DETERMINANTS OF OFFSHORE WIND ENERGY ACCEPTANCE ON THE COAST OF CEARÁ

1 INTRODUCTION

Wind energy has experienced significant advancement in recent years, establishing itself as a central topic on the global political agenda in response to the growing demand for renewable energy sources. This growth has garnered interest not only from public policy but also from the academic community. According to Tabassum-Abbasi et al. (2014), wind energy exhibits the lowest adverse environmental impacts among renewable energy sources, with the exception of direct solar heat and sunlight. However, the authors caution that the negative impacts, particularly on the climate, can be substantial and are likely to increase in complexity and magnitude as the use of wind energy expands (Abbasi et al., 2016). Wind energy is considered the first renewable energy source to achieve economic viability, capable of generating electricity at costs comparable to conventional sources, which has been crucial for its global adoption (Tabassum-Abbasi et al., 2014; GWEC, 2023).

Specifically concerning offshore wind energy (OWE), Díaz and Guedes Soares (2020) review the current state of technology and future trends in offshore wind farms, discussing technological advancements, challenges, and future prospects. De Castro et al. (2019) explore the different approaches adopted in the key regions of OWE development, including Europe, China, and the United States, comparing policies, strategies, and practices, and providing a comprehensive overview of the perspectives and approaches driving the growth of this energy source. In the Brazilian context, although studies on OWE are still limited and the country lacks experience in its installation, onshore wind energy has already established itself as an important source in the national energy matrix. In Northeast Brazil, favorable wind conditions have led to successive records in wind energy generation in recent years. Of the 619 wind farms installed in the country, 523 are located in this region, accounting for 86% of all wind energy produced in continental Brazil (Neoenergia, 2023).

Given this potential, Chen et al. (2015) note that the implementation of OWE has been the subject of intense debates and conflicts in various regions around the world. These projects face challenges related to economic viability, socio-environmental impacts, and governance issues. In this context, society plays a crucial role in the discussions surrounding these conflicts, making it essential to consider the diverse interests and perspectives involved.

In this context, the present research aims to identify the factors that influence stakeholder acceptance of OWE implementation. To achieve this, a survey was administered to local residents, business owners, tourists, fishers, and public officials, followed by a logistic regression analysis of the data. The study was conducted along the western coast of the state of Ceará. The findings of this research contribute to the ongoing debate by addressing issues related to personal characteristics, knowledge, and perception of impact concerning OWE, particularly in a region targeted by ocean exploitation policies for energy generation.

2 THEORETICAL BACKGROUND

The exploration and development of blue energy in coastal and marine environments have garnered increasing global interest. However, the utilization of these renewable energy sources faces specific challenges in terms of regulation, legislation, and planning (García et al., 2019). Regarding planning, the development of coastal and marine spatial planning (MSP) aims to balance the interests and needs of various sectors, promoting an integrated and sustainable approach to maritime space use (Salvador et al., 2018). As noted by Garcia et al. (2019), such planning plays a crucial role in identifying and mitigating potential socio-environmental impacts associated with blue energy. This approach is essential for minimizing negative effects and promoting the harmonious coexistence of blue energy with other maritime space uses, such as fishing and nautical tourism.

In the economic sphere, conflicts of interest are a constant issue, as different stakeholders have distinct optimal or desirable allocations for the scarce resources available. This dynamic also applies to offshore wind energy (OWE) production. Government bodies, energy production companies, local residents, fishers, environmentalists, and other groups have divergent interests regarding the use of the sea (Christie et al., 2014). Conflicts may arise concerning the utilization of maritime areas for activities such as shipping, fishing, tourism, scientific research, infrastructure installation (such as those related to OWE production), and marine environment protection (Christie et al., 2014). Each activity is managed by stakeholders with potentially conflicting interests, necessitating careful balancing and effective management to mitigate conflicts, considering both existing and potential impacts (Chen et al., 2015).

The stakeholder approach underscores the importance of considering the broad interests of those involved in or affected by a project or enterprise. According to Elsner and Suarez (2019), this approach is fundamental to supporting the management of complex environments and actions, highlighting the relevance of the various interests at play. These authors argue that collective and diffuse interests, including local communities, environmental groups, and government agencies, are directly affected by the projects. By prioritizing stakeholder engagement and considering their interests, developers can create OWE projects that are socially and environmentally responsible (Chen et al., 2015; Elsner & Suarez, 2019).

In this sense, the effective planning, development, and operation of OWE farms depend on robust governance. In addition to consulting local communities to address issues such as environmental impact and maritime space occupation, this management can help companies and governments identify key stakeholders, understand their expectations and needs, and work towards establishing transparent agreements and mutual benefits. From this perspective, cooperation among stakeholders is essential for the development of OWE, as it involves decision-making based on principles of good governance (Elsner & Suarez, 2019).

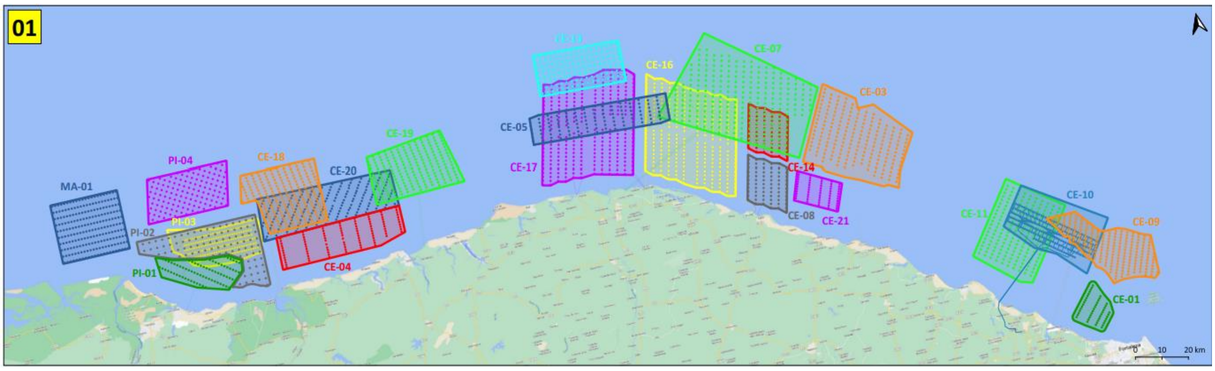
OWE is a significant source of renewable energy that offers notable advantages compared to onshore wind energy. Although offshore energy is more expensive and presents additional challenges in terms of installation and maintenance, it brings several important benefits (GWEC, 2023). Magar et al. (2023) highlight several positive aspects: offshore winds are typically stronger and more stable, resulting in significantly higher production per installed unit; wind turbines can be larger at sea, as the transportation of large turbine components is facilitated; and the installation of turbines far from the coast practically eliminates issues of visual impact and noise, allowing the use of varied designs that enhance efficiency.

Thus, it is essential to identify areas of marine species occurrence to avoid adverse impacts and to continue monitoring the response of these species to the construction and operation of OWE farms. Furthermore, coastal communities also occupy, use, and depend on the oceans and coastal environment for their livelihoods and well-being. As emphasized by Bennett (2019), all these issues necessitate an understanding of the complex relationship between humans and the oceans. Bennett (2019) stresses the interaction between oceans and living beings and highlights the importance of understanding this relationship for decision-making in all areas of marine policy. A critical element in OWE planning is the development of projects that avoid or mitigate potential negative environmental and social impacts. Scientific research must underpin the assessment of these impacts associated with OWE projects. In this context, it is essential to consider the characteristics, knowledge, and impact perceptions of all stakeholders, including the local population, to ensure the sustainability of these enterprises.

3 METHODOLOGY

A survey was conducted with various stakeholders, including residents, business owners, fishers, and researchers from the beaches of Acaraú, Caucaia, Cruz, Itarema, and Trairi, located in the western region of the state of Ceará. Figure 1 illustrates the OWE areas proposed by companies along the coast of Ceará.

Figure 1 - Offshore wind complexes in Ceará undergoing environmental licensing process



Source: Ibama (2024)

The objective of the research was to identify the factors that influence the acceptance of OWE implementation. Data collection was carried out using a questionnaire developed based on Chen et al. (2015), specifically designed to assess the acceptance of OWE. The questionnaire was created and distributed to stakeholders in the field. A sample of n equal to 29 was obtained. The structure of the adapted questionnaire included, in addition to the question on OWE acceptance, items based on three dimensions considered predictors of acceptance: personal characteristics, knowledge about OWE, and perception of impacts.

With the responses obtained, a logistic regression (logit) analysis was performed using SPSS software. This modeling allowed for the estimation of coefficients indicating the average effect on the probability of the event of interest, in this case, the acceptance of OWE. The intention was to calculate the odds ratio (exp(B)), which represents the change in the probability of the event of interest occurring for each unit change in the predictor (Agresti, 2013).

Given the sample size, a simpler model specification was suggested, aiming for greater parsimony in the modeling in terms of goodness-of-fit (Agresti, 2013). Thus, considering the sample size and the set of variables addressed, three simpler models were evaluated separately: the first addressed personal characteristics (model 1), the second focused on knowledge about OWE (model 2), and the third dealt with perceptions of OWE impacts (model 3).

Table 1 describes the variables studied in each of these models.

Table 1 – Description of variables

Dimensions	Variables	Questions	Answers
Acceptance	Accept	Do you agree/would you agree with the installation of OWE here in your city?	Yes = 1; No = 0
Personal characteristics	Gender	What is your gender?	Male = 1; Female = 0
	Age	How old are you?	Up to 30 years = 1; 31 to 40 years = 2; 41 to 50 years = 3; More than 50 years = 4
	Education	What is your educational level?	Up to high school = 1; Undergraduate = 2; Postgraduate = 3
	Family income	How much is your family income?	Up to BRL 2,000 = 1; BRL 2,001 to BRL 5,000 = 2; BRL 5,001 to BRL 10,000 = 3; More than BRL 10,000 = 4
Knowledge on OWE	Saw a turbine	Have you ever seen a turbine?	Yes = 1; No = 0
	Know OWE	Do you know what OWFs are?	Yes = 1; No = 0
	Participated in a public meeting	Have you ever participated in related meetings or conferences? (e.g., public hearing, briefing)	Yes = 1; No = 0
Perceptions of the impacts of OWE	Limited access to fishing areas	Can OWE limit access to fishing areas?	Yes = 1; No = 0
	Employment opportunities	Can OWE create local employment opportunities?	Yes = 1; No = 0
	Allows the development of mariculture	Can OWE allow the development of mariculture in the waters surrounding the turbines?	Yes = 1; No = 0

Source: authors

4 RESULTS AND DISCUSSION

The three models fit the collected data satisfactorily. The Variance Inflation Factor values for each independent variable were below 5.0, indicating the absence of multicollinearity. Models (1) and (3) performed better than model (2), which did not show significance in the χ^2 goodness-of-fit test. Additionally, models (1) and (3) demonstrated higher overall efficiency, with correct prediction rates exceeding 75%, as well as higher pseudo-R^2 (Nagelkerke) values. In model (1), which addresses personal characteristics, household income was the only significant variable, showing a positive effect. It was observed that the higher the household income, the greater the probability of accepting the installation of OWE. Specifically, the odds ratio increase by more than 882% for each shift in the considered income strata. In contrast, in model (3), which deals with impact perceptions, the belief that OWE will limit access to fishing areas reduced the likelihood of acceptance by almost 95%. On the other hand, the perception that the implementation of OWE could generate job opportunities increased the chances of acceptance by over 541%.

The positive effects of household income on OWE acceptance suggest important insights. Individuals involved in activities that provide higher income may be more inclined to accept the installation of OWE, in contrast to traditional, lower-income populations such as fishers. The lack of significance of the variables related to knowledge on OWE may indicate a lack of broad stakeholder engagement in the discussion concerning the use of the sea for OWE, which is often limited to political agents and sector companies. Table 2 summarizes the results.

Table 2 - Results of binary logistic regression

Variables	(1)		(2)		(3)	
	B (SE)	OR	B (SE)	OR	B (SE)	OR
Gender (Man)	1.495 (1.044)	4.459				
Age	0.112 (0.437)	1.119				
Education	-1.624 (1.127)	0.197				
Family income	2.285** (0.963)	9.823**				
Saw a turbine (Yes)			-0.724 (1.439)	0.485		
Know OWE (Yes)			0.691 (1.314)	1.997		
Participated in a public meeting (Yes)			-0.947 (0.942)	0.388		
Limited access to fishing areas (Yes)					-2.970** (1.294)	0.051**
Employment opportunities (Yes)					1.859* (1.107)	6.418*
Allows the development of mariculture (Yes)					0.593 (1.104)	1.810
Correct predictions % (Global; Accept; No accept)	75.9; 69.2; 81.3		55.2; 76.9; 37.5		79.3; 76.9; 81.3	
Log-likelihood	27.113		38.529		26.719	
Model fit test χ^2(df)	12.779** (4)		1.363(3)		13.173***(3)	
Hosmer Lemeshow χ^2_{HL}(df)	5.141(7)		0.247(2)		0.187(4)	
Pseudo-R^2_N	0.477		0.061		0.489	
Number of observations	29		29		29	

Notes: B = Beta estimate, SE = Standart erro, OR = Odds ratio. Significance level (Wald test): *** p < 0.01, ** p < 0.05, * p < 0.10. Logit function link.
Source: authors

It is interesting to note that the perception of restricted access to the sea for fishing activities had a negative effect on OWE acceptance, while the expectation of job creation in the region had a positive effect. These findings are consistent with the literature, as pointed out by Chen et al. (2015), which also suggests that the perception of impacts affects OWE acceptance. The promotion of good governance, involving various stakeholders, is crucial for mitigating conflicts and ensuring multiple uses of the oceans. As indicated by Christie et al. (2014), it is possible to reconcile access to marine waters with different activities.

5 CONCLUSION

This research contributed to the understanding of the factors influencing stakeholder acceptance of OWE farm installations, focusing on the coast of Ceará as a case study. Among personal characteristics, household income level was found to have a significant influence on acceptance. None of the variables related to knowledge about OWE showed statistical significance in determining stakeholder acceptance. Regarding the impact perception dimension, the identification of a potential restriction on access to fishing areas demonstrated a negative effect on acceptance, while the perception of emerging job opportunities had a positive effect. These results should be interpreted with caution, particularly due to an important limitation of the research: the small sample size. For future research, it is recommended to conduct interviews in addition to the questionnaire to capture issues related to experience, local context, and the future expectations of stakeholders.

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