impact human health [1], [3]. As shown in

(Figure 1), recent capacity data also highlight the rapid growth of both offshore and onshore wind power, with offshore installations gaining significant momentum by 2024 [4]
The technological maturity of offshore wind continues to advance. A key development is the evolution from fixed-bottom structures to floating wind platforms, which enable installations in deeper waters often exceeding 90 meters far beyond the reach of earlier systems. Modern offshore turbines now range between 15 and 20 MW in capacity until 2030 [1]; [3]; [5], with tower heights surpassing 250 meters. These advances have contributed to significant reductions in cost. Between 2010 and 2021, the levelized cost of electricity (LCOE) for offshore wind declined from 0.1879 USD/kWh to 0.0752 USD/kWh, while onshore wind decreased from 0.1021 to 0.0331 USD/kWh [6]. Although cost disparities remain, the gap is steadily closing due to technological innovation and economies of scale.
According to (Figure 2), the development of offshore wind farms is a long-term process. Early phases, including site selection, licensing, and construction, can take over a decade.

Figure 1. Onshore vs. offshore wind capacity (MW), 2021–2025. Offshore growth peaks in 2024



Once operational, wind farms may function for up to 40 years, requiring durable infrastructure and careful long-term planning. Effective siting must therefore account for both immediate feasibility and sustained technical, environmental, and social performance [5]

Figure 2. Offshore wind farm lifecycle: planning, construction, operation

One often overlooked factor in offshore site assessment is turbulence intensity (TI). Offshore areas generally experience lower and more stable turbulence than land-based sites due to the absence of terrain obstacles. This reduces mechanical stress on turbine components, supporting longer operational life and reduced maintenance. Despite its impact on performance and durability, TI is rarely included in current site selection frameworks [7].

However, the environmental footprint of offshore wind must also be acknowledged. Offshore turbines commonly use permanent magnet generators (PMGs) containing rare earth elements (REEs), which pose ecological and geopolitical challenges due to their mining and processing impacts [8]. In parallel, the installation of fixed-bottom foundations can disrupt marine habitats, especially during construction. These concerns underscore the importance of environmentally sensitive siting and design [9].

Given these multifaceted trade-offs, the offshore siting process demands robust spatial and analytical tools. Geographic Information Systems (GIS) play a central role in identifying suitable zones by mapping key spatial constraints such as wind speed, water depth, shipping lanes, and ecological sensitivities. Complementing GIS, multi-criteria decision analysis (MCDA) methods including AHP, TOPSIS, and fuzzy logic enable structured evaluation of site alternatives based on weighted suitability across diverse factors [10]; [11]. Despite their promise, many existing studies lack transparency, suffer from inconsistent application of weighting schemes, or omit dynamic variables like turbulence, cost-efficiency, or grid accessibility [12].

To address these challenges, this review undertakes a comprehensive methodological analysis of 97 studies published from 2015 to date, except 3 published in 2011. It systematically classifies modelling approaches, identifies thematic patterns in keyword usage, evaluates hybrid decision-making frameworks, and highlights underexplored yet critical criteria in OWF siting. In doing so, it aims to guide the development of more transparent, integrative, and future-ready siting methodologies for the offshore wind sector.

2. Underexploited Offshore Wind Potential in the Red Sea and Arabian Maritime Zones

2.1. Global Disparities in Offshore Wind Deployment

Despite the rapid expansion of offshore wind energy, deployment remains geographically uneven. As shown in (Figure 3a), when normalized by population, countries in Northern and Western Europe exhibit significantly higher offshore wind capacity per capita, indicating more equitable access to renewable energy benefits among their citizens.

(Figure 3b) presents the top 10 countries by total installed offshore wind capacity (MW), with Brazil, China, and the United Kingdom emerging as leading producers in absolute terms.

Additionally, the global spatial distribution map (Figure 4);[4], visually emphasizes this geographic imbalance, showing dense clusters of installations across Europe and East Asia, in stark contrast to the minimal offshore activity in the Red Sea, Arabian Gulf, and Arabian Sea regions.

Figure 3. Offshore wind capacity per capita and top producers (Operation, Construction, & pre-Construction). (a) Offshore wind power per capita by country (MW per million people), with highest values in Northern Europe. (b) Top 10 countries by total installed offshore wind capacity (MW), led by Brazil, China, and the UK. Together, the figures highlight disparities between absolute capacity and population-adjusted access. See Section X for details.

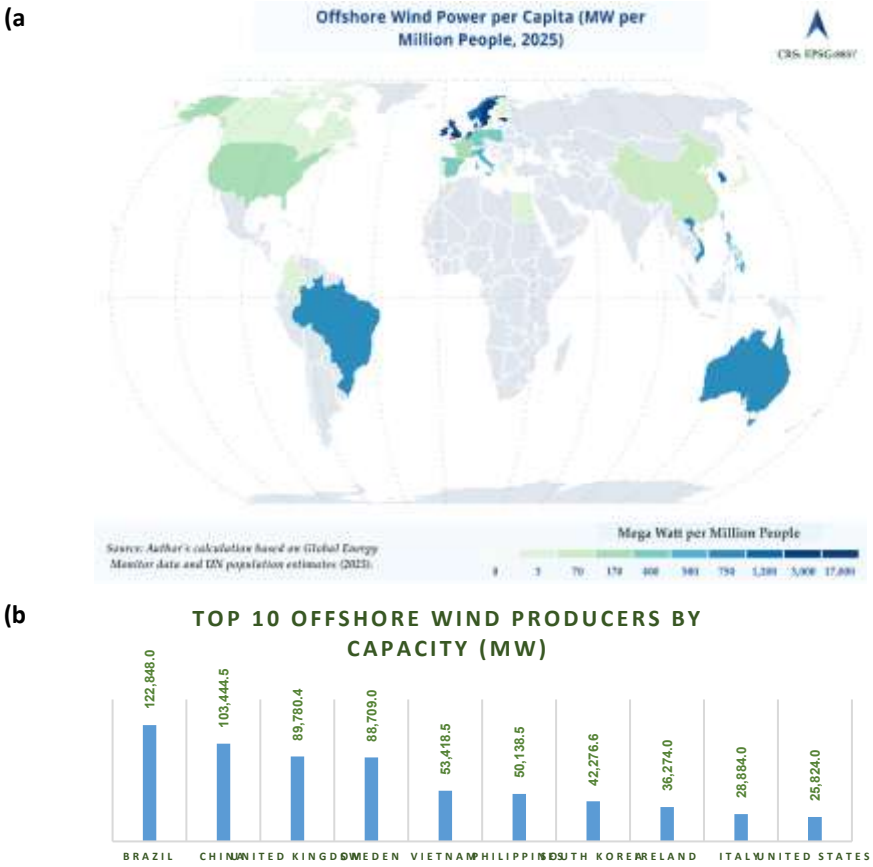
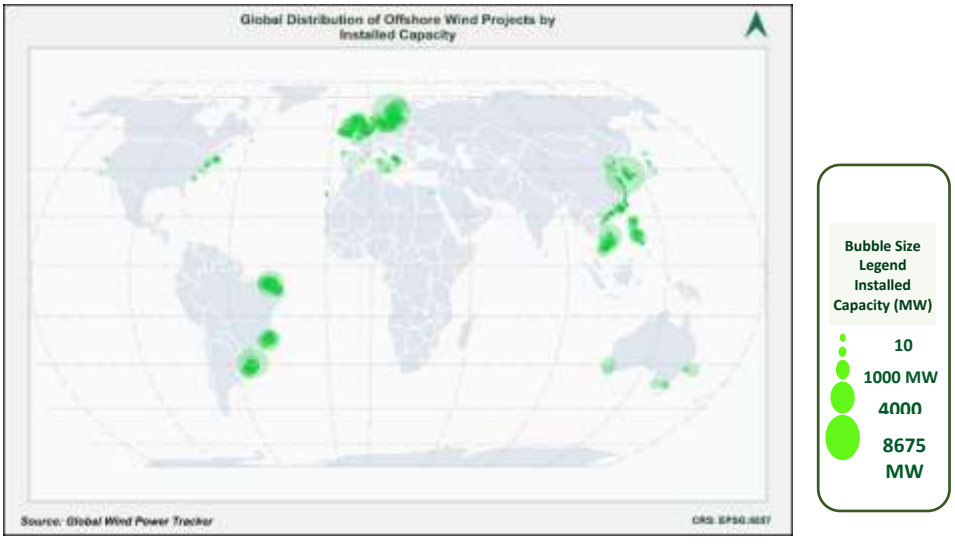


Figure 4. Global spatial distribution of offshore wind projects by capacity (Operational, Construction, and Pre-Construction).
The map illustrates a pronounced clustering of high-capacity offshore wind developments in Europe and East Asia, with limited activity across Africa, the Middle East, and South Asia. Bubble sizes represent total installed capacity (MW), scaled proportionally to emphasize disparities in deployment density. This visualization highlights the global imbalance in offshore wind development and reinforces the need for targeted investment in underrepresented regions.



Together, these visualizations highlight a core disparity: high-capacity nations do not always translate into high per capita availability. This mismatch points to an imbalance in deployment strategies and suggests the need for targeted policies that consider both total potential and demographic equity in offshore wind development.

2.2. Geopolitical Context of the Red Sea and Arabian Seas

Although the coastlines of the Red Sea, Arabian Gulf, and Arabian Sea span thousands of kilometres and border countries such as Egypt, Sudan, Saudi Arabia, Yemen, and Somalia, these regions remain virtually absent from the global offshore wind map [13], these nations lie adjacent to areas with strong offshore wind speeds and high wind power densities.

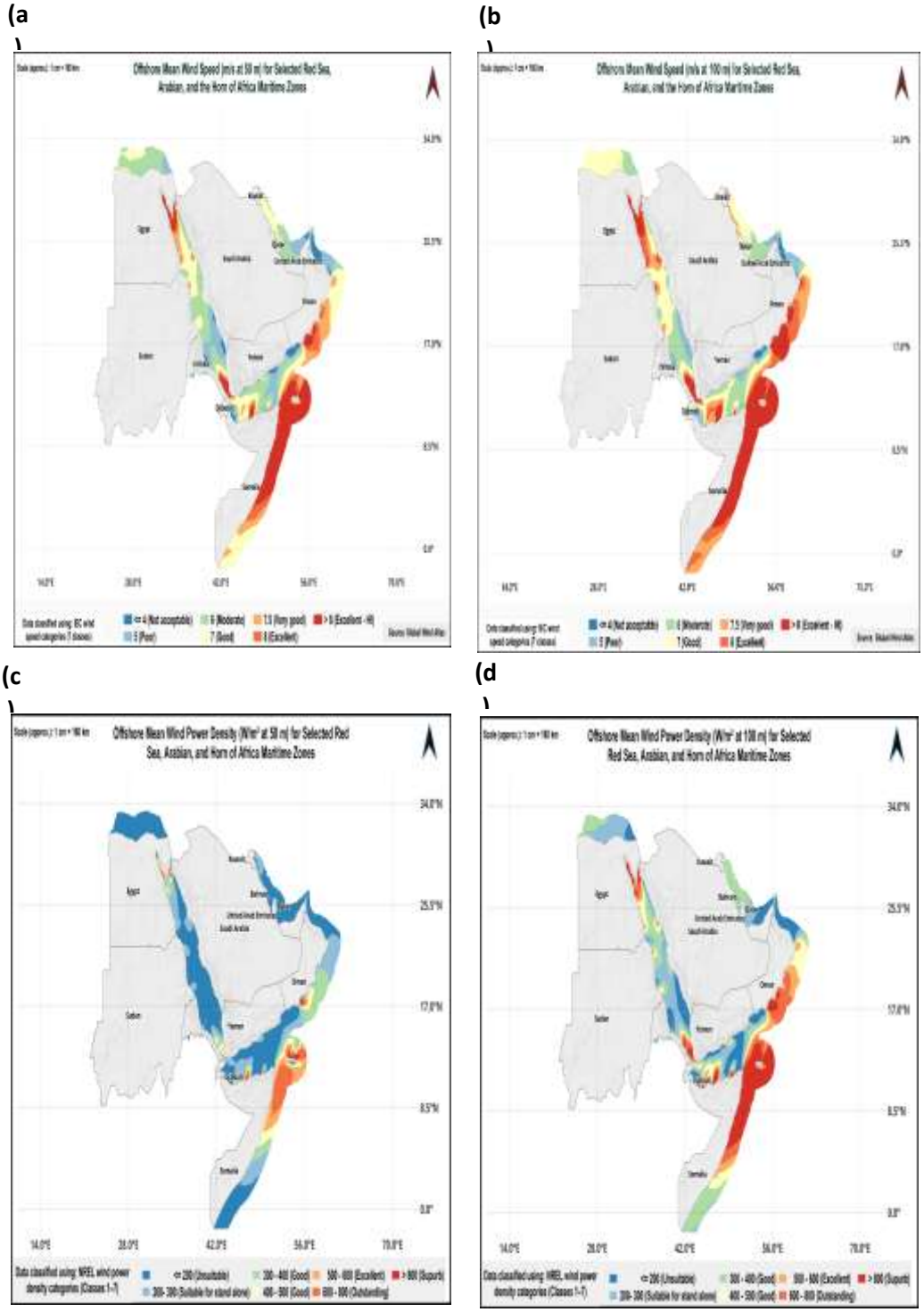
To date, however, only a single offshore wind project has been documented in this region a pre-construction site in Egypt [4], with no operational offshore capacity across the wider maritime zone. This lack of activity suggests that non-resource-related barriers, such as limited policy frameworks, regulatory uncertainty, and infrastructure constraints, are the main inhibitors to development.

2.3. Wind Speed Resource in the Region

The Red Sea and surrounding maritime zones exhibit wind regimes highly favourable for offshore energy generation. As presented in (Figure 5b). wind speeds at 100 meters elevation frequently exceed 8 m/s in coastal waters off Somalia, Djibouti, and southern Oman, placing them within IEC seven wind classes, optimal for high-efficiency offshore turbines [14] Wind speed is one of the most critical factors affecting turbine performance, energy yield, and capacity factor. Higher and more stable wind speeds translate into lower levelized costs of electricity (LCOE) and more favourable project economics [15]

Figure 5. Offshore wind resource assessment maps for the Red Sea and surrounding maritime zones.

(a) Mean wind speed at 50 meters elevation, showing large zones exceeding 8 m/s offshore Somalia, Djibouti, and southern Oman classified as IEC Class 7 and suitable for high-efficiency turbines. (b) Mean wind speed at 100 meters elevation, demonstrating vertical consistency in wind regimes across nearshore zones, supporting the technical viability of fixed-bottom installations. (c) Wind power density (WPD) at 50 meters, where several coastal areas surpass 800 W/m², confirming globally "superb" energy yield potential. (d) WPD at 100 meters, reinforcing spatial and depth-related suitability for both floating and fixed-bottom offshore wind systems.



Supporting this, (Figure 5a) shows wind speed conditions at 50 meters, indicating similar strength in nearshore zones, which may be particularly attractive for fixed-bottom installations. This vertical consistency in wind profiles enhances site viability and lowers modelling uncertainty, thereby
strengthening investment confidence [16]

2.4. Power Density and Energy Yield Potential

Beyond mere wind speed, wind power density (WPD) provides a more comprehensive indicator of offshore energy potential. As shown in (Figure 5d), WPD values at 100 meters exceed 800 W/m^2 in several regions particularly offshore Somalia, Djibouti, and Oman qualifying them as “superb” by global standards [17]. Lower-altitude WPD estimates (Figure 5c), at 50 meters reaffirm these findings and confirm the technical suitability of both floating and fixed-bottom systems, depending on local water depth.
Since WPD incorporates air density and the cube of wind speed, it is often viewed as a more robust metric than wind speed alone for determining turbine productivity, project bankability, and long-term cost efficiency [18]; [16].

2.5. Bathymetric Suitability for Offshore Infrastructure

Bathymetry is a key constraint in offshore wind siting, directly affecting the feasibility of foundation types [19]; [20]. According to standard engineering criteria, fixed bottom (e.g. monopile and jacket) (Figure 6b) foundations are typically feasible at depths below 60 m, while floating platforms are necessary in deeper waters (Figure 6c) [21]; [9].
As shown in (Figure 6a) bathymetry map, much of the Red Sea and Arabian Sea features depths >60 m, especially near Saudi Arabia, Oman, and Somalia, indicating a need for floating turbine technology. In contrast, shallower waters such as those found in Kuwait’s Arabian Gulf zone (<50 m) are more conducive to traditional fixed-bottom systems [12].
This spatial variability calls for technology-specific planning, aligning depth constraints with the most suitable turbine platforms to ensure technical and economic viability [16][22]

3. Methodology

The methodological framework of this review follows a structured, systematic approach designed to rigorously extract, analyse, and visualize relevant academic literature focusing on offshore wind farm site selection and geospatial methodologies. The methodological framework adopted in this review is summarized in (Figure 7), illustrating each step from literature retrieval and manual screening to classification, visualization, and validation.

3.1.Literature Search and Assembly

Initially, an automated literature search was conducted using the OpenAlex database, recognized for its comprehensive indexing of scholarly works [23] However, preliminary assessments revealed that variations in keyword usage such as authors employing terms like "siting" instead of "site selection, "geographic information system" instead of "GIS," and "MCDM" instead of "MCDA" resulted in a significant number of irrelevant publications. Consequently, the automated search was insufficient for accurately capturing the precise scope of interest.
Therefore, the automated approach was supplemented by a comprehensive manual screening of papers (see Supplementary File), involving full-text PDF assessments to ensure that selected studies were relevant. This step involved careful selection and meticulous metadata extraction directly from each article to confirm their applicability and methodological relevance.

3.2.Metadata Extraction and Keyword Normalization

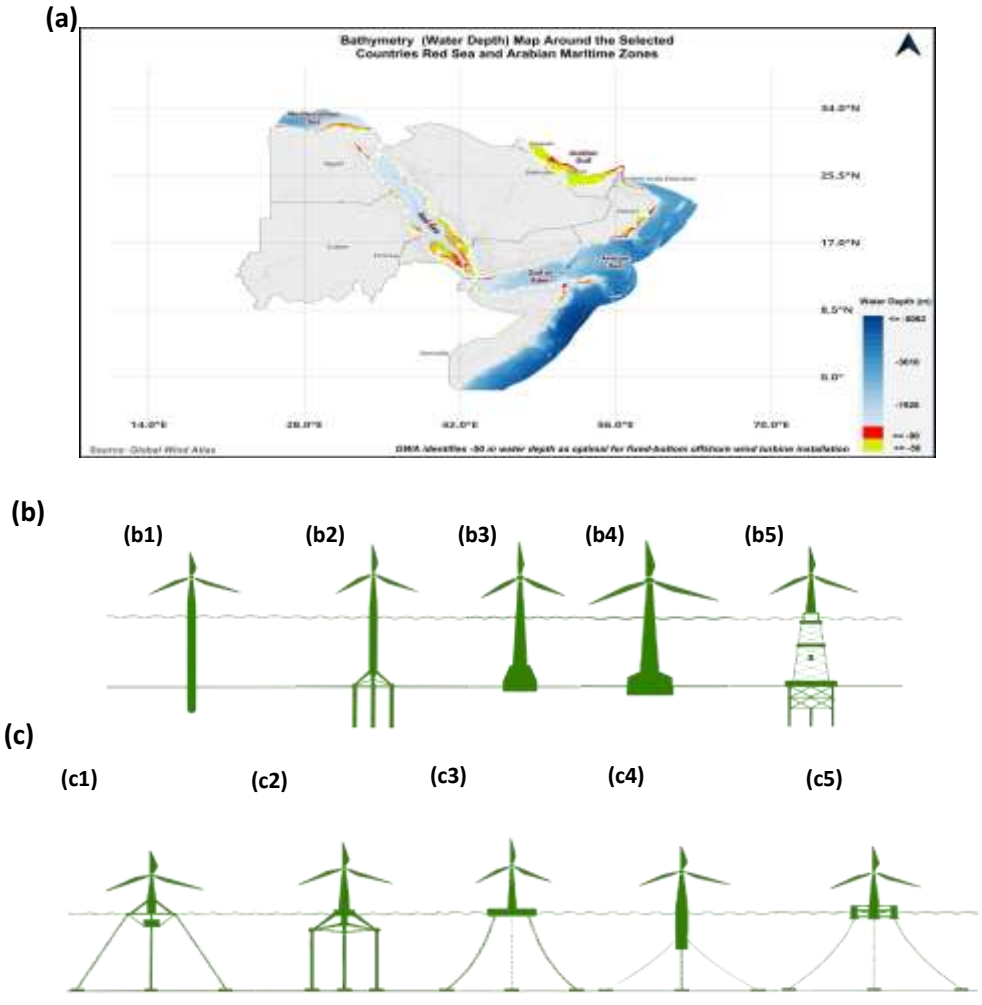
Metadata including titles, abstracts, authors, publication dates, and keywords was systematically extracted from each selected paper. To address variations in terminology, a keyword normalization process [24] was employed based on the dominant themes identified during methodological classification, Standardization, Tagging, and Splitting. This

ensured consistency across the collected dataset and provided a reliable basis for subsequent thematic categorization, comparative analysis, and visualization.

3.3.Methodological Classification

Papers selected through manual screening underwent detailed methodological classification. This included technical categorization of turbine structure types (fixed-bottom, floating, or both), identification of GIS usage (explicitly mentioned, non-explicitly mentioned, or not used) [10], analysis of study areas, and documentation of publication dates. These classifications provided structured insight into recurring themes, enabling targeted analysis and accurate interpretation of spatial, technical, and methodological trends within the reviewed literature.

Figure 6. Offshore wind foundation types and bathymetric conditions across the Red Sea and Arabian maritime zones.
(a) Bathymetry map indicating regional water depth variability, where green zones represent nearshore areas shallower than 50 meters typically suitable for fixed-bottom installations while red zones highlight deeper regions exceeding 90 meters, where floating structures are more viable. (b) Fixed-bottom offshore wind turbines, including: (b1) Monopile, (b2) Tripod, (b3) Suction Caisson, (b4) Gravity Base, (b5) Jacket. These foundations are generally used in shallow to moderate depths (up to 50–



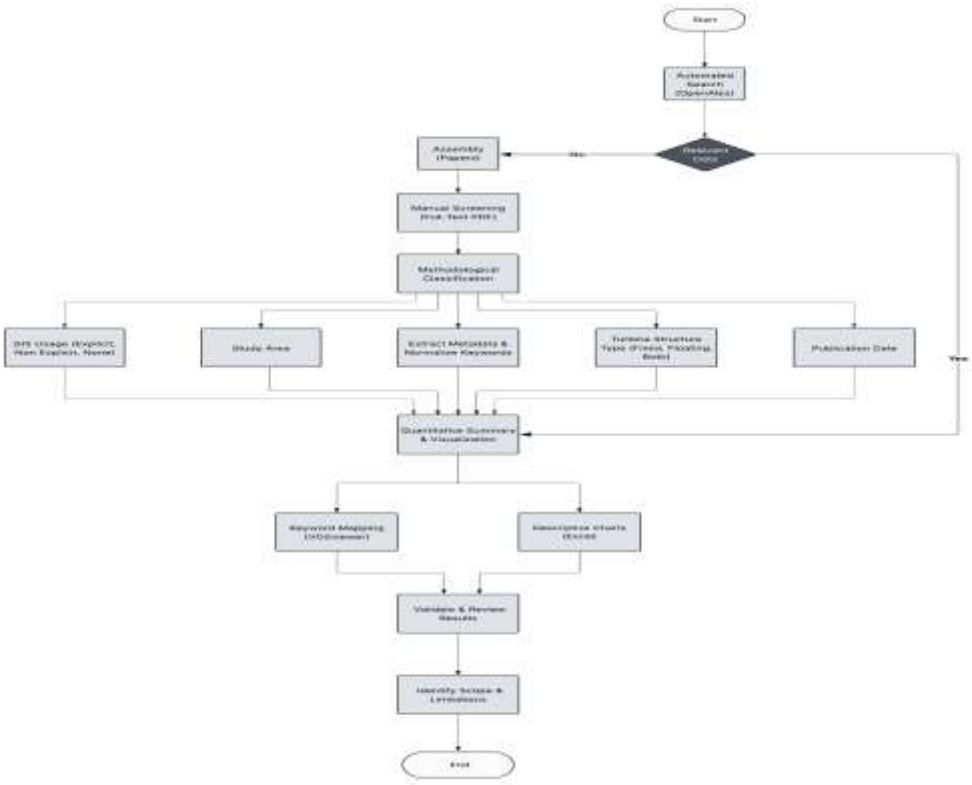
60 m). (c) Floating offshore wind turbines, including: (c1) Pendulum Floater, (c2) Tension Leg Platform (TLP), (c3) Barge, (c4) Spar Buoy, (c5) Semisubmersible.

These technologies are designed for deep-water applications, typically exceeding 60 meters, as shown in the red-marked zones of the bathymetric map. This composite figure contextualizes the bathymetric constraints that govern the technical applicability of foundation types and underscores the need for floating solutions in deeper offshore settings.

3.3.1. Tagging

In several reviewed studies, methodological models or frameworks were employed without being explicitly identified in the authors' keywords. To ensure accurate representation of the methodological scope and maintain consistency in bibliometric mapping, keywords such as "MCDA," "fuzzy logic," "hybrid methods," and "Bayesian networks" were manually assigned where applicable. For instance, if a study employed the Analytic Hierarchy Process (AHP) but did not include "MCDA" among its keywords, the broader term "MCDA" was added to reflect its methodological classification. This approach was adopted to mitigate the underrepresentation of analytical trends resulting from inconsistent or incomplete keyword labelling by the original authors.

Figure 7. Methodological flowchart summarizing the review process from literature search to analysis and validation.



3.3.2. Splitting

In addition to thematic mapping, a splitting strategy was applied to accurately categorize compound or hybrid terms. For instance, terms such as PGIS were divided into GIS and participatory method; Fuzzy GIS into fuzzy logic and GIS; and Fuzzy MCDA into fuzzy logic

and MCDA. This ensured that integrated methodologies were fully represented across all relevant categories, thereby improving the accuracy of co-occurrence analysis and cluster visualizations.

3.3.3.Standardization of Terminology

Since authors often use different terms for the same concept, we grouped similar keywords under common labels. This helped create a clearer, more consistent dataset for analysis, as illustrated in

Table1. Standardization of Keywords.

Original Keywords	Standardized Term
geographical information system, geographic information system, QGIS, gis, GIS-Based software, Quantum GIS,	gis
AHP, analytical hierarchy process, analytical hierarchy process (AHP)	ahp
Site selection, site identification, renewable site selection, siting, suitable map, site selection process, feasibility site selection, suitability map, site selection method, location, feasible site secretion, site assessment, spatial decision making, optimal selection.	Site selection
Offshore wind power station, offshore wind energy, offshore wind farm, offshore wind resource, offshore wind potential, offshore wind energy potential, offshore wind park, wind farm, offshore wind site criteria, offshore area	owf
MCDA, MCDM, multi-criteria decision-making, multi criteria decision methods, multiple attribute decision analysis, multi-criteria group decision-making (MCGDM), spatial multi criteria decision analysis.	mcda
Spatial planning, marine spatial planning, spatial interpolation, maritime spatial planning, spatial energy analysis,	spatial analysis
Wind energy, renewable energy search, marine renewable source, ocean energy, sustainable energy.	renewable energy
Floating offshore wind turbines (FOWT), floating offshore wind turbine, floating platform.	floating offshore wind turbines
Levelized cost of electricity (LCOE), LCOE	levelized cost of energy
Fixed offshore wind	fixed offshore wind turbines

3.4. Quantitative Summary and Visualization

Following metadata extraction and classification, quantitative summaries and visual representations were generated. Descriptive statistical charts and tables were created using Excel to illustrate patterns in turbine types, GIS usage, and publication trends. Concurrently, VOSviewer software [25] was used to perform keyword mapping, revealing thematic clusters, keyword co-occurrences, and emerging research trends.

3.5. Validation and Review

The generated quantitative summaries and thematic visualizations were critically examined and reviewed to ensure accuracy and methodological rigor. Expert validation refined the classifications, clarified the interpretations, and confirmed the reliability and relevance of the identified patterns and insights.

3.6. Identification of Scope and Limitations

Finally, the scope and limitations of the reviewed literature and methodological processes were explicitly documented. Identifying these limitations provides essential context for the findings, enhances transparency, and clearly defines the applicability and generalizability of the insights derived from this systematic review.

4. Keyword Network Mapping

To capture the conceptual landscape and methodological dynamics within offshore wind farm (OWF) site selection studies, a detailed keyword network mapping was conducted. This builds directly on the manual classification process and provides a bibliometric foundation for visualizing relationships between key concepts, decision-making approaches, and spatial analysis techniques. The keyword maps collectively reveal the thematic structure and methodological evolution of the field. They confirm the dataset's alignment with the study's objectives while exposing underlying patterns, preferred decision frameworks, and hybridization trends. Each visualization offers a focused perspective on specific methodological clusters and their interconnections.

The general visualization (Figure 8a) prominently features "OWF" (88 occurrences) as the largest and most centralized node, with the highest total link strength (257) (Table 2). Strong connections with "site selection" (56), "MCDA" (56), "GIS" (47), and "renewable energy" (42) underscore their critical interdependence and thematic centrality.

In the MCDA-focused map (Figure 8b), "MCDA" (56) emerges as a dominant node, closely linked with frameworks such as AHP (19), PROMETHEE (2), and TOPSIS (2). These connections highlight both the widespread application of AHP and the presence of alternative methods, reinforcing the methodological diversity of OWF siting research.

The fuzzy logic visualization (Figure 8c) identifies "fuzzy logic" (15) as central, with strong ties to variations including intuitionistic fuzzy sets, spherical fuzzy sets, and interval-valued fuzzy sets. These links demonstrate the frequent use of fuzzy approaches to address uncertainty and imprecision in siting decisions. Hybrid method maps (Figures 8d); (Figure 8e) reveal the substantial integration of fuzzy logic with MCDA approaches, producing combinations such as fuzzy AHP, fuzzy DEMATEL, and fuzzy MADM. These emphasize the growing trend toward hybridization, where integrated frameworks enhance decision-making precision and robustness under uncertainty.

The GIS-focused map (Figure 8f) highlights "GIS" (47) as an indispensable spatial decision-support tool, strongly connected with MCDA and fuzzy logic. Its central role reflects how GIS enables both visualization and the practical application of decision-making methodologies within spatial contexts.

Beyond the dominant methods, the literature also shows a wide spectrum of less frequently applied frameworks. Techniques such as MOORA (1), WPM (1), VIKOR (1), TODIM (1), GAIA (1), PROSA (1), Borda Method (1), and Electre-III (1) appeared sporadically, reflecting ongoing methodological experimentation. The Best–Worst Method (BWM) (2), including a Bayesian variant, points to growing interest in preference-modelling approaches, while fuzzy extensions—such as fuzzy ANP, fuzzy ELECTRE, fuzzy DEMATEL, and fuzzy MADM—underscore the field's emphasis on uncertainty management. A few studies further applied Bayesian modelling (2) and Game Theory (1), capturing probabilistic reasoning and strategic interactions. Though far less prevalent than AHP, PROMETHEE, or TOPSIS, these methods contribute to the field's methodological

richness and highlight researchers' pursuit of alternative perspectives to tackle the multifaceted challenges of OWF site selection.

Table2. Top Standardized Keywords by Occurrence and Total Link Strength in the Co-occurrence Network

	Keyword	Occurrences	Total Link Strength
1	owf	88	257
2	site selection	56	189
3	mcda	56	165
4	gis	46	164
5	renewable energy	42	138
6	ahp	19	68
7	spatial analysis	14	50
8	fuzzy logic	15	49
9	floating offshore wind turbines	13	38
10	evaluation criteria	3	19
11	borda method	2	17
12	decision alternatives	2	17
13	multiple criteria evaluation	2	17
14	participatory methods	2	17
15	spatial decision support system	2	17
16	wind energy	4	14
17	offshore wind energy potential	3	12

5. Descriptive Charts

This stage involved the quantitative summarization and visual representation of key methodological findings derived from the manual screening and classification phases. Specifically, descriptive charts were created to illustrate the distribution of GIS usage (explicit vs. non-use) across the reviewed offshore wind farm site selection studies (Figure 9a), as well as the prevalence of different offshore wind turbine structure types (fixed-bottom, floating, and hybrid solutions) (Figure 9b). Additionally, a temporal distribution chart and accompanying summary table were developed to highlight annual research trends and structural typology shifts within the period from 2015 to 2025 (Figure 9c); (Figure 9d). These visualizations, generated using Excel, enable a clear and comparative understanding of methodological patterns, trends, and shifts within the reviewed literature.

Importantly, a clear upward trend is observed in the number of studies addressing floating and hybrid (both) turbine structures over the past five years. This increase indicates that floating wind technology has matured significantly and is emerging as a dominant trajectory for future offshore wind developments, particularly suited to deep-water applications and challenging seabed conditions.

6. Validate & Review Results

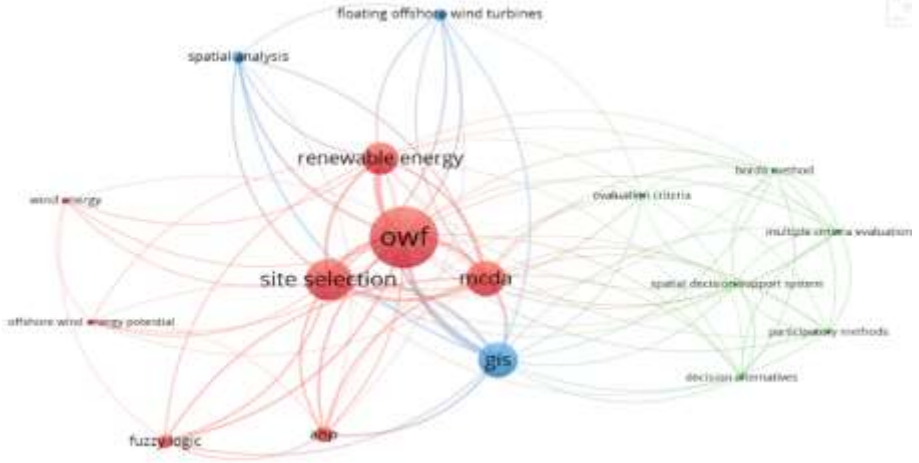
Validation of the findings was systematically undertaken to ensure methodological accuracy and analytical robustness. Generated keyword networks and quantitative summaries were cross-verified against original data sources to confirm metadata accuracy, classification correctness, and visualization validity. Additionally, expert review

was incorporated to critically assess thematic clusters, inter-node connections, and emerging patterns identified through keyword mapping and statistical analyses. This comprehensive validation process minimized potential biases and interpretive errors, significantly enhancing the credibility and reliability of the presented results.

Figure 8. Keyword co-occurrence maps generated using VOS viewer to visualize methodological and thematic structures in offshore wind farm (OWF) site selection studies.

Panels (a)–(f) illustrate: (a) overall landscape, (b) MCDA models, (c) fuzzy logic methods, (d) hybrid MCDA- Based integration, (e) hybrid AHP - Based integration, and (f) GIS-driven frameworks.

(a)



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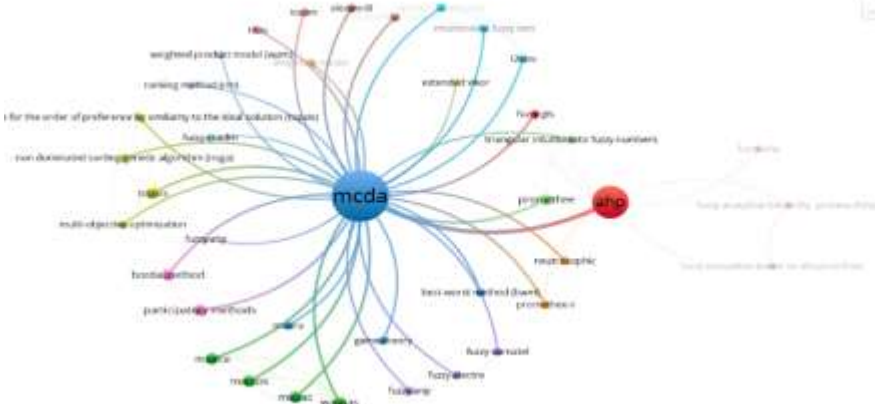

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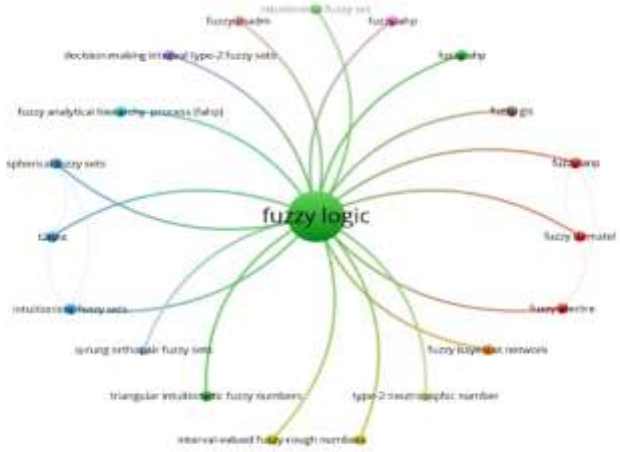

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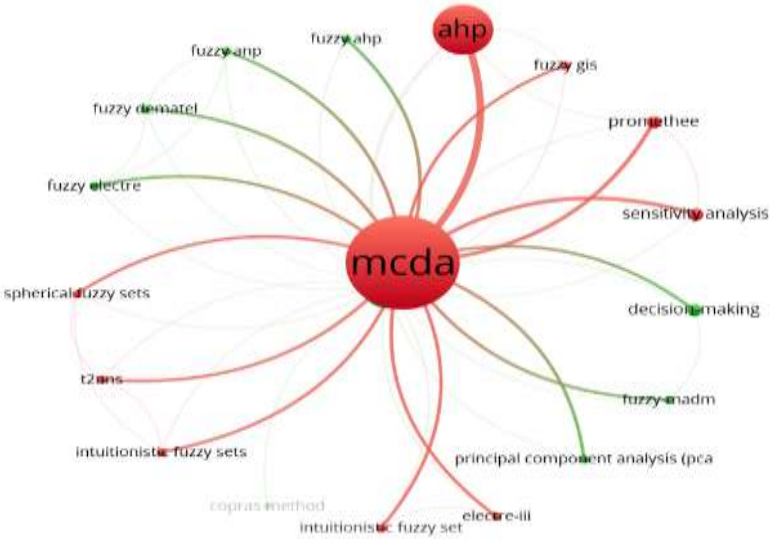
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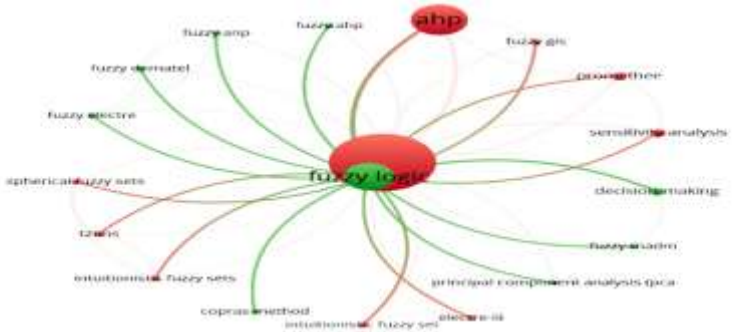
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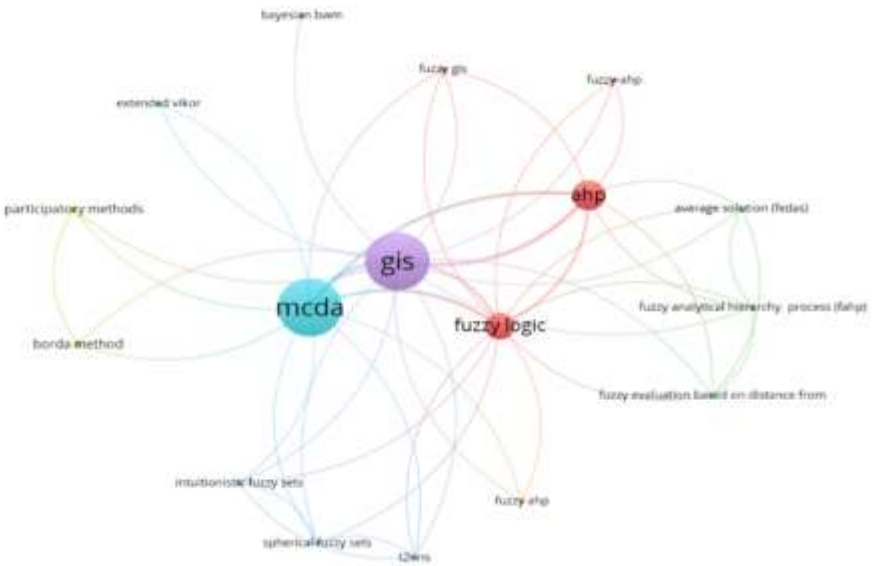
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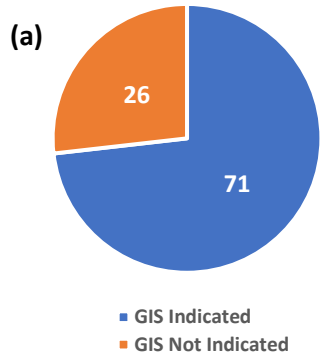
Figure 9. (a) Distribution of GIS usage across reviewed offshore wind site selection studies, distinguishing between studies that explicitly indicate GIS use and those that do not. (b) Distribution of offshore wind turbine structure types Fixed-Bottom, Floating, and Both across the reviewed literature. (c) Annual distribution of turbine structure types from 2015 to 2025, highlighting publication trends. (d) Tabulated summary of annual counts for each structure type.

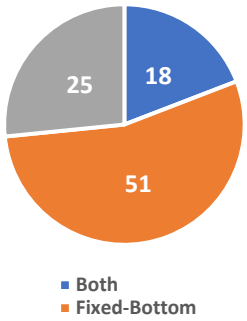
The increase in floating and hybrid (both) structures over the last five years reflects the growing technological maturity and future potential of deep-water offshore wind solutions.

(a)



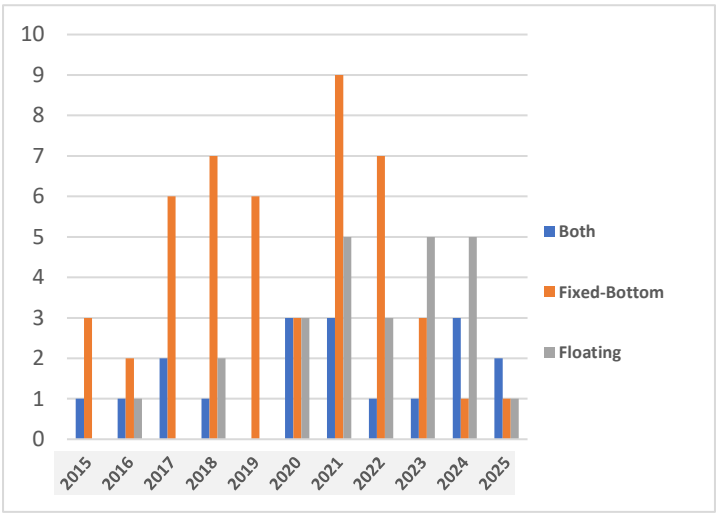
Use of GIS in Offshore Wind Farm Site Selection Studies (N =

(b)



Distribution of Offshore Wind Turbine Structure Types in Reviewed Studies

(c)



(d)

Year	Both	Fixed-Bottom	Floating	Grand Total
2015	1	3		4
2016	1	2	1	4
2017	2	6		8
2018	1	7	2	10
2019		6		6
2020	3	3	3	9
2021	3	9	5	17
2022	1	7	3	11
2023	1	3	5	9
2024	3	1	5	9
2025	2	1	1	4
Grand Total	**18**	**48**	**25**	**91**

7. Identify Scope & Limitations

This review systematically addressed offshore wind farm (OWF) site selection methodologies, specifically focusing on GIS applications, and MCDA frameworks. While

comprehensive within its specified focus, inherent limitations remain. Firstly, variations in keyword usage and potential indexing inconsistencies might lead to the omission of relevant studies. Secondly, subjective interpretations in classifying GIS usage could introduce biases. Lastly, the temporal scope (2015–present) excludes historical influences and immediate technological advancements beyond this range. Recognizing these limitations contextualizes the review's conclusions and highlights opportunities for future research to refine site selection methodologies.

8. Conclusions

This systematic review comprehensively explored the offshore wind energy (OWE) resource potential, methodological practices, and associated GIS-based site selection strategies, focusing specifically on the underexploited maritime regions of the Red Sea and Arabian Seas. Several key insights emerged from the analytical and bibliometric assessment conducted in this study:

• Despite significant global expansion in offshore wind installations, stark geographical disparities persist, particularly with substantial underutilization of wind resources in the Red Sea and Arabian maritime regions. This indicates a critical gap between the high technical potential identified in wind speed and wind power density maps and the currently limited offshore wind deployment, emphasizing the urgent need for targeted regional policy interventions and investments.

• Through rigorous metadata extraction, keyword normalization, and network mapping utilizing VOSviewer, this study identified prevalent and emerging methodologies in offshore wind site selection. The centrality of key methodologies such as GIS, MCDA, and fuzzy logic confirms their importance and interconnectivity, demonstrating methodological coherence and maturity within offshore wind energy studies.

• Analysis of publication trends reveals a growing research interest in floating and hybrid turbine structures over the past five years. This reflects technological advancements and a transition toward deeper waters, aligning with observed depth profiles in the Red Sea and Arabian maritime zones, where significant potential for floating technologies exists.

• Descriptive statistical visualizations highlight explicit GIS usage in approximately three-quarters of reviewed studies, underscoring its operational significance in offshore wind farm site selection and spatial planning.

• Methodological diversity in reviewed studies emphasizes the importance of integrating robust MCDA frameworks and fuzzy-based hybrid models with GIS platforms. These approaches facilitate nuanced, accurate, and decision-relevant spatial analysis, particularly valuable in regions characterized by environmental uncertainty and diverse stakeholder perspectives.

• The study addresses notable gaps in existing literature by standardizing and normalizing disparate terminologies, significantly enhancing comparative analysis and clarifying future offshore wind research. The absence of consistent keyword usage complicates literature analysis and impedes precise identification of research trends. Therefore, establishing standardized terminologies will facilitate better data retrieval, more precise bibliometric analyses, and ultimately, more cohesive scientific discourse.

• Comprehensive spatial analysis conducted through detailed wind resource and bathymetric mapping has demonstrated substantial potential within the Red Sea and Arabian maritime regions. The robust methodological framework proposed herein provides a systematic, replicable, and transparent analytical foundation for future site selection studies.

The absence of standardized keyword protocols in academic publishing presents a critical barrier to synthesizing knowledge and constructing coherent methodological frameworks. When authors use inconsistent or overly specific terminology, it complicates

efforts to trace thematic patterns, analyse methodological trends, and build cumulative insights particularly in interdisciplinary fields like offshore wind energy. Establishing a common protocol for keyword selection would significantly enhance the visibility, comparability, and analytical utility of published research. This issue is especially consequential in underrepresented regions such as Somalia and Yemen, where offshore wind resources remain largely untapped due to infrastructural, economic, and data limitations. Even in resource-rich countries like Oman, which possess favourable wind conditions, energy systems still rely heavily on unsustainable sources. Addressing these challenges requires not only investment in infrastructure and regulatory reform, but also more coordinated knowledge-sharing practices. Future research should therefore prioritize both the harmonization of metadata practices and the removal of structural barriers to unlock the full potential of offshore wind in both developing and developed contexts by doing more study to motivate the governments to invest or simplify the investment for private sector in offshore wind energy and other sustainable resources.

Declaration of Interests

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.

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