J E M T
Journal of Earth and Marine Technology
homepage URL: ejurnal.itats.ac.id/jemt

Integration of Renewable Energy and Blue Carbon Ecosystems for Coastal Climate Change Mitigation and Adaptation in Indonesia's Oil and Gas Industry

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Article info
Received:
Dec 21, 2023
Revised:
Feb 24, 2024
Accepted:
Mar 20, 2024
Published:
Mar 31, 2024

Keywords:
Blue-carbon, coastal ecosystems, renewable energy, climate change mitigation, adaptation, oil and gas industry

Abstract
This study investigates the potential of integrating renewable energy and the ecosystems of blue-carbon for coastal climate change adaptation and mitigation in Indonesia's upstream and downstream oil and gas industry. The urgency for the integration is also discussed, including climate change mitigation, energy security, technological innovation, social and environmental justice, and long-term planning and resilience. The study uses Army Design Methodology to identify the key challenges and opportunities of integrating renewable energy and blue carbon ecosystems. The findings suggest that the integration of renewable energy and blue carbon ecosystems can play a crucial role in coastal climate change mitigation and adaptation, particularly in Indonesia's oil and gas industry. The paper concludes with recommendations for further research and policy development in this area.

1. Introduction

The Indonesian oil and gas sector is vital to the country's economy, contributing to job creation, energy security, and economic progress. However, the sector confronts other obstacles, including the effects of climate change, environmental degradation, and regulatory compliance. Although the combustion of fossil fuels (e.g coal, oil, and gas) contributes significantly to greenhouse gas emissions and climate change, the effects of climate change, such as sea level rise, storm surges, and extreme weather events, can disrupt infrastructure and operations, and the oil and gas sector is particularly susceptible to these effects [1]. On the other hand, the techniques used to extract and produce oil and gas may has substantial negative impacts on the environment, including soil contamination, water pollution, and the loss of habitats [2]. These effects may be detrimental to ecosystem health, human health, and biodiversity. This problem created a “trilemma” for Indonesia which still depends on the oil and gas sector to meet its energy demand.

Due to the “trilemma” that has been shown by [3], one of many methods that may balance it could be the concept of carbon capture, utilization, and storage (CCUS). The CCUS concept became a trending topic in the last 2 years due to the pressure that followed the Net Zero Emissions target [4, 5]. However, as the implementation of the CCUS concept is still in the early phase and expensive, these issues may be resolved by integrating blue carbon ecosystems with renewable energy sources as alternatives and may open up possibilities for resilient coastal communities and sustainable development [6]. Integrating renewable energy and blue carbon ecosystems could present another potential solution that still adheres

to the CCUS concept. In addition, renewable energy sources provide a sustainable substitute for fossil fuels, lowering greenhouse gas emissions and lessening the effects of climate change while the blue carbon ecosystems can capture and store carbon up to six times greater than terrestrial forests.

Hence, this study aimed to investigate the potential of integrating renewable energy and the ecosystems of blue carbon for coastal climate change adaptation and mitigation in Indonesia's upstream and downstream oil and gas industry. The paper uses the Army Design Methodology to identify the key challenges and opportunities of integrating renewable energy and blue carbon ecosystems and proposes alternative methodologies for data collection and analysis. This study will highlight the importance of sustainable development and resilience in coastal communities, and the potential of renewable energy and blue carbon ecosystems to contribute to these goals. The paper also emphasizes the need for collaboration and coordination among key stakeholders, including the government, oil and gas companies, and local communities, to ensure the successful implementation of these solutions. The study later will conclude with recommendations for further research and policy development in this area, including prioritizing the protection and restoration of the ecosystem of the blue-carbon, diversifying energy sources, and promoting sustainable development and resilience in coastal communities.

2. Methodology

The methodology section of this research paper provides a detailed description of the Army Design Methodology (ADM) and the data sources that could be used to collect data for the methodology. ADM is a process for understanding, visualizing, and describing new challenges by using critical and creative thinking. [7]. The methodology consists of several steps, including framing the problem, developing a preliminary understanding of the operational environment, identifying critical and decisive points, and developing and testing hypotheses as shown in Figure 1. ADM is particularly useful for complex and uncertain problems, such as those facing the oil and gas industry in Indonesia.

As shown in Figure 1, ADM consists of a three-step approach that employs critical and creative thinking to comprehend, conceptualize, define, and construct solutions to complicated issues. The first step is to create an environmental frame that includes both the present and desired settings. The problem can be framed in the second stage so that a better comprehension can be achieved regarding what is inhibiting progress towards the intended end state. The third phase in the design methodology is the creation of an operational strategy that outlines broad activities that may be taken to solve the problem. This method, known as the philosophy of victory, serves as the conceptual framework for the specific strategy.

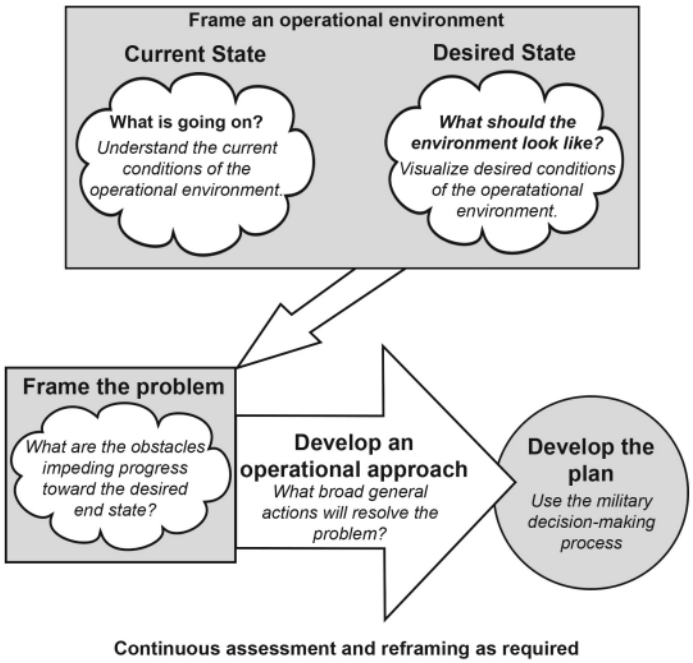

Figure 1. Army Design Methodology Flowchart [6].

Table 1. The Environmental Frame of ADM.

No.	Present Settings	Desired Settings
1	High dependence on fossil fuels	Diversified energy sources, including renewable energy
2	Limited protection and restoration of blue-carbon ecosystems	Prioritized protection and the restoration of blue-carbon ecosystems
3	Limited coordination and integration among key stakeholders	Collaborative and coordinated efforts among key stakeholders
4	Limited awareness and understanding of the benefits of renewable energy and blue-carbon ecosystems	Increased awareness and understanding of the benefits of renewable energy and blue carbon ecosystems
5	Limited policy and regulatory support for renewable energy and blue-carbon ecosystems	Strong policy and regulatory support for renewable energy and blue-carbon ecosystems

Hence, to fulfill the ADM requirement, this study has used a list of reports and publications that was compiled by [8] to collect data for ADM related to renewable energy, blue carbon ecosystems, and the oil and gas industry in Indonesia. The reports were selected based on their relevance, reliability, and validity, and were obtained from reputable sources such as government agencies, academic institutions, and international organizations. However, due to limited reports that could be used in conjunction with the topic, this study used five selected agencies to become the main sources of the references: The Blue Carbon Initiative (BCI), The Intergovernmental Panel on Climate Change (IPCC), The International Union for Conservation of Nature (IUCN), The United Nations Environment Programme (UNEP), and The World Bank. Overall, the Army Design Methodology provides a structured and systematic approach to problem-solving, enabling the research team to identify the key challenges and opportunities of integrating renewable energy and blue carbon ecosystems for coastal climate change mitigation and adaptation in Indonesia's upstream and downstream oil and gas industry. The methodology also provides a framework for data collection and analysis, ensuring that the research is comprehensive and rigorous.

3. Results and discussions

3.1. The Environmental Frame

For the first step of ADM, the environmental frame for the integration of renewable energy and the ecosystems of the blue carbon for coastal climate change adaptation and mitigation in Indonesia's oil and gas industry consists of the present and desired settings. As shown in Table 1, the result of summarizing from the secondary data source as mentioned in methodology that the present and desired setting is characterized as follows.

The environmental frame in Table 1 provides a comprehensive overview of the present and desired settings for the integration of renewable energy and blue carbon ecosystems in Indonesia's oil and gas industry. The present setting includes high dependence on fossil fuels, limited protection and restoration for the ecosystems of the blue carbon, limited coordination and integration among key stakeholders, limited awareness and understanding of the benefits, and limited policy and regulatory support for renewable energy and blue carbon ecosystems. On the other hand, the desired setting includes diversified energy sources, prioritized protection and restoration for the ecosystems of the blue carbon, collaborative and also coordinated efforts among key stakeholders, increased awareness and understanding of the benefits, and creation of strong policy and regulatory support for renewable energy and blue carbon ecosystems.

The environmental frame also highlights the importance of sustainable development and resilience in coastal communities, which can be achieved through the integration of renewable energy and blue-carbon ecosystems. The socioeconomic circumstances of coastal populations can be improved by the preservation and restoration of the blue carbon ecosystems, which offer chances for employment, food security, and natural barriers against coastal hazards brought on by climate change [9]. Renewable energy sources can also provide employment opportunities and promote economic growth in the energy sector [10, 11, 12]. The environmental frame emphasizes the need for collaboration and coordination

among key stakeholders [13], including the government, oil and gas companies, and local communities, to ensure the successful implementation of these solutions. Overall, the environmental frame provides a human-centered and sustainable approach to the integration of renewable energy and blue carbon ecosystems in Indonesia's oil and gas industry, highlighting the potential benefits and limitations of the proposed solutions. The frame will guide the study in framing the problem and developing solutions that are relevant, feasible, and effective.

3.2. The Problem Frame

The study focuses on the environmental aspects of integrating renewable energy and blue carbon ecosystems in Indonesia's oil and gas industry. The present and desired settings for this study are outlined within the framework, which is the first step of the ADM process. The problem can then be framed as follows in the second step of ADM:

a. **Limited protection and restoration of blue carbon ecosystems**: Blue carbon ecosystems can help mitigate and adapt to climate change [14], but the degree of damage and degradation is concerning, and the ecosystem's health has been threatened by several issues. The problem is how to protect and restore blue carbon ecosystems in Indonesia's oil and gas industry to ensure their long-term viability and sustainability.

b. **High dependence on fossil fuels**: The oil and gas industry in Indonesia is highly dependent on fossil fuels, which contribute to greenhouse gas emissions and climate change [15]. The problem is how to diversify energy sources and reduce dependence on fossil fuels in Indonesia's oil and gas industry.

c. **Limited coordination and integration among key stakeholders**: The integration of renewable energy and blue carbon ecosystems requires collaboration and coordination among key stakeholders, including the government, oil and gas companies, and local communities. The problem is how to improve coordination and integration among key stakeholders to ensure the successful implementation of these solutions.

d. **Limited policy and regulatory support for renewable energy and blue carbon ecosystems**: The oil and gas industry acts as the subject to a complex regulatory framework that governs its operations, including environmental regulations, health and safety standards, and labor laws. The problem is how to improve policy and regulatory support for renewable energy and blue carbon ecosystems in Indonesia's oil and gas industry.

Overall, the problem framing highlights the need for sustainable development and resilience in coastal communities, which can be achieved through the integration of renewable energy and blue carbon ecosystems. The problem framing emphasizes the importance of collaboration and coordination among key stakeholders, including the government, oil and gas companies, and local communities, to ensure the successful implementation of these solutions.

3.3. The Solution Frame

Last, for the final step, based on the problem framing, the operational strategy for the integration of renewable energy and blue carbon ecosystems combined with the strategy advised in [16] for Indonesia's oil and gas industry can be framed as shown in Table 2. The operational strategy for the integration of renewable energy and blue carbon ecosystems in Indonesia's oil and gas industry, as presented in Table 2, outlines broad activities that may be taken to solve the problem of limited protection and restoration of blue carbon ecosystems, high dependence on fossil fuels, limited coordination and integration among key stakeholders, and limited policy and regulatory support for renewable energy and blue carbon ecosystems. The operational strategy is based on the Army Design Methodology (ADM), which emphasizes critical and creative thinking, collaboration and dialogue, framing, visual modeling, and narrative construction. The operational strategy provides a comprehensive and structured approach to the integration of renewable energy and blue carbon ecosystems, highlighting the potential benefits and limitations of the proposed solutions.

Table 2. The Solution Frame of ADM

No.	The Solutions	The Strategies
1	Protect & restore blue-carbon ecosystems	● Create and put into effect municipal and national laws and policies that give the preservation and restoration of blue-carbon ecosystems a priority. ● Conducting research and monitoring to assess the health and status of blue carbon ecosystems and identify areas that require protection and restoration. ● Engaging local communities and other stakeholders in the protection and restoration of blue carbon ecosystems, including through education and awareness-raising campaigns. ● Develop and implement sustainable management practices that balance conservation and economic development.
2	Diversify energy sources	● Create and put into effect municipal, state, and national legislation and regulations that encourage the use of renewable energy sources including geothermal, ocean thermal and wave, wind, and solar power. ● To increase the efficacy and efficiency of renewable energy technology, carry out research and development. ● Providing incentives and subsidies to encourage the adoption of renewable energy sources. ● Engaging local communities and other stakeholders in the development and implementation of renewable energy projects.
3	Improve coordination and integration among key stakeholders	● Develop and implement collaborative governance structures that involve all relevant stakeholders in decision-making processes. ● Establishing communication channels and platforms that facilitate information sharing and coordination among key stakeholders. ● Conduct regular meetings and consultations to ensure that all stakeholders are informed and engaged in the integration of renewable energy and blue carbon ecosystems. ● Developing and implementing capacity-building programs that enhance the skills and knowledge of key stakeholders in the integration of renewable energy and blue carbon ecosystems.
4	Improve policy and regulatory support for renewable energy and blue carbon ecosystems	● Develop and implement national and local policies and regulations that provide incentives and support for the integration of renewable energy and blue carbon ecosystems. ● Conduct research and analysis to identify the economic, social, and environmental benefits of renewable energy and blue carbon ecosystems. ● Engaging with policymakers and regulators to raise awareness of the benefits of renewable energy and blue carbon ecosystems and advocate for policy and regulatory changes. ● Developing and implementing capacity-building programs that enhance the skills and knowledge of policymakers and regulators in the integration of renewable energy and blue carbon ecosystems.

The operational strategy emphasizes the need for collaboration and coordination among key stakeholders, including the government, oil and gas companies, and local communities, to ensure the successful implementation of these solutions. The strategy also highlights the importance of sustainable development and resilience in coastal communities, which can be achieved through the protection and restoration of blue carbon ecosystems and the diversification of energy sources. The operational strategy provides a human-centered and sustainable approach to the integration of renewable energy and blue carbon ecosystems in Indonesia's oil and gas industry, highlighting the potential benefits and limitations of the proposed solutions.

The operational strategy also emphasizes the need for policy and regulatory support for renewable energy and blue carbon ecosystems, which can be achieved through the development and

implementation of national and local policies and regulations, research and analysis, engagement with policymakers and regulators, and capacity-building programs. The operational strategy provides a comprehensive and structured approach to the integration of renewable energy and blue carbon ecosystems, highlighting the potential benefits and limitations of the proposed solutions. The operational strategy provides a roadmap for the successful implementation of the proposed solutions, emphasizing the need for collaboration, coordination, and policy and regulatory support.

4. Conclusion

In conclusion, this study has investigated the potential of integrating renewable energy and the ecosystems of the blue carbon for coastal climate change adaptation and mitigation in Indonesia's upstream and downstream oil and gas industry. It highlighted the importance of sustainable development and resilience in coastal communities, which can be achieved through the protection and restoration of blue carbon ecosystems and the diversification of energy sources. It also emphasized the need for collaboration and coordination among key stakeholders, including the government, oil and gas companies, and local communities, to ensure the successful implementation of these solutions.

Further, the study has used the Army Design Methodology (ADM) to identify the key challenges and opportunities of integrating renewable energy and blue carbon ecosystems. The ADM process has involved several key activities, including framing the operational environment, framing problems, framing solutions, and reframing as necessary while utilizing specific tools, techniques, and key concepts. The study also presented an operational strategy for the integration of renewable energy and blue carbon ecosystems in Indonesia's oil and gas industry, which outlines broad activities that may be taken to solve the problem of limited protection and restoration of blue carbon ecosystems, high dependence on fossil fuels, limited coordination and integration among key stakeholders, and limited policy and regulatory support for renewable energy and blue carbon ecosystems. The operational strategy provides a comprehensive and structured approach to the integration of renewable energy and blue carbon ecosystems, highlighting the potential benefits and limitations of the proposed solutions.

This study has highlighted that there are several potential difficulties in integrating renewable energy and blue carbon ecosystems for coastal climate change adaptation and mitigation in Indonesia's oil and gas sector. However, through the ADM, the study also evaluated that there are a lot of possibilities for integration and provided viable strategies to overcome these problems. The results imply that energy security, socioeconomic growth, and climate change mitigation and adaptation may all be facilitated by the combination of renewable energy and blue carbon ecosystems. The study also has emphasized the need for capacity building and technical support for renewable energy and blue carbon ecosystem management, as well as the necessity of a national plan for managing blue carbon ecosystems and encouraging investments in renewable energy in the oil and gas sector which can contribute to the sustainable development and resilience of coastal communities.

Meanwhile, the study has noted the research's shortcomings, such as a lack of empirical evidence to support the recommended solutions and the need for more research and policy development in this area. Hence in summary, the oil and gas sector in Indonesia has both possibilities and problems in mitigating the effects of coastal climate change and adapting to it as a result of the integration of renewable energy and blue carbon ecosystems. The resilience and sustainable development of coastal communities can be enhanced by the suggested solutions. To ensure the success of these ideas and to promote their implementation, more research and policy development are required. For future research and policy development, this study's recommendations include data collecting and analysis on greenhouse gas emissions, carbon sequestration, energy security, and stakeholder knowledge and ability. The findings of these experiments can help shape policies and strategies to encourage the integration of renewable energy and blue carbon ecosystems into Indonesia's oil and gas sector.

Acknowledgment

We extend our sincere gratitude to *Pusat Penelitian dan Pengembangan* for their unwavering support and funding that have been instrumental in the successful completion of this research. we also want to express our appreciation to Inovastek Glomatra for their valuable contributions, enhancing the depth

and impact of this project. We are thankful for the collaboration and innovative insights provided by both organizations. Additionally, We acknowledge the support from various individuals and institutions whose contributions have played a crucial role in shaping this research. Overall, I am deeply thankful for the collective efforts that have made this endeavor possible.

References:

[1] International Renewable Energy Agency, 'Indonesia energy transition outlook', 2022.
[2] M. A. M. Mohd Noor, 'Environmental Impacts of Oil Industry: An overview of the impacts and source management EEEE Environmental Impacts of Oil Industry: An overview of the impacts and source management', *Environmental Management*, Jan. 2021, doi: 10.30880/eeee.0000.00.00.000.
[3] World Bank Group and Asian Development Bank, *Climate Risk Country Profile: Indonesia*. World Bank, 2021. doi: 10.1596/36379.
[4] C. Bertram, M. Quaas, T. B. H. Reusch, A. T. Vafeidis, C. Wolff, and W. Rickels, 'The blue carbon wealth of nations', *Nat. Clim. Chang.*, vol. 11, no. 8, Art. no. 8, Aug. 2021, doi: 10.1038/s41558-021-01089-4.
[5] P. I. Macreadie *et al.*, 'Blue carbon as a natural climate solution', *Nat Rev Earth Environ*, vol. 2, no. 12, pp. 826–839, Nov. 2021, doi: 10.1038/s43017-021-00224-1.
[6] D. P. Hanak and V. Manovic, 'Linking renewables and fossil fuels with carbon capture via energy storage for a sustainable energy future', *Front. Chem. Sci. Eng.*, vol. 14, no. 3, pp. 453–459, Jun. 2020, doi: 10.1007/s11705-019-1892-2.
[7] A. P. Directorate, *ATP 5-0.1 Army Design Methodology (July 2015)*. Independently Published, 2020.
[8] 'International Blue Carbon Scientific Working Group publications 2011-2022', The Blue Carbon Initiative. Accessed: Dec. 28, 2023. [Online]. Available: https://www.thebluecarboninitiative.org/ibcswgpublications2011-22
[9] C. Feng *et al.*, 'Sustainably developing global blue carbon for climate change mitigation and economic benefits through international cooperation', *Nat Commun*, vol. 14, no. 1, p. 6144, Oct. 2023, doi: 10.1038/s41467-023-41870-x.
[10] IRENA, 'Fostering a blue economy: Offshore renewable energy', 2020.
[11] IRENA and ILO, 'Renewable energy and Jobs: Annual review 2022', 2022.
[12] P. A. Owusu and S. Asumadu-Sarkodie, 'A review of renewable energy sources, sustainability issues and climate change mitigation', *Cogent Engineering*, vol. 3, no. 1, p. 1167990, Dec. 2016, doi: 10.1080/23311916.2016.1167990.
[13] J. Hamilton and K. Kasprzyk, 'Blue Carbon and Natioannly Determined Contributions', Jul. 2023.
[14] ASEAN, 'ASEAN Blue Economy Framework', 2023.
[15] IEA, 'Executive summary – An Energy Sector Roadmap to Net Zero Emissions in Indonesia – Analysis', 2022.
[16] Diez, Sylvia Michele *et al.*, 'Unlocking Blue Carbon Development: Investment Readiness Framework for Governments'. Washington, D.C.: World Bank, 2023