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How Do Oil Companies in Emerging Country Manage Carbon Emissions to Improve Sustainability Reporting? A Case Study of PT Pertamina

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This study examines PT Pertamina's management of decarbonization initiatives and the improvement of its Environmental, Social, and Governance (ESG) performance. This study evaluates corporate carbon management strategies by examining scientific literature and sustainability disclosures. It focuses on three main areas: direct emissions from operations (Scope One), indirect emissions from energy purchases (Scope Two), and indirect emissions from the entire value chain, including product usage (Scope Three). PT Pertamina exceeded its 2023 emissions reduction target by 124%, decarbonizing 1.13 million tonnes of CO_2e and earning the highest global ESG rating among integrated oil and gas companies, according to Sustainalytics. The sale of B35 biodiesel has further reduced emissions by 28 million tonnes annually, underscoring its leadership in green energy development. However, critical challenges remain, including reliance on palm oil-based biofuels, which raise concerns over deforestation and biodiversity loss, and the high capital and policy barriers facing carbon capture, utilization, and storage technologies. Despite improved ESG ratings, high Scope Three emissions highlight the need for a more profound systemic transformation beyond operational improvements. Thus, while PT Pertamina's achievements contribute to Indonesia's 2060 net-zero goal, long-term sustainability requires transparent reporting, technological innovation, and a fundamental shift in business models. This case offers key insights into the opportunities and limitations of decarbonization strategies within emerging economy contexts.

Keywords: PT Pertamina, oil and gas, sustainability reporting, decarbonizing, emissions.

Introduction

Globally, the oil and gas sub-sector is responsible for approximately 15% of emissions attributed to energy production. A 50% decrease in emission intensity by 2030 is imperative for fulfilling the International Energy Agency's (IEA) Net Zero Emissions Scenario by 2050 (Guo et al., 2023; IEA, 2023a; Jäger et al., 2023). The Indonesian Government has pledged to reduce greenhouse gas (GHG) emissions by 29% by 2030, relative to a business-as-usual trajectory, with the prospect of increasing this commitment to 41% contingent upon international support (Panjaitan et al., 2018; Fauzan et al., 2020). This pledge signifies the government's acknowledgment of the need to tackle climate change and mitigate the ecological ramifications of GHG emissions. In 2022, Indonesia augmented its Nationally Determined Contributions (NDC) by elevating the 2030 emission reduction objective to 31.89% domestically and 43.20% with the assistance of international allies (UNFCCC, 2022).

As a prominent state-owned energy corporation, PT Pertamina assumes a pivotal role in endorsing government policies to diminish GHG emissions under Indonesia's Enhanced NDC (E-NDC) targets and the ambition of achieving Net Zero by 2060. In pursuit of these objectives, the company has instituted a range of initiatives designed to curtail GHG emissions, encompassing investments in renewable energy, enhancements in efficiency within refining and production operations, and exploration of natural gas, which is regarded as a cleaner energy alternative (Dhina and Permana, 2021; Pertamina, 2021). These initiatives are also aimed at minimizing flaring and methane emissions. Through these concerted efforts, PT Pertamina is positioned to fulfill Indonesia's GHG reduction objectives while promoting sustainable development (Pertamina, 2023c; Rahman et al., 2023).

PT Pertamina has committed to augmenting the proportion of gas in its energy portfolio from 3% to 19% by 2030, designating 14% of its investment budget for gas and renewable energy initiatives (UNFCCC, 2022). The company's Environmental, Social, and Governance (ESG) strategy prioritizes the reduction of emissions, the enhancement of energy efficiency, and the advancement of renewable energy projects, thereby aligning with Indonesia's national emissions reduction aspirations and reinforcing Pertamina's commitment to sustainability (Naeem et al., 2022; Pertamina, 2022a, 2023a; Billio et al., 2024). Pertamina's devotion to ESG practices extends beyond emissions reduction, encompassing broader innovations in decarbonization and sustainability. The company's efforts include advancements in technology, improvements in operational efficiency, and the transformation of business models to support long-term environmental stewardship (Jannah and Sumanto, 2019; Nasir, 2019; Setiawan and Iswati, 2019; Pertamina, 2024b). These initiatives have contributed to cost savings and reflect Pertamina's growing commitment to biodiversity conservation and waste management (Pertamina, 2023c, 2023b, 2024c).

Nevertheless, the decarbonization of the oil industry necessitates considerable changes in policy, technological advancements, and investments in renewable energy sources (Bórawski et al., 2022; Wang et al., 2022; Oruwari and Itsekor, 2023; Wang et al., 2023), thereby presenting formidable challenges, particularly in developing nations such as Indonesia, where the oil sector is integral to the national economy (Atteridge and Strambo, 2020; Okoh and Okpanachi, 2023; Yang et al., 2023). This research analyzes PT Pertamina's emission reduction initiatives, achievements, and advancements toward its net-zero aspirations. By scrutinizing business reports, including sustainability reports, and evaluating the company's performance in mitigating scopes one and two emissions, this study aims to ascertain whether PT Pertamina's carbon management strategies effectively align with its targets (IEA, 2023a). However, the long-term profitability of sustainability initiatives in the oil and gas sector is not guaranteed due to financial, operational, and regulatory constraints.

Methods

This research employs a qualitative case study methodology centered on PT Pertamina, Indonesia's largest state-owned energy enterprise. The analysis primarily relies on PT Pertamina's sustainability reports from 2020 to 2024, supplemented by secondary data from independent entities including the International Energy Agency (IEA), UNFCCC, Greenpeace, and Sustainalytics.

The methodology comprises:

1 Document Analysis: Evaluation of PT Pertamina's sustainability reports to ascertain principal emission reduction strategies, components of the ESG strategy,

and stated progress measures (Scope One, Two, and Three emissions).

2 Comparative Benchmarking: Assessing PT Pertamina's performance in relation to other international oil and gas corporations, including Shell, BP, and Petronas, using publicly accessible ESG ratings and climate initiatives.

3 Triangulation: Verifying company disclosures through third-party evaluations to confirm assertions and detect discrepancies or omissions.

The emphasis was on discerning patterns of decarbonization strategies, alignment with national targets, and the long-term viability of existing sustainability measures.

Company Overview

Overview of PT Pertamina

PT Pertamina is a state-owned enterprise (BUMN) and has been operational for over sixty years to deliver energy equitably and sustainably, particularly within the Indonesian context. PT Pertamina operates as an integrated energy corporation employing over 40,000 personnel and managing assets estimated at approximately USD 88 billion (Pertamina, 2023a). PT Pertamina encompasses six sub-holdings with functions across the entire value chain, from exploration to initiatives in renewable energy, thereby ensuring a comprehensive and integrated approach to energy production and sustainability (NRE, 2024). The company aims to become a Global Energy Champion with a market value of USD 100 billion by 2034, and it remains the only Indonesian company on the Fortune Global 500 list (Pertamina, 2023a).

Pledges

PT Pertamina pledges to reduce carbon emissions in pursuit of its sustainability goals. This commitment aligns with international frameworks such as the Paris Agreement, which underscores the role of corporations in mitigating climate change impacts (UNFCCC, 2015). PT Pertamina has outlined specific carbon emission reduction targets, pledging to achieve significant reductions by 2030 through strategic energy efficiency initiatives and investments in renewable energy (Pertamina, 2023c). This pledge is consistent with Indonesia's national agenda to curb GHG emissions, as mandated by the Government's NDCs (Panjaitan et al., 2021; Rahman et al., 2023). The company has also committed to enhancing transparency by following global sustainability reporting standards like the Global Reporting Initiative (GRI) and aims to achieve net-zero emissions by 2060 through decarbonization, carbon capture, and biofuel initiatives (Pertamina, 2023c, 2024a).

ESG (Environmental, Social, Governance)

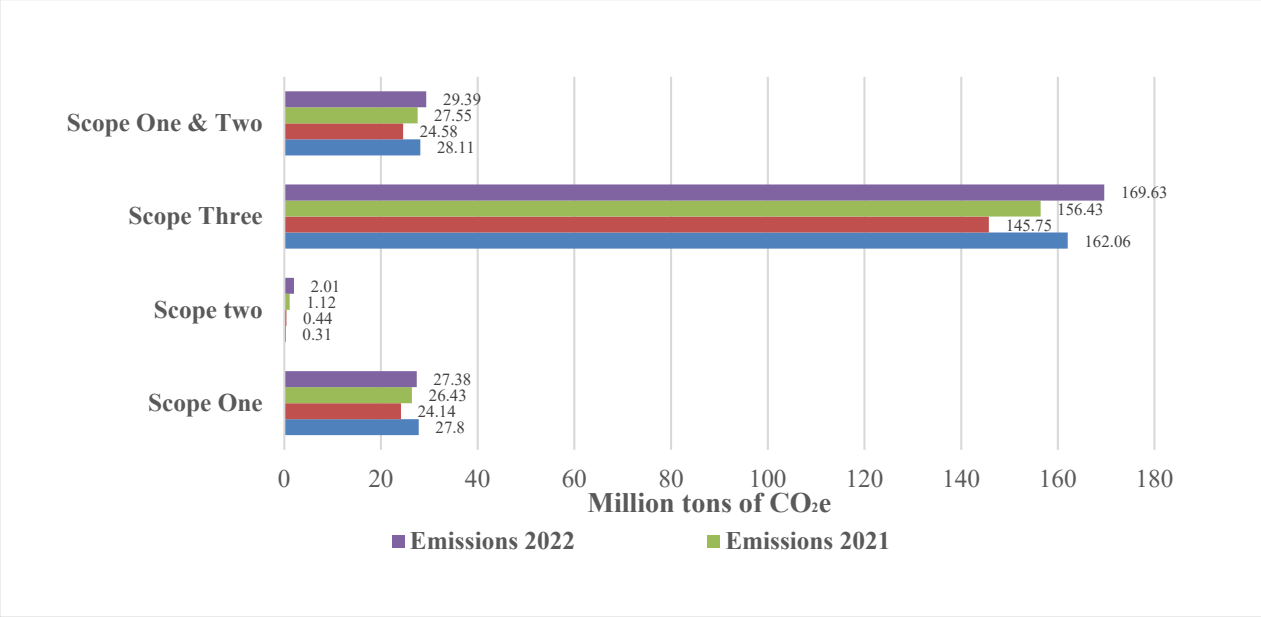
PT Pertamina's ESG rating upgrade reflects its commitment, with its score on Sustainalytics, a global ESG performance assessor, dropping from a severe risk of 41.6 in early 2021 to 28.1 by year-end, and the following year to 22.1 and 20.7 (both moderate risks) in 2023. It makes PT Pertamina successful in achieving the top rank among 61 integrated oil and gas subsector companies in the world in 2023 (Pertamina, 2024b). PT Pertamina's ESG performance is increasingly shining in line with decarbonization innovation, a concrete manifestation of the company's support for the national target of reaching NZE by 2060. Internal operational processes and biodiesel sales, a biofuel blend of palm oil and diesel fuel, have also supported this. Biodiesel sales have reduced emissions by around 28 million tonnes of carbon dioxide equivalent (tCO_2e) annually (Pertamina, 2023c, 2024b).

Results and Analysis

Emission estimates

Continuous monitoring and analysis of emission sources yield significant insights into the evolving nature of environmental impacts for businesses. These actions highlight the significance of strategic planning and sustainability initiatives in effectively managing and reducing carbon footprints. This enables companies to assess their environmental performance, identify areas for improvement, and enhance sustainability. Reducing Scope One emissions (direct emissions) from company-operated activities can be achieved by implementing cleaner technologies. Improving energy efficiency to mitigate Scope Two emissions resulting from purchased electricity and heat is essential. Addressing Scope Three emissions, which include indirect emissions across the value chain such as those from supplier operations, product use, and logistics, may require initiatives like supply chain optimization, sustainable sourcing, and improved transportation efficiency.

Fig.1. *Emissions by scope from 2019 to 2022*



From *Fig. 1*, it can be seen that the number of emissions experienced slight fluctuations. Scope One emissions experienced a slight increase from 2019 to 2021, but a slight decrease in 2022 (Pertamina, 2023c). This could be due to the variability in direct emissions from sources such as fuel combustion or industrial processes. Scope Two shows a significant increase from 2019 to 2022, and Scope Three generally indicates an upward trend. Increased business activity, changes in supply chains, or transportation inefficiencies can result from these changes. Meanwhile, combined Scope One and Two also show an increasing trend from 2020 to 2022. This shows a cumulative increase in both types of emissions, likely influenced by business growth or changes in operational practices.

Emission reductions

PT Pertamina is committed to decarbonization through initiatives targeting New and Renewable Energy (NRE), energy conservation, and emission reduction, including potential cutbacks in Scope 3 emissions, which form a significant part of its footprint. PT Pertamina aims to reduce Scope One and Scope Two emissions by 30% by 2030 compared with the 2010 baseline (Pertamina, 2020, 2023b). Since 2010, Pertamina's initiatives to reduce emissions have been incorporated into Indonesia's national program. The company's decarbonization strategy targets lowering emissions by 30% by 2030. The 2010 baseline for measuring reductions was set at 25.078 million tonnes of CO_2e, comprised of 9.22 million tonnes from upstream activities, 15.42 million tonnes from refining, and 0.48 million tonnes from marketing and trading (Pertamina, 2020, 2021).

The company adopts two strategies to support 2030 decarbonization and the 2060 national Net Zero Emission (NZE) goal: decarbonizing business activities and developing new green businesses (Pertamina, 2023b). These efforts include building green energy plants, using zero-carbon fuel for ship fleets, implementing carbon capture and storage/carbon capture, utilization, and storage (CCS/CCUS), reducing methane emissions, and maximizing hydrogen usage. Environmentally friendly programs focus on battery and renewable energy use, nature-based solutions, and the carbon market. These initiatives rely on stakeholder involvement, sustainable organization, and continuous performance management. Further details on these strategies are presented in *Table 1*, highlighting short-term, medium-term, and long-term plans for PT Pertamina's sub-holdings. Furthermore, environmentally friendly business development programs are implemented through initiatives to increase battery use, renewable energy use, nature-based solutions, and carbon market businesses (Pertamina, 2023a, 2023c).

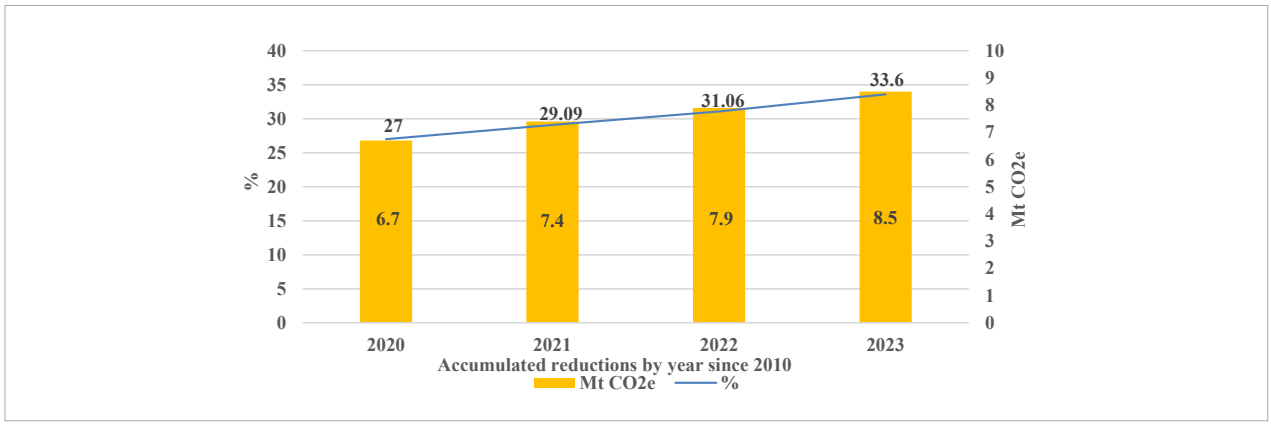
Table 1. *Short-term, medium-term, and long-term strategies at six sub-holdings*

Strategy	Short term	Medium term	Long term
Upstream	Solar PV campaign and diesel-to-gas conversion	Commercialize CCUS and convert diesel to gas	Electrification of equipment using environmentally friendly electricity
Refining and Petrochemical	Solar PV campaign and implementation of energy efficiency	Energy efficiency, flaring/venting	Application of CCUS technology
Commercial and Trading	Low-carbon energy initiative	Charging station installation	Converting to low-carbon batteries and heavy-duty trucks (HDT)
Power and Renewable Energy	Low-carbon energy and Sei Mangkei Biogas Power Plant (PLTBg)	Efficiency of generators and combined-cycle gas turbine (CCGT)	CCUS of geothermal assets and CCGT
Gas	Solar PVs; efficiency of gas transmission and operations	Switching to green electricity for transmission assets	CCS in gas pipeline networks and gas turbine electrification
Integrated Marine Logistics	Optimization of speed, ship routes, and increased efficiency	Tanker for ammonia transport	Updated 200 ships with dual fuels (Hydrogen and CO_2)

The accumulated annual emission reductions from Scope One and Two have reflected PT. Pertamina's operational decarbonization efforts began with a significant decrease in emissions of 6.7 million tCO_2e, or 27%, in 2020 compared to 2010 (*Fig. 2*). By 2022, this progress exceeded the company's 2030 target of 30% (Pertamina, 2022a, 2023c). Critical initiatives for emissions reduction include enhancing energy efficiency through advanced technologies, augmenting investments in renewable energy sources like natural gas and solar power, mitigating methane emissions and gas flaring, and employing fuel gasification alongside flare gas in upstream and refining activities (Kurmala, 2023). By 2022, the company's emissions were 7.9 million tonnes, an increase from 7.4 million tonnes in 2021, reflecting 31.06% and 29.1% of 2010 emissions, respectively. In 2023, the reductions rose to 8.5 million tonnes of CO_2, achieving 33.6% of the 2010 baseline (Pertamina, 2024a).

Given its outstanding performance, the company received an ESG assessment indicating low-performance risks, earning it a top ranking compared with similar companies rated by Sustainalytics. Furthermore, PT Pertamina has launched two CCUS projects in Java (Setiawan, 2024) and has planted more than 6 million trees, anticipated to absorb more than 120,000 tCO_2e annually (Pertamina, 2024d).

Fig.2. *Accumulated reductions in Scope One and Scope Two emissions 2020–2023*



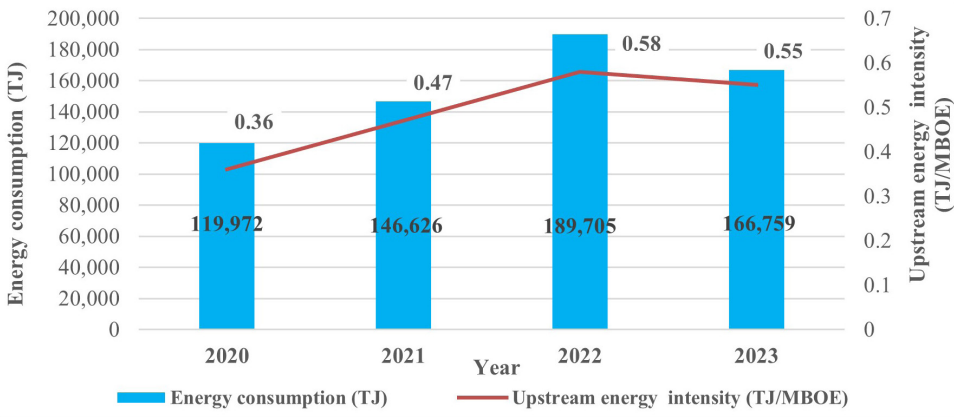
Energy efficiency

PT Pertamina has clearly stated that energy efficiency efforts to reduce emissions or support decarbonization targets are a no-regret initiative. It is an initiative that is impossible to regret because it is believed to be able to, and has even been proven, to save the corporation's operational costs (Ferdiansyah, 2023; Pertamina, 2024c). The savings from modifying operating models, streamlining procedures, and reducing expenses can help implement programs and achieve targets at lower cost (Dechezleprêtre et al., 2019; Midor et al., 2022; Ibn Batouta et al., 2023). The company implements cost-saving measures through energy efficiency initiatives that concurrently lower carbon emissions, executed via two strategic roadmaps: decarbonizing existing operations and promoting the growth of green businesses (Pertamina, 2023c).

Fig. 3 shows an overall increase in PT Pertamina's energy consumption from 2020 to 2022, with a slight decline in 2023. The exact timeframe saw upstream energy intensity peak in 2022 and slightly improve in 2023. This shows initial growth in energy demand and efficiency issues, followed by later intensity reduction. This indicates less energy efficiency in oil equivalent production. The company's oil and gas production rose 9% over the previous year due to increasing domestic demand, due to extended holidays and COVID-19 limitations being lifted (Setiawan, 2023).

Therefore, PT Pertamina still needs to set specific targets for energy reduction. Despite this, the company continues to innovate to increase renewable energy usage and energy efficiency in operating units within its sub-holdings. In 2022, the company implemented various strategies to decrease energy usage, including enhancements of fuel, electricity, heating, and cooling efficiency, achieving a total energy reduction of 36,133 TJ, with the refining and petrochemical sectors accounting for nearly 90% of this reduction (Pertamina, 2023a).

Fig. 3. *Energy consumption and (upstream) intensity of PT Pertamina from 2020 to 2022* (Pertamina, 2023a)



New, renewable energy and energy conservation (NREEC)

In response to the transition to green energy from fossil fuels, PT Pertamina appointed an electricity and new and renewable energy (NRE) Subholding for NRE development and a refining and petrochemicals subholding for palm oil for biofuel development. The company is also developing NRE using environmentally friendly materials and resources widely available in Indonesia. This strategy anticipates declining oil and gas demand, addresses climate change and low-carbon development challenges, opens future business opportunities, and supports the company's transformation into a world-class energy provider. Furthermore, by 2026, the company is expected to support the achievement of Indonesia's 2025 energy mix, reaching 23%. More detailed information regarding targets, investment value, and types of projects to be carried out can be found in *Table 2* (Pertamina, 2022a, 2023a).

Table 2. *NRE projects up to 2026*

New and renewable energy projects up to 2026	
Targets:	Projects:
Augment producing capacity by 10.2 gigawatt-hours (GWh)	5.7 GW gasification power plant
Produced at roughly 30.2 GWh	1.1 GW of geothermal energy
Attain the Indonesian energy mix target of 23% by 2025	3.4 GW hydropower, wind, solar energy, and bioenergy plants
Capital allocation:	
USD 6.96 Billion	30.2 GWh electric vehicle battery

Despite the NRE target, challenges remain, such as the government's policy to prioritize NRE in the electricity sector and the limitations of the proposed NRE technologies over the next 10 to 20 years. Through these challenges, PT Pertamina developed numerous NRE initiatives in 2020, such as (Pertamina, 2021):

- Geothermal power plants with capacities of 1877 MW.
- Bioenergy: In 2019, the company began producing biodiesel B30, a biofuel blend of 70% diesel fuel and 30% crude palm oil as a renewable material, to meet the government's 2020 target of 7.15 billion liters.
- Green diesel (D100): The company has produced 1000 barrels of D100, a product obtained by processing crude palm oil (CPO) into refined, bleached, and deodorized palm kernel oil (RBDPKO). The company also produces sustainable aviation fuel, a mixture of 2.4% CPO and RBDPKO, in Avtur.
- A 2.4 MW Biogas Power Plant.
- The Independent Power Plant (IPP) project integrated a floating storage and degasification unit (FSRU) with a 1760 MW combined cycle power plant (CCPP).

Furthermore, PT. Pertamina's renewable energy strategy must also consider the opportunities and challenges presented by these initiatives, as in *Table 2*. Projects such as the 5.7 GW gasification power plant and the 30.2 GWh electric vehicle battery industry highlight the company's commitment to sustainable energy, backed by $6.96 billion in investment. However, these efforts face significant hurdles, including large capital requirements, the need for long-term technological innovation, and regulatory support (Janus and Murphy, 2013). In addition, PT Pertamina must balance these renewable initiatives with its core fossil fuel operations while pursuing its goal of achieving a market valuation of $100 billion by 2034. This tension arises between short-term financial growth and long-term sustainability (Mujiyanto and Tiess, 2013). Exploring these complexities provides a more nuanced understanding of the trade-offs between economic goals and environmental responsibility (Gabriel et al., 2022). It enhances educational value and offers a more profound perspective that warrants further study.

Scope Three emissions and the sustainability challenge

PT Pertamina and other companies in the fossil fuel sector face significant challenges in managing Scope Three emissions, which mainly result from the downstream use of fossil fuels. These emissions, representing the most substantial part of the company's carbon footprint, raise the question of whether a fossil fuel company can achieve genuine sustainability. Despite efforts to reduce Scope One and Two emissions, the carbon intensity of fossil fuels continues to drive significant greenhouse gas emissions.

In 2023, PT Pertamina's Scope Three emissions reached 175.86 million tonnes of CO_2e, an increase from 163.83 million tonnes in 2022. This reflects the ongoing challenge of reducing indirect emissions while meeting energy demands, as the measurement only accounts for emissions from purchased crude oil, fuel products, and the use of sold products (Pertamina, 2023a, 2023c, 2024a). This 7.3% increase starkly contrasts with the company's celebrated reductions in Scope One and Two emissions, highlighting a fundamental challenge in PT Pertamina's sustainability strategy.

PT Pertamina acknowledges the impact of these emissions, which are primarily influenced by their end use and remain difficult to manage directly. The company's

fossil fuel sales represent significant revenue, creating tensions between decarbonization ambitions and business growth targets. Unlike global peers such as Shell and BP, which have established specific Scope Three reduction targets and invested significantly in low-carbon businesses (Kolk and Levy, 2001; Egbumokei et al., 2024). For example, Shell aims to reduce its products' carbon intensity by 30% by 2035 and 65% by 2050 (from 2016 levels), while BP has committed to a 40% reduction in oil and gas production by 2030 and a tenfold increase in low-carbon investment by the same year (Chen et al., 2022; Wang, 2022). The gap represents a significant weakness in a company's overall climate strategy, particularly as global investors increasingly scrutinize companies' approaches to managing their complete emissions footprint.

Therefore, the company has diversified its energy portfolio by investing in CCUS and expanding the use of alternative fuels, such as B35 biodiesel, in alignment with Indonesia's renewable energy goals (NRE, 2024; Pertamina, 2024a). PT Pertamina assigned PT Pertamina NRE as one of its strategic subsidiaries to accelerate the energy transition by diversifying the energy mix and reducing GHG emissions, targeting a 17% share of renewable energy by 2030 through solar, geothermal, and other projects (NRE, 2024).

However, the IEA suggests that biofuel initiatives may have a limited impact on overall emissions when considering complete lifecycle assessments, including land-use changes for palm oil production (IEA, 2023b). Environmental organizations, such as Greenpeace and Mongabay, have criticized carbon offset programs as potentially enabling continued fossil fuel production rather than driving the necessary systemic changes in business models (Jong, 2023; ONeill, 2024). These independent perspectives suggest that while Pertamina's initiatives are in the right direction, achieving a credible long-term decarbonization pathway requires greater transparency, third-party monitoring, and alignment with science-based climate targets.

While PT Pertamina has made notable progress in managing operational emissions, the structural challenge of transforming its downstream value chain remains critical. Addressing Scope Three emissions would require transformative shifts in energy production, customer engagement, regulatory support, and fundamental changes to Pertamina's business model and product portfolio. Thus, the tension between decarbonization ambitions and traditional business growth presents a sustainability paradox for PT Pertamina and the broader oil and gas industry. PT Pertamina's sustainability investments come with significant economic trade-offs. High upfront costs, uncertain returns on green technologies, and dependency on palm oil biofuels may cause the company to lose market competitiveness due to environmental concerns and export restrictions. Unlike Shell or BP, Pertamina has not diversified into low-carbon business lines, making it vulnerable if fossil demand declines rapidly.

Discussion

Businesses, particularly PT Pertamina, are prioritizing ESG considerations for increased performance, reputation, and market access (Alareeni and Hamdan, 2020; Aydoğmuş et al., 2022; Naeem et al., 2022). However, measuring ESG performance remains challenging due to the lack of a universally accepted standard, and determining materiality in ESG reporting can be complex, leading to assessment inconsistencies (Billio et al., 2024).

PT Pertamina actively supports Indonesia's NDC targets by committing to achieving Net Zero emissions by 2060. The company plans to increase the share of gas in its portfolio from 3% to 19% by 2030 and allocate 14% of its investment budget to gas and renewable energy projects. It continues to expand its green energy initiatives. It has achieved a 33.6% reduction in Scope One and Two emissions from the 2010 baseline by 2023, prompting the evaluation of a more ambitious 38% reduction target for 2030 (Pertamina, 2022b, 2023c, 2024a).

Although Indonesia's E-NDC targets provide a more transparent and ambitious emission reduction framework, their effectiveness in driving corporate-level decarbonization, particularly in the energy sector, remains mixed. Much of Pertamina's progress is driven more by internal corporate strategies than direct regulatory enforcement. Weak regulatory incentives, insufficient carbon pricing mechanisms, and strong national reliance on fossil fuel revenues have constrained the full realization of E-NDC ambitions. Economic constraints also challenge the assumption that sustainability equals long-term profitability. High compliance costs, uncertain demand for alternative fuels, and a

weak domestic carbon market reduce financial predictability. Regulatory reform, robust carbon pricing, and supportive fiscal policy are needed to align sustainability with profitability. While the E-NDC has encouraged state-owned enterprises to pursue decarbonization, achieving more profound structural changes, especially concerning Scope Three emissions, requires stronger policy frameworks, fiscal support for low-carbon transitions, and long-term market incentives (Qalbie and Rahmaniah, 2023; Siregar, 2024).

PT Pertamina has improved its ESG performance but still lags behind some regional and global peers. Sustainalytics places Pertamina in the "medium risk" category, similar to Petronas, but below Shell and ExxonMobil (Sustainalytics, 2023), which have more advanced Scope Three emission strategies and net-zero targets (ExxonMobil, 2023; Petronas, 2023; Shell, 2023). This comparison underscores the need for Pertamina to strengthen its long-term climate commitments and transparency further.

However, it is essential to note that Pertamina's sustainability performance occurs within a regulatory context that may be less stringent than that in developed countries. Indonesia's ESG and climate disclosure frameworks are still evolving, and companies operate relatively more flexibly than firms subject to stricter regulations, such as the EU taxonomy or the U.S. SEC climate rules (UNFCCC, 2022; IEA, 2023b). Therefore, while Pertamina's progress appears favorable in a regional context, its achievements should be interpreted cautiously and assessed alongside international benchmarks to gauge the depth of its sustainability leadership.

The difficulty in managing Scope Three emissions highlights the fundamental sustainability challenge for oil and gas companies. Emissions from fossil fuel combustion by end users remain primarily unaddressed, despite improvements in operational efficiency and technology adoption. Achieving genuine climate neutrality requires an operational decarbonization and a fundamental shift from fossil-based products toward renewable energy services, energy efficiency offerings, and new business models that decouple revenue from carbon emissions (Naeem et al., 2022; Billio et al., 2024). Future strategies must focus beyond carbon offsets, realigning core businesses with low-carbon energy futures to meet Indonesia's long-term net-zero ambitions (Pertamina, 2024a).

One of PT Pertamina's key initiatives to support the energy transition involves expanding the use of crude palm oil (CPO)-based biodiesel. CPO-based biodiesel contributes significantly to enhancing energy security, reducing diesel imports, and promoting economic growth through job creation and increased agricultural productivity (Novindra et al., 2019; Halimatussadiah et al., 2021; Yasinta and Karuniasa, 2021). The government's B30 policy further supports renewable energy adoption (Purwanto and Lutfiana, 2023; Yanita et al., 2023), and CPO is viewed as a feasible alternative to fossil fuels, especially amid volatile oil prices (Erinto Simbolon and Aisyah, 2022; Fardilah et al., 2023). In addition, integrating local farmers into the CPO supply chain fosters rural community development (Fardilah et al., 2023).

However, expanding palm oil plantations poses significant environmental risks, including deforestation, biodiversity loss, and increased carbon emissions, with land conversion estimated to generate up to 62 million tonnes of CO_2 annually (Rahmadi et al., 2013). As Greenpeace warns, "palm oil-based biofuels risk causing more harm than good if sustainability safeguards are not enforced, particularly concerning deforestation and land-use change (ONeill, 2024). Moreover, potential air quality degradation from biodiesel production (Beyer et al., 2020; Ari Kabul Paminto et al., 2022; Kurniawati et al., 2022; S. Radjarejesri et al., 2023) and economic concerns about export competitiveness (Susanto, 2020; Halimatussadiah et al., 2021) have raised questions about the net environmental benefits of large-scale CPO-based biofuel programs.

While PT Pertamina's proactive initiatives demonstrate a strong commitment to sustainability, the long-term challenges of transforming an oil and gas company into a genuinely low-carbon enterprise remain formidable. Critical hurdles include managing Scope Three emissions, scaling renewable energy investments amid fluctuating global markets, and ensuring that biofuel initiatives do not exacerbate ecological degradation (Rahmadi et al., 2013; Beyer et al., 2020). Furthermore, the credibility of ESG achievements is increasingly dependent on transparent disclosures, third-party verifications, and the company's willingness to shift its energy portfolio toward low-carbon solutions fundamentally (Alareeni and Hamdan, 2020; Billio et al., 2024). Therefore, PT Pertamina's sustainability journey

should be viewed as an ongoing transition requiring continuous critical evaluation, adaptation, and bold structural transformation.

Lastly, regulatory gaps and implementation hurdles could still limit their real impact. The absence of a strong carbon pricing mechanism reduces motivation for companies to cut emissions (IEA, 2023b; Qalbie and Rahmaniah, 2023), delays or inconsistencies in renewable energy policies have added uncertainty for investors (Siregar, 2024). Oversight capacity also remains limited, especially in tracking Scope Three emissions. According to the IEA, Indonesia's policy framework lacks the consistency and clarity needed to attract long-term investment in clean energy (IEA, 2023b). To improve outcomes, policy efforts could be strengthened through clearer incentives, sectoral carbon budgets, third-party monitoring, and better alignment with international frameworks like the EU CBAM (UNFCCC, 2022; Panjaitan et al., 2023).

Critical Reflections

While PT Pertamina has made significant strides in advancing its decarbonization agenda, assessing these initiatives' depth and sustainability is essential. One key concern is the potential for greenwashing, wherein companies may emphasize environmental achievements without substantially transforming their carbon-intensive business models. Although Pertamina's expansion into biodiesel and renewable energy sources is commendable, reliance on palm oil for biofuel production has been associated with environmental challenges such as deforestation, biodiversity loss, and indirect land use changes (Beyer et al., 2020; Kurniawati et al., 2022). These unintended consequences risk undermining the net environmental benefits of the company's initiatives.

Moreover, the implementation limitations of CCUS remain substantial and require significant capital investments, advanced infrastructure, and long-term policy support to become economically viable (Johnson et al., 2021). In Indonesia, regulatory uncertainty and financing constraints could hamper the scaling of such technologies (Panjaitan et al., 2023). The effectiveness of ESG strategies also warrants closer scrutiny. Despite Pertamina's improved ESG ratings, questions persist regarding the comprehensiveness of ESG evaluations and whether such ratings adequately reflect Scope Three emission challenges. With Scope Three emissions remaining significantly high and difficult to manage, there is a risk that sustainability claims may overemphasize operational improvements while neglecting broader downstream impacts. These reflections suggest that while Pertamina's efforts represent essential progress, achieving true sustainability requires more profound, systemic transformations beyond current initiatives. These efforts are capital-intensive and uncertain. The profitability of carbon capture and renewable energy projects depends on market incentives, stable policies, and technological advancements.

Conclusions

This study emphasized PT Pertamina's noteworthy sustainability and carbon emission management initiatives. The company's strategic decarbonization program and firm adherence to ESG principles have exceeded its reduction target for Scope One and Two emissions. Pertamina improved its ESG standing and placed it at the top of 61 international integrated oil and gas businesses.

PT Pertamina's sustainable strategy includes investing in renewable energy sources, boosting energy efficiency, and using carbon capture technology. These initiatives promote the state's shift to a low-carbon economy and are consistent with Indonesia's larger goals under an increase in the nationally determined contribution (E-NDC). Furthermore, biodiesel sales have helped reduce CO_2 emissions by around 28 million tonnes annually. However, it needs sustained attention despite environmental issues related to palm oil extraction, like deforestation and biodiversity loss. Better farming methods and stricter laws drive this effect and pave the way for a more sustainable biofuel industry.

Pertamina has made significant strides in cutting direct emissions, but controlling Scope Three emissions from downstream fossil fuel products remains challenging. Pertamina is actively seeking solutions, as seen by initiatives like increasing biodiesel production and funding carbon offset projects, but more innovation and regulatory assistance are crucial. Lastly, Pertamina demonstrated a strong leadership commitment to achieving sustainability in the energy industry through its ESG performance and emission reduction advancements. However, for businesses to adequately combine

economic growth with environmental obligations and promote the achievement of long-term net-zero targets, technological advancements and sustainable policy reforms are crucial.

Although PT Pertamina's decarbonization initiatives have yielded notable successes, critical challenges persist. Managing Scope Three emissions, ensuring the environmental integrity of biofuel projects, and the long-term economic viability of CCUS technology could determine the true sustainability of Pertamina's transition. Achieving Indonesia's Net Zero target by 2060 requires technological advancements, broader institutional reforms, transparent stakeholder engagement, and a strategic rebalancing of Pertamina's core business model toward renewable and low-carbon energy. Future research should continue to monitor these developments to ensure a holistic and critical assessment of corporate sustainability efforts. Pertamina's long-term economic viability is uncertain. Its ESG ratings and emissions reductions are impressive, but do not guarantee profitability. The company's transformation depends on its ability to adapt its business model and manage economic and policy risks effectively.

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References

Alareeni B. A., and Hamdan A. (2020) ESG impact on performance of US S&P 500-listed firms. Corporate Governance: The International Journal of Business in Society 20(7): 1409-1428. doi:10.1108/CG-06-2020-0258

Atteridge A., and Strambo C. (2020) Seven principles to realize a just transition to a low-carbon economy: Stockholm Environment Institute.

Aydoğmuş M., Gülay G., Ergun K. (2022) Impact of ESG performance on firm value and profitability. Borsa Istanbul Review 22: S119-S127. Available at: https://doi.org/10.1016/j.bir.2022.11.006

Beyer R. M., Durán A. P., Rademacher T. T., Martin P., Tayleur C., Brooks S. E., Coomes D., Donald P. F., Sanderson F. J. (2020) The environmental impacts of palm oil and its alternatives. bioRxiv 2020.2002.2016.951301. Available at: https://doi.org/10.1101/2020.02.16.951301

Billio M., Costola M., Hristova I., Latino C., Pelizzon L. (2024) Sustainable Finance: A Journey Toward ESG and Climate Risk. International Review of Environmental and Resource Economics 18(1-2): 1-75. Available at: http://dx.doi.org/10.1561/101.00000156

Bórawski P., Wyszomierski R., Bełdycka-Bórawska A., Mickiewicz B., Kalinowska B., Dunn J. W., Rokicki T. (2022) Development of Renewable Energy Sources in the European Union in the Context of Sustainable Development Policy. Energies 15(4): 1545. Available at: https://doi.org/10.3390/en15041545

Chen X., Shao N., Zhang H., Fang W., Xu X., Xu T., Lv H., Li Y. (2022) A Green and Low-Carbon Transformation of Oil and Gas Companies. Advances in Transdisciplinary Engineering 23.

Dechezleprêtre A., Kozluk T., Kruse T., Nachtigall D., de Serres A. (2019) Do Environmental and Economic Performance Go Together? A Review of Micro-level Empirical Evidence from the Past Decade or So. International Review of Environmental and Resource Economics 13(1-2): 1-118. Available at: http://dx.doi.org/10.1561/101.00000106

Dhina N. and Permana T. (2021) Natural gas transportation business contribution to Indonesia's national energy policy and carbon emission offset by on-grid solar PV utilization: Surabaya, East Java, Indonesia. IOP Conference Series: Earth and Environmental Science 753(1): 012022. DOI:10.1088/1755-1315/753/1/012022

Egbumokei P. I., Dienagha I. N., Digitemie W. N., Cynthia,E. (2024). Sustainable business strategies for decarbonizing the oil and gas industry: A roadmap to net-zero emissions. International Journal of Multidisciplinary Research and Growth Evaluation 5(5): 1014-1028. Available at: https://doi.org/10.54660/.ijmrge.2024.5.5.1014-1028

ExxonMobil (2023) Advancing Climate Solutions Report. Available at: https://corporate.exxonmobil.com/-/media/global/files/advancing-climate-solutions-progress-report/2023/2023-advancing-climate-solutions-progress-report.pdf (accessed 15 January 2025).

Fardilah V. A., Pusparizkita Y. M., Tauviqirrahman M., Bayuseno A. P. (2023) An overview of biodiesel, a fuel blend made from palm oil. IOP Conference Series: Earth and Environmental Science 1268(1): 012057. Available at: https://doi.org/10.1088/1755-1315/1268/1/012057

Fauzan M., Cangara A. R., Syafik M., Burhanuddin A., Marifat I. D. N. (2020) The implementation of Copenhagen Accord in the greenhouse gas emission reduction in Indonesia: a case study of the province of South Sulawesi. IOP Conference Series: Earth and Environmental Science 575(1): 012229. Available at: https://doi.org/10.1088/1755-1315/575/1/012229

Ferdiansyah B. (2023) Pertamina sebut efisiensi energi sebagai „no regret initiative". ANTARA. Available at: https://www.antaranews.com/berita/3693711/pertamina-sebut-efisiensi-energi-sebagai-no-regret-initiative (accessed 15 January 2025).

Gabriel V. M. d. S., Lozano M. B., Matias M. F. L. I. (2022) The low-carbon equity market: A new alternative for investment diversification? Global Policy 13(1): 34-47. Available at: https://doi.org/10.1111/1758-5899.13024

Guo Y., Yang Y., Bradshaw M., Wang C., Blondeel M. (2023) Globalization and decarbonization: Changing strategies of global oil and gas companies. WIREs Climate Change 14(6): e849. Available at: https://doi.org/10.1002/wcc.849

Halimatussadiah A., Nainggolan D., Yui S., Moeis F. R., Siregar A. A. (2021) Progressive biodiesel policy in Indonesia: Does the Government's economic proposition hold? Renewable and Sustainable Energy Reviews 150: 111431. Available at: https://doi.org/10.1016/j.rser.2021.111431

Ibn Batouta K., Aouhassi S. & Mansouri K. (2023) Energy efficiency in the manufacturing industry – A tertiary review and a conceptual knowledge-based framework. Energy Reports 9: 4635-4653. Available at: https://doi.org/10.1016/j.egyr.2023.03.107

IEA (International Energy Agency) (2023a) Emissions from Oil and Gas Operations in Net Zero Transitions. Available at: https://iea.blob.core.windows.net/assets/2f65984e-73ee-40ba-a4d5-bb2e2c94cecb/EmissionsfromOilandGasOperationinNetZeroTransitions.pdf (accessed 11 January 2025).

IEA (International Energy Agency) (2023b) World Energy Outlook 2023. Available at: https://www.iea.org/reports/world-energy-outlook-2023 (accessed 7 January 2025).

Jäger J., Brutschin E., Pianta S., Omann I., Kammerlander M., Sudharmma Vishwanathan S.,Vrontisi Z., Macdonald J., van Ruijven B. (2023) Stakeholder engagement and decarbonization pathways: Meeting the challenges of the COVID-19 pandemic. Frontiers in Sustainability 3: 1063719. Available at: https://doi.org/10.3389/frsus.2022.1063719

Jannah N. and Sumanto I. R. (2019) Gold PROPER; Business world concern upon environmental aspect: Case study CSRPT Pertamina EP Asset 3 Subang Field. IOP Conference Series: Earth and Environmental Science 399(1): 012004. Available at: https://doi.org/10.1088/1755-1315/399/1/012004

Janus B. and Murphy H. (2013) Sustainability reporting and the oil and gas industry - challenges and emerging trends. Paper presented at the European HSE Conference and Exhibition.

Johnson O., Mete G., Sanchez F. B., Shawoo Z., Talebian S. (2021) Toward climate-neutral heavy industry: An analysis of industry transition roadmaps. Applied Sciences 11(12):5375. Available at: https://doi.org/10.3390/app11125375

Jong H. N. (2023) Indonesia pushes carbon-intensive 'false solutions' in its energy transition. Mongabay. Available at: https://news.mongabay.com/2023/12/indonesia-pushes-carbon-intensive-false-solutions-in-its-energy-transition/ (accessed 5 January 2025).

Kolk A. and Levy D. (2001) Winds of change: corporate strategy, climate change and oil multinationals. European Management Journal 19(5): 501-509. Available at: https://doi.org/10.1016/S0263-2373(01)00064-0

Kurmala A. (2023) Pertamina reaffirms its commitment to net zero emissions by 2060. Available at: https://en.antaranews.com/news/300027/pertamina-reaffirms-its-commitment-to-net-zero-emissions-by-2060 (accessed 5 January 2025).

Kurniawati A. S., Pratiwi A. I., Ariyani N. R., Septiani M., Sasongko N. A. (2022) Utilization of palm oil based biofuel to support sustainable energy transition in Indonesia. IOP Conference Series: Earth and Environmental Science 1108(1): 012038. Available at: https://doi.org/10.1088/1755-1315/1108/1/012038

Midor K., Ivanova T. N., Molenda M., Biały W., Zakharov O. V. (2022) Aspects of energy saving of oil-producing enterprises. Energies 15(1): 259.

Mujiyanto S. and Tiess G. (2013) Secure energy supply in 2025: Indonesia's need for an energy policy strategy. Energy Policy 61: 31-41. Available at: https://doi.org/10.1016/j.enpol.2013.05.119

Naeem N., Cankaya S. and Bildik R. (2022) Does ESG performance affect the financial performance of environmentally sensitive industries? A comparison between emerging and developed markets. Borsa Istanbul Review 22: S128-S140. Available at: https://doi.org/10.1016/j.bir.2022.11.014

Nasir A. (2019) The implementation of corporate social responsibility (CSR) program by an oil and gas state company (PERTAMINA) in Indonesia. Paper presented at the Proceedings of the International Symposium on Social Sciences, Education, and Humanities (ISSEH 2018).

Novindra N., Sinaga B. M., Hartoyo S. and Erwidodo E. (2019) Impact of increasing in production capacity of CPO downstream industries on competitiveness and welfare of oil palm farmers in Indonesia. International Journal of Oil Palm 2(2): 61-73. Available at: https://doi.org/10.35876/ijop.v2i2.33

NRE P. P. (2024) Pertamina New & Renewable Energy. Available at: https://api.pertaminanre.com/assets-be/pdf_1719200296412.pdf (accessed 8 January 2025).

Okoh A. S. and Okpanachi E. (2023) Transcending energy transition complexities in building a carbon-neutral economy: The case of Nigeria. Cleaner Energy Systems 6: 100069. Available at: https://doi.org/10.1016/j.cles.2023.100069

ONeill I. (2024) Indonesia's carbon offset failures show climate polluters must pay, can't 'trade' away their responsibilities. Greenpeace. Available at: https://www.greenpeace.org/southeastasia/press/66545/carbon-offset-failures/ (accessed 8 January 2025).

Oruwari H. O. and Itsekor L. (2023) Strategies for decarbonizing the oil and gas industries. Paper presented at the SPE Nigeria Annual International Conference and Exhibition. Available at: https://doi.org/10.2118/217179-MS

Paminto A., Karuniasa M., Frimawaty E. (2022) Potential environmental impact of biodiesel production from palm oil using lca (life cycle assessment) in indonesia. Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan 12(1): 64-71. Available at: https://doi.org/10.29244/jpsl.12.1.64-71

Panjaitan T. W. S., Dargusch P., Aziz A. A. Wadley D. (2018) Carbon management in an emissions-intensive industry in a developing economy: Cement manufacturing in Indonesia. Case Studies in the Environment 2(1): 1-9. Available at: https://doi.org/10.1525/cse.2017.000976

Panjaitan T. W. S., Dargusch P., Wadley D. & Aziz A. A. (2021) Meeting international standards of cleaner production in developing countries: Challenges and financial realities facing the Indonesian cement industry. Journal of Cleaner Production 318: 128604. Available at: https://doi.org/10.1016/j.jclepro.2021.128604

Panjaitan T. W. S., Dargusch P., Wadley D. & Aziz A. A. (2023) A study of management decisions to adopt emission reduction measures in heavy industry in an emerging economy. Scientific Reports 13(1): 1413. Available at: https://doi.org/10.1038/s41598-023-28417-2

Pertamina (2020) Pertamina Sustainability Report 2019. Available at: https://www.pertamina.com/file/files/2025/04/pertamina-sustainability-report-2019-2.pdf (accessed 8 January 2025).

Pertamina. (2021). 2020 Sustainability Report. Retrieved from https://www.pertamina.com/file/files/2025/03/pertamina-sustainability-report-2020.pdf (accessed 8 January 2025).

Pertamina (2022a) Pertamina_Sustainability Report 2021. Available at: https://www.pertamina.com/file/files/2025/03/pertamina-sustainability-report-2021-2.pdf (accessed 8 January 2025).

Pertamina (2022b) Pertamina's Commitment to Sustainability Programs [Press release]. Available at: https://www.pertamina.com/en/news/berita-energia-komitmen-pertamina-terhadap-program-keberlanjutan (accessed 8 January 2025).

Pertamina (2023a) Annual Report. Available at: https://www.pertamina.com/file/files/2025/03/pertamina-annual-report-2022.pdf (accessed 8 January 2025).

Pertamina (2023b) New chapter in Pertamina's carbon business. Available at: https://www.pertamina.com/file/files/2025/03/energia-monthly-november-2023.pdf (accessed 8 January 2025).

Pertamina (2023c) Pertamina_Sustainability Report 2022. Available at: https://www.pertamina.com/file/files/2025/03/pertamina-sustainability-report-2022.pdf (accessed 8 January 2025).

Pertamina (2024a) Ensuring Transition, Energizing the Nation. Available at: https://www.pertamina.com/file/files/2025/03/pertamina-sustainability-report-2023.pdf (accessed 8 January 2025).

Pertamina (2024b) ESG Performance, Pertamina's Decarbonization Exceeds 124% Target [Press release]. Available at: https://www.pertamina.com/en/news/siaran-pers-kinerja-esg-dekarbonisasi-pertamina-lampaui-target-124-persen (accessed 8 January 2025).

Pertamina (2024c) Pertamina Successfully Achieves Cost Optimization of up to USD 1.25 Billion [Press release]. Available at: https://www.pertamina.com/en/news/siaran-pers-pertamina-sukses-meraih-cost-optimization-hingga-usd-1-25-miliar (accessed 8 January 2025).

Pertamina (2024d) Pertamina Supports the 100,000 Tree Seedlings Planting Movement for Environmental Sustainability [Press release]. Available at: https://www.pertamina.com/en/news/siaran-pers-pertamina-dukung-gerakan-penanaman-100-000-bibit-pohon-untuk-kelestarian-lingkungan (accessed 8 January 2025).

Petronas (2023) Sustainability Report 2023. Retrieved from https://www.petronas.com/pcg/sites/default/files/2024-03/Sustainability%20Report%202023.pdf (accessed 8 January 2025).

Purwanto A. J., Lutfiana D. (2023) Toward an optimized biofuel use pathway for Indonesia road transport. In: Taghizadeh-Hesary F., Zhang D. (eds) The Handbook of Energy Policy. Singapore: Springer Nature Singapore pp. 555–586

Qalbie A. S. S. And Rahmaniah R. (2023) The opportunity to achieve net zero emissions in Indonesia through the implementation of a green economy to address climate change. Global South Review 5(1):80–102. Available at: https://doi.org/10.22146/globalsouth.86381

Radjarejesri S., Mani M., Sharma A., Arunkumar M., Singh B. K.,Kannan S., Eldosoky G. E., Wabaidur S. M., Aftab S. (2023) Environmental and chemical changes in palm oil biodiesel using homogeneous catalysts. Global NEST Journal 25(8); 101-108. Available at: https://doi.org/10.30955/gnj.004984

Rahmadi A., Aye L., Moore G. (2013) The feasibility and implications for conventional liquid fossil fuel of the Indonesian biofuel target in 2025. Energy Policy 61:12–21. Available at: https://doi.org/10.1016/j.enpol.2013.06.103

Rahman A., Richards R., Dargusch P., Wadley D. (2023) Pathways to reduce Indonesia's dependence on oil and achieve longer-term decarbonization. Renewable Energy 202:1305–1323. Available at: https://doi.org/10.1016/j.renene.2022.11.051

Setiawan P., Iswati S. (2019) Carbon emissions disclosure, environmental management system, and environmental performance: Evidence from the plantation industries in Indonesia. Indonesian Journal of Sustainability Accounting and Management 3(2):215–226. DOI: 10.28992/ijsam.v3i2.99

Setiawan V. N. (2023) Top! Produksi Migas Pertamina di tahun 2022 lampaui target [Top! Pertamina's 2022 Oil and Gas Production Exceeds Target]. CNBC. Available at: https://www.

cnbcindonesia.com/news/20230131171305-4-409808/top-produksi-migas-pertamina-di-tahun-2022-lampaui-target (accessed 8 January 2025) *(in Indonesian)*.

Setiawan V. N. (2024) Pertamina berhasil pakai teknologi CCUS di blok migas, ini buktinya. CNBC Indonesia [Pertamina Successfully Uses CCUS Technology in Oil and Gas Blocks, Here's the Proof. CNBC Indonesia.]. Available at: https://www.cnbcindonesia.com/news/20240529154920-4-542167/pertamina-berhasil-pakai-teknologi-ccus-di-blok-migas-ini-buktinya (accessed 8 January 2025) *(in Indonesian)*.

Shell (2023) Energy transition strategy report. Available at: https://www.shell.com/sustainability/reporting-centre/reporting-centre-archive.html

Simbolon E. and Aisyah L. (2022) Palm oil biodiesel: challenges, risks and opportunities for reducing and replacing the non-renewable fossil fuel dependancy - a review. Scientific Contributions Oil & Gas 36(1): 15-29. Available at: https://doi.org/10.29017/scog.36.1.645

Siregar Y. I. (2024) Pathways towards net-zero emissions in Indonesia's energy sector. Energy 308:133014. Available at: https://doi.org/10.1016/j.energy.2024.133014

Susanto D. A. (2020) Daya saing ekspor produk CPO Indonesia dan potensi hilirisasi diolah menjadi biodiesel [The export competitiveness of Indonesian CPO products and the potential for downstream processing into biodiesel]. Jurnal Perspektif Bea Dan Cukai 4(2). Available at: https://doi.org/10.31092/jpbc.v4i2.952 *(in Indonesian)*.

Sustainalytics (2023) Company ESG risk ratings. Available at: https://www.sustainalytics.com/esg-rating/pt-pertamina-persero/1012021232 (accessed 8 January 2025).

UNFCCC (United Nations Framework Convention on Climate Change) (2022) Enhanced nationally determined contribution. Republic of Indonesia. Available at: https://unfccc.int/sites/default/files/NDC/2022-09/ENDC%20Indonesia.pdf (accessed 8 January 2025).

Wang F., Harindintwali J. D., Wei K., et al., (2023) Climate change: Strategies for mitigation and adaptation. The Innovation Geoscience 1(1):100015. doi:10.59717/j.xinn-geo.2023.100015

Wang X. (2022) Research on the low-carbon transformation path of Shell Oil Company. BCP Business & Management 21:27–31. Available at: : https://doi.org/10.54691/bcpbm.v21i.1170

Wang Z., Li S., Li Z. (2022) A novel strategy to reduce carbon emissions of heavy oil thermal recovery: Condensation heat transfer performance of flue gas-assisted steam flooding. Applied Thermal Engineering 205:118076. Available at: https://doi.org/10.1016/j.applthermaleng.2022.118076

Yang M., Chen L., Wang J., Msigwa G., Osman A. I., Fawzy S., Rooney D. W., Yap P.-S. (2023) Circular economy strategies for combating climate change and other environmental issues. Environmental Chemistry Letters 21(1):55–80. Available at: https://doi.org/10.1007/s10311-022-01499-6

Yanita M., Alamsyah Z., Fauzia G., Hamid E., Napitupulu D. (2023) Development prospects of Indonesia's biodiesel industry: A study of raw material, market, and policy aspects. E3S Web of Conferences 373:04021. Available at: https://doi.org/10.1051/e3sconf/202337304021

Yasinta T., Karuniasa M. (2021) Palm oil-based biofuels and sustainability in Indonesia: Assess social, environmental and economic aspects. IOP Conference Series: Earth and Environmental Science 716(1):012113. DOI:10.1088/1755-1315/716/1/012113