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Original research article

"Act local, Impact global": Mapping the social acceptance of offshore wind energy in Greece and advancing social engagement planning processes

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ABSTRACT

In this study, a set of original methods is introduced to advance the development of socially acceptable offshore wind projects (OWPs) at both global and national scales. Specifically, two complementary approaches are proposed: (1) a preparatory framework designed to support decision-makers in establishing an effective citizen participation process; and (2) a pioneering participatory planning framework aimed at systematically eliciting and integrating citizen perspectives during the early stages of OWP planning, thereby facilitating the identification of socially acceptable installation areas. To achieve these objectives, a semi-structured questionnaire survey was methodically designed using the LimeSurvey platform in conjunction with a probability sampling strategy. The collected primary data were analyzed through a combination of qualitative and quantitative techniques, including descriptive statistical analysis, thematic analysis, and advanced correlation methods, all conducted within the Statistical Package for the Social Sciences. In parallel, a versatile geoprocessing site-suitability model was developed within a Geographic Information System (GIS), enabling GIS-based assessments at multiple stages of the planning process (exclusion and evaluation phases). The proposed framework was applied in Greece, with the active participation of 1802 citizens, thereby demonstrating its capacity to enhance the legitimacy, inclusiveness, and social acceptability of OWP planning outcomes. Importantly, OWPs' social acceptability is shaped by aesthetic and environmental considerations, while citizens' acceptance levels and residence influence placement decisions. Sustainability criteria reveal high installation potential, positioning the South Aegean and the area east of Crete as optimal marine regions. The findings highlight planning guidelines for socially legitimate global OWP roadmaps and robust social impact assessments.

1. Introduction

Different geopolitical movements have triggered the current energy crisis and have further increased the political willingness to accelerate renewables deployment, as the only right way forward. Therefore, it is necessary to create the conditions required for this transition to occur. Global renewable power capacity increased by 36 % in 2023, reaching a cumulative total of 4.87 TW by year's end [1]. Wind energy is one of the leading renewable energy sources (RES) in terms of installed power capacity on a global scale, bolstering energy security and contributing to a sustainable future for society. In particular, the cumulative installed capacity of global wind power reached nearly 1.06 TW by the end of 2023 [2]. In the last 15 years, offshore wind projects (OWPs) have proven that they have the potential to produce tremendous amounts of green energy at reasonable and feasible cost, thereby becoming a key solution in decarbonization plans worldwide. Global offshore wind capacity reached 75.2 GW by the end of 2023 [3]. In Greece, OWPs have not yet been deployed due to the lack of necessary legislative frameworks and relevant spatial planning regulations. However, the Ministry of Environment and Energy [4] has recently established a framework for the acceleration of OWP deployment in the coming years, as the Greek government is currently focusing on the effective exploitation of offshore wind power.

One of the most important issues of OWP deployment is the identification of ideal locations for their installation [5,6]. Determining site suitability is a complex and multidimensional process that requires the consideration of several exclusion and/or assessment criteria, such as economic, social, and environmental criteria. Social criteria are linked with the sustainability of OWP installation sites in relation to the potential impact of OWPs on the standard of living, quality of life, cultural significance of sites, landscape, biodiversity, citizens' health, coastal property values, and other societal issues [7]. Therefore, social criteria can significantly affect or even limit the suitability of marine areas for OWP placement. In addition, lack of social acceptance remains a major constraint to the fulfillment of global energy targets in the medium term

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Abbreviations

AC	Assessment Criteria
AHP	Analytical Hierarchy Process
CCA	Complex Correlation Analysis
EC	Exclusion Criteria
GIS	Geographic Information System
MCDA	Multi-Criteria Decision Analysis
NIMBY	Not In My Back Yard
OWP	Offshore Wind Project
PEC	Political Exclusion Criteria
RES	Renewable Energy Sources
SEC	Societal Exclusion Criteria
SFSPSD-RES	Specific Framework for the Spatial Planning and Sustainable Development of Renewable Energy Sources
SPSS	Statistical Package for the Social Sciences
SQL	Structured Query Language
SQS	Systematic Questionnaire Survey
TEEC	Techno-Economic Exclusion Criteria
TM	Thematic Module
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
VIKOR	VIseKriterijumska Optimizacija I kompromisno Resenje

(2030) and long term (2050) [7]. Considering this, the participation of local citizens in various planning phases of OWPs is of significant importance and directly assists in the determination of socially acceptable marine areas for OWP placement. Moreover, citizens' concerns over the potential adverse impacts of OWP installations on their local environment should be investigated and addressed. Citizen perspectives relating to the distance of OWPs from residential areas, touristic zones, and various societal, cultural, and political areas of interest must also be integrated into the planning processes. Accordingly, participatory tools should be developed to facilitate the exploration of citizen perspectives, and offshore wind development roadmaps must be formulated to address the fundamental challenge of locating socially acceptable marine areas for OWP installation.

Geographic Information System (GIS) provides the ability to simplify real-world complexities, analyze and combine multiple valuable datasets, and produce sustainable placement solutions for offshore wind installations. Multi-Criteria Decision Analysis (MCDA) techniques are often used in combination with GIS to improve planning processes. A great number of OWP siting studies have developed various GIS-based methods and/or MCDA techniques and applied a series of exclusion criteria (EC), aiming to solve this complex placement problem, as evidenced by [8–26]. Indicatively, Castro-Santos et al. [8] created two tools in GIS, namely a tool for general restrictions and a tool for restrictions of ports and shipyards, to determine installation sites for floating OWPs in the North-West of Spain. Mahdy and Bahaj [13] applied a GIS-based assessment in combination with the Analytical Hierarchy Process (AHP) and Pairwise Comparison methods to identify suitable areas for OWPs in Egypt. Emeksiz and Demirci [10] assessed the suitability of 31 coastal regions by using ten siting criteria and the AHP method, determining the siting configuration of wind turbines in potential installation sites and, finally, estimating their offshore wind energy potential. A comparative analysis among fuzzy versions of MCDM methods was conducted by Sánchez-Lozano et al. [17] for OWP placement in the Gulf of Maine, USA. They compared triangular and linear GIS fuzzy membership functions and applied AHP combined with two distance-based methods—TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and VIKOR (VIseKriterijumska Optimizacija I kompromisno Resenje)—for ranking alternative sites. Loughney et al. [11] investigated the North Coast of Scotland for potential siting of floating OWPs by applying 11 EC to eliminate prohibitive and unsuitable areas. The eligible sites were then prioritized based on their overall performance on 16 assessment criteria (AC) using the AHP and Pairwise Comparison methods along with the Evidential Reasoning algorithm.

Even though several studies have investigated the siting challenges of OWPs, methods that attempt to identify socially acceptable sites for OWPs by advancing public participation in the planning stages and incorporating citizen perspectives into the decision-making process are still missing. After conducting a thorough systematic review [6] of the current OWP siting studies, and even examining the most recent investigations (e.g., [21]), only two studies [12,14] have been identified as incorporating public opinion in the planning process, and only in the assessment stages (late stages of the process) (Table 1). Mekonnen and Gorsevski [14] developed a web-based participatory GIS planning approach for the incorporation of any type of participant in the assessment stage of the placement process; however, a hypothetical case study was used to test the proposed approach. Thus, the actual impact of public participation in the planning process is lacking, and citizen perspectives on OWP development should be further investigated. In another study, Loukogeorgaki et al. [12] developed a site selection approach by combining GIS, AHP, and an online questionnaire survey for the incorporation of citizen opinions in the prioritization of potential offshore wind installation sites. They applied this approach in the Exclusive Economic Zone of Greece, where 122 citizens (a) provided their preferences on the significance of six AC and (b) declared their opinion on the priority of suitable sites for OWPs. Consequently, a holistic methodological framework for citizens' participation in the early stages (exclusion stage) of the planning process is still missing (Table 1). Citizen perspectives should be investigated on several additional important issues of the OWP planning problem, and significantly more citizens must participate in various planning phases to enhance the accuracy and quality of the potential findings. As highlighted by Johnston et al. [27], there is a necessity for innovative solutions and strategic site selection to navigate social challenges effectively.

The most recent social-related studies have focused on: public participation in the planning of electricity grid infrastructure [28]; community acceptance of five different seasonal energy storage technologies [29]; the social acceptance of two industrial applications of green hydrogen (green methanol and green steel) [30]; the significance of community energy systems in facilitating the transition to a cleaner energy future [31]; the significance of broader place-specific dependencies in the incentive-driven obstacles to the legitimacy of offshore wind technology, along with an assessment of the offshore wind industry in France [32]; and the examination of five frontline coastal communities affected by offshore wind in the northeast US, conducted through 37 interviews and an exploratory qualitative analysis of energy justice experiences [33]. However, none of the current studies have focused on the social acceptability of offshore wind turbines by supporting the participation of a large number of citizens in the decision-making process and by determining precise, socially acceptable installation sites for new OWPs that are committed to fulfilling the site selection requirements of the participating society.

The necessity for the development of a participatory planning method that investigates NIMBY (Not-In-My-Back-Yard) oppositions and transcends NIMBYism is apparent. Dear (1992) [34] defines NIMBYism as "*the protectionist attitudes of and oppositional tactics adopted by community groups facing an unwelcome development in their neighborhood*" and highlights that planners need to comprehend the characteristics of standard opposing viewpoints. Several studies [35–37] have investigated NIMBYism in the development of renewable energy technologies. Boyle et al. [35] examined NIMBY using a choice experiment and identified public concerns about specific elements of community wind projects in the US. The study indicates that opponents of wind energy may remain resistant to wind-farm developments, even when financial incentives are offered. Devine-Wright [37] applied an alternative approach to empirically examine how place attachment and the

Table 1
Comparison between current studies integrating citizens' perspectives in OWP planning and the present original research.

Study	Investigation Area	Stage of the Planning Process	Issues Related to the Planning of OWPs	Methods	Number of Citizens
Mekonnen and Gorsevski [14]	Lake Erie, Northern Ohio, USA	Assessment Stage (Late Stage): Prioritization of Suitable OWP Sites	(i) Determination of the Importance of Eight AC; (ii) Prioritization of Suitable OWP Sites	Web Participatory GIS Approach, Borda Count	0 (hypothetical case study)
Loukogeorgaki et al. [12]	EEZ of Greece	Assessment Stage (Late Stage): Prioritization of Suitable OWP Sites	(i) Determination of the Importance of Six AC; (ii) Prioritization of Suitable OWP Sites	GIS Approach, AHP, Online Questionnaire	122
Current Original Research	Territorial Waters of Greece	Exclusion Stage (Early Stages): Definition of the Exclusion Criteria and Incompatibility Zones, and Spatial Determination of Suitable and Socially Acceptable Offshore Wind Project Installation Areas	(i) Degree of social acceptance for RES exploitation; (ii) Degree of social acceptance for OWP deployment; (iii) Key reasons for citizens' disagreement with OWP installation, in cases where they oppose deployment; (iv) Unsuitable marine areas (selection of EC) for locating socially acceptable offshore wind installations; (v) Incompatibility zones (definition of exclusion limits) for locating socially acceptable offshore wind installations; (vi) Preferred alternative tools of social engagement through which citizens wish to participate in the OWP planning process; (vii) Degree of citizen participation in the OWP planning process through the proposed SQS; (viii) Stakeholder groups with a leadership role in the decision-making process of OWP deployment; (ix) Importance of the OWP planning process in the effort to install eligible and socially acceptable projects for the local society; (x) Correlation between citizens' perspectives on unsuitable offshore wind installation areas and their degree of acceptance; (xi) Correlation between citizens' perspectives on unsuitable offshore wind installation areas and their place of residence; (xii) Correlation between citizens' perspectives on unsuitable offshore wind installation areas and their education level; (xiii) Correlation between citizens' perspectives on unsuitable offshore wind installation areas and their age group; (xiv) Correlation between citizens' degree of acceptance for RES exploitation and their degree of acceptance for OWP deployment across spatial planning scales.	Geoprocessing Site Suitability Modelling in GIS, Systematic Questionnaire Survey Using the LimeSurvey Tool and a Probability Sampling Method, Qualitative and Quantitative Methods of Analysis (Descriptive Statistical Analysis and Thematic Analysis) for Primary Data in SPSS, Complex Correlation Analysis Techniques for Primary Data in SPSS, Preparatory Method	1802

symbolic significance of place influence societal reactions to the installation of a tidal energy converter. In total, 271 residents of two nearby villages participated in the survey, and regression analyses of the public's responses revealed that place attachment was a statistically significant and positively associated factor influencing project acceptance across both villages. In a case study of a proposed 750 MW OWP in North Wales [36], empirical insights were incorporated from participatory group dialogues and questionnaires distributed among community members in two coastal towns ($n = 488$). Evidence from the analysis revealed that the degree of trust in key institutional agents moderates the effect of place attachment on negative wind-farm perceptions. Nevertheless, studies that develop a participatory planning framework—designed to assess NIMBY oppositions in matters pertaining to the spatial development of new OWPs, examine public opposition to designated elements of the OWP planning process, and identify the determinants that shape citizens' preferences in the siting of OWPs—are still missing.

To advance originality, methodological rigor, and stylistic excellence in energy social science, it is essential to clearly articulate research objectives, questions, and methodological design; to establish a framework

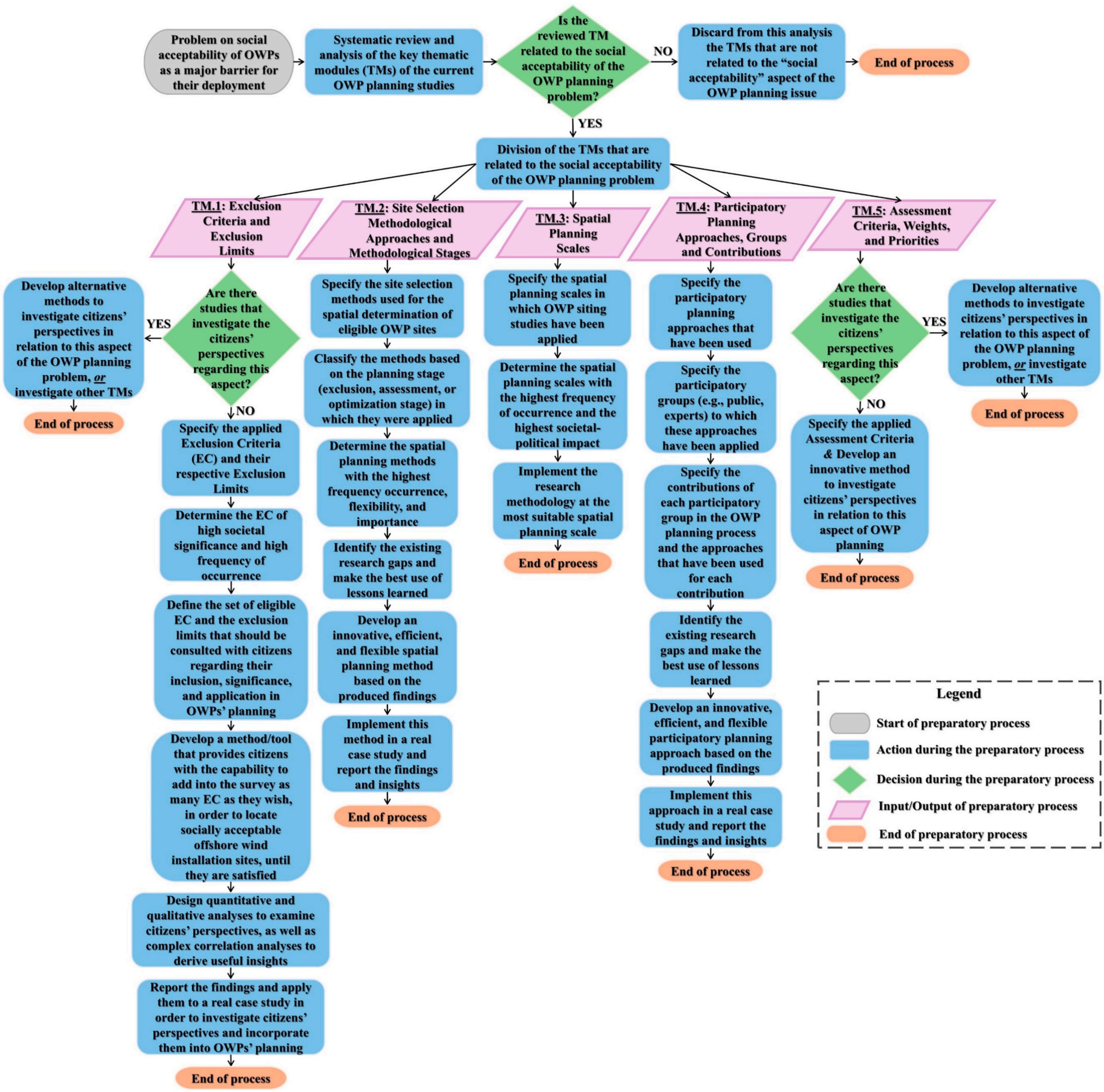

Fig. 1. A preparatory method for enhancing the social acceptability of OWPs.

for analyzing the concept of novelty; and to communicate research insights in a structured and comprehensible manner [38]. In contributing to the existing body of knowledge by bridging identified research gaps and emphasizing the importance of methodological robustness, the present work seeks to pave the way toward socially acceptable offshore wind installations. This is achieved through the formulation of a participatory methodological framework designed to investigate citizen perspectives (a total of 1802 citizens participated in this study) on 14 previously unexplored issues concerning the development and siting of OWPs. These issues include, but are not limited to (Table 1): (a) the degree of acceptance of OWP development; (b) the principal reasons for disagreement with OWP installation, where opposition exists; (c) unsuitable marine areas (selection of EC) for socially acceptable offshore wind siting; (d) incompatibility zones (exclusion buffer limits) for OWP installation; (e) preferred alternative tools of social engagement through which citizens wish to participate in OWP placement; and (f) stakeholder groups that should assume a leadership role in the decision-making process for OWP development. Accordingly, original and sequential methods are developed and proposed in this work, as detailed in Table 1.

In pursuit of the above objectives, the key contributions of this work are as follows: (1) a preparatory method is proposed to assist decision-makers in developing an effective citizen participatory approach for the planning of OWPs; (2) a participatory planning method is developed to investigate and incorporate citizen requirements in the early stages of OWP planning; (3) citizen perspectives are analyzed and presented on several previously unexplored issues of OWP planning; (4) valuable results and breakthrough insights are provided, as this constitutes the

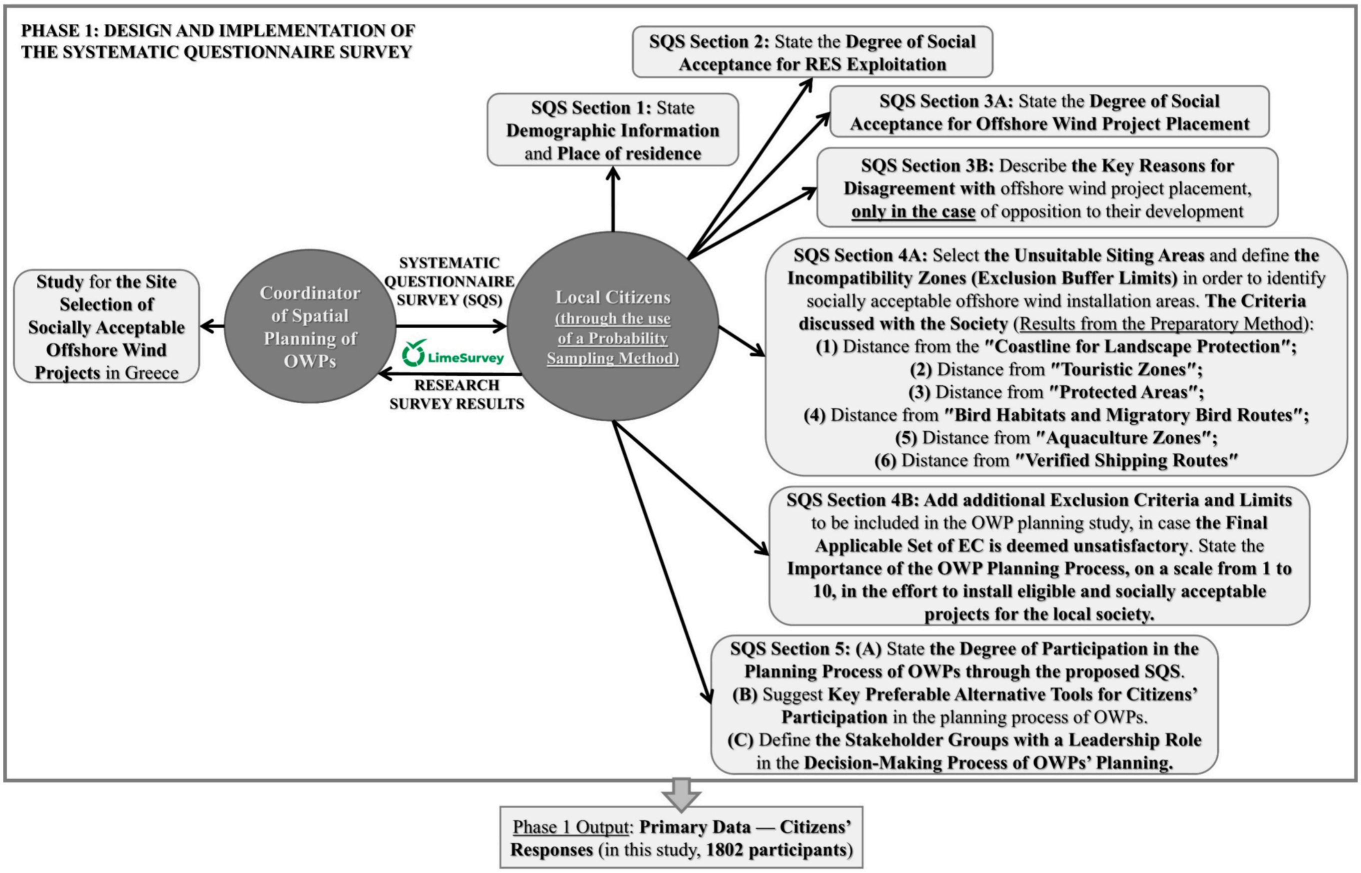

Fig. 2. Design and implementation of the research survey (Phase 1 of the participatory planning method).

largest research study conducted to date with the participation of 1802 citizens in OWP planning; (5) socially acceptable offshore wind installation areas are identified for the first time within the territorial waters of Greece, by integrating this important political factor with local citizen perspectives in the site suitability analysis; (6) a holistic OWP development roadmap, highlighting the precise location and siting characteristics of marine areas with high economic feasibility and social acceptability, is produced through the development of a versatile geoprocessing site suitability model in GIS; (7) a set of factors influencing citizens' decisions on OWP placement is described for the first time by conducting complex correlation analyses (CCA) of primary data in SPSS (Statistical Package for the Social Sciences); (8) planning guidelines for offshore wind installations are provided by the local society, which can facilitate the establishment of national standards and regulations for conducting social impact assessment studies of offshore wind turbines; and (9) the proposed participatory planning method and the study's insights can strengthen the current legislative framework of Greece (Law 4759/2020) [39], which lacks institutional mechanisms for citizen participation in spatial planning.

In light of the preceding points, this original research study addresses multiple research questions, with five core questions outlined as follows: (1) What combination of participatory planning tools and methodological approaches should be developed to effectively integrate citizen perspectives into the early stages of OWP planning? (2) Which site selection criteria (EC) should be deliberated with the local society for the identification of socially acceptable OWP sites, and which of these criteria are recognized as critical societal determinants influencing the social acceptability of potential OWP installation areas? (3) Which determinants shape citizens' preferences in the siting of OWPs, and which methodological frameworks should be established to identify and analyze them? (4) What principal objections do citizens articulate toward the development of OWPs (e.g., the establishment of setback distances from designated areas)? (5) How are citizens' acceptance levels of RES and OWPs interlinked, and what is the nature of their interplay across spatial planning scales (national, regional, and local)?

Section 2 describes the preparatory and participatory planning methods developed to investigate and incorporate citizens' perspectives in the early stages of the OWP planning process. Section 3 presents the results of citizen participation in OWP planning and discusses valuable insights derived from the qualitative and quantitative analyses of participants' responses. Finally, Section 4 provides the concluding remarks and key findings.

2. Materials and methods

The present work introduces original and sequential methods to pave the path toward socially acceptable OWPs on a global scale: (1) a preparatory method designed to build an effective citizen participatory process; and (2) a participatory planning method developed to investigate and incorporate citizens' perspectives into the OWP planning process, thereby identifying socially acceptable OWP installation areas through the creation of a systematic questionnaire survey (SQS) using the LimeSurvey tool [40,41], the development of a versatile geoprocessing site suitability model in GIS, the conduct of qualitative and quantitative analyses together with CCAs of primary data in SPSS [42,43], and the performance of GIS-based assessments [8,27] at different stages of the planning process.

2.1. A preparatory method for enhancing the social acceptability of OWPs

The proposed preparatory method is illustrated in the flowchart of Fig. 1. It aims to address the problem of social acceptability of OWPs

Table 2
Qualitative and quantitative analysis techniques for investigating citizen perspectives on issues concerning the development and siting of OWPs.

No.	Qualitative and Quantitative Analysis of Citizen Responses (A.1–9)	Qualitative and Quantitative Analysis Techniques
A.1	Analysis and categorization of participants' demographic information (gender, age group, education level) and place of residence (national, regional, and municipality scales of analysis)	Descriptive Statistical Analysis of Categorical (Qualitative) Data
A.2	Estimation of the degree of social acceptance for RES exploitation (e.g., 90 %)	Descriptive Statistical Analysis of Categorical Data and Thematic Analysis of Qualitative and Quantitative Data
A.3	Estimation of the degree of social acceptance for OWP installation (e.g., 88 %) across spatial planning scales (national, regional, and local)	Descriptive Statistical Analysis of Categorical Data and Thematic Analysis of Qualitative and Quantitative Data
A.4	Identification of the key reasons for citizen disagreement with the OWP installation (e.g., disturbance of marine mammal habitats)	Descriptive Statistical Analysis of Categorical Data and Thematic Analysis of Qualitative Data
A.5	Identification of unsuitable siting areas (selection of the EC, e.g., distance from military zones) based on their societal importance, and definition of incompatibility zones (calculation of the exclusion limits, e.g., buffer zone of 2000 m) to precisely locate socially acceptable OWP installation sites	Descriptive Statistical Analysis of Categorical Data and Thematic Analysis of Qualitative and Quantitative Data
A.6	Calculation of the citizens' degree of participation in the OWP planning process through the proposed SQS (e.g., 8 on a scale of 0 to 10)	Descriptive Statistical Analysis of Quantitative Data
A.7	Identification and classification of the key alternative tools of social engagement through which citizens prefer to participate in the OWP planning process (e.g., public consultations)	Descriptive Statistical Analysis of Categorical Data and Thematic Analysis of Qualitative Data
A.8	Identification and classification of the stakeholder groups with a leadership role in the decision-making process of OWP development (e.g., policymakers, citizens, spatial planning engineers, academic experts)	Descriptive Statistical Analysis of Categorical Data and Thematic Analysis of Qualitative Data
A.9	Assessment of the importance of the OWP planning process for the installation of eligible and socially acceptable projects for the local society (e.g., 9.5 on a scale of 0 to 10)	Descriptive Statistical Analysis of Quantitative Data

(research objective and starting point of the preparatory process) by providing key findings to formulate a novel citizen participatory approach. This method corresponds to a workflow that can be employed to specify and analyze the key thematic modules (TMs) of OWP placement studies related to social acceptability, thereby fulfilling the above research objectives. Initially, a systematic review of current OWP siting studies was conducted [6] (the first action of the preparatory method; Fig. 1), while the most recent and relevant studies were also examined (e.g., [21]), to confirm the robustness of the findings and of the proposed preparatory method. The sources of the studies assessed as eligible and included in this systematic review are provided in [6], and the methodology applied within this framework is explained in detail in the Supplementary Materials. The rationale for adopting a systematic analysis approach is that it enables the methodical identification of studies exhibiting the greatest relevance and significance to the research topic, followed by the rigorous application of predefined review criteria to confirm their eligibility for analysis. This enhances the study's credibility, ensures methodological rigor, and supports the development of sophisticated methodological instruments, including the preparatory method advanced in the present study. Based on the results of the systematic analysis [6], the key TMs of the OWP planning issue were defined and subsequently categorized (Fig. 1) according to the important aspects they embody in the context of OWP placement and their relation to the social acceptability of OWPs, by implementing the steps of the preparatory method.

From the analysis of TM1 (EC and Exclusion Limits; Fig. 1), it is demonstrated that no study has investigated citizens' perspectives regarding the EC and limits that must be applied in the OWP placement process. Therefore, according to the preparatory method (Fig. 1), the next action involves determining the EC to be applied in OWP siting studies. Subsequently, the EC of high societal importance are selected by examining their impact on the sustainable future of society. At this stage, the EC with high frequence of occurrence are also identified. A set of eligible EC and limits—intended for consultation with citizens regarding their inclusion and importance in OWP planning—is then defined. Next, a structured technique must be developed to investigate citizens' perspectives on the selected EC. This technique should provide participants with the capability to add as many EC to the survey as they wish, ensuring their full satisfaction with potential OWP installation sites. To thoroughly examine the results of citizen participation and derive breakthrough insights, it is necessary to design suitable quantitative and qualitative analyses of citizens' opinions, together with related CCAs, using established statistical procedures for the social sciences. The findings of this preparatory method for TM.1 must ultimately be reported and applied to a real case study. Accordingly, the preparatory process was also applied to TM.2–TM.5 (Fig. 1). Significant knowledge and information can be derived by executing, step-by-step, the actions of the proposed preparatory process. The research outcomes of this process are then utilized as inputs to the participatory planning method, thereby effectively investigating and incorporating citizens' perspectives into the early stages of OWP planning.

2.2. A strategic decision-making method for citizen participation within the OWP planning process

The proposed participatory planning method for sustainable OWP deployment is applied at the national planning scale, drawing on the valuable findings derived from the preparatory process, and comprises four sequential phases.

2.2.1. Phase 1: design and implementation of the SQS

In Phase 1, an SQS was designed to investigate citizens' perspectives on the development and siting of OWPs in Greece. Specifically, this part of the participatory method consisted of two main components (Fig. 2): (a) the coordinator of OWP spatial planning and (b) the local citizens. The coordinator (in this case, the author) was responsible for the rigorous implementation of the study. Accordingly, a semi-structured questionnaire survey was developed and performed with the use of the LimeSurvey tool, hosted on the official server of the Aristotle University of Thessaloniki, and distributed to local citizens.

LimeSurvey is an open-source web application that enables users to design, manage, and publish online surveys, collect responses, generate statistics, and export results to other applications (e.g., SPSS software) [40]. Shkilniuk et al. [41] thoroughly compared LimeSurvey with four other online survey tools and reported that it achieved a higher overall rating. In the present study, the sample was collected through this versatile survey tool. After participants completed the SQS, their responses were stored on the Aristotle University of Thessaloniki server and could subsequently be exported in .xlsx format, SPSS Data File (editable in SPSS software), or other compatible applications.

The population of interest comprised the entire population of Greece (local society), including both mainland and island residents. A probability sampling method (random selection of survey participants) was formulated, allowing strong statistical inferences to be drawn about the

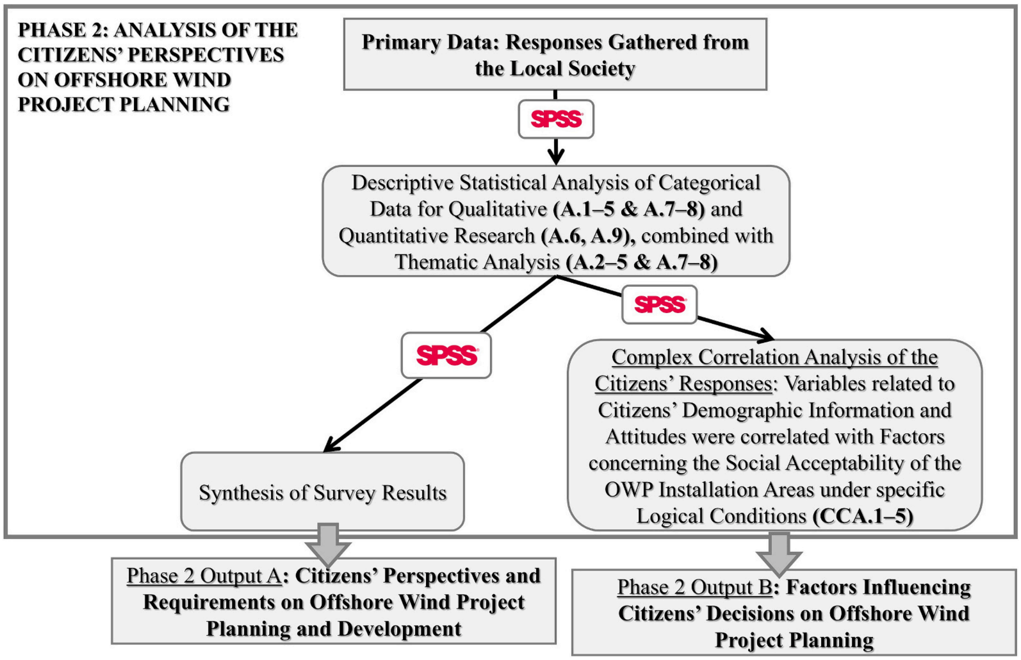

Fig. 3. Phase 2 of the proposed participatory planning method.

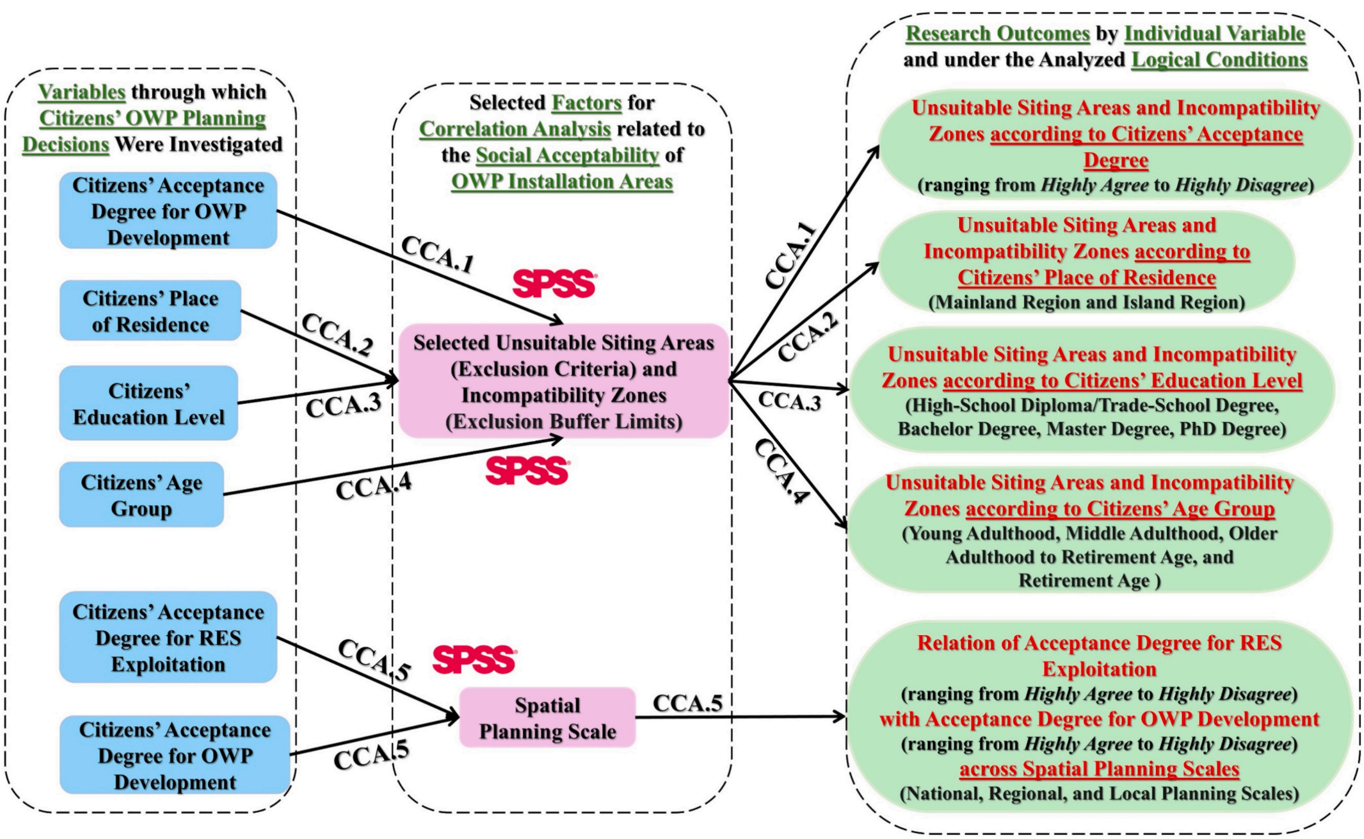

Fig. 4. Complex correlation analyses of the citizen responses performed in SPSS.

whole population of interest while minimizing the risk of selection bias [44], and all participants fully completed the survey, further reducing concerns about non-response bias. Specifically, the survey was disseminated in public mode through multiple open-access channels—including social media platforms, organizational mailing lists, professional networks, and institutional distributions—ensuring that all individuals within the defined sampling frame had an equal opportunity to participate. Importantly, the survey was disseminated across entire organizations irrespective of hierarchical position, personal characteristics, or professional specialization. This broad, non-restrictive strategy ensured an equal probability of selection. In particular, the SQS was distributed via email to government employees across 13 Administrative Regions

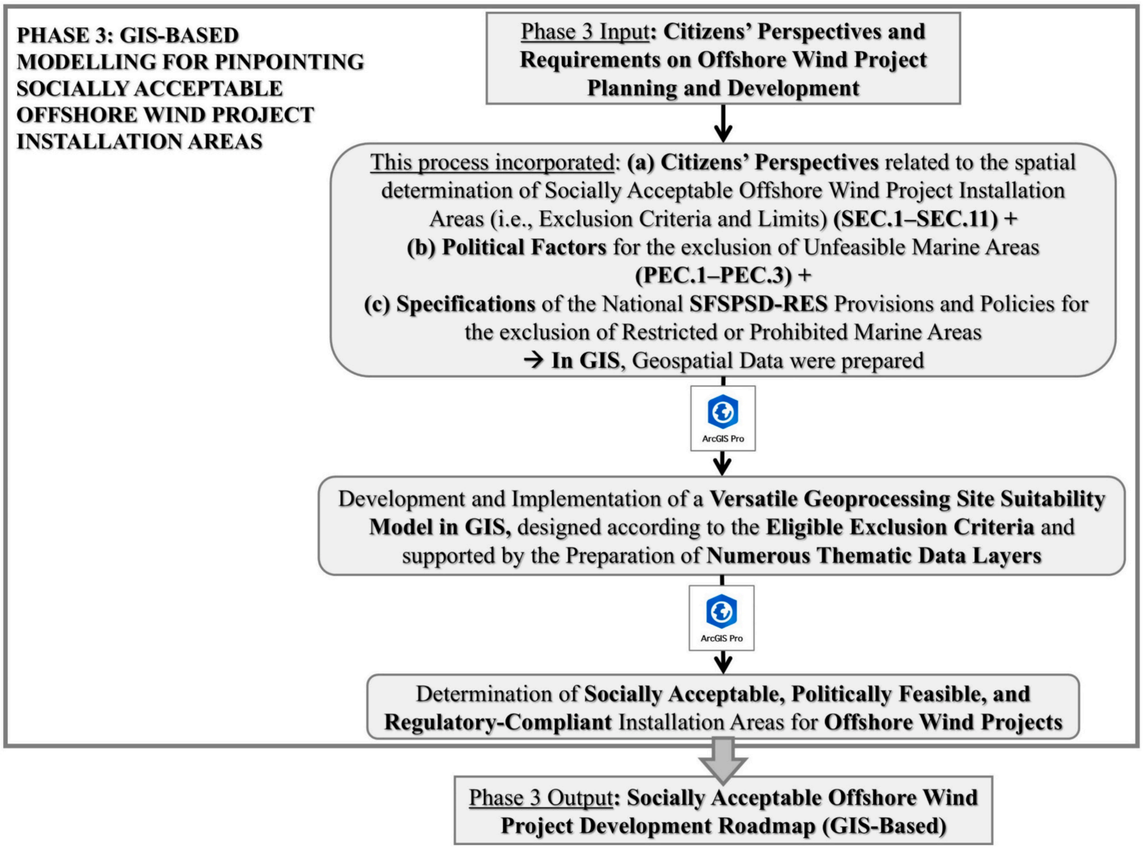

Fig. 5. Phase 3 of the proposed participatory planning method.

and 203 Municipalities of Greece; to official members of the Technical Chamber of Greece (17 Independent Regional Departments in mainland and island regions); to students, professors, researchers, and administrative staff of the Aristotle University of Thessaloniki and other Greek Universities; and to employees of the private sector (energy, spatial planning, and environmental sectors). The SQS was also disseminated through social media platforms, including social groups, engineering groups, and local news pages on Facebook, and via online messages to local contacts. Thus, the SQS was distributed to a broad and diverse group of individuals, with the aim of gathering information from a wide range of perspectives and experiences within the population of interest and maximizing participation. This sampling frame was developed by considering both the online accessibility of each population group and the objectives of the study.

Through this survey, citizens first provided their demographic information (gender, age group, education level) and place of residence. Subsequently, they participated in several issues concerning the development and siting of OWPs, specifically addressing the following topics: (a) the degree of social acceptance of RES exploitation; (b) the degree of social acceptance of OWP installation; (c) the key reasons for disagreement with OWP installation, in case they opposed its development in the study area; (d) unsuitable marine areas (selection of the EC) for the delineation of socially acceptable offshore wind installations; (e) incompatibility zones (exclusion buffer limits) for OWP installation; (f) additional EC and limits to be incorporated into an OWP placement study, in cases where the final applicable set of EC is deemed unsatisfactory; (g) their degree of participation in the OWP planning process through the proposed SQS; (h) key preferable alternative tools of social engagement through which citizens wish to participate in OWP placement; (i) stakeholder groups with a leadership role in the decision-making process of OWP development; and (j) the importance of the OWP planning process in advancing the installation of eligible and socially acceptable projects for the local society. To fully describe the proposed original SQS, it must be noted that: (a) the degree of social acceptance is estimated based on primary data collected from citizens, specifically in accordance with their approval of RES exploitation and OWP installation within the study area (for example, if 1000 citizens participated in the survey and 950 of them strongly agreed, fairly agreed, or agreed with the OWP installation, the social acceptance degree is calculated as 95 %); (b) the EC (Fig. 2; SQS Section 4A), which consulted with the local society for the identification of socially acceptable OWP sites, are fully presented in Fig. 2 and in the Results Section, as they constitute key findings of the preparatory method; and (c) citizens were given the option to include as many EC in the survey as they wished, thereby ensuring that the comprehensive opinion of the local society was captured. This original SQS is also illustrated in Fig. 2, while the complete research survey instrument is provided in the Supplementary Materials. The EC proposed by the citizens are further explained in Section 3.2.2 and Table 6. The survey was conducted over a period of 163 days. The SQS results (citizen responses) represent the final outcome of the first phase of the proposed participatory planning method and serve as input for the subsequent phase.

2.2.2. Phase 2: analysis of citizen perspectives on the challenges of OWP planning

In Phase 2, nine qualitative and quantitative analyses of citizens' responses were conducted (A.1–9; Table 2), to specify their perspectives on the previously cited OWP planning challenges. The primary data analyses performed are thoroughly explained in Table 2. SPSS software was employed to conduct all primary data analyses, with the aim of deriving the most accurate results from the citizens' responses. In addition, CCAs were performed in SPSS, as comprehensively described in Fig. 3, to identify the parameters influencing the participants' planning decisions.

Table 3
PEC included in Phase 3 of OWPs' planning process.

No.	Exclusion Criterion	GIS Data Sources	Description	Unsuitable Areas	Integration Phase
PEC.1	National Territorial Waters	–	Any marine area located more than 12 nautical miles from the Greek Ionian Sea coastline and more than 6 nautical miles from the Greek Aegean and Cretan Sea coastlines is excluded.	Outside	Phase 3
PEC.2	Distance from Aviation Areas (Civil/ Military)	[46,47]	To prevent radar interferences and harmful effects on the performance of air traffic controls caused by nearby OWP installations [48], specific exclusion zones are established.	≤ 3000 m	Phase 3
PEC.3	Project Minimum Required Area	–	A minimum required area was defined to exclude sites that are too small for OWP installation [49]. This PEC was applied at the end of Phases 3 and 4.	< 2 km^2	Phases 3 and 4

Table 4
Geoprocessing tools [51] properly modified for integration into the proposed OWP site suitability model.

Geoprocessing Tool	Description
Buffer	Creates buffer polygons around input features at a specified distance.
Merge	Combines multiple input datasets into a single new output dataset.
Intersect	Computes the geometric intersection of the input features.
Erase	Creates a feature class by overlaying the input features with the erase features; only those portions of the input features outside the erase features are written to the output feature class.
Select	Extracts features from an input feature layer, typically using a Structured Query Language (SQL) expression, and stores them in an output feature class.

Table 5
TEEC included in Phase 4 of OWPs' planning process.

No.	Exclusion Criterion	GIS Data Source (s)	Description	Unsuitable Areas
TEEC.1	Wind Velocity (at a height of 50 m)	[52]	The higher the wind velocity in a potential installation area, the greater the economic viability of the potential OWP [53].	< 6 m/s
TEEC.2	Wind Power Density (at a height of 50 m)	[52]	Wind power density contributes to estimating the wind power potential that could be theoretically produced from OWP installations in eligible areas [53].	< 500 W/ m^2
TEEC.3	Water Depth	[54]	An upper limit of 300 m and a lower limit of 5 m were established, based on design engineering constraints and the techno-economic feasibility of offshore wind turbine support structures [55,56].	< 5 m and >300 m
TEEC.4	Distance from Domestic Ports	[57,58]	The total investment cost (e.g., installation and maintenance costs) of an OWP increases with its distance from a domestic port [59].	> 30,000 m
TEEC.5	Distance from Electricity Substations for RES Connection	[60]	OWPs should be installed as close as possible to national electricity substations for RES connection, in order to avoid unprofitable installation, operation, and maintenance costs [26,59].	> 50,000 m
TEEC.6	Distance from Underwater Cables and Pipelines	[57,61]	To prevent any damage to underwater cables and pipelines (for electricity transmission, telecommunication, or other purposes) during the installation of OWPs, appropriate exclusion zones are established.	≤ 750 m

The qualitative data of the research survey (Table 2) consist primarily of categorical variables (21 out of 29 questions), with a smaller subset combining categorical and open-ended textual responses. The open-ended textual data were transformed into categorical form through thematic analysis, whereby participants' responses were grouped according to recurring themes. These qualitative data, provided in the Supplementary Materials, were analyzed in SPSS by converting textual information into numerical codes (i.e., coding the data), without necessitating the development of a coding manual. At this methodological phase, the importance of the preparatory method (Fig. 1), developed prior to the survey, is underscored. Specifically, this preparatory method facilitated the analysis of citizen responses by clearly defining what data to collect, how to gather it, and how to analyze it.

Descriptive statistical analysis of categorical data was conducted in SPSS for both qualitative and quantitative research, thereby supporting the interpretation of the data outlined in this study (A.1–9, Table 2). This primary analysis involved describing the characteristics of the data using frequencies and percentages, and, where appropriate, estimating measures of central tendency such as the mean, mode, and, median values, particularly for ordinal data. Thematic analysis was also employed to interpret the data in analyses A.2–5 and A.7–8, by identifying, examining, and interpreting recurring patterns (themes). To ensure analytical rigor, thematic analysis followed a structured process: (a) familiarization with the data; (b) coding; (c) theme generation; (d) reviewing and defining themes; and (e) interpreting the themes. Table 2 outlines the qualitative and quantitative analytical techniques applied to ensure a comprehensive and robust examination of the survey data.

For analyses A.2 and A.3, categorical-level responses (i.e., strongly agree, fairly agree, agree, slightly agree (mirror of disagree to fairly disagree), strongly disagree, and uncertain) were combined into an

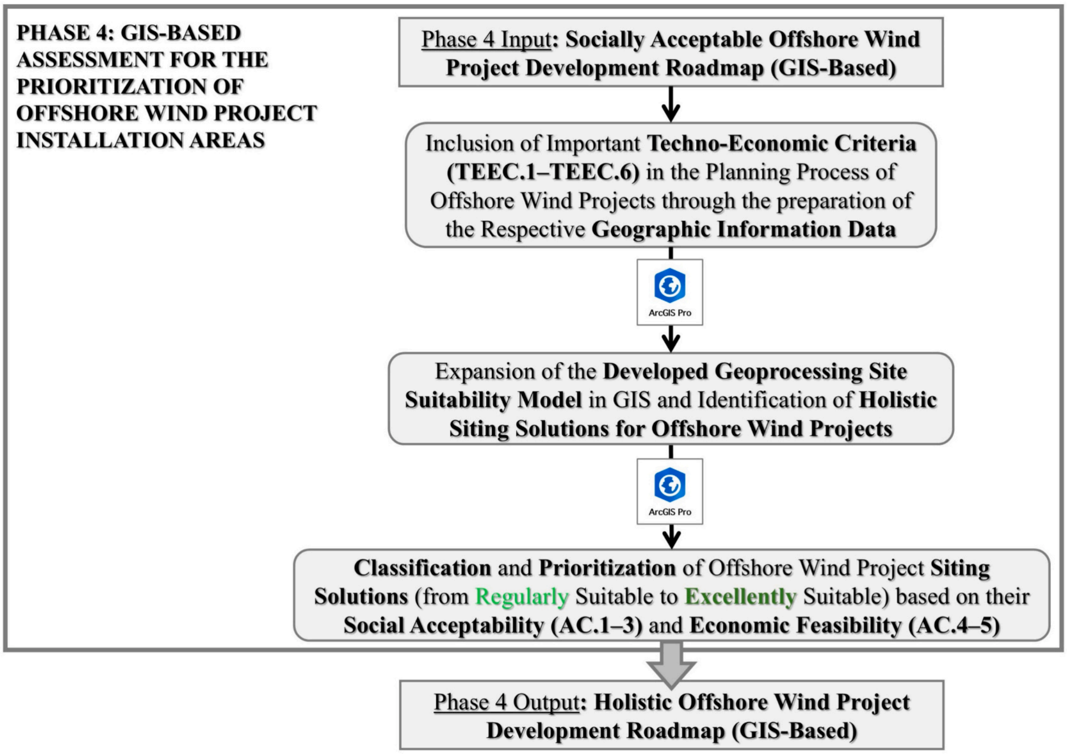

Fig. 6. Phase 4 of the proposed participatory planning method.

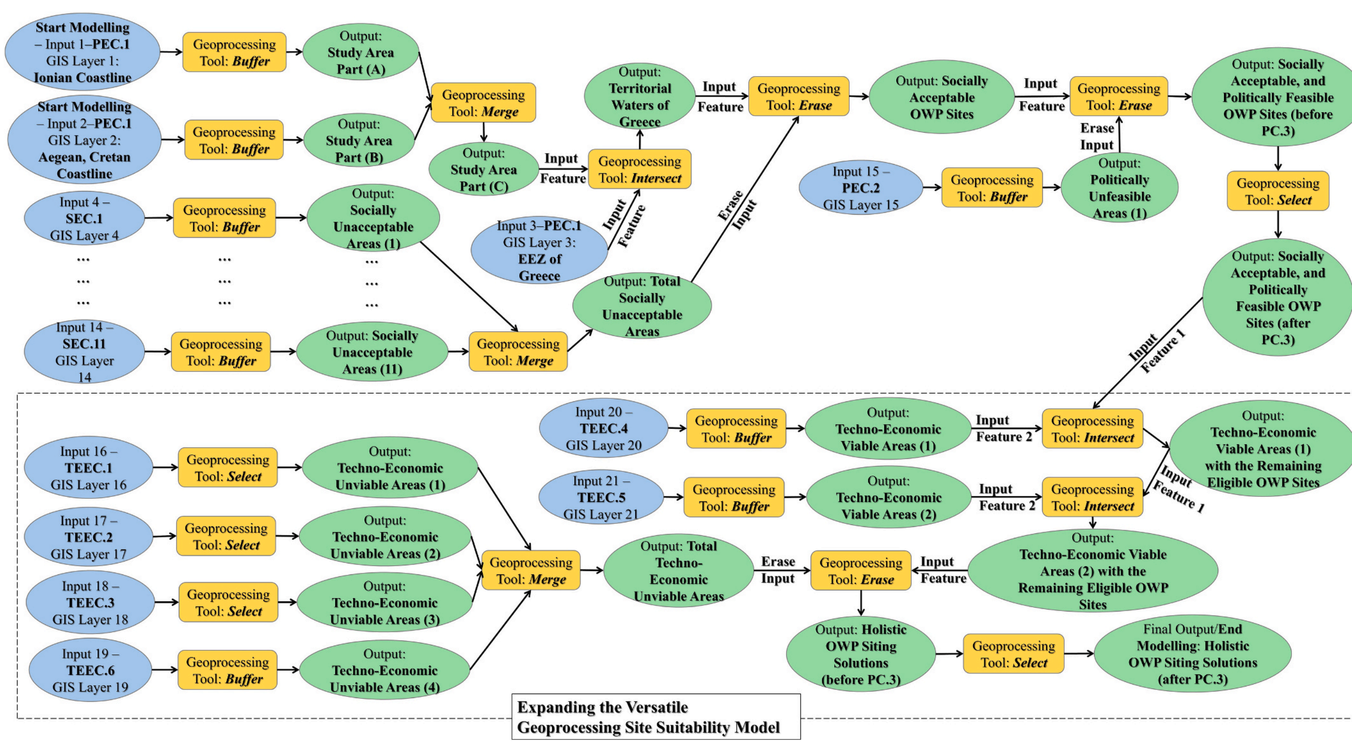

Fig. 7. The geoprocessing site suitability model developed in GIS.

index, as specified in the survey design (Section 2.2.1), to calculate the degree of social acceptance for RES exploitation and OWP development.

The CCAs undertaken during this phase of the study are considered complex, as the responses were examined in SPSS based on particular cases, through the definition of specific variables and logical conditions. By way of example, for the execution of CCA.2 (Fig. 4), the variable "place of residence" was selected (i.e., a variable related to the citizens' demographic information). The condition was set to "mainland", and the factors chosen for correlation analysis with the selected variable were "unsuitable siting areas" and "incompatibility zones" (i.e., factors related to the social acceptability of OWP installation areas). This analysis was then repeatedly performed in SPSS for all possible

Table 6
AC used for the prioritization of eligible marine areas for OWP installation.

No.	Assessment Criterion	Criterion Type	Function Type
AC.1	Distance from Urban and Residential Areas	Societal	Maximization (Benefit)
AC.2	Distance from Touristic Zones	Societal	Maximization (Benefit)
AC.3	Distance from Archaeological, Historical, and Cultural Heritage Areas	Societal	Maximization (Benefit)
AC.4	Wind Velocity (at a height of 50 m)	Economic	Maximization (Benefit)
AC.5	Wind Power Density (at a height of 50 m)	Economic	Maximization (Benefit)

Table 7
Main outcomes of the preparatory method used to develop the participatory planning method.

No.	Thematic Module	Research Outcomes
TM.1	Exclusion Criteria and Associated Limits	a) A set of unsuitable siting areas and incompatibility zones that must be consulted with citizens in order to identify socially acceptable OWP installation areas (Table 8); b) The lack of versatile and structured tools for citizen participation in the early stages of OWP planning; c) The need to design quantitative and qualitative analyses for the investigation of citizens' opinions, together with related complex correlation analyses, through the use of established social science software.
TM.2	Site Selection: Methodological Approaches and Stages	The high-importance of GIS-based methods for OWP planning, especially at the Exclusion Stage, and the need to create versatile GIS-based models to precisely determine the suitability of marine areas for OWP installation.
TM.3	Spatial Planning Scales	National and regional planning scales emerge as the most suitable spatial planning scales for maximizing the societal and political impact of the produced results.
TM.4	Participatory Planning: Approaches, Groups, and Contributions	a) Studies that incorporate citizens' perspectives in the early stages of the OWP planning process are still missing, and there is a lack of essential information regarding citizens' concerns on numerous challenging issues of OWP planning; b) A structured QS should be systematically designed (research gap), taking into account the outcomes of TM.1.
TM.5	Assessment Criteria, Weights, and Priorities	Current participatory site selection studies investigate citizens' perspectives on AC and employ methods to incorporate them into the assessment stages (AC weighting and prioritization) of the OWP planning process.

Table 8
EC of societal importance that result from the proposed preparatory method.

Exclusion Criterion	Exclusion Range
Distance from the Coastline for Landscape Protection and the Avoidance of Visual and Acoustic Disturbances	from 1000 to 8000 m
Distance from Touristic Zones	from 500 to 2000 m
Distance from Protected Areas	from 0 to 3000 m
Distance from Bird Habitats and Migratory Bird Routes	from 0 to 3000 m
Distance from Aquaculture Zones	from 0 to 1000 m
Distance from Verified Shipping Routes	from 0 to 5000 m

Table 9
Demographic information of participants.

Category	Demographic Information	Participation Rate
Age Group	Young Adulthood (aged 18–24 years)	43 %
	Middle Adulthood (aged 25–44 years)	30.5 %
	Older Adulthood to Retirement Age (aged 45–64 years)	25.1 %
	Retirement Age (aged over 64 years)	1.4 %
Education Level[a]	High-School Diploma or Equivalent Trade-School Degree	35.3 %
	Bachelor Degree	26.7 %
	Master Degree	26.1 %
	Ph.D. Degree	9.8 %

[a] The remaining participants (2.1 %) hold a lower education degree (1.1 %) or a professional specialization degree (1 %).

conditions of the selected variable (in this case, the two conditions "mainland" and "island region"), until conclusive data were obtained. In these CCAs, citizen perspectives concerning the spatial determination of socially acceptable offshore wind installation sites (results derived from A.5; Table 2) were further examined based on the following variables: (CCA.1) the participants' acceptance degree for OWP placement, (CCA.2) the participants' place of residence (mainland or island region), (CCA.3) the participants' education level, and (CCA.4) the participants' age group. In addition, a CCA was conducted to investigate the relationship between the degree of social acceptance for RES exploitation and the degree of social acceptance for OWP placement, across spatial planning scales (CCA.5).

The proposed CCAs have never been performed before and are presented for the first time in this paper, with the aim of providing breakthrough insights into the factors that strongly influence citizens' decisions regarding the placement of OWPs. Specifically, neither correlation assessments nor suitable analytical techniques, as outlined in the relevant OWP siting studies [12,14], have been employed to achieve greater analytical depth in understanding citizens' perspectives. Previous social-related studies on the wind energy transition have demonstrated that, although wind turbine distance correlates with changes in other variables, its direct influence remains unclear [45], while the socioeconomic impacts of wind development are intrinsically linked to acceptance [33,45]. Boyle et al. [35] further indicated that individuals who support wind energy also tend to support wind farm development, particularly when focused on community onshore wind farms. Consequently, the literature lacks analyses that precisely elucidate how the degree of social acceptance varies across different offshore wind project sites and spatial planning scales, identify the principal factors shaping public siting decisions, and provide the level of in-depth examination advanced in this study. Hence, the critical role and usefulness of the complex analytical framework (Figs. 3 and 4) developed herein are demonstrated.

At the end of Phase 2, citizen perspectives on OWP placement are derived from the final synthesis of the survey results, while the factors influencing participants' planning decisions are specified through the implementation of the CCAs.

2.2.3. Phase 3: GIS-based modelling for identifying socially acceptable offshore wind installation areas

In the third phase of the participatory method, the unsuitable siting areas (EC) and their incompatibility zones (respective exclusion limits), as selected and proposed by the citizens, are implemented in GIS to delineate socially acceptable marine areas for OWP installation (Fig. 5).

The eligible EC of societal importance are described in Section 3.2.2, as they result from the citizens' participation process (with results derived from the SQS). Significant political exclusion criteria (PEC) are also incorporated into the site suitability analysis (as explained in Table 3) in order to identify politically feasible sites in GIS.

The respective provisions and policies of the Greek Specific

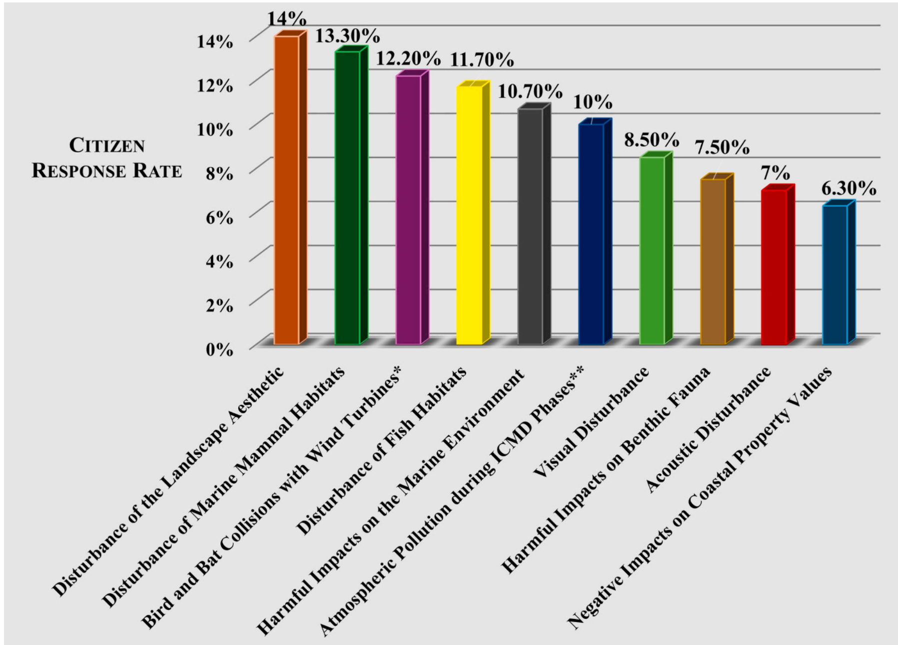

Fig. 8. Key reasons behind citizen disagreement with OWP installation in Greece. Note*: Citizen opposition reflects not only bird and bat collisions with turbines but also the disturbance of their habitats. Note**: ICMD Phases; Installation, Construction, Maintenance, and Decommissioning Phases.

Table 10
SEC, derived from citizens' participation in the early stages of OWP planning and from the methods used for the production of results.

No.	Method	Exclusion Criterion	Description	Exclusion Limit	GIS Sources
SEC.1	Preparatory, Participatory	Distance from the Coastline for Landscape Protection and the Avoidance of Visual and Acoustic Disturbances	To minimize the visual and acoustic impact of OWPs and to protect the landscape	≤ 5000 m	[46,62]
SEC.2	Participatory	Distance from Urban and Residential Areas	To preserve the standard of living of citizens and to avoid visual and acoustic disturbances	≤ 5000 m	[46,62]
SEC.3	Preparatory, Participatory	Distance from Protected Areas	To preserve the environmental, ecological, and biological importance of protected areas	≤ 1500 m	[63]
SEC.4	Preparatory, Participatory	Distance from Bird Habitats and Migratory Bird Routes (incl. Ramsar Wetlands)	To prevent bird collisions with offshore wind turbines and to avoid harmful impacts on their habitats	≤ 1500 m	[63,64]
SEC.5	Participatory	Distance from Archaeological, Historical, and Cultural Heritage Sites	To preserve the socio-cultural importance of historical and cultural heritage areas (e.g., submerged prehistoric settlements)	≤ 3000 m	[47,65]
SEC.6	Preparatory, Participatory	Distance from Verified Shipping Routes[a]	To protect the shipping routes connecting the Greek islands with the mainland and neighboring countries for the purposes of trade and tourism	≤ 2000 m	[66]
SEC.7	Participatory	Distance from Areas of Landscape Value	To preserve protected landscapes of significant value	≤ 5000 m	[57,63]
SEC.8	Preparatory, Participatory	Distance from Touristic Zones	To preserve the economic and societal importance of areas of touristic interest (e.g., beaches).	≤ 5000 m	[46,47]
SEC.9	Preparatory, Participatory	Distance from Aquaculture Zones	To preserve the environmental and economic importance of aquaculture zones and to aid the social acceptance of OWPs	≤ 1500 m	[57]
SEC.10	Participatory	Distance from Coastal Bathing Water Areas	To preserve the coastal bathing water areas of exceptional importance, according to the Monitoring Programme of Bathing Water Quality [67]	≤ 5000 m	[57]
SEC.11	Participatory	Distance from Military Zones	To protect national interests and ensure the regular operation of OWPs—since these zones are mainly offshore and are used as training or firing fields, among other purposes—specific regulatory measures must be implemented	≤ 2000 m	[47,57]

[a] Note: To facilitate OWP deployment, 53.5 % of citizens suggested the restructuring of current shipping routes. This insight can be utilized in a future study to examine the proposed possibility by organizing public meetings with the local society and consulting key stakeholders.

Framework for the Spatial Planning and Sustainable Development of RES (SFSPSD-RES) are considered at this phase [50], particularly in configuring the specifications of the eligible EC (i.e., the definition of the eligible EC and the applicable exclusion limits), in order to pinpoint legally suitable sites for OWPs in Greece. This spatial planning regulation defines the incompatibility zones for wind project installations. These incompatibility zones are areas where wind project development is restricted or prohibited due to environmental, social, and technical constraints. Subsequently, a versatile geoprocessing site suitability model is formulated in GIS (Fig. 7) by producing multiple thematic data layers according to the eligible EC. Each input of the developed model corresponds to a GIS data layer that represents the spatial information of each selected EC. The definition of PEC, TEEC (techno-economic EC), and SEC (societal EC) used in the model, together with their importance in the OWP planning process, are provided in Tables 3, 5 and 10, respectively. The geoprocessing tools utilized and appropriately modified for the site suitability model are explained in Table 4. Overall, the developed placement model begins by spatially defining the boundaries

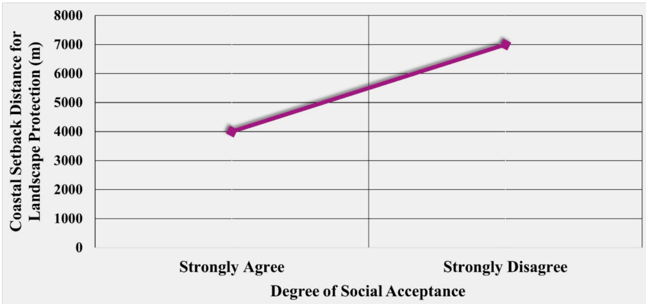

Fig. 9. Safety distances from the coastline according to citizens' acceptance degree for OWP siting.

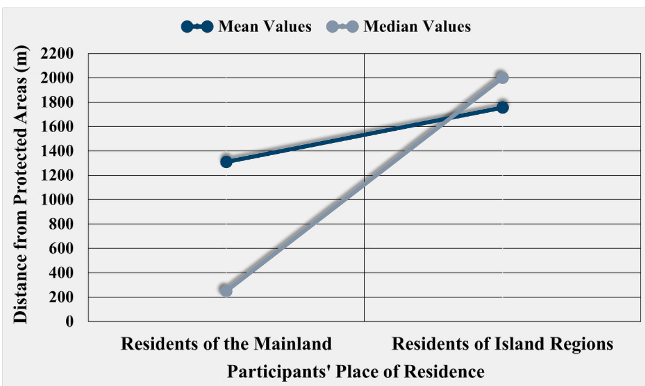

Fig. 10. Safety distances from the protected areas according to participants' place of residence.

of the study area (PEC.1: Inputs 1–3). It then proceeds by identifying, merging, and excluding socially unsuitable siting areas (SEC.1–11: Inputs 4–14) from the investigation area (Fig. 7). After locating the socially acceptable installation areas, the model further defines and excludes the remaining politically unfeasible siting areas (Fig. 7; PEC.2: Input 15 and PEC.3). At the end of Phase 3, the geoprocessing model outputs the precise location of the socially acceptable and politically feasible marine areas for OWP installation, together with the necessary spatial information related to their examined characteristics (available surface area, SEC.1–11, PEC.1–3). This final output constitutes a GIS-based, socially acceptable roadmap for OWP development in Greece.

2.2.4. Phase 4: GIS-based assessment for the prioritization of OWP installation areas

In the final phase, six TEEC are defined and incorporated into the site suitability analysis (Table 5) to exclude unprofitable and technically unfeasible areas for OWP placement, through the production of additional thematic data layers corresponding to TEEC.1–TEEC.6 (Fig. 6). Accordingly, the geoprocessing planning model was expanded, as illustrated in Fig. 7.

At this phase, the model proceeds by identifying, merging, and eliminating techno-economic unviable installation areas (TEEC.1–3 and TEEC.6: Inputs 16–19), while the techno-economic feasible areas are delineated and intersected (TEEC.4–5: Inputs 20–21) with the remaining eligible OWP sites (Fig. 7). The final output of the geoprocessing model is a set of holistic OWP planning solutions. The PEC and TEEC were defined by the coordinator of the OWP planning process, drawing on years of research experience and the review of relevant studies. In contrast, the SEC were defined through citizen participation, as the public typically lacks expertise in the techno-economic or political dimensions of OWPs, yet these criteria directly affect them.

The final eligible sites were assessed and classified according to their social and/or economic features. The AC employed for the effective classification and prioritization of the marine areas are presented in Table 6. The selected AC serve as maximization criteria, whereby higher values of the eligible sites in the AC indicate greater suitability (i.e., benefit criteria).

The AC of societal importance were selected by considering the general feedback obtained through citizen participation in OWP planning. The best installation areas are ultimately determined according to their high social acceptability and economic feasibility, thereby forming a holistic OWP planning roadmap.

3. Results and discussion

3.1. Findings and insights derived from the preparatory method

The main outcomes of the proposed preparatory method, and the means by which these outcomes were used as research objectives to develop the participatory planning method, are described in Table 7.

The specified EC (Table 8) are thoroughly described in Table 10, after verifying their societal importance for OWP planning through input from the local society, by means of the developed SQS.

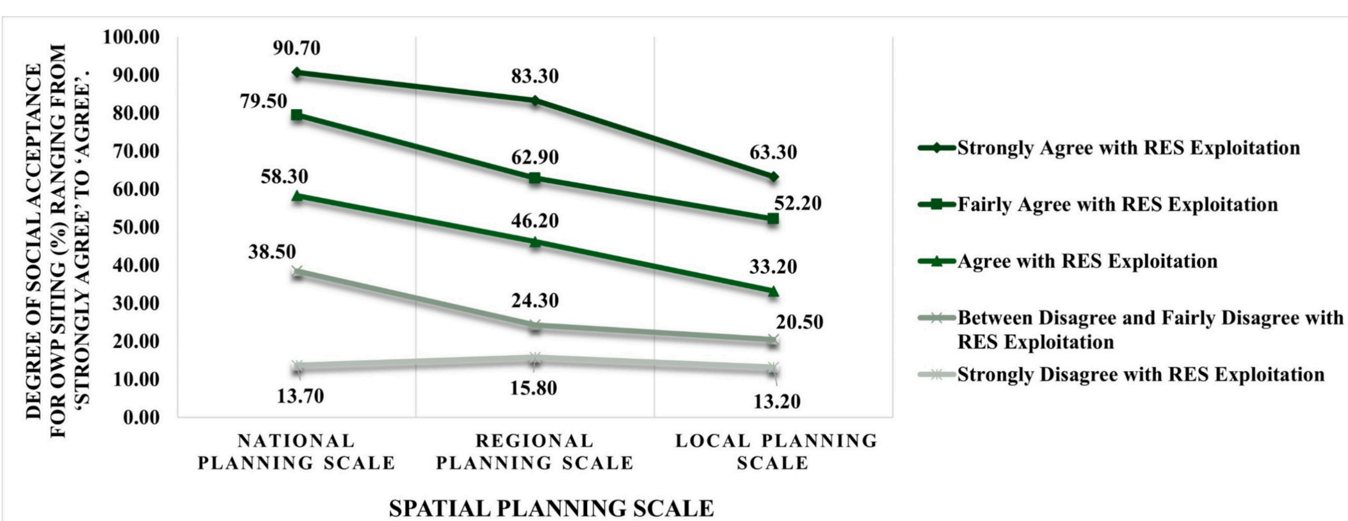

Fig. 11. Citizens' acceptance degree for RES exploitation in relation to their acceptance degree for OWP deployment across spatial planning scales.

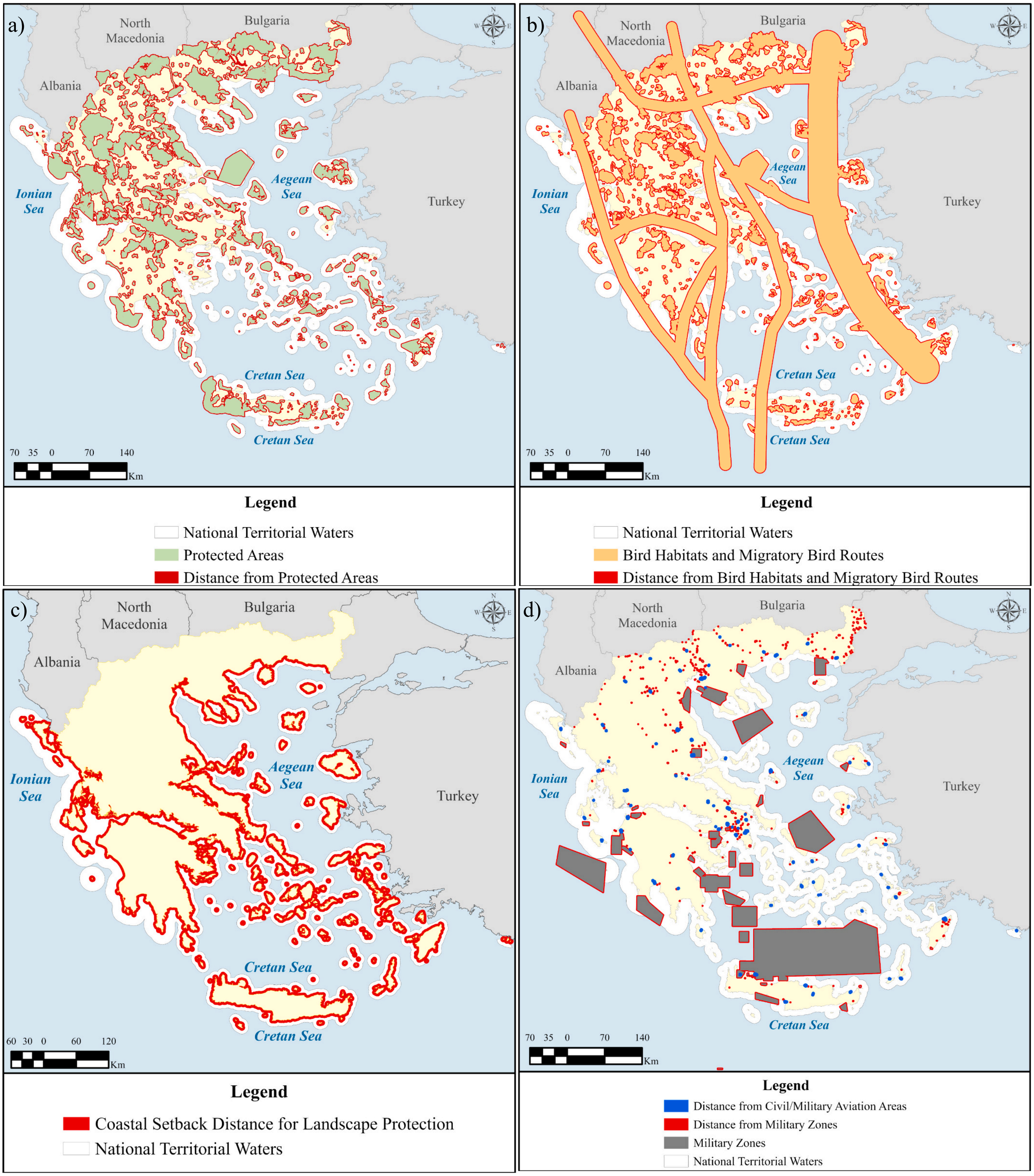

Fig. 12. Thematic maps of (a) SEC.3, (b) SEC.4, (c) SEC.1, (d) SEC.11, and PEC.2.

3.2. *Findings and insights derived from the participatory planning method*

3.2.1. *Citizen responses*

A total of 1802 citizens participated in the OWP planning process and fully completed the SQS. As a result, this constitutes the largest research study on citizen participation in the OWP planning process at both the national level (in Greece) and the global scale.

Participation is gender-balanced, with 47.7 % of the participants being male and 52.3 % female. The participants represent various locations across all 13 Regions of Greece. Essential demographic information is presented in Table 9. Despite equal participation opportunities, the online mode may have attracted younger (18–44-year-olds), digitally active individuals whose strong engagement with OWPs renders their proportional representation consistent with the

Fig. 13. Socially acceptable OWP development roadmap for Greece.

survey's research focus.

3.2.2. Citizens' perspectives on the challenges of OWP planning and the factors influencing public site selection choices

The social acceptance degree for RES exploitation is 92.7 % in Greece, 89.9 % in the region of participants' residence, and 86.7 % in the municipality of participants' residence, while for OWP development it is 80.6 %, 72.87 %, and 66.6 %, respectively. Therefore, a reduction in citizens' acceptance degree is observed as the proximity of potential RES projects and OWPs to their place of residence increases.

The six most popular reasons for citizen disagreement with OWP installation in Greece are (Fig. 8): (a) disturbance of landscape aesthetics (14 %); (b) disturbance of marine mammal habitats (13.3 %); (c) bird and bat collisions with offshore wind turbines and disturbance of their habitats (12.2 %); (d) disturbance of fish habitats (11.7 %); (e) harmful impacts on the marine environment (e.g., water contamination by chemical pollutants) (10.7 %); and (f) atmospheric pollution during the installation, construction, maintenance, and decommissioning phases (10 %). Accordingly, the social acceptability of OWPs is directly linked to their environmental sustainability, as the grounds of disagreement have strong environmental significance. The aesthetic value of the OWP installation site is also of high importance to citizens, while several of the most significant grounds of disagreement additionally carry cultural, economic, and/or social importance (Fig. 8).

From the qualitative and quantitative analyses of primary data, the following SEC, together with the respective exclusion limits, are revealed and must be applied to determine socially acceptable offshore wind installation areas (Table 10). As a result, the societal importance of the EC, as indicated by the findings of the preparatory method, was verified by the participants, while the added value of both methods (preparatory and participatory) is highlighted below.

The proposed eleven SEC (Table 10), derived from citizens' participation in the early stages of the OWP planning process, together with their exclusion limits, should be regarded as valuable inputs for future OWP planning studies, contributing to the effective identification of socially acceptable installation sites in any investigation area.

According to the present survey results, the key alternative practices of social engagement in which citizens would like to participate for the sustainable development of OWPs are as follows: (a) public consultations (3.83 %); (b) public workshops to comprehensively inform citizens about OWPs (3.39 %); (c) the use of participants' professional qualifications (e.g., legal advisors contributing to the development of integrated planning regulations (2.16 %)); and (d) referendums/plebiscites (1.05 %). On the other hand, the majority of participants (54.9 %) declared uncertainty regarding their preferred method of social engagement, while a notable portion of 28.9 % expressed willingness to participate through the proposed SQS or a similar survey. This finding demonstrates that citizens are largely unfamiliar with OWPs and unaware of how they could contribute to their development. This insight can be explained by the fact that OWPs have not yet been developed in Greece. Furthermore, participatory processes are not a standard feature of spatial planning in Greece, since the national legislative framework (Law 4759/2020) [39] lacks institutional mechanisms for citizen participation in spatial planning. Consequently, local society is typically inexperienced in these methods.

Citizens evaluated their participation positively through the proposed SQS. Specifically, they assessed their degree of involvement in the OWP planning process with a score of 6 (on a scale of 1–10), while the mode values were 10, 8, and 5. Furthermore, participants acknowledged the high importance of the OWP planning process in ensuring eligible and socially acceptable projects, assigning it the maximum score of 10.

According to the survey results, the stakeholder groups that should assume a leadership role in the decision-making process of OWP planning are, in order of preference: (a) experts in spatial planning and site selection of OWPs (79.6 %), (b) citizens/society (60.8 %), (c) certified engineers and RES development companies with experience in OWP installation (59.5 %), (d) policymakers (25.6 %), (e) non-governmental organizations (18 %), (f) tourism industry professionals (17.7 %), and (g) investors (8 %).

According to the CCA results, the citizens' acceptance degree and their place of residence (mainland or island region) strongly influence their decisions on OWP planning, both quantitatively and qualitatively (Figs. 9 and 10). Specifically, citizens who strongly disagree with OWP development, and residents of island regions, are substantially more demanding regarding the areas that should be considered unsuitable for placement (excluding additional areas) and the safety distances that must be applied (selecting higher exclusion limits). Therefore, a negative relationship between citizens' acceptance degree and the extent of designated incompatibility zones is identified.

On the contrary, the education level and age group of the participants slightly affect their decisions regarding OWP planning, although certain patterns can be observed. In some cases, citizens with university education are more demanding with respect to the safety distances that must be applied from unsuitable siting areas, defining higher exclusion limits, whereas, younger participants tend to be less conservative, selecting shorter safety distances. Nevertheless, no connection is identified between the education level or age group of the participants and either the type or the number of EC chosen for OWP placement, indicating a neutral relationship between the examined variables. Importantly, CCA results showed that only citizens' acceptance level and residence influenced OWP placement responses, further minimizing concerns about non-response bias and supporting the validity of the study's inferences.

From the final CCA, it is revealed that some citizens strongly disagree with RES exploitation in their place of residence, yet they agree with OWP placement (i.e., in certain cases, a negative relationship between the variables is observed), and vice versa (Fig. 11). Additionally, as the degree of citizens' acceptance of RES exploitation decreases, so too does their acceptance of potential OWP development (i.e., in general, a positive relationship between the specified variables is identified). Lastly, the issue of NIMBY opposition emerges: the smaller the spatial planning scale to which potential OWP installation (or RES exploitation) refers,

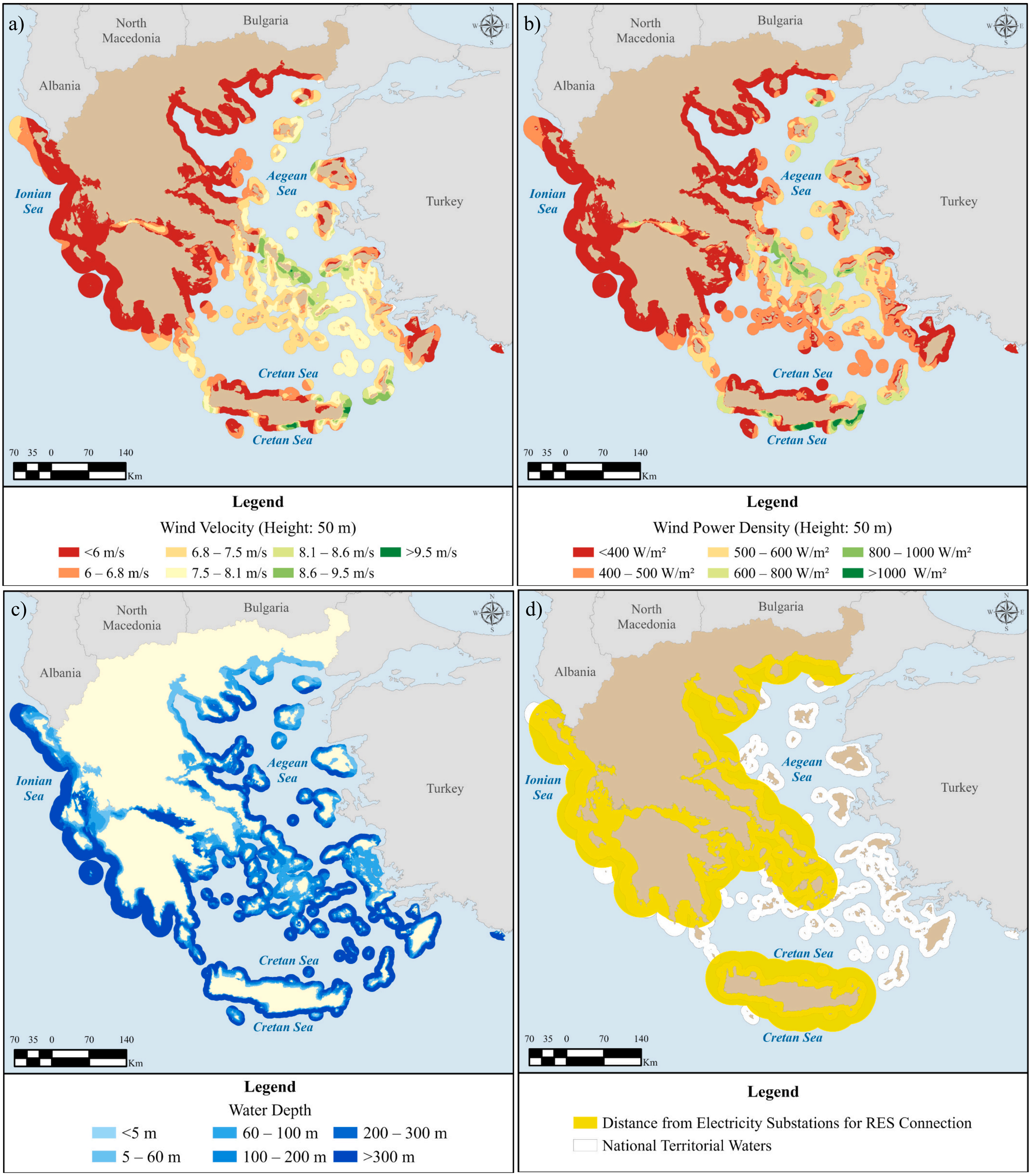

Fig. 14. Thematic maps of (a) TEEC.1, (b) TEEC.2, (c) TEEC.3, and (d) TEEC.5.

the lower the degree of citizens' acceptance (a positive relationship between the selected variables is demonstrated).

3.2.3. *A socially acceptable development roadmap for OWPs*

Numerous thematic data layers were created to illustrate the spatial information of essential EC of societal, political, and legal importance (Fig. 12), such as "distance from civil/military aviation areas". The national territorial waters of Greece (PEC.1) are also illustrated in each thematic map.

A total of two-hundred sixteen (216) socially acceptable, politically and legally feasible, sites with a combined surface area of 25,637.702 km^2 were determined as eligible for OWP installation in Greece (Fig. 13). The proposed marine areas were identified by synthesizing the thematic data layers related to PEC.1–PEC.3, and SEC.1–SEC.11

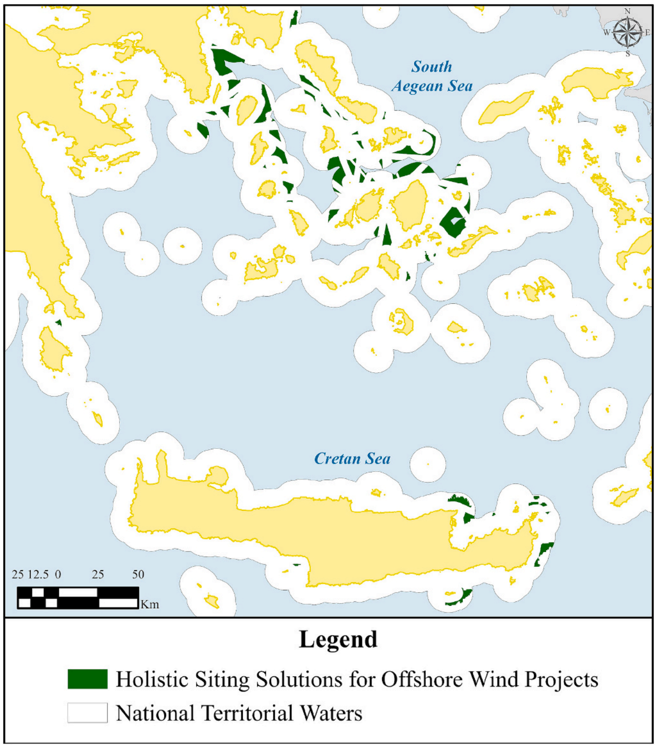

Fig. 15. Holistic offshore wind project installation areas in Greece.

(Tables 3 and 10), together with an investigation of local citizen perspectives on OWP planning. The majority of the socially acceptable sites are situated in the Aegean Sea (175 sites, 55.02 % of the total surface area), 24 sites are located in the Ionian Sea (34.28 % of the total surface area), while the remaining 17 sites are identified in the Cretan Sea (10.7 % of the total surface area) (Fig. 13).

As previously highlighted, current studies [12,14] have focused on integrating citizens' perspectives into the assessment stages of OWP placement by assigning weights to the AC. In this study, however, citizens' requirements were efficiently incorporated for the first time in the early stages of the OWP planning process (Section 3.2.2) by defining unsuitable siting areas (EC), and their incompatibility zones (exclusion buffer limits). As a result of this original participatory process, socially acceptable offshore wind development areas are determined for the first time (Fig. 13). Moreover, these areas could also be identified in any other investigation area by applying the proposed method and utilizing the findings presented in this work (Section 3.2). The opinion of the local society was further investigated on several unexplored OWP planning issues (Sections 2.2.2 and 3.2.2). Importantly, public opinion can be considered a key factor in enhancing the social acceptability of future OWPs worldwide, improving citizens' participation in the OWP planning process, addressing societal requirements for OWP placement, and supporting high-quality decision-making processes for OWP development.

3.2.4. *Holistic OWP development roadmap*

Additional thematic data layers were created in the final phase to illustrate the spatial impact of essential techno-economic criteria, represented both in suitability classes (Fig. 14a–c) and as distance measurement criteria (Fig. 14d; TEEC.5). A total of fifty-nine (59) socially acceptable, politically and legally feasible, and techno-economically viable sites, with a combined surface area of 1490.225 km^2 were determined as eligible for OWP installation in Greece. The proposed marine areas were identified by synthesizing the thematic data layers related to PEC.1–PEC.3, SEC.1–SEC.11, and TEEC.1–TEEC.6 (Tables 3, 5 and 10), together with an investigation of local citizen perspectives on OWP planning. The majority of these sites are situated in the South Aegean Sea (48 sites, 86.47 % of the total surface area), while 11 eligible sites are located in the Cretan Sea. No eligible sites were identified in the Ionian or North Aegean Seas (Fig. 15). This outcome is explained by the low wind power potential in the Ionian Sea and the absence of electricity substations for OWP connection in the North Aegean Sea (Fig. 14a, b, d).

The final eligible sites were prioritized and classified according to their economic and sociocultural characteristics. Specifically, marine areas with wind velocity greater than 8.1 m/s and/or wind power density exceeding 500 W/m^2 (at a height of 50 m) are characterized as having excellent to superb wind resource potential, according to the National Renewable Energy Laboratory [53] and, thus demonstrate excellent economic feasibility for OWP installation. As a result, 27 eligible sites are identified as having excellent economic feasibility and

Table 11
Marine areas of excellent economic feasibility for OWP installation.

Priority Position	Project ID.	Total Surface Area	Wind Velocity	Wind Power Density	Excellent Social Acceptability
1	OWP.13	37,118,453.51 m^2	9.575 m/s	1030 W/m^2	NO
2	OWP.55	2,486,968.4 m^2	8.766 m/s	928 W/m^2	NO
3	OWP.50	3,104,052.42 m^2	8.702 m/s	891 W/m^2	NO
4	OWP.28	11,720,515.1 m^2	8.314 m/s	904 W/m^2	NO
5	OWP.49	3,246,221.6 m^2	9.070 m/s	763 W/m^2	NO
6	OWP.41	5,285,074.8 m^2	8.447 m/s	808 W/m^2	NO
7	OWP.5	79,316,009.52 m^2	8.728 m/s	707 W/m^2	NO
8	OWP.57	2,125,910.7 m^2	8.716 m/s	702 W/m^2	YES
9	OWP.17	28,421,281.1 m^2	7.854 m/s	766 W/m^2	NO
10	OWP.52	2,858,208 m^2	8.500 m/s	670 W/m^2	YES
11	OWP.11	43,068,126.2 m^2	7.394 m/s	821 W/m^2	NO
12	OWP.40	6,084,022 m^2	8.358 m/s	656 W/m^2	YES
13	OWP.1	176,890,486.3 m^2	8.471 m/s	636 W/m^2	NO
14	OWP.36	7,236,013.44 m^2	8.244 m/s	665 W/m^2	NO
15	OWP.37	7,058,805.8 m^2	8.499 m/s	624 W/m^2	YES
16	OWP.9	44,070,443.8 m^2	8.323 m/s	626 W/m^2	NO
17	OWP.32	9,020,907.2 m^2	8.106 m/s	648 W/m^2	YES
18	OWP.24	20,921,144.2 m^2	8.366 m/s	605 W/m^2	NO
19	OWP.22	21,958,967.9 m^2	8.250 m/s	622 W/m^2	NO
20	OWP.6	70,399,335 m^2	8.148 m/s	627 W/m^2	YES
21	OWP.18	26,813,499.3 m^2	8.279 m/s	593 W/m^2	YES
22	OWP.59	2,001,662 m^2	7.900 m/s	647 W/m^2	YES
23	OWP.7	46,884,899 m^2	8.248 m/s	592 W/m^2	NO
24	OWP.43	4,928,056.1 m^2	8.177 m/s	599 W/m^2	NO
25	OWP.38	6,694,817.8 m^2	8.300 m/s	575 W/m^2	YES
26	OWP.30	10,724,692.7 m^2	8.100 m/s	590 W/m^2	YES
27	OWP.19	26,181,414.2 m^2	7.859 m/s	619 W/m^2	NO

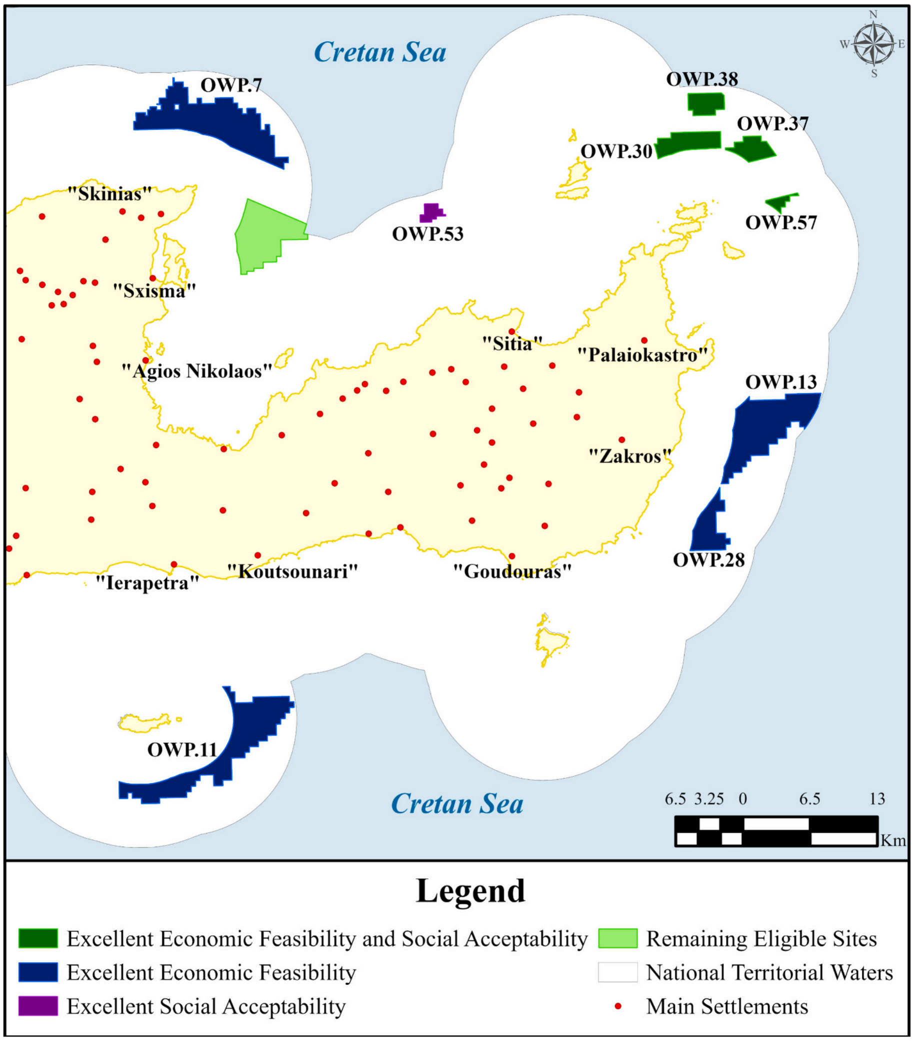

Fig. 16. Holistic offshore wind project development roadmap for the Cretan Sea.

are presented in priority order in Table 11, based on their overall performance across the examined economic criteria. Of these, seven sites (Fig. 16) are pinpointed in the East (OWP.13, OWP.28) and North-East (OWP.7, OWP.30, OWP.37, OWP.38, OWP.57) of Crete, while one site is located in the South-East of Crete (OWP.11). The main settlements of Crete Island relevant to OWP development are also presented in Fig. 16. Furthermore, twelve sites are situated in the northern part of the South Aegean Sea (Fig. 17), next to Euboea (OWP.18), Andros (OWP.17), Tinos (OWP.41, OWP.49, OWP.50, OWP.55), Kythnos (OWP.19, OWP.59), Rineia (OWP.32), Dilos (OWP.36), and Mykonos-Ktapodia (OWP.5, OWP.40). The remaining seven sites are pinpointed in the central-eastern part of the South Aegean Sea (Fig. 17), next to Naxos (OWP.6, OWP.22, OWP.43), Donousa (OWP.9, OWP.24, OWP.52), and Amorgos (OWP.1).

The eligible sites located at a distance greater than 8000 m from urban and residential areas, touristic zones, and archaeological, historical, and cultural heritage areas are characterized by excellent social acceptability. This distance threshold was determined based on the general feedback obtained through citizens' participation in the OWP planning process. As a result, 21 eligible sites with excellent social acceptability are identified and presented in priority order in Table 12, according to their overall performance on the examined sociocultural criteria. Specifically, four sites of excellent social acceptability (Fig. 16) are located in the North-East of Crete (OWP.53, OWP.30, OWP.37, OWP.38, OWP.57); seven sites are pinpointed in the northern part of the South Aegean Sea (Fig. 17), next to Euboea (OWP.18), Gyaros (OWP.26), Tinos (OWP.25), Rineia (OWP.32, OWP.45), Syros (OWP.21), and Mykonos (OWP.40); one site is situated in the north-western part of the South Aegean Sea (Fig. 17), next to Agios Georgios (OWP.12); and the remaining six sites are positioned in the central-eastern part of the South Aegean Sea (Fig. 17), next to Paros (OWP.42, OWP.27, OWP.46), Naxos (OWP.39, OWP.6), and Amorgos (OWP.56).

Considering the above results, the sites OWP.6, OWP.18, OWP.30, OWP.32, OWP.37, OWP.38, OWP.40, OWP.52, OWP.57, and OWP.59 are characterized by both excellent economic feasibility and social acceptability. These marine areas, together with the remaining excellent and eligible areas, constitute a holistic offshore wind development roadmap for Greece (Figs. 16 and 17).

4. Conclusions

In the present work, original and consecutive methods are introduced to pave the path toward socially acceptable OWPs on a global scale: (1) a preparatory method designed to build an effective citizen participatory process; and (2) a participatory planning method developed to investigate and incorporate citizens' perspectives into the OWP planning process and, thus, determine socially acceptable OWP installation areas. This is achieved by creating an SQS with the use of the LimeSurvey tool, conducting qualitative and quantitative analyses

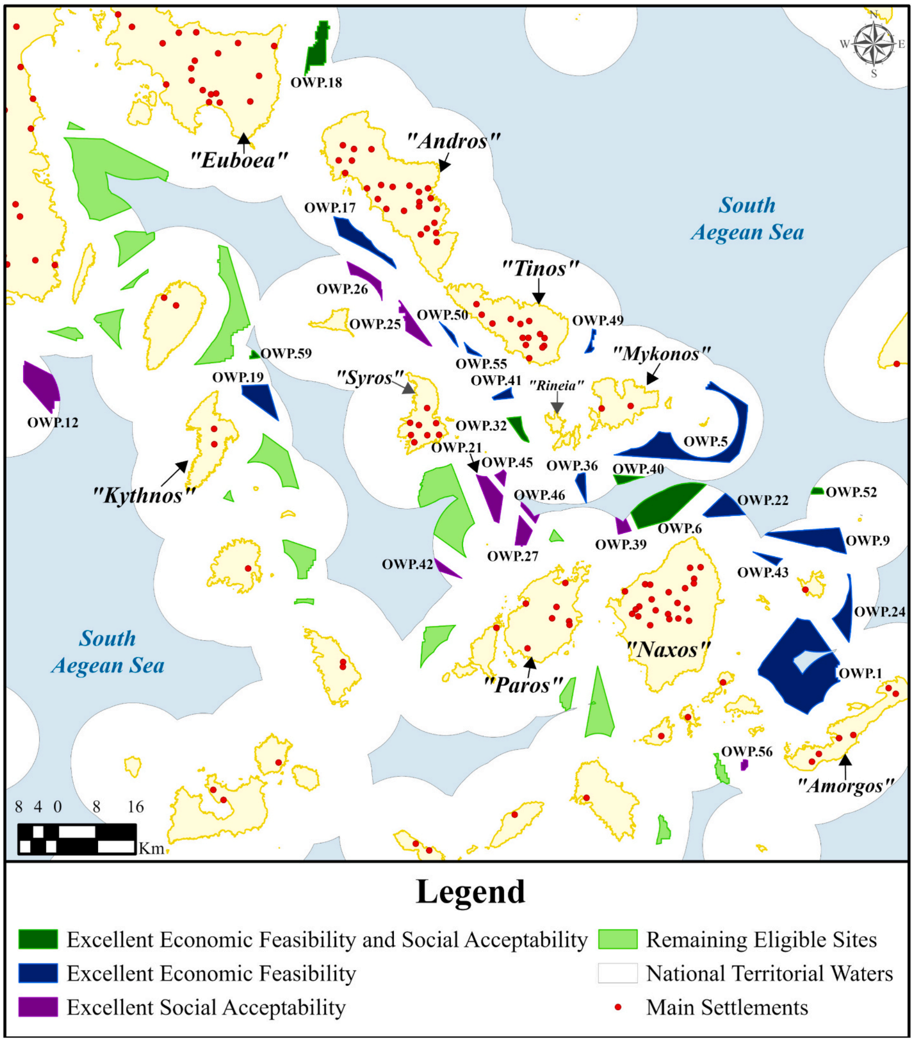

Fig. 17. Holistic offshore wind project development roadmap for the South Aegean Sea.

Table 12
Marine areas of excellent social acceptability for OWP installation.

Priority Position	Project ID.	Total Surface Area	DURA[a]	DTZ[a]	DAHCHA[a]	Excellent Economic Feasibility
1	OWP.52	2,858,208 m^2	17,200 m	19,630 m	38,600 m	YES
2	OWP.38	6,694,817.8 m^2	22,645 m	14,930 m	14,770 m	YES
3	OWP.37	7,058,805.8 m^2	19,455 m	12,965 m	12,880 m	YES
4	OWP.18	26,813,499.3 m^2	12,680 m	15,345 m	19,260 m	YES
5	OWP.45	3,778,794.1 m^2	13,710 m	13,810 m	15,940 m	NO
6	OWP.57	2,125,910.7 m^2	17,100 m	12,000 m	11,940 m	YES
7	OWP.42	5,137,396.2 m^2	12,800 m	13,440 m	13,000 m	NO
8	OWP.30	10,724,692.7 m^2	17,480 m	10,400 m	10,200 m	YES
9	OWP.12	41,710,221.8 m^2	12,760 m	13,030 m	12,890 m	NO
10	OWP.59	2,001,662 m^2	13,400 m	11,510 m	13,475 m	YES
11	OWP.21	23,701,665 m^2	10,560 m	11,100 m	15,860 m	NO
12	OWP.46	3,726,901.1 m^2	11,970 m	10,875 m	10,960 m	NO
13	OWP.39	6,243,768 m^2	10,100 m	10,645 m	11,790 m	NO
14	OWP.26	12,660,784.1 m^2	10,387 m	10,225 m	10,900 m	NO
15	OWP.25	14,453,975.6 m^2	9815 m	11,315 m	8220 m	NO
16	OWP.40	6,084,022 m^2	9730 m	9910 m	11,210 m	YES
17	OWP.56	2,182,967.4 m^2	10,100 m	8155 m	13,180 m	NO
18	OWP.53	2,684,676.6 m^2	8900 m	9200 m	13,000 m	NO
19	OWP.6	70,399,335 m^2	8450 m	9000 m	13,230 m	YES
20	OWP.32	9,020,907.2 m^2	9515 m	9440 m	9370 m	YES
21	OWP.27	12,502,343.2 m^2	9020 m	8640 m	8620 m	NO

[a] Note: DURA, Distance from Urban and Residential Areas; DTZ, Distance from Touristic Zones; DAHCHA, Distance from Archaeological, Historical, and Cultural Heritage Areas.

together with CCAs of primary data in SPSS, developing a geoprocessing site suitability model in GIS, and performing GIS-based assessments at different stages of the planning process. The proposed participatory decision-making approach was applied in Greece.

Key concluding remarks of this study can be summarized as follows: (a) this is the largest research study conducted on public engagement in the development and siting of OWPs at both the national (in Greece) and global scale, with the participation of 1802 citizens; (b) the degree of social acceptance for OWP installation in Greece is notably high (80.6 % of citizens agree); (c) the two most common reasons for citizens' disagreement with OWP installation are the disturbance of landscape aesthetics and the disturbance of marine mammal habitats; (d) eleven EC are identified as important societal criteria, and along with their exclusion limits, must be considered as valuable inputs in every OWP planning study to determine socially acceptable installation sites; (e) citizens' acceptance degree and place of residence are the two factors that most strongly influence their decisions on OWP placement, both quantitatively and qualitatively; (f) a high OWP installation potential, in terms of both social acceptability and techno-economic viability, is highlighted in the South Aegean and Cretan Seas by pinpointing 59 eligible sites covering 1490.225 km^2; (g) no eligible sites with techno-economic viability are found in the Ionian or North Aegean Seas, due to low wind power potential in the former marine region and the absence of electricity substations for OWP connection in the latter; (h) 27 eligible sites are characterized by excellent economic feasibility, with the highest-priority sites located in the eastern part of Crete (OWP.13) and in the northern part of South Aegean, next to Tinos (OWP.55, OWP.50); (i) 21 eligible sites are characterized by excellent social acceptability, with the highest-priority sites located in the central-eastern part of South Aegean (OWP.52) and the north-eastern part of Crete (OWP.38, OWP.37); (j) the southern Aegean Sea and eastern Sea of Crete are identified as the most suitable marine regions for sustainable OWP development in Greece; (k) exceptionally high wind power potential is highlighted in the northern, central-eastern, and south-eastern parts of the South Aegean Sea, and in the eastern and southern parts of Crete; (l) the geographic information database, together with the findings, illustrations, and insights presented in this work, constitute a holistic offshore wind development roadmap that can contribute both to national and global energy independence and to the socially acceptable installation of OWPs worldwide.

Every study is subject to limitations. In this study, the following limitations are recognized: (a) the accuracy of the geographic information data may affect the final results, regardless of the complexity of the participatory site suitability model and the high quality of the methodological analysis, even though entirely reliable geospatial data were employed; (b) consideration of the capacity availability of existing electricity substations in different geographic regions is required, although such information is lacking, while the continued development of substations remains essential for the sustainable exploitation of offshore wind energy; and (c) consideration of the coexistence of offshore wind power with aquaculture, fishing activities, and marine ecosystems through nature-positive approaches is necessary, despite the strong social opposition to OWP placement in these areas.

Future research studies could focus on communicating this study's results to local citizens and measuring their validation level at the national planning scale. By way of example, the country could be divided into community levels, where participatory workshops may be organized. The results derived from community participation could then be compared with those of the present study, and validation metrics could ultimately be estimated. Finally, the proposed methods can be readily adopted and applied to other RE projects, such as onshore wind and PV projects, and to any other study area, in order to assist decision-makers in identifying strategic installation areas, addressing important social challenges related to planning issues, and conducting social impact assessment studies.

CRediT authorship contribution statement

Sofia Spyridonidou: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2025.104434.

Data availability

The sources of the geographic information data used in this study are cited in the References.

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