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Socio-Economic Assessment of Wind and Tidal Energy in Maritime Regions: Advancing SDG 7 Through Renewable Energy Development

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Abstract. This study evaluates the comparative socio-economic impacts of wind and tidal energy in maritime regions, specifically examining their contribution to achieving SDG 7 (Affordable and Clean Energy) through job creation, economic benefits, and sustainable energy production. The research employs sustainable energy transition theories and socio-economic impact assessment models, incorporating frameworks for renewable energy development in coastal regions and SDG implementation strategies. A mixed-methods approach combines quantitative analysis of economic indicators (employment, revenue, tariffs) with qualitative assessment of stakeholder perspectives. Data collection included document analysis, stakeholder interviews, and comparative case studies of wind and tidal energy projects. Analysis reveals wind energy's superior immediate economic viability, generating 3.68 jobs/MW during construction with competitive tariffs (7-8 cents/kWh). Tidal energy demonstrates higher job intensity (9 jobs/MW) but faces higher operational costs. Both technologies show distinct environmental impacts and stakeholder acceptance patterns, contributing differently to SDG 7 targets through clean energy provision and economic development. The findings provide evidence-based guidance for policymakers implementing SDG 7 in maritime regions, offering insights into optimizing renewable energy development for both economic benefit and sustainable development goals. This research presents a novel comparative analysis integrating socio-economic impacts with SDG 7 objectives, providing practical insights for sustainable energy development in maritime regions.

Keywords: Energy, Maritime Development, Renewable, SDG 7, Sustainable Development, Tidal Energy, Wind Energy.

1. INTRODUCTION

The global transition to renewable energy stands as a cornerstone in achieving the United Nations Sustainable Development Goals, particularly SDG 7, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all. As maritime regions worldwide seek to contribute to this goal while fostering economic development, the choice between different renewable energy technologies becomes increasingly significant. Wind and tidal energy emerge as prominent options for these regions, each offering distinct advantages and challenges in the pursuit of sustainable development.

The imperative to develop renewable energy sources is driven by multiple factors: the urgent need to address climate change, increasing energy security demands, and the potential for economic growth through green technology development. Maritime regions are uniquely positioned in this transition, possessing both wind and tidal resources that could contribute significantly to clean energy production. However, the socio-economic implications of choosing between these technologies, or implementing them in combination, remain insufficiently understood.

Recent developments in both wind and tidal energy technologies have demonstrated their potential for contributing to SDG 7 targets. Wind energy has shown remarkable growth globally, with technological improvements driving down costs and increasing efficiency. Tidal energy, while less developed commercially, offers the advantage of predictability and could provide stable baseload power for coastal communities. The choice between these technologies, or their optimal combination, requires careful consideration of their respective socio-economic impacts within the maritime context.

The significance of this research lies in its comprehensive examination of how wind and tidal energy projects compare in their ability to deliver both clean energy solutions and socio-economic benefits to maritime communities. This study addresses a critical gap in current knowledge by providing a detailed comparative analysis of job creation potential, economic impacts, environmental considerations, and stakeholder perspectives for both technologies. Understanding these aspects is crucial for policymakers and stakeholders working to implement SDG 7 while maximizing local economic benefits.

This research seeks to answer the fundamental question: How do wind and tidal energy projects compare in terms of their socio-economic viability and contribution to SDG 7 in maritime regions? By examining factors such as job creation, revenue generation, environmental impacts, and community acceptance, this study aims to provide evidence-based insights for decision-makers in maritime regions pursuing sustainable energy development.

The timing of this research is particularly relevant as governments worldwide accelerate their efforts to meet SDG targets by 2030. Maritime regions face unique opportunities and challenges in this transition, as they often possess abundant renewable resources but must carefully balance energy development with existing marine industries, environmental conservation, and community interests. The findings of this study will contribute to informed decision-making in renewable energy planning and implementation, supporting the achievement of both sustainable development goals and local economic objectives.

2. THEORETICAL FRAMEWORK

The analysis of renewable energy development in maritime regions requires a multifaceted theoretical

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foundation that encompasses environmental, social, and economic dimensions. This research integrates several key theoretical frameworks to provide a comprehensive understanding of wind and tidal energy's socio-economic impacts while supporting SDG 7 implementation.

At its core, Sustainable Development Theory serves as the primary theoretical foundation, particularly in its application to SDG 7. As Soergel et al. (2024) emphasize, this theory articulates the critical balance between economic advancement, environmental stewardship, and social equity in energy development. Building on this foundation, Ahmad et al. (2024) have expanded our theoretical understanding by demonstrating how energy transition policies effectively contribute to sustainable development objectives across different regional contexts, with relevance to maritime settings.

Energy Transition Theory further enriches our theoretical framework by elucidating the processes through which societies transform their energy systems. Recent work in "The Energy Transition: Navigating the Realities" (2024) has enhanced this theoretical perspective by developing robust approaches for assessing wind energy potential under climate change scenarios. Complementing this work, Shangguan et al. (2024) have advanced the theory by examining hybrid energy systems in maritime contexts, revealing crucial synergies between different renewable technologies for enhancing system reliability and efficiency.

Social Impact Assessment Theory provides essential insights into the human dimensions of renewable energy development. Viktorelius et al. (2022) have strengthened this theoretical framework through their comprehensive analysis of Indigenous perspectives and community engagement principles. Further theoretical development by Caballero et al. (2023) has illuminated how Indigenous Economic Development Corporations can effectively participate in and benefit from renewable energy projects, adding crucial understanding to the social dynamics of energy transitions.

Stakeholder Engagement Theory builds upon these social considerations by offering structured approaches for understanding stakeholder interactions in renewable energy development. Nguyen et al. (2024) have established fundamental principles for stakeholder engagement in Marine Renewable Energy projects, while Hurlbert et al. (2024) have advanced our theoretical understanding of community perception formation through deliberative processes. Together, these contributions underscore the crucial role of community acceptance in project success.

Environmental Impact Assessment Theory provides systematic approaches for evaluating ecological implications of renewable energy projects. Grove et al. (2024) and Kirk et al. (2024) have strengthened this theoretical foundation through their analysis of tidal lagoon interactions. This work has been further enhanced by comprehensive studies from the Task Force on Sustainable Tidal Energy Development (2024) and Grandjean et al. (2024), who have expanded the theoretical framework to address specific considerations for maritime environments and coastal communities under climate change conditions.

The evolution of Technological Innovation Systems theory, particularly in its application to renewable energy, has been marked by significant recent developments. Feng et al. (2024) have enhanced this theoretical framework through their examination of technological innovation in offshore wind platforms, while recent environmental impact studies (New Report on Environmental Effects of Marine Renewable Energy, 2024) have contributed to our understanding of how technological advancement intersects with environmental and social considerations.

The synthesis of these theoretical frameworks - Sustainable Development, Energy Transition, Social Impact Assessment, Stakeholder Engagement, Environmental Impact Assessment, and Technological Innovation Systems - creates a comprehensive analytical lens for examining renewable energy development in maritime regions. As Nawaz & Lezaun (2024) and Bach et al. (2024) argue, these interconnected theoretical perspectives enable us to understand how different aspects of renewable energy development interact and influence each other. This integrated theoretical approach provides the foundation for analyzing how wind and tidal energy projects can simultaneously address technological feasibility, economic viability, social acceptance, environmental sustainability, and governance structures while contributing to SDG 7 implementation (Soergel et al., 2024). Through this theoretical synthesis, we establish a robust framework for evaluating the comparative socio-economic impacts of wind and tidal energy in maritime settings.

3. METHODOLOGY

This research employs a comprehensive mixed-methods approach to evaluate the socio-economic viability of wind and tidal energy in maritime regions, with particular focus on their contribution to SDG 7 implementation. The methodology integrates quantitative economic analysis with qualitative assessment of stakeholder perspectives to provide a holistic understanding of renewable energy impacts.

Data collection proceeded through three main channels. First, we gathered quantitative economic data from existing wind and tidal energy projects, focusing on key performance indicators including employment generation, revenue streams, and electricity tariffs. This data was standardized to enable meaningful comparisons between projects of different scales, with financial figures converted to current values and normalized to per-megawatt metrics where appropriate. Project documentation, economic impact assessments, and industry reports provided primary sources for this quantitative data.

Second, we conducted semi-structured interviews with key stakeholders to capture qualitative insights into project impacts and implementation challenges. Interview participants included government officials responsible for energy policy, renewable energy project developers, local community leaders, Indigenous representatives, and environmental experts. These interviews followed a standardized protocol while allowing flexibility to explore emerging themes. All interviews were recorded with participant consent, transcribed, and systematically coded for analysis.

Third, we analyzed policy documents and regulatory frameworks to understand the governance context for renewable energy development. This analysis included reviewing energy policies, development strategies, and regulatory requirements affecting wind and tidal energy projects, with particular attention to their alignment with SDG 7 objectives.

Our analytical framework combined several approaches to ensure robust results. Quantitative analysis focused on comparing economic impacts across different project types and scales, using standardized metrics to enable meaningful comparisons. We employed statistical analysis to identify patterns in employment generation, revenue distribution, and cost structures. For job creation analysis, we distinguished between construction and operational phases, calculating both absolute numbers and per-megawatt ratios to understand scale effects.

Qualitative data analysis followed a systematic coding approach to identify key themes and patterns in stakeholder perspectives. We used qualitative analysis software to code interview transcripts, focusing on themes including community acceptance, environmental concerns, economic benefits, and implementation challenges. This analysis paid particular attention to Indigenous perspectives and local community impacts.

Environmental impact assessment integrated both quantitative metrics and qualitative stakeholder perspectives. We analyzed environmental assessment reports and monitor data while considering stakeholder views on environmental effects and mitigation strategies. This dual approach enabled us to understand both measurable environmental impacts and community perceptions of environmental change.

To ensure research quality and reliability, we employed several validation strategies. These included triangulation of data from multiple sources, member checking of interview transcripts, and peer review of analysis procedures. We also carefully documented all data collection and analysis procedures to ensure reproducibility.

The methodology acknowledges several limitations. These include potential data gaps in newer tidal energy projects, challenges in standardizing economic impacts across different contexts, and the inherent complexity of comparing technologies at different maturity levels. We addressed these limitations through careful data validation and transparent reporting of methodological constraints.

4. RESULTS AND DISCUSSION

The comparative analysis of wind and tidal energy projects reveals significant patterns in their socio-economic impacts and contributions to sustainable development in maritime regions. Employment generation emerges as a key differentiator between these technologies, with distinct patterns observed across project phases. Table 1 Presents the job creation comparison between wind and tidal energy projects during both construction and operational phases.

Table 1: Job Creation Comparison - Wind vs. Tidal Energy.

Energy Type	Phase	Jobs per MW
Wind Energy	Construction	3.68
	Operational	0.16
Tidal Energy	Construction	9.00
	Operational	0.30

As shown in Table 1, wind energy projects demonstrate substantial job creation during construction, generating approximately 3.68 jobs per megawatt of installed capacity. In comparison, tidal energy projects show higher job intensity during construction, creating about 9 jobs per megawatt, though typically at a smaller absolute scale due to smaller project sizes. This higher job intensity in tidal energy projects suggests value for local workforce development, especially in coastal communities seeking to develop specialized technical skills.

The economic impacts of these renewable energy projects extend beyond direct employment, encompassing various channels of financial benefit to local communities. Figure 1 illustrates the breakdown of local economic benefits across different categories.

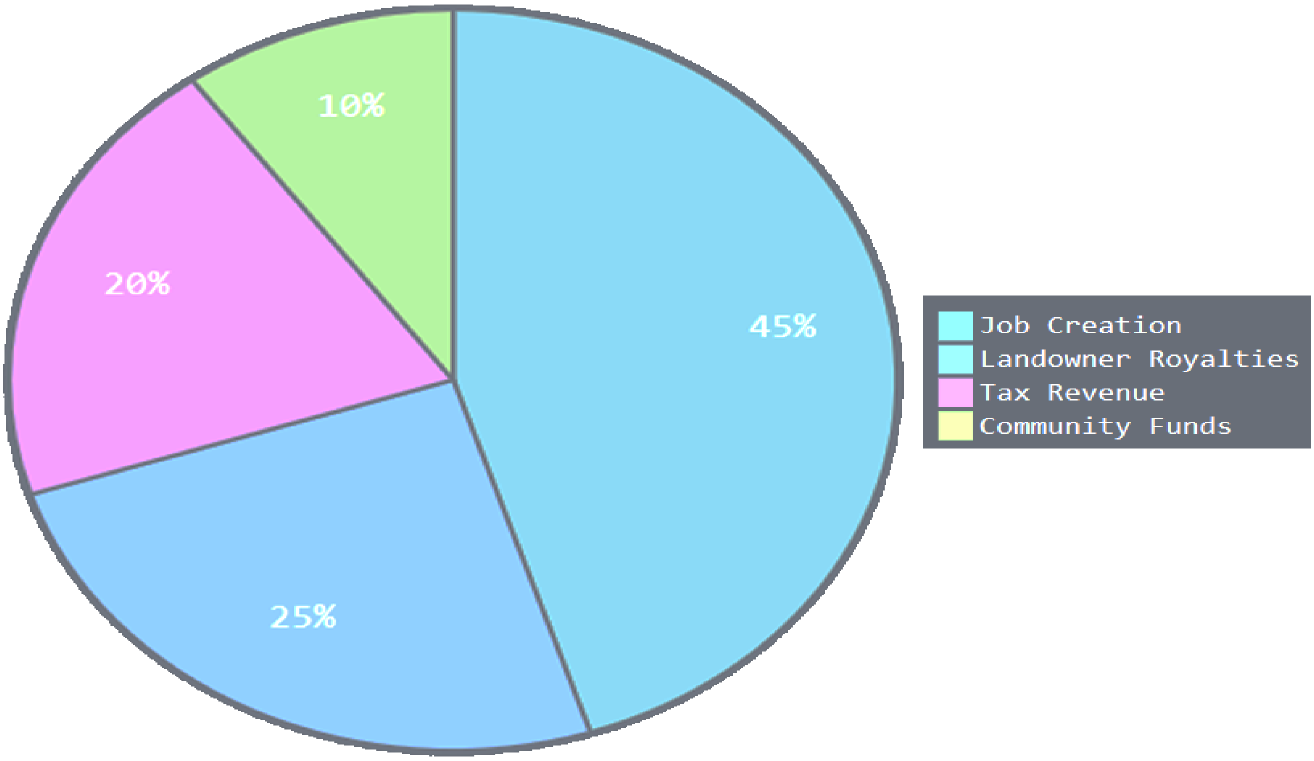

Figure 1: Breakdown of Local Economic Benefits.

As demonstrated in Figure 1, job creation represents the largest share (45%) of local economic benefits, followed by landowner royalties (25%), tax revenue (20%), and community funds (10%). These proportions reflect the comprehensive nature of economic impacts generated by renewable energy projects in maritime regions.

Table 2 provides a detailed comparison of the economic impacts between wind and tidal energy projects.

Table 2: Economic Impact Comparison.

Economic Indicator	Wind Energy (100 MW)	Tidal Energy (5 MW)
Annual Landowner Royalties	$500,000	N/A
Annual Community Fund	N/A	$200,000
Annual Tax Revenue	$934,852	$562 (estimated)
Tax Revenue per MW	$9,348	$112
Electricity Tariff	7-8 cents/kWh	15-20 cents/kWh

The economic data presented in Table 2 reveals significant differences in the financial structures of wind and tidal energy projects. Wind energy projects demonstrate stronger performance in terms of tax revenue generation and lower electricity tariffs, while tidal energy projects show innovative approaches to community benefit distribution.

Environmental considerations and stakeholder perceptions play crucial roles in project development and implementation. Figure 2 presents the distribution of stakeholder perceptions regarding renewable energy projects in maritime regions.

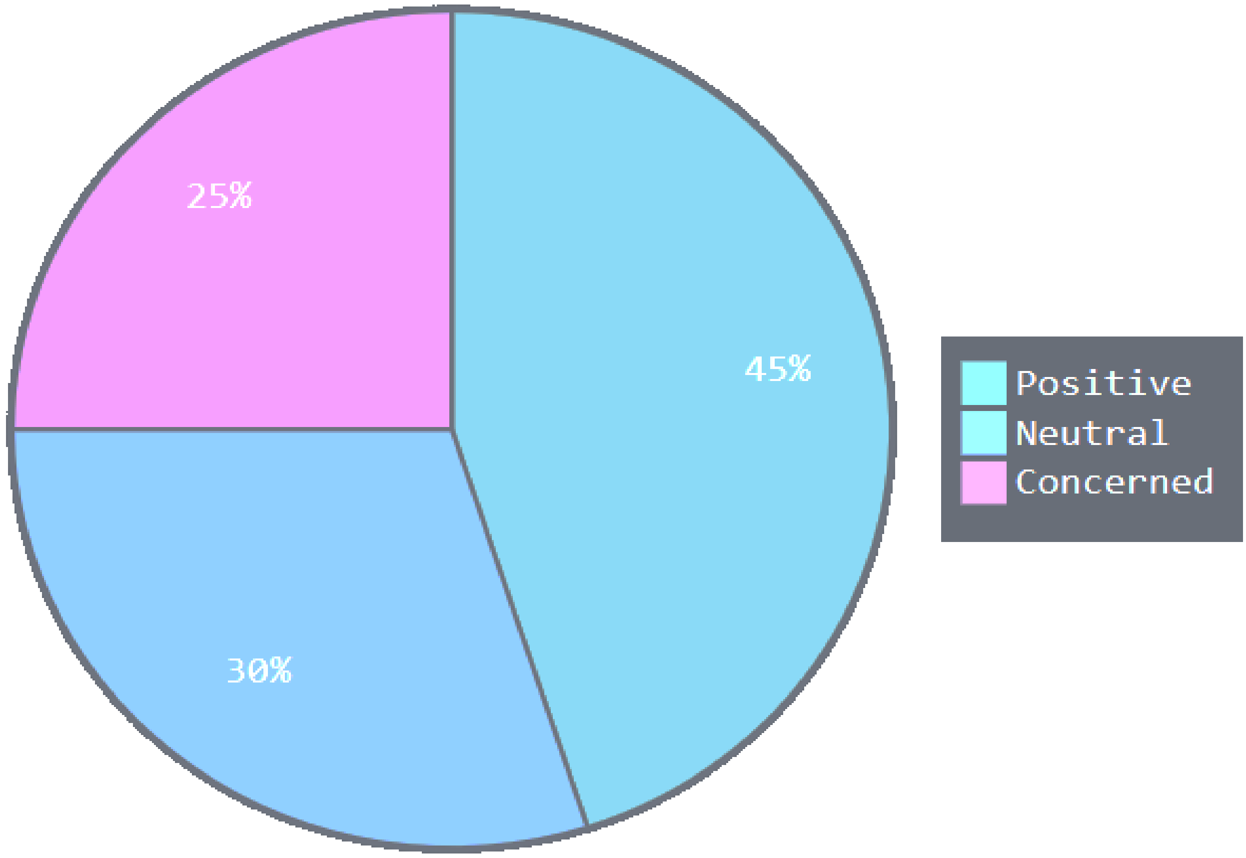

Figure 2: Stakeholder Perceptions.

As illustrated in Figure 2, stakeholder perceptions show a generally positive trend, with 45% expressing positive views toward renewable energy development. However, the significant proportion of neutral (30%) and concerned (25%) stakeholders highlight the importance of comprehensive engagement strategies and careful consideration of local impacts.

The environmental impacts of both technologies present distinct challenges and opportunities, as detailed in Table 3.

Table 3: Environmental Impact Comparison.

Environmental Factor	Wind Energy	Tidal Energy
Visual Impact	High	Low
Noise Pollution	Moderate	Low
Wildlife Impact	Birds, Bats	Marine Life
Land Use	Extensive	Minimal
GHG Emissions	Very Low	Very Low
Ecosystem Alteration	Moderate	High

As shown in Table 3, the environmental impacts of wind and tidal energy present distinct challenges. Wind energy projects face significant concerns regarding visual impact and land use, while tidal energy projects must address potential effects on marine ecosystems. Both technologies demonstrate very low greenhouse gas emissions, directly supporting SDG 7's objective of increasing renewable energy in the global energy mix. The moderate ecosystem alteration from wind projects primarily relates to habitat fragmentation and changes in local microclimate, while the high ecosystem alteration in tidal projects reflects the more intensive interaction with marine environments.

Stakeholder interviews reveal that environmental concerns significantly influence project acceptance and implementation strategies. Wind energy developers have responded to these challenges by implementing wildlife monitoring programs and adopting newer turbine designs that reduce bird and bat collisions. Similarly, tidal energy projects have incorporated extensive marine life monitoring systems and adaptive management approaches to minimize impacts on marine ecosystems.

The analysis of electricity tariffs and economic viability reveals important implications for achieving SDG 7's goal of ensuring access to affordable energy. Wind energy's lower tariffs (7-8 cents/kWh) make it more immediately accessible for large-scale deployment, while tidal energy's higher current costs (15-20 cents/kWh) suggest the need for continued technological development and policy support to improve competitiveness. However, tidal energy's predictability offers valuable grid stability benefits that may justify premium tariffs in certain contexts.

The stakeholder perception data presented in Figure 2 highlights the importance of community engagement in renewable energy development. The 45% positive perception rate suggests growing acceptance of renewable energy technologies, while the significant proportion of neutral (30%) and (25%) stakeholders indicate opportunities for improved engagement and benefit-sharing arrangements. Indigenous communities have expressed strong interest in participating in renewable energy projects, viewing them as opportunities for economic development while maintaining environmental stewardship.

The economic benefits analysis, illustrated in Figure 1, demonstrates the multi-faceted nature of renewable energy's contribution to local economies. The dominance of job creation (45%) in the benefit distribution highlights the sector's potential for supporting sustainable economic development in maritime regions. The significant contribution of landowner royalties (25%) and tax revenue (20%) indicates substantial financial flows to both private landowners and public entities, while community funds (10%) provide direct support for local development initiatives.

Policy implications emerging from this analysis suggest the need for differentiated but complementary support mechanisms for wind and tidal energy development. While wind energy benefits from established regulatory frameworks and proven technology, tidal energy requires targeted policy support to overcome current cost barriers and accelerate technological development. This dual approach aligns with SDG 7's emphasis on expanding renewable energy access while promoting innovation and technological advancement.

The research findings suggest that maritime regions can optimize their renewable energy development through a balanced approach that leverages the strengths of both wind and tidal technologies. Large-scale wind projects can provide cost-effective renewable energy and significant economic benefits, while strategic deployment of tidal energy projects can foster technological innovation, create specialized employment opportunities, and contribute to energy system resilience.

This comprehensive analysis demonstrates that both wind and tidal energy contribute significantly to sustainable development in maritime regions, though through different mechanisms and with varying challenges. The success of these renewable energy projects in supporting SDG 7 implementation depends on careful consideration of local contexts, meaningful stakeholder engagement, and appropriate policy frameworks that recognize and support the distinct characteristics and requirements of each technology.

5. CONCLUSION

This comparative analysis of wind and tidal energy in maritime regions has revealed significant insights into their socio-economic viability and contributions to sustainable development goals. The research findings demonstrate that both technologies offer distinct advantages and challenges in supporting the transition to renewable energy while providing economic benefits to local communities.

The study's results highlight the complementary nature of wind and tidal energy in maritime regions. Wind energy demonstrates immediate economic viability through lower electricity tariffs (7-8 cents/kWh) and significant job creation during construction (3.68 jobs/MW), while tidal energy shows promise for specialized skill development and higher job intensity (9 jobs/MW), albeit at currently higher operational costs. These findings suggest that a diversified approach to renewable energy development can optimize both economic benefits and contributions to SDG 7 implementation.

Our analysis reveals several critical factors for successful renewable energy development in maritime regions. First, project scale significantly influences both economic viability and social impacts, with larger wind projects benefiting from economies of scale while smaller tidal projects often achieve stronger community acceptance. Second, stakeholder engagement emerges as crucial for project success, particularly regarding Indigenous participation and benefit-sharing arrangements. Third, environmental considerations require careful balance, with wind projects facing visual impact challenges and tidal projects requiring careful management of marine ecosystem effects.

Based on these findings, we recommend several key actions for policymakers and stakeholders in maritime regions. First, develop comprehensive renewable energy strategies that leverage the complementary strengths of wind and tidal technologies. Second, establish targeted support mechanisms for tidal energy development to improve cost competitiveness while maintaining focus on local economic benefits. Third, implement robust stakeholder engagement frameworks that ensure meaningful community participation throughout project lifecycles. Fourth, create specialized workforce development programs to support the growth of technical skills required by both sectors.

The study also identifies important areas for future research. Further investigation is needed into the long-term socio-economic impacts of renewable energy projects in maritime communities, particularly regarding job creation sustainability and community benefit distribution. Additional research should explore innovative approaches to reducing tidal energy costs while maximizing local economic benefits. Studies examining the integration of wind and tidal energy systems could provide valuable insights into optimizing renewable energy deployment in maritime regions.

The research contributes to existing knowledge by providing a comprehensive comparative analysis of wind and tidal energy's socio-economic impacts in maritime contexts. It extends the current understanding of how different renewable energy technologies can support SDG 7 implementation while generating local economic benefits. The findings offer practical insights for policymakers and stakeholders working to advance sustainable energy development in maritime regions.

Finally, this study demonstrates that successful renewable energy development in maritime regions requires careful consideration of multiple factors, including economic viability, environmental impacts, social acceptance, and policy frameworks. The path forward involves balancing these considerations while maintaining focus on both immediate energy needs and long-term sustainable development goals. Through thoughtful planning and implementation, maritime regions can leverage both wind and tidal energy to create sustainable energy systems that benefit local communities while contributing to global climate change mitigation efforts.

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