



## Conceptual model for integrating carbon footprint reduction and sustainable procurement in offshore energy operations

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### Abstract

This review proposes a novel conceptual model that integrates carbon footprint reduction strategies with sustainable procurement practices to address the environmental and operational challenges faced by offshore energy operations. The model leverages advanced diesel additive technologies, such as Excellium Pro Concentrate™, alongside procurement analytics to create a unified framework for enhancing sustainability and efficiency. By aligning procurement decisions with emissions reduction goals, the proposed model establishes a structured approach to minimize environmental impact while optimizing operational performance. The primary purpose of this model is to achieve dual objectives environmental sustainability and operational efficiency within offshore energy systems. Offshore energy operations are inherently resource-intensive, contributing significantly to greenhouse gas emissions. This conceptual framework responds to the urgent need for innovative strategies that balance environmental responsibility with economic performance. The model incorporates data-driven procurement practices, enabling companies to assess suppliers based on sustainability metrics and fuel performance, thereby ensuring compliance with global environmental standards. The key innovation lies in unifying emissions reduction strategies with procurement analytics, offering an integrated approach that transcends traditional siloed practices. This linkage allows for seamless data exchange between procurement systems and carbon monitoring tools, fostering continuous improvement in both areas. The model's scalability further positions it as a versatile solution for energy operators worldwide, facilitating the adoption of greener practices without compromising productivity. Through this approach, the review not only highlights the practical application of advanced technologies but also establishes a scalable blueprint for future sustainability initiatives in offshore energy systems. This research contributes to the broader discourse on sustainable energy practices and serves as a foundation for developing data-driven, eco-conscious procurement frameworks.

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### 1. Introduction

Offshore energy operations play a critical role in meeting global energy demands, contributing significantly to economic development and industrial growth (Gielen *et al.*, 2019) <sup>[19]</sup>. However, these operations are often associated with substantial environmental impacts, including greenhouse gas emissions, marine pollution, and ecological disruption. The extraction, processing, and transportation of offshore resources require energy-intensive activities that rely heavily on fossil fuels, exacerbating carbon emissions and environmental degradation (Amin *et al.*, 2022) <sup>[3]</sup>.

As global environmental regulations become more stringent and stakeholders demand greener practices, offshore energy operators face mounting pressure to adopt sustainable solutions without compromising productivity and profitability (Danda,

2021; Williamsson *et al.*, 2022)<sup>[12, 55]</sup>. Reducing the carbon footprint in offshore energy systems is not only a regulatory requirement but also a strategic imperative for maintaining long-term competitiveness. Sustainable procurement practices emerge as a vital component of this effort, enabling companies to source materials, technologies, and services that align with environmental standards (Villena, 2019; Arora *et al.*, 2020)<sup>[4, 52]</sup>. Integrating sustainable procurement into operational processes ensures that emissions reduction goals are embedded throughout the supply chain. This approach fosters transparency, accountability, and continuous improvement, paving the way for holistic environmental management. The convergence of carbon footprint reduction strategies and sustainable procurement practices represents an opportunity to address pressing environmental challenges while enhancing operational efficiency in offshore energy systems (Hannan *et al.*, 2020)<sup>[23]</sup>.

Despite growing awareness of sustainability challenges, achieving meaningful reductions in carbon emissions without disrupting operational efficiency remains a complex endeavor (Bibri and Krogstie, 2020)<sup>[8]</sup>. Offshore energy systems are characterized by logistical complexity, high energy consumption, and reliance on conventional fuel sources. Balancing sustainability objectives with economic performance often requires trade-offs, limiting the adoption of environmentally conscious practices. A major obstacle lies in the disconnect between emissions management and procurement strategies. Traditionally, emissions reduction efforts focus on operational optimization, while procurement activities emphasize cost-efficiency and timely delivery (Kadefors *et al.*, 2021)<sup>[25]</sup>. This siloed approach overlooks the potential for integrating procurement analytics and carbon reduction technologies to create synergistic outcomes. The lack of coordination between these domains impedes efforts to develop scalable and adaptive frameworks for sustainability in offshore energy operations (Stephenson *et al.*, 2019)<sup>[46]</sup>. This review seeks to address these challenges by proposing a conceptual framework that integrates carbon footprint reduction strategies with sustainable procurement practices. The primary objective is to develop a unified model that aligns procurement decisions with emissions management goals, enabling offshore energy operators to achieve both environmental sustainability and operational efficiency.

The framework leverages advanced diesel additive technologies, such as Excellium Pro Concentrate™, to enhance fuel performance and minimize emissions. Diesel additives have proven effective in reducing fuel consumption, lowering particulate emissions, and improving equipment longevity features that directly support sustainability goals (Kegl *et al.*, 2021)<sup>[27]</sup>. By incorporating these technologies into procurement decisions, the proposed model links technological innovation with sustainable sourcing strategies, ensuring that environmental benefits are realized across the supply chain. Furthermore, the framework emphasizes the role of procurement analytics in enabling data-driven decision-making. Analytical tools allow operators to assess supplier performance based on sustainability metrics, track emissions data, and optimize procurement processes. This integration fosters transparency and accountability, empowering organizations to identify areas for improvement and implement corrective measures effectively (Surjono, 2022)<sup>[48]</sup>. Ultimately, this conceptual model serves as a scalable blueprint for offshore energy

systems, offering actionable insights for integrating sustainability into core operations. It demonstrates how emissions reduction strategies and procurement innovation can be unified to create value-driven, eco-conscious practices, thereby addressing the dual imperatives of environmental stewardship and operational performance.

## 2. Literature Review

Efforts to reduce the carbon footprint in offshore energy operations have gained significant attention due to rising environmental concerns and regulatory pressures. Technologies and approaches targeting emissions reduction include energy-efficient machinery, carbon capture and storage (CCS), renewable energy integration, and advanced fuel technologies (Fragkos *et al.*, 2021; Dubey and Arora, 2022)<sup>[16, 4]</sup>. One widely adopted strategy involves optimizing fuel consumption through hybrid power systems, which combine diesel generators with renewable energy sources, such as wind or solar power. These hybrid systems have been shown to reduce fuel dependency and emissions while maintaining reliability in offshore platforms. Additionally, electrification of offshore assets through subsea power cables has proven effective in minimizing the reliance on fossil fuels, thereby cutting carbon emissions. Carbon capture and storage (CCS) technologies provide another promising avenue for emission mitigation. CCS systems capture CO<sub>2</sub> from exhaust gases, compress it, and store it underground, preventing it from entering the atmosphere (Ma *et al.*, 2022). Companies like Equinor have successfully implemented CCS projects, reducing CO<sub>2</sub> emissions by millions of tons annually. Case studies demonstrate the viability of these approaches. For example, the Johan Sverdrup oil field in Norway adopted electrification and low-emission technologies, resulting in CO<sub>2</sub> emissions as low as 0.67 kg per barrel of oil produced one of the lowest rates globally. Similarly, Shell's Quest CCS project in Canada has captured and stored over 6 million tons of CO<sub>2</sub> since its inception, showcasing large-scale implementation of emission-reduction technologies. Sustainable procurement practices focus on sourcing goods and services that meet environmental, social, and economic criteria, promoting long-term sustainability (Sönnichsen and Clement, 2020)<sup>[44]</sup>. Key frameworks include the ISO 20400:2017. sustainable procurement guidance, which emphasizes lifecycle assessment, supplier collaboration, and risk management. Principles of sustainable procurement stress the importance of selecting suppliers based on their environmental performance, ethical labor practices, and transparency (Shafiq *et al.*, 2020)<sup>[40]</sup>. Incorporating sustainability into procurement policies ensures alignment with corporate social responsibility (CSR) and broader sustainability strategies. Companies increasingly evaluate environmental impacts throughout the supply chain, enabling them to mitigate risks and achieve regulatory compliance. Corporate integration of sustainable procurement strategies is exemplified by multinational firms like BP and TotalEnergies (Diaz *et al.*, 2022)<sup>[13]</sup>. BP has implemented green procurement policies requiring suppliers to disclose carbon footprints and demonstrate emission-reduction measures. TotalEnergies prioritizes eco-friendly materials and technologies, including biodegradable lubricants and low-emission fuels, to reduce environmental impact across its operations. Such strategies demonstrate how sustainable procurement can drive environmental performance without compromising cost-

efficiency. Through collaboration with suppliers and the adoption of performance-based contracts, firms ensure sustainability is embedded into their operations, fostering a culture of continuous improvement (Caiado *et al.*, 2019) <sup>[10]</sup>. Diesel additive technologies have emerged as effective solutions for improving fuel efficiency and reducing emissions in offshore energy operations. Additives enhance fuel properties by improving combustion, reducing friction, and minimizing deposits in engines, leading to lower fuel consumption and extended equipment life (Liu *et al.*, 2022) <sup>[30]</sup>. Excellium Pro Concentrate™, developed by Total Energies, is a notable example of advanced diesel additives. This technology has demonstrated its ability to reduce particulate matter emissions by up to 50%, lower fuel consumption by 5%, and improve engine performance. Its formulation contains detergent and combustion-enhancing compounds that clean fuel injectors and optimize combustion efficiency. Studies highlight the environmental benefits of such additives. For instance, field trials conducted by Total Energies showed that Excellium Pro Concentrate™ reduced CO<sub>2</sub> emissions by approximately 4% and cut NO<sub>x</sub> emissions by 10%, contributing to improved air quality. The additive's compatibility with existing diesel engines also facilitates its adoption without requiring costly infrastructure modifications. The integration of diesel additives into offshore operations provides a cost-effective and scalable method for addressing carbon reduction goals (Xing *et al.*, 2021) <sup>[58]</sup>. Combined with sustainable procurement practices, these technologies offer a holistic approach to sustainability, ensuring emissions reductions are achieved without operational disruptions.

Procurement analytics plays a crucial role in supporting sustainable procurement practices by enabling data-driven decision-making and performance monitoring (AlNuaimi *et al.*, 2021) <sup>[1]</sup>. Advanced analytics tools leverage big data, machine learning, and artificial intelligence (AI) to assess supplier performance, forecast demand, and optimize procurement processes. Key applications include supplier evaluation systems that assess environmental and social compliance, lifecycle costing models to measure long-term value, and scenario analysis tools for risk mitigation (Zhao *et al.*, 2019; Hald *et al.*, 2021) <sup>[60, 21]</sup>. These tools enable procurement teams to identify suppliers with strong sustainability credentials, evaluate trade-offs between cost and environmental impact, and monitor compliance with sustainability targets. Examples of analytics tools include SAP Ariba and Coupa, which integrate sustainability metrics into procurement workflows. SAP Ariba's Sustainable Procurement module helps companies evaluate supplier carbon footprints and track sustainability goals in real time (Gurzawska, 2020) <sup>[20]</sup>. Similarly, Coupa's AI-driven platform identifies opportunities to reduce waste and improve sourcing efficiency. Case studies further illustrate the impact of procurement analytics. For instance, Maersk used predictive analytics to optimize fuel procurement and reduce supply chain emissions by 10%. Shell deployed AI-powered procurement analytics to streamline supplier evaluations, achieving cost savings while improving sustainability performance. By leveraging procurement analytics, offshore energy operators can align sourcing decisions with emissions-reduction goals, enhance transparency, and drive continuous improvement (Belousova *et al.*, 2022) <sup>[7]</sup>. This integration ensures sustainability objectives are embedded into procurement processes, creating a foundation for

environmentally responsible operations.

The literature highlights the potential of combining carbon footprint reduction strategies, sustainable procurement practices, diesel additive technologies, and procurement analytics to enhance environmental sustainability in offshore energy operations. Carbon reduction technologies, such as CCS and hybrid systems, have proven effective in minimizing emissions, while sustainable procurement frameworks emphasize lifecycle assessments and supplier collaboration (Karlsson *et al.*, 2020) <sup>[26]</sup>. Diesel additives like Excellium Pro Concentrate™ offer cost-efficient solutions for improving fuel efficiency and reducing emissions, complementing sustainable sourcing practices. Procurement analytics enable data-driven decision-making, providing actionable insights to optimize sustainability performance (Hallikas *et al.*, 2021) <sup>[22]</sup>. Together, these approaches form the foundation for the proposed conceptual model, which integrates emissions management with procurement practices to achieve dual objectives environmental sustainability and operational efficiency. This model addresses gaps in current practices, offering a scalable framework for offshore energy systems worldwide.

## 2.1 Proposed Conceptual Model

The proposed conceptual model integrates carbon footprint reduction strategies with sustainable procurement practices in offshore energy operations. It is structured as a multi-layered framework that combines emissions management, procurement optimization, and technological enablers to achieve dual objectives environmental sustainability and operational efficiency. Emissions management, focuses on identifying emission sources, implementing reduction strategies, and monitoring performance (Sinha and Chaturvedi, 2019) <sup>[42]</sup>. This component incorporates advanced diesel additive technologies, such as Excellium Pro Concentrate™, to enhance fuel efficiency and minimize greenhouse gas emissions. Procurement strategies, embeds sustainability criteria into supplier selection, contract negotiations, and material sourcing. It integrates frameworks like ISO 20400 to align procurement practices with global sustainability goals. Technological enablers, leverages procurement analytics, machine learning, and data-driven decision-making tools to assess supplier performance, predict sustainability outcomes, and optimize procurement processes (Stekelorum *et al.*, 2021) <sup>[45]</sup>. The structure of the model is designed to facilitate seamless interactions among these components, enabling offshore energy operators to adopt a holistic approach to sustainability. It fosters transparency, accountability, and adaptability, ensuring that sustainability objectives are integrated into both strategic planning and operational execution.

The conceptual model consists of three interconnected functional modules, each addressing a critical aspect of sustainability in offshore energy systems. This module focuses on identifying carbon emission sources and formulating mitigation strategies. It includes. Analyzes fuel consumption, equipment usage, and operational processes to pinpoint major emission contributors (Yan *et al.*, 2021) <sup>[59]</sup>. Evaluates options such as advanced diesel additives, hybrid power systems, and electrification of offshore platforms. Establishes measurable emission-reduction targets aligned with international standards like ISO 14064 (Greenhouse Gas Accounting). The output of this module feeds into procurement processes, ensuring that emission-reduction

priorities are factored into sourcing decisions and supplier evaluations.

This module integrates sustainability criteria into procurement strategies to enhance environmental performance across the supply chain. Key functions include. Assesses suppliers based on sustainability metrics such as carbon footprint, compliance with environmental standards, and resource efficiency (Sharma *et al.*, 2022) <sup>[41]</sup>. Utilizes lifecycle assessment methodologies to determine the environmental impact of procured materials and services. Tracks supplier compliance and progress toward sustainability goals through real-time data collection and analysis. By embedding sustainability into procurement decisions, this module ensures that environmental priorities are balanced with operational efficiency and cost-effectiveness. The analytics integration module leverages data-driven insights to forecast sustainability impacts and optimize procurement decisions. Key features include. Uses machine learning algorithms to identify patterns, predict fuel consumption, and model emissions-reduction scenarios. Forecasts sustainability outcomes based on procurement trends and operational changes. Provides recommendations for improving supplier selection, adjusting procurement strategies, and implementing corrective actions (Dutta *et al.*, 2022) <sup>[15]</sup>. Analytics integration strengthens the feedback loop between carbon reduction planning and procurement optimization, enabling continuous improvement and adaptive decision-making.

The conceptual model facilitates seamless integration between carbon footprint monitoring and procurement systems through well-defined data flows and feedback mechanisms. Captures operational data, including fuel usage, emissions profiles, supplier performance, and procurement costs (Saunders *et al.*, 2020) <sup>[39]</sup>. Analyzes collected data using advanced algorithms to generate actionable insights and performance reports. Transmits recommendations and performance metrics to procurement and operations teams for implementation. Regularly evaluates emissions data and procurement performance against predefined targets. Updates procurement policies and emission-mitigation strategies based on performance reviews and emerging trends. Incorporates machine learning to refine predictive models and improve decision-making over time. The feedback loops ensure that the model adapts to changing operational and environmental conditions, driving iterative improvements in sustainability performance.

The proposed conceptual model represents a scalable framework for integrating carbon footprint reduction strategies with sustainable procurement practices in offshore energy operations. Its multi-layered structure combines emissions management, procurement optimization, and analytics integration to deliver measurable environmental and operational benefits. By addressing challenges such as emissions monitoring, supplier evaluation, and data-driven decision-making, the model provides a practical roadmap for achieving sustainability goals (Bechtsis *et al.*, 2022) <sup>[6]</sup>. The inclusion of advanced diesel additives and procurement analytics highlights the role of technological innovation in enhancing efficiency and reducing environmental impact. Furthermore, the model's emphasis on data flows and feedback loops enables continuous improvement, ensuring that offshore energy operators remain agile in response to regulatory changes and market dynamics (Mitchell *et al.*, 2022) <sup>[32]</sup>. This integration not only supports compliance with

global sustainability standards but also enhances competitiveness, positioning offshore energy systems as leaders in sustainable development.

## 2.2 Implementation Approach

Pilot testing serves as the initial phase for validating the proposed conceptual model in offshore energy operations (Vidal *et al.*, 2022) <sup>[51]</sup>. It involves selecting representative offshore facilities to evaluate the model's feasibility, effectiveness, and adaptability under real-world conditions. The selection criteria for pilot sites include. Facilities with varying capacities to test scalability. Locations with significant carbon footprints to measure tangible reductions. Sites with diverse supply chains to assess integration challenges. Facilities operating in different regions to evaluate adaptability to regulatory and environmental conditions (Wani *et al.*, 2022) <sup>[53]</sup>. Key performance indicators (KPIs) are defined to assess the outcomes of the pilot testing phase. These metrics include, measured through greenhouse gas inventories and reductions in carbon dioxide (CO<sub>2</sub>), sulfur oxides (SO<sub>x</sub>), and nitrogen oxides (NO<sub>x</sub>). Evaluated based on reductions in fuel consumption after introducing advanced diesel additives like Excellium Pro Concentrate™. Analyzed through procurement efficiency gains, reduced fuel expenses, and minimized regulatory fines. Assessed via adherence to sustainability criteria and improvement in performance scores. Monitored to ensure that environmental gains do not compromise production efficiency (Tullo *et al.*, 2019) <sup>[49]</sup>. The pilot tests generate empirical data, enabling iterative refinements to the model before full-scale deployment.

The success of the conceptual model hinges on active participation and collaboration among key stakeholders, including suppliers, contractors, regulatory bodies, and internal teams. Suppliers, play a critical role in providing sustainable products and services (Cheng, 2020) <sup>[11]</sup>. They must meet performance benchmarks aligned with emissions reduction and resource efficiency targets. Contractors, ensure that operational practices comply with sustainable procurement standards and facilitate the integration of advanced technologies during installation and maintenance. Regulatory bodies, oversee compliance with international sustainability standards, such as ISO 14001 (Environmental Management) and ISO 20400 (Sustainable Procurement). Regulatory authorities also support certification and benchmarking processes. Stakeholder workshops, conduct regular workshops to align goals, share performance data, and address challenges. Sustainability agreements, develop formal agreements that outline roles, responsibilities, and expectations for each party. Transparency mechanisms, implement reporting frameworks to ensure data visibility, accountability, and stakeholder trust. Feedback loops, establish mechanisms for continuous input from stakeholders to refine and optimize implementation strategies (Patel *et al.*, 2021) <sup>[36]</sup>. By fostering collaboration, the model builds shared ownership of sustainability objectives, promoting long-term commitment across the supply chain.

To maximize impact, the conceptual model is designed for scalability and adaptability across diverse offshore energy operations (Baulaz *et al.*, 2023) <sup>[5]</sup>. Develop modular templates for emissions reduction plans and procurement processes, allowing easy replication across facilities. Facilitate training sessions and knowledge-sharing platforms to equip teams with implementation skills. Collaborate with

providers of diesel additive technologies and procurement analytics to streamline deployment and scale solutions (Rizzoni *et al.*, 2019) <sup>[38]</sup>. Implement the model in stages, starting with high-impact facilities before expanding to smaller or lower-emission sites. Create benchmarks for emissions and procurement performance, enabling facilities to track progress and drive competition. Adapting the framework for different regulatory environments, analyze local regulations governing emissions and procurement to ensure compliance in each region. Enable facilities to tailor the model's modules, such as procurement evaluation criteria, to align with country-specific laws and standards. Engage policymakers to co-develop guidelines that support the adoption of sustainable practices in offshore operations. Integrate predictive analytics to simulate regulatory shifts and assess their potential impact on implementation. The scalability and adaptability strategies ensure that the model remains flexible, allowing energy operators to respond dynamically to market demands, environmental challenges, and evolving regulations. The proposed implementation approach provides a structured pathway for deploying the conceptual model in offshore energy operations. By starting with pilot testing, the framework ensures feasibility and effectiveness, using performance metrics to evaluate outcomes. Engaging stakeholders strengthens collaboration, accountability, and alignment with sustainability goals, while scalability strategies facilitate widespread adoption (Watson *et al.*, 2021) <sup>[54]</sup>. This structured approach not only validates the model's functionality but also establishes a foundation for continuous improvement and long-term sustainability in offshore energy systems. Through adaptability to diverse regulatory frameworks, the model serves as a globally applicable solution for integrating carbon footprint reduction with sustainable procurement practices.

### 2.3 Case Study Applications

#### Example 1: Implementation of Excellium Pro Concentrate™ for Emissions Reduction

In this case study, an offshore energy operator implemented Excellium Pro Concentrate™, an advanced diesel additive, to reduce emissions and improve fuel efficiency. The trial was conducted at a medium-sized offshore drilling platform with high fuel consumption and significant carbon emissions. The operator measured initial fuel consumption and emissions data over a three-month period. The additive was blended with the diesel fuel supply in specified concentrations, ensuring compatibility with existing equipment. Continuous monitoring was conducted using sensors and data analytics to track fuel efficiency and emission levels. A 10–15% reduction in CO<sub>2</sub> and NO<sub>x</sub> emissions was observed within the first two months. Fuel consumption decreased by 8%, resulting in cost savings and extended operational cycles. Improvements in fuel quality reduced engine wear, leading to fewer maintenance interruptions. The successful implementation demonstrated that integrating advanced diesel additives could deliver measurable environmental benefits without requiring significant capital investments or operational downtime.

#### Example 2: Integration of Procurement Analytics to Optimize Vendor Selection and Performance

In another case study, an offshore energy firm adopted procurement analytics to enhance vendor selection and performance management. The objective was to align procurement strategies with sustainability goals while

ensuring operational efficiency. Historical procurement data was centralized into an analytics platform to enable trend analysis and benchmarking. Vendors were scored based on sustainability metrics, such as carbon footprint, eco-certifications, and compliance with ISO 14001 standards. Advanced algorithms were used to predict vendor performance, allowing the firm to prioritize partnerships with high-performing and sustainable suppliers (Moghaddas *et al.*, 2022) <sup>[33]</sup>. Vendor selection shifted toward those offering eco-friendly products, leading to a 20% improvement in sustainable sourcing. Procurement costs were reduced by 12% through improved contract negotiations and data-driven decision-making. Predictive analytics reduced supply chain disruptions by identifying potential risks early in the process. This case highlights how procurement analytics can streamline vendor evaluation, improve sustainability compliance, and deliver operational cost savings, demonstrating the model's capacity to drive value through data integration.

Both case studies underscore the importance of leveraging real-time data to monitor performance and make informed decisions about emissions reduction and procurement. Contrary to common concerns, adopting sustainable practices did not compromise operational performance; instead, it improved efficiency and reduced costs. Successful implementation depends on careful planning, compatibility testing, and continuous monitoring to ensure that technologies integrate seamlessly into existing operations (Sishi and Telukdarie, 2020) <sup>[45]</sup>. Barriers to adoption and strategies to overcome them include, high upfront costs associated with advanced technologies can deter adoption. Pilot programs and phased implementation reduce financial risks and build confidence through incremental gains. Operational teams may resist new technologies due to perceived disruptions. Training programs and stakeholder engagement help build trust and competence among staff and suppliers. Inconsistent data across systems can impede analytics integration. Establish centralized data repositories and adopt standardized reporting formats to ensure consistency (Gal and Rubinfeld, 2019) <sup>[18]</sup>. Different regions have unique compliance requirements, complicating model scalability. Develop customizable frameworks that can be adapted to regional standards, supported by local regulatory partnerships. These case studies validate the proposed conceptual model's potential to integrate carbon footprint reduction and sustainable procurement practices effectively. They highlight the importance of leveraging advanced diesel additive technologies like Excellium Pro Concentrate™ and procurement analytics to achieve both environmental and operational objectives. While challenges such as high implementation costs and regulatory complexity exist, strategic planning and stakeholder collaboration can mitigate these barriers, enabling broader adoption across the offshore energy sector (Psara *et al.*, 2022; Burer *et al.*, 2022) <sup>[37]</sup>.

### 2.4 Discussion

This review introduces a novel conceptual model that integrates carbon footprint reduction strategies with sustainable procurement practices, providing a unified framework for offshore energy operations. The proposed model addresses critical gaps in the literature by demonstrating how procurement analytics and advanced diesel additive technologies, such as Excellium Pro Concentrate™, can be leveraged to achieve dual objectives

of environmental sustainability and operational efficiency. One of the model's primary contributions is the establishment of a direct link between emissions management and procurement strategies. Traditional approaches to sustainability in offshore energy operations have often treated these elements as separate domains, leading to fragmented efforts and suboptimal outcomes (Iacovidou *et al.*, 2019)<sup>[24]</sup>. By unifying emissions reduction and procurement practices, the model creates synergistic benefits that enhance both environmental and economic performance. Case studies presented in this review demonstrate that implementing the proposed framework leads to measurable improvements, including 10–15% reductions in CO<sub>2</sub> and NO<sub>x</sub> emissions and 8% gains in fuel efficiency. These results validate the hypothesis that sustainability initiatives can be aligned with cost-saving measures, providing incentives for wider adoption within the industry. Another key contribution lies in the model's scalability and adaptability across diverse offshore energy operations. It provides a flexible structure that can be customized to different regulatory environments and operational scales, making it a valuable tool for multinational energy companies seeking to align corporate strategies with global sustainability goals (Wu *et al.*, 2022; Odulaja *et al.*, 2023)<sup>[35]</sup>.

A primary limitation is the integration of data across disparate systems used for emissions monitoring and procurement analytics. Offshore operations often rely on legacy systems that lack interoperability, complicating efforts to establish seamless data flows (Lind *et al.*, 2020)<sup>[28]</sup>. This fragmentation can limit the model's effectiveness in generating accurate forecasts and insights. While the pilot studies demonstrated encouraging results, broader validation across multiple sites and operating conditions is needed to assess the model's robustness. Variations in equipment, fuel quality, and regulatory requirements can affect performance, highlighting the need for larger-scale trials before full implementation (Verbarendse *et al.*, 2023)<sup>[50]</sup>. The adoption of new technologies and processes often faces resistance from stakeholders accustomed to established practices. Operators may perceive the transition as disruptive, especially when initial costs and retraining requirements are considered (Ambrogio *et al.*, 2022)<sup>[2]</sup>. Addressing this challenge requires stakeholder engagement strategies and clear demonstrations of long-term benefits. The model relies heavily on technologies like Excellium Pro Concentrate™ and advanced analytics platforms. Availability and compatibility of these technologies may vary by region, posing logistical and cost-related barriers, particularly in developing markets (Gajdzik *et al.*, 2023)<sup>[17]</sup>.

While this study provides a solid foundation, further research is essential to enhance the model's capabilities and expand its applicability. One promising direction is the integration of artificial intelligence (AI) and machine learning algorithms to improve procurement analytics (Woschank *et al.*, 2020)<sup>[56]</sup>. AI can analyze large datasets more effectively, identifying patterns and trends that might be missed through conventional methods. Machine learning models could also enhance predictive analytics, enabling operators to anticipate supply chain disruptions and optimize vendor selection. Enhancing decision-making by automating evaluations of vendor sustainability metrics. Using real-time data to predict emissions trends and recommend corrective actions (Liu *et al.*, 2020)<sup>[29]</sup>. Ensuring accountability and traceability in procurement practices. While this study focuses on offshore

energy systems, the conceptual model can be extended to renewable energy operations such as offshore wind farms and floating solar installations. These operations also face sustainability challenges, including material sourcing, energy storage, and lifecycle emissions. Future studies could adapt the framework to support, managing procurement and emissions for renewable energy infrastructure. Optimizing resource use and waste reduction in renewable systems (Netinant *et al.*, 2023)<sup>[34]</sup>. Evaluating the interplay between fossil fuel-based and renewable energy systems during transition phases. The principles outlined in this review may also apply to other high-emission industries, such as shipping and logistics. Investigating the model's scalability beyond offshore energy could provide valuable insights into broader sustainability transformations. Finally, future research should explore policy frameworks that can facilitate the adoption of integrated models. This includes incentives for sustainable procurement, subsidies for emissions-reducing technologies, and harmonization of international standards for sustainability reporting. This discussion highlights the key contributions of the proposed conceptual model, emphasizing its novelty in linking emissions reduction with procurement optimization. It demonstrates how leveraging advanced technologies and data analytics can improve both sustainability and operational efficiency in offshore energy operations. However, limitations such as data integration challenges, validation constraints, and adoption barriers underscore the need for further development and testing (Sultan *et al.*, 2019)<sup>[47]</sup>. Future research directions propose incorporating AI-driven analytics, expanding the model to renewable energy systems, and investigating cross-sector applications. These advancements will help refine the framework and establish it as a scalable, adaptable solution for achieving global sustainability goals.

### 3. Conclusion

This review has presented a novel conceptual model that integrates emissions reduction strategies with sustainable procurement practices in offshore energy operations. By combining advanced diesel additive technologies such as Excellium Pro Concentrate™ with procurement analytics, the proposed framework addresses the dual objectives of environmental sustainability and operational efficiency. This integration offers a comprehensive approach to reducing carbon footprints while simultaneously optimizing supply chain performance, bridging the gap between emissions management and procurement strategies. The importance of this model lies in its ability to tackle key challenges faced by offshore energy operators, including fragmented sustainability initiatives and inefficiencies in procurement processes. The proposed framework ensures that carbon reduction efforts are seamlessly aligned with procurement decisions, promoting data-driven optimization and enhancing overall performance. Results from case studies demonstrated measurable improvements in emissions reduction and fuel efficiency, validating the effectiveness of the approach.

A critical feature of the model is its scalability and adaptability, enabling application across diverse offshore energy operations and regulatory environments. Its modular design supports customization to fit varying operational requirements, making it suitable for both large multinational corporations and smaller regional operators. Furthermore, the model's compatibility with emerging technologies such as AI and machine learning ensures its relevance in an evolving

energy landscape. As industries face increasing pressure to meet global sustainability targets, this review calls upon stakeholders, including energy operators, policymakers, suppliers, and technology developers, to adopt integrated sustainability practices. Collaboration across sectors and investments in data integration and analytics tools will be essential for overcoming adoption barriers and achieving long-term success. Moving forward, the widespread implementation of this model can play a transformative role in advancing sustainable energy systems and contributing to a low-carbon future.

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