

OFFSHORE WIND AT CROSSROADS: ANALYSIS OF OPPORTUNITIES, CHALLENGES AND STRATEGIC APPROACHES

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Abstract: *The global shift to renewables – especially Offshore Wind (OW) – drives climate action, economic growth, and sustainability, notably in emerging countries. Despite positive developments and prospects, many countries, especially developing and emerging countries, face various complex challenges, such as ensuring regulatory support and addressing environmental concerns. This study employs a critical literature review to evaluate OW's strategic role in promoting low-carbon energy, job creation, and ecosystem protection. While progress is evident, challenges like regulatory gaps and environmental concerns remain. The findings highlight OW's potential and underscore the need for strong government cooperation and supportive frameworks to overcome barriers and guide long-term development. Findings provide comprehensive insights and understanding of the strategic direction for OW projects and their long-term impacts, as well as address the influence of framework conditions on implementation.*

Keywords: Offshore Wind; Emerging Markets; Renewable Energy; Sustainability, Clean Energy

INTRODUCTION

According to the World Meteorological Organization (WMO), 2024 is projected to be the warmest year on record, marking the end of a decade characterized by extreme heat driven by human activities. The year experienced 151 record-breaking weather events, leading to at least 550 disasters, including heatwaves, floods, storms, droughts, and wildfires, which have been intensified or made more frequent by global warming (Carrington 2025). The impact of global climate change on developing countries is profound. These nations are the most vulnerable to climate change, already experiencing eight times more natural disasters than they did in the 1980s (Bhargawa and Bhargava 2023). These countries, which have limited resources and lower adaptive capacity, experience significantly higher relative damage to GDP from climate extremes compared to industrialized nations (Ravindranath and Sathaye 2002, p. 248). Sustainable green electricity technologies, especially OW, are significant technical solutions to handle global climate change. Those energy sources are crucial for reducing greenhouse gas emissions, a major reason for climate impacts, by replacing fossil fuel-based energy production with clean electricity with minimal environmental impact (Devadasa and Laxminarayana 2023, p. 1019). OW energy, for instance, can provide significant amounts of electricity near load centers, reduce greenhouse gas emissions, and complement other renewable sources while lowering the overall cost of achieving climate targets (Cranmer and Baker 2020, p. 2). Therefore, the research question is how OW energy can be established as a central component for sustainable growth in emerging markets.

RESEARCH METHODOLOGY

This paper analytically reviews existing literature on renewable energy with a focus on OW, highlighting key insights, research gaps, and integrating reputable sources.

RESULTS

Assessing the role of OW expansion in climate change across global markets:

The publication “Future Global Offshore Wind Energy Under Climate Change and Advanced Wind Turbine Technology” (Jung, Sander and Schindler 2024, pp. 1–2) analyzes OW growth, finding technology more influential than climate shifts, with capacity and space for key future output.

The study analyses 33 nations, identifying key regions across six continents.

The study shows that OW’s capacity factors will decline 80% of sites by 2054, especially under high emission scenarios. Brazil sees slight increases, while China may lead in yield by 2030. Location and turbine choice, particularly the NREL model, are key, with minimal impact from climate events (Jung, Sander and Schindler 2024, pp. 15–16).

Key gaps include climate impacts on OW infrastructure, limited data on advanced turbines, and effects on marine ecosystems.

Climate benefits and economic viability & challenges and opportunities for OW:

The study “The Global Climate Value of Offshore Wind Energy” (Cranmer and Baker 2020) proposes an strategy to aligning emission reduction costs and efficiency in OW, tackling greenhouse cuts and economic gains across policy and technology scenarios.

The study uses a GCAM model to compare total costs with and without the technology, considering emissions and climate damage. Even with conservative assumptions, OW shows strong returns, \$24.6 billion to \$2.5 trillion. Its value increases with technological advances and cost reductions, while regional and policy differences influence benefits. The findings emphasize the need for investments in R&D, as climate benefits far outweigh costs.

Further studies should incorporate a regional component.

An important study was carried out by Wu et al. (2018) aiming to identify obstacles to OW development in China through literature analysis, using the Grey-DEMATEL method, to model complexity, assess causality, and prioritize challenges.

The study highlights the challenges in China’s OW developments, including fragmented coordination, lack of financial incentives, inadequate standards, and labor shortage. Barriers are grouped into causes – like policy gaps and skill deficits – and effects driven by external factors such as high capital costs.

Further studies should expand research on global trends and long-term policy strategies.

A study by González et al. (2024) analyzes OW development in emerging markets like Brazil, South Africa, India, Poland, and Turkey, proposing a supply chain framework from literature and case analysis to guide policymakers.

Based on 107 articles it compares mature and new markets, mapping growth factors across the OW life cycle. The findings stress that political support, local capacity, and public-private collaboration are key to OW success. The framework guides investments, infrastructure, and policy for sustainable growth.

Future research should focus on addressing key ecological, social, and regional challenges.

Guiding strategic development for OW industrialization in emerging markets:

A study by Satriano et al. (2024) provides an analysis for 30 developing countries from 1998-2022, examining the impact of renewable energy, environmental quality, and energy consumption on economic growth.

The study finds that sustainable energy ecological quality boosts growth, while general energy use and natural gas show no significant impact. Positive effects stem from foreign investment and population growth, while trade openness and workforce size show limited influence, underlining the importance of strategic infrastructure investment and clean energy policies.

Future research should explore the economic, political, and infrastructure factors on sustainability.

Synergies between renewables, innovation, and sustainable development:

A study by Fang et al. (2025) analyses how renewables, innovation and ecological quality interact with SDG's in developing countries, using South Africa 1990-2018 as a case to explore causal links via DARDL model and spectral tests and support sustainable policy strategies (Fang *et al.* 2025, pp. 561–564).

The Synergy Effects study shows that renewables, innovation, and ecological quality together promote sustainable development in developing countries, calling for low-carbon economies via supportive policies, tech investments, and clean energy.

Further research should explore regional and socio-economic variations, and external global factors like geopolitics, that shape renewable energy sustainability.

Social Acceptance and Economic Impact:

The study “Investment in Offshore Wind Energy in Poland and Its Impact on Public Opinion” (Chomać-Pierzecka 2024) reveals that 68% of respondents support the OW project, a 5% increase from the previous year. 65% see economic benefits like lower energy costs, while 53% believe that OW drives regional job growth.

Support is strongest among people under 30 and logistic regression shows strong links between OW support and broader energy transition. Despite its lim-

ited geographic scope, the findings underscore the growing acceptance of OW as a sustainable and economical source.

Further research should expand the scope, regional insights, and economic analysis.

Environmental and regulatory dimension:

The study “Environmental Impacts of Global Offshore Wind Energy Development until 2040” (Li *et al.* 2022) aims to assess OW’s ecological impact through 2040, focussing on emissions, ecosystems, resource use, and technologies that mitigate environmental effects.

The study finds that by 2040, OW could reach 342-562GW capacity, cutting environmental impact per MWh, about 20% and reducing lifecycle emissions through 6-9% gain from recycling, despite 2.6-3.6Gt CO₂e projected emissions. (Li *et al.* 2022).

A deeper analysis of political and regulatory frameworks could clarify global demand for recycled OW materials across their lifecycle.

Policies, challenges and regional potential:

A report by RCREEE (2024) aims to provide a comprehensive overview of the current regulatory framework, strategic plans, and policies for OW in the Mediterranean region by analyzing the national regulations and strategies, underlining growth opportunities and regional potential, how effective policies can be adopted, and how OW contributes to a sustainable energy transition (RCREEE 2024, p. 6).

The study combines environmental, economic, and social aspects, and national regulations to benchmark OW against other marine renewables. It identifies OW fixed-bottom turbines as cost-effective, floating platforms as emerging, and OW as promising, despite ecological risks and investment gaps.

Building on these studies, it could be examined how regulatory and political strategies are harmonized in the context of the Regional Approach, especially with regard to different political frameworks and regulations.

Structural design and implementation strategies:

The study “Future Obstacles and Possible Solutions for Offshore Wind Facilities” (Deb, Rana and Agili 2024) explores OW turbine evolution, focusing on fixed and floating foundations, and layout optimization using static, frequency-based assessments and temporal-domain analysis, supported by recent studies to develop a comprehensive roadmap (Deb, Rana and Agili 2024, pp. 9–10).

The study emphasises OW’s growing role in CO₂ reduction and energy security, while addressing technical, economic, and environmental challenges through innovations in design, floating foundation systems, modularity, hydrogen integration, and workforce development. Site selection is highlighted as a crucial factor that, when guided by a multidisciplinary approach based on physical, political, and global regulations, can reduce conflicts, balance maritime interests, and speed up approvals.

CONCLUSION

On the basis of the reviewed literature, we can make the following conclusions:

1. Climate and environmental impact:

OW is vital for climate goals, economic growth, and socio-economic development in emerging countries, offering a low-CO₂ electricity as a sustainable fossil fuel alternative.

2. Economic and industrial development and market expansion:

OW offers a sustainable alternative to fossil fuels, supports marine conservation, and fosters economic development. At the same time, positive perception, job creation, and regional investment drive regional development.

Figure 1 outlines a strategy for developing the OW sector in new markets, detailing four life cycle phases that reveal key challenges, opportunities, and stakeholder connections.

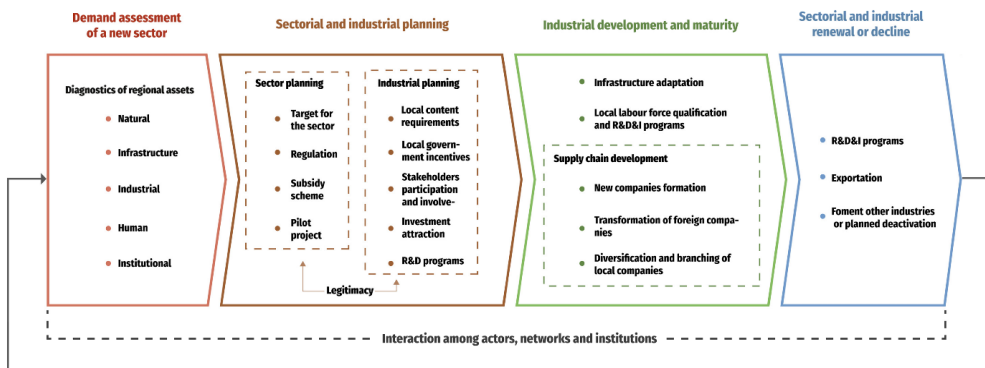


Figure 1. Framework for industrial development of the offshore wind sector in new markets. (González et al. 2024)

3. Socio-economic advancements:

The study “The Synergy of Renewable Energy Consumption, Technological Innovation, and Ecological Quality: SDG Policy Proposals for Developing Countries” shows how technological progress improves living standards and social development.

4. Technological and regulatory challenges:

Challenges remain in developing regulatory frameworks. However, new approaches to floating wind turbine technologies for deeper waters (still in their early stages), paired with improved supply chains could drive long-term advances in OW technologies.

Policy recommendations and future directions:

The findings show that OW can drive sustainable growth and climate protec-

tion in emerging countries. Required is greater intergovernmental cooperation on site planning, technology, and policy support.

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ОФШОРНА ВЯТЪРНА ЕНЕРГИЯ НА КРЪСТОПЪТ: АНАЛИЗ НА ВЪЗМОЖНОСТИТЕ, ПРЕДИЗВИКАТЕЛСТВОТА И СТРАТЕГИЧЕСКИТЕ ПОДХОДИ

Резюме: Глобалният преход към възобновяеми енергийни източници – особено офшорната вятърна енергия (OW) – насърчава действията за климата, икономическия растеж и устойчивото развитие, особено в развиващите се страни. Въпреки положителното развитие и перспективи, много държави, особено развиващите се и нововъзникващи пазари, се сблъскват с различни сложни предизвикателства, като осигуряване на регулаторна подкрепа и справяне с екологични проблеми. Настоящото изследване използва критичен преглед на литературата, за да оцени стратегическата роля на OW в насърчаването на нисковъглеродна енергия, създаването на работни места и опазването на екосистемите. Въпреки напредъка остават предизвикателства, като пропуски в регулациите и екологични рискове. Резултатите подчертават потенциала на OW и необходимостта от силно правителствено сътрудничество и подкрепящи рамки за преодоляване на бариери и насочване към дългосрочно развитие. Те предоставят задълбочено разбиране за стратегическото планиране на OW проекти и влиянието на институционалните условия върху тяхната реализация.

Ключови думи: офшорна вятърна енергия; развиващи се пазари; възобновяема енергия; устойчивост; чиста енергия

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