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Perspective

Emerging challenges of offshore wind energy in the Global South: Perspectives from Brazil

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ABSTRACT

Government authorities and lobbying groups have promoted wind power in Brazil as offering win-win outcomes for electricity consumers and investors and, increasingly, for green hydrogen exporters. Analysis of siting and planning processes for Latin America's first proposed offshore wind farm, in Brazil's Ceará state, show that elites and state authorities are exploiting conditions of the offshore marine environment, resulting in the reproduction of injustices and negative environmental externalities that have characterized some onshore wind farms. These emerging processes are not unique to Brazil and should be analyzed in other areas of the Global South where power and information asymmetries impede marginalized communities from meaningful participation in siting and licensing decisions and obtaining benefits in line with principles of energy justice.

1. Introduction

Wind quality in the offshore marine environment is attractive to wind energy investors. Brazil's high offshore wind potential, estimated at ~3 TW and more than 14,800 TWh of average annual electricity production for the viable shallow-water continental shelves [1], is increasingly desired as the power source for producing exportable green hydrogen via electrolyzers [2]. Brazil's *Empresa de Pesquisa Energética* ([3], p. 127) highlighted a key challenge for offshore wind: "*uncertainty regarding potential socio-economic conflicts that may arise between offshore wind and other activities*." Other Brazilian experts have created models with socio-environmental exclusion criteria, but their work requires additional knowledge of how fishing communities will interact with offshore wind farms [4].

In this Perspectives essay, we analyze a proposal for an offshore wind farm in the state of Ceará, Brazil, which is relevant because it was the first in Latin America to start the environmental licensing process. An energy justice framework [5,6] informs this work's concerns for recognition, participatory, and distributive justice. As scholars of renewable energy conflicts in Brazil, India, and Mexico have shown, onshore wind and solar farms have facilitated land and resource dispossessions, increased the power of elites over marginalized groups, heightened social differentiation, and encouraged numerous other social and political problems [7–10]. In parallel, scholars have identified numerous concerns for social injustices arising from the "unprecedented attention" of investors to ocean resources [11]. Our analysis of Brazil's first proposed offshore wind farm allows the opportunity to identify emerging challenges of siting wind farms in the offshore environment using insights from terrestrial solar and wind farms with attention to specific issues of marine resource tenure and users.

Our research is not motivated by an opposition to offshore (or onshore) wind energy development, but rather by the need for renewable energy development in all forms to be part of a just energy transition [5,6]. The co-authors represent scholar-activist positionality that conducts rigorous social-environmental research into topics that may empower marginalized people. Our efforts are closely aligned to recent calls for "place-based reflexivity" among energy social scientists [12]. For exemple, we are empathetic to the struggles of marginalized groups,

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but we avoid advancing their causes in settings that could be construed as overtly political, nor do we provide consultancy services to firms investing in wind energy. We accept invitations by elected leaders to present data in public forums aiming to inform policy debates. In this way we maintain a form of "situated solidarity" [13]. A limitation of the scholar-activist positionality with traditional communities, social movements, and the state actors who regulate (and fine or sanction) wind energy firms would have been complicated interviews with certain actors, such as representatives of wind energy firms; however, in this Perspectives essay we relied on analysis of the impact report and the public hearing facilitated by the Brazilian Institute for the Environment and Renewable Resources (IBAMA).

We structure this Perspectives essay as follows: the Background section synthesizes the state of offshore wind farms in Brazil and suggests the need for dialogue between studies of onshore and offshore renewable energy infrastructure. The Case Study, focusing on one offshore wind farm, includes our critique of the environmental analysis and the public hearing. The fourth section describes how the case is suggestive of emerging justice challenges for offshore wind farms. The Conclusion synthesizes our findings and emering research area.

2. Background

In January 2024, Brazil had 96 offshore wind projects planned for electricity and green hydrogen production in the environmental licensing phase (Fig. 1), 25 of which were in Ceará State (northeastern Brazil). In total, these planned offshore wind farms have capacity of nearly 234 GW from 15,499 turbines (Appendix 1), which represents eight times more power compared to Brazil's ~ 29 GW of current (according to Brazil's electricity regulator, ANEEL) onshore wind capacity. Governance of offshore wind farms was defined by a January 2022 federal government decree (Appendix 2) [14]. Potential impacts of offshore wind energy in Latin America, and tropical Brazil in particular [15], are significant because coral reefs, seagrass and rhodolith beds, and mangroves are already seriously threatened by pollution, urbanization, shrimp farms, and global warming, among other drivers, while providing high-value ecosystem goods and services to fishing communities and worldwide [16].

The Caucaia offshore project, which we analyze below, was the first to request an environmental license; moreover, critical analysis of the Caucaia project may improve the quality of environmental assessments and planning procedures for future offshore wind farms. Brazil's federal environmental agency, IBAMA, rejected the Caucaia environmental impact assessment (EIA) in July 2023, but the same investors filed plans for licensing a new offshore wind farm in the Camocim municipality in the west coast of Ceará state and expressed intent of building another wind farm in neighboring Rio Grande do Norte state [17].

We frame this Perspectives essay at the intersection of literatures that show remarkable parallels but have thus far engaged in modest dialogue. Oceans are the "new frontier for economic development" with potential for social injustices, such as dispossession/ocean grabbing, livelihood impacts for small-scale fishers, loss of marine resources with food security implications, and exclusion from governance ([11], p. 1). Marine renewable energy "has the potential to present a major challenge to traditional conception of rights and may play an important role in redistributing rights in the marine environment" ([18], p. 110) to the detriment of traditional users. Recent studies in Europe and North America have argued for re-centering social dimensions [19], offered deeper understandings of community ownership [20,21], community benefits [22], underlying ocean beliefs [23], and distributional fairness [24] relating to offshore wind farms. These scholars offer claims strikingly similar to those made by studies of terrestrial wind and solar farms, which have offered evidence for how wind and solar investments facilitate land and resource dispossessions, increase the power of elites over marginalized groups, heighten social differentiation, and encourage varied social and political problems [7–10].

We offer a corrective to the argument made by [25] that specific characteristics of the marine environment make insights from onshore renewable energy not directly applicable. The many parallels between onshore and offshore wind farm politics and siting issues, namely relating to aesthetics, place attachment, lack of tangible benefits to host communities, and lack of trust with developers, are well known [26,27]. Our findings support an emerging middle position, which acknowledges some key differences between offshore and onshore siting controversies, such as relatively low levels of public knowledge about offshore infrastructure and different stakeholders and siting processes, while emphasizing the similar processes [28] and maintaining that recognition, distributional, and procedural justice concepts commonly used in studies of onshore wind and solar should be applied to offshore renewable energy [29].

In the remainder of this Perspectives essay we offer evidence from an exploratory case study showing that offshore and onshore injustices in wind and solar developments are two sides of the same coin, even if the characteristics of tenure regimes, environmental resources, and siting processes may differ considerably between onshore and offshore renewable energy. Future research on offshore renewable energy conflicts may be enriched considerably through deeper engagement with studies of onshore wind and solar conflicts. Policies for just energy transitions should view renewable energy investments in terrestrial and marine environments as potentially subject to the same dispossessions and flawed participatory processes.

3. Case study

An offshore wind farm comprising 48 wind turbines with a total capacity of 576 MW in an area 12–24 m deep was planned for coastal waters in Caucaia, near Fortaleza, the capital of Ceará state, Brazil (Fig. 1B, CE-1). Fishers using the marine spaces are organized in fishing villages, dependent on subistence and market-based fishing, and reliant on both motorized and sailing vessels [30]. The application for environmental licensing by the investors to the IBAMA began in August 2016, and in March 2020 the first public hearing was held with the host community. In August 2020 IBAMA denied the preliminary license due to the poor quality of the EIA (Environmental Impact Assessment) presented by the investors, who appealed in September 2020. IBAMA denied the appeal owing to the absence of additional primary data presented, but the investors continue to address omissions and faults in the components of the documentation presented to IBAMA. After receiving appeals from the investors, IBAMA definitively rejected the proposal in July 2023 with a "not environmentally viable" ("inviabilidade ambiental") decision based on several weaknesses of the EIA.

Here we synthesize our own analysis of the more than 2,500-page EIA, which was available to the public for six days before the 11 March 2020 public hearing.[1] The first author participated in the public hearing; the first, the third and fourth authors qualitatively analyzed the EIA sections on social, physical, and biological aspects, and relied on a 55-page transcript from the public hearing supplied by IBAMA to the first author. The wind farm EIA attracted a second critique, from a professor at the Federal University of Ceará, focusing on marine turtle nesting sites near the proposed wind farm. We found significant flaws, inaccuracies, and omissions in the diagnosis of the biotic, socioeconomic, and physical marine environment summarized here:

- No analysis of possible underwater archaeological heritage.

[1] The environmental impact study, "Parque Eólico Offshore Caucaia" (SEI_02001.003915_2016_68), may be obtained through IBAMA's portal http://www.ibama.gov.br/sistemas/sei-ibama. We sent IBAMA a longer version of the bullet points presented here, but we do not know if our analysis influenced their decision to reject the Caucaia project.

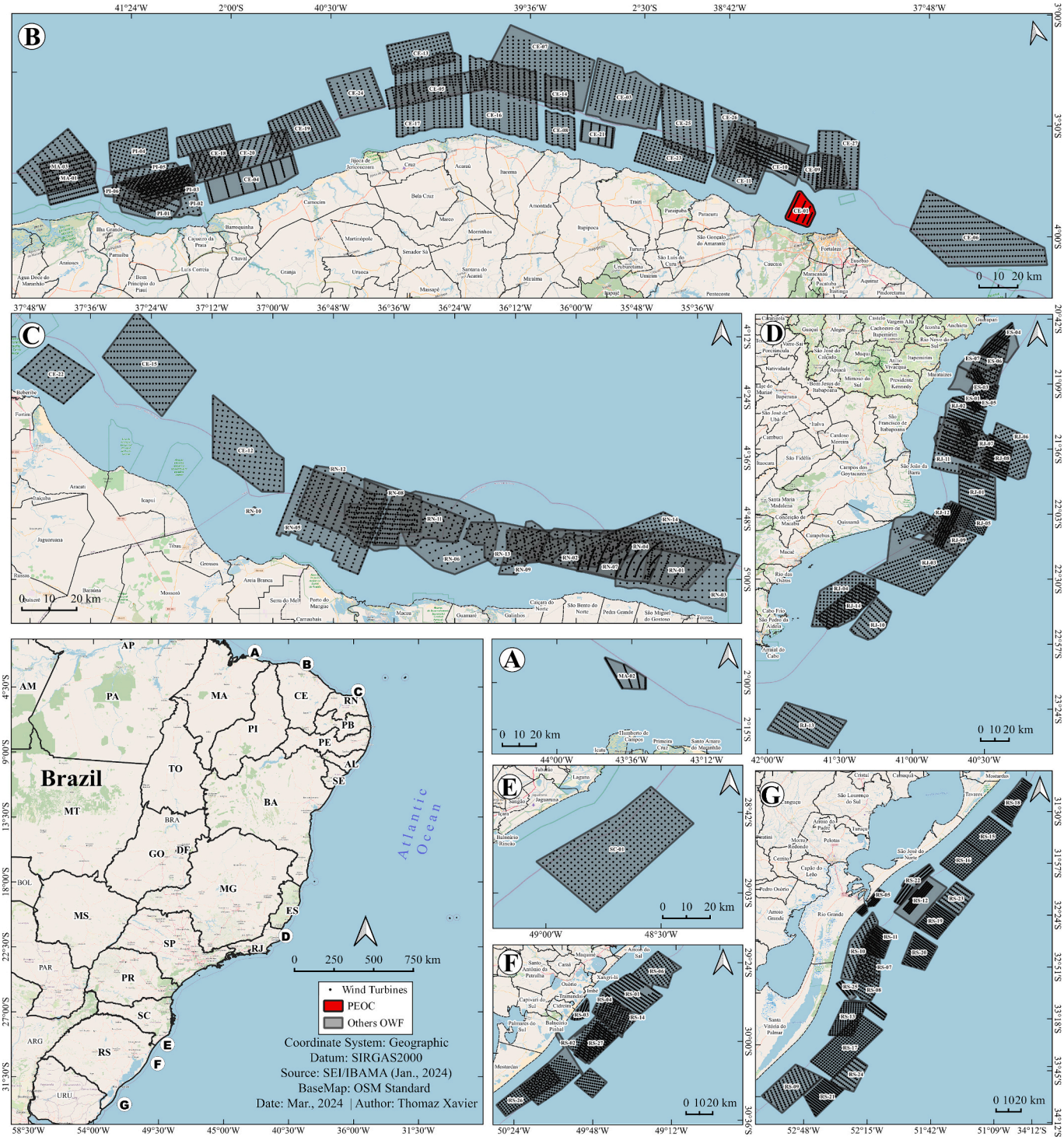

Fig. 1. Geographic location of offshore wind farm projects in Brazil registered in the Electronic Information System (SEI) of the Brazilian Institute for the Environment and Renewable Resources (IBAMA), January 2024. Inset maps show wind farms planned in Maranhão (A), Ceará (B), Rio Grande do Norte (C), Rio de Janeiro and Espírito Santo (D), Santa Catarina (E), Rio Grande do Sul (F and G) states. The Caucaia offshore wind farm is shown as PEOC on inset (B). Source: SEI/IBAMA (January 2024).

- Flawed and simplistic socioeconomic study, lacking primary ecological and socioeconomic data, of the affected region, even though the area includes fishing communities, indigenous groups (Tapeba and Anacé), a *quilombola* group (Cercadão dos Dicetas), tourists, and recreationists. The report erroneously claims, without any supporting data, that artisanal fishing is a coastal activity and therefore will not be affected by the offshore wind farm.
- Analysis presented in Chapter 3 uses a cartographic scale (all coastal Ceará) that prevents the identification of areas of possible conservation or biodiversity value and the identification of areas directly and indirectly affected by the proposed wind farm.
- Faulty diagnosis of the marine environment (Chapter 4) owing to lack of data collection, which leads to under-estimation of environmental impacts of the proposed wind farm (Chapters 5–9).

- The synthesis (Chapter 4, pp. 538–540) includes vulnerability maps of the terrestrial environment but lacks the high-resolution seafloor mapping and impacts on unique habitats such as the coral reefs [31,32], rhodolith beds [33], and seagrass beds [34] where the wind farm would be located.
- The data on marine biodiversity (Chapter 4, pp. 454–6) was obtained by walking along the beach, without a clear methodology.
- Diagnosis of the marine environment (Chapter 4) was based on faulty analysis of marine currents and on data collected in a neighboring state, approximately 500 km distant from the proposed wind farm.
- Numerical modeling studies were not validated.
- Underestimation of negative cumulative impacts and the absence of mitigating measures, adequate compensatory measures, and adequate monitoring strategies for the offshore wind farm.
- No plan for decommisioning offshore wind turbines. In fact, the investors argued in response to IBAMA's first denial that "a project of this size will not be decommissioned" (Recurso Administrativo, September 2020).

The investors engaged in a public relations campaign, which we observed directly, to promote the offshore wind farm. First, they targeted associations of realtors, managers of beachfront condominiums, surfers, and owners and employees of beachfront restaurants who lived close to an eroded section of beach. The reason for this approach was to appeal to stakeholders who have been trying to manage coastal erosion unsuccessfully for two decades [35]. Aiming to improve social acceptance for the project, investors promised to build 11 jetties on the coast as a "social investment" directed to the local population and the municipal administration. It became clear, especially during the first public hearing, that the construction of the jetties was used to justify the construction of the offshore wind farm as a bargaining chip by the investors and representatives of the municipal government. Caucaia's mayor started the meeting by summarizing how he and his political allies had worked for years to stop beach erosion, and that no one could be opposed to "such a beautiful project," as he referred to the jetties that were intended to solve the problem of "the ocean's advance." He told the audience that "we're trying to solve [beach erosion], and here the [wind farm investors] want our support to start [the project]." By tying the offshore wind farm to jetties, opposing the wind farm would mean supporting continued beach erosion. Municipal and state authorities used nearly 1 h to promote the jetties and offshore wind farm, but their plan for jetties neglected the fact that the construction of the jetties required environmental licensing owing to potential social, environmental, and ecological damage [36–40].

The coastal erosion approach also neglected artisanal fishers who use the resources in the areas of directly and indirectly affected by the proposed wind farm. In fact, the wind farm would be built on fishing grounds that parallel the coast and may substantially affect thousands of families that depend on this small-scale activity, besides causing the possible migration of fauna (concentration of highly mobile predators) and changes in marine habitats [41–43].

During this first public hearing, the company and the municipal leaders encouraged conflict between the residents who positioned themselves for or against the project. The company representative behaved rudely and disrespectfully towards people who positioned themselves against the project, including ridiculing the fact that some people in the audience had not understood the EIA or the presentation made in the first stage of the meeting. She stated that the EIA "is made for someone with elementary school education [ensino fundamental]." The representative mocked a fisherman, who was president of the Fishing *Colônia* of Cumbuco. This fisherman was one of the first to sign up for a three-minute speaking slot, but the last to speak, appearing after the elected officials and investors near midnight. He noted his concerns with navigating around the offshore wind farms, commented on how the EIA did not list the types of fish and shellfish that he knew were among local landings, and then stated his key concern: "I won't be able to fish" because of the minimum distance required between vessles and wind turbines. He argued that "there needs to be a study of fishing, because the [mitigation measures] don't have any relationship to artisanal fishing, because I'm a fisher and I know all about fishing." In response, the company representative told him that she would "teach him how to fish" and then "eat fried fish and beer" with him, then encouraging audience members in favor of the project to continue to ridicule the fisher.

These attitudes created a tense atmosphere for almost 5 h of the hearing (7:40 PM to midnight), stimulating a feud between the groups supporting and the group opposing the wind farm, clearly counterproductive to the purpose of the meeting, and generating chaos at the expense of reasoned dialogue, reflection, or analysis on the socio-economic and ecological implications of the large-scale project. The elementary school hosting the hearing lacked conditions for security and for basic confort of the large audience. This experience was contradictory with technical and scientific practices of participatory environmental enterprise planning [44].

4. Emerging justice challenges in offshore wind farm siting and licensing

Our analysis of the Caucaia hearing and EIA, informed by our previous and ongoing research and the energy justice literature [5,6,45], indicates several emerging challenges that may resonate with other sites of proposed offshore wind in the Global South. Three characteristics of Brazil's offshore tropical environment have direct bearing on justice outcomes for host communities.

First, federal ownership of marine spaces leads to federal involvement in licensing. This in theory could break the grip of local elites on the licensing process, but in practice similar patterns of elite control are observed as compared to onshore wind farms, in which elites control information and serve as interlocutors with investors [10,46]. Public participation in discussions about this federal (public) resource is dominated by local authorities, similar to flaws described for the public consultation process for onshore wind farms in southern Mexico [47,48]. As we observed, the information provided by authorities was highly technical and the host community had only one opportunity for response. Procedural justice, defined as information sharing, participation in decision making opportunities, the ability to influence outcomes, and relations with project developers [5,6], will be impossible to achieve if affected groups do not have access to information and are ridiculed in public meetings held to solicit public comment. Future research should focus on determining whether public meetings are spaces of participation or exclusion for affected individuals and groups, and whether participatory (in)justices are perpetuated by certain forms of public meetings.

Second, Brazil's coastline is home to many traditional and artisanal fishing communities that rely on diverse marine resources for livelihood reproduction [30], although fishing data are poor [49]. Offshore wind farms may result in significant changes for traditional fishers and shellfish gatherers since the decline of tropical ecosystems will necessarily influence the diversity and fisheries productivity. If projects are built without rigorous planning and broad participation, they will create negative impacts on areas currently used for artisanal fishing, leisure, tourism, and water sports, creating distributional injustices for host communities. These processes show many parallels with land and resource enclosures and dispossessions reported in India for onshore solar [8], southern Mexico for onshore wind [47,48,50], select offshore sites [18], and more broadly the suggestions that onshore and offshore siting and politics are similar [26,27]. These findings suggest that offshore wind farms could become means for elites to carry out resource enclosures [18]. Future research could determine how and why political processes for offshore enclosures differ from terrestrial environments, building upon earlier suggestions [28].

Third, the characteristics of coastal resources in areas desired for offshore wind farms present challenges owing to high tropical

biodiversity (e.g., coral reefs, seagrass beds, and rhodolith beds) [16] and the fact that resources in the offshore tropical environment (e.g., fishes, turtles, and sediments) are mobile and not fixed in space, so they may appear to have no identifiable owner [11,18]. Moreover, artisanal fishing activities organized around tropical marine resources may be easily characterized as archaic and destined to disappear, rather than legitimate livelihood strategies. Making fishers "visible" through counter-mapping [51], the practice of mapping people and resources in opposition to state or elite power, would be a means to democratize offshore renewable energy planning in the context of marine territorialization and likely resource appropriation. Future research could determine the spatial and livelihood dimensions of marine territories used by artisanal fishing, and possible impacts on food security if fishers are excluded because of offshore wind farms, suggested in a discussion of ocean dispossession of small-scale fishers [11,18]. Data on fishing vessels, landings, and commerce would be critical to determine economic implications of offshore wind farms to coastal communities. Scholar-activists could partner with fishing communities to map resource uses through co-produced cartographic representations of marine territories, adding to an agenda for social studies of marine renewable energy [25].

5. Conclusions and final considerations

Offshore wind energy in the Global South will likely be built where host communities may be marginalized politically with poor access to information, low formal education attainment, and weak leverage over investors and state authorities. Reducing conflicts among goals of environmental conservation, socio-economic development, and offshore power generation requires an integrated research approach that includes participation of affected groups, analysis of power relations of elites, and attention to the oceanographic environment. These elements are critical to an emerging research agenda for just development of offshore wind in the Global South that incorporates insights from studies on onshore wind and solar conflicts while recognizing the different stakeholders, governance processes, and resource uses of the marine environment. A research approach informed by "place-based reflexivity" [12] deployed in the unique biological, environmental, and governance systems of the marine environment, while applying recognition, distributive, and procedural justice categories, would offer much needed comparative analysis of offshore renewable energy [25,28] in a context of imminent rapid expansion in the Global South.

Our analysis of the Caucaia case indicates that elites and state authorities are exploiting institutional and biophysical conditions of the marine environment to reproduce injustices and negative environmental externalities that have characterized onshore wind and solar farms in the Global South and resemble concerns about marine renewable energy [11,18,25–28]. Characteristics of Brazil's marine environment create several challenges for offshore wind farms to be compatible with socially just outcomes. A critique of the Caucaia offshore wind farm helps illustrate the urgent need for developing best practices guided by energy justice principles [5,6,52] for future offshore wind farms in the Global South.

CRediT authorship contribution statement

Adryane Gorayeb: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization, Project administration, Resources, Supervision. **Christian Brannstrom:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Thomaz Xavier:** Writing – review & editing, Writing – original draft, Software, Formal analysis. **Marcelo de Oliveira Soares:** Writing – original draft, Formal analysis. **Carlos Eduardo Peres Teixeira:** Writing – original draft. **Ana Maria Ferreira dos Santos:** Writing – original draft. **Rodrigo Guimarães de Carvalho:** Writing – original draft.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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