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MORALITY BEFORE KNOWLEDGE

Transition risk analysis in the mining sector and its implications for environmental conflict: A Case study approach

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ABSTRACT

Background: Climate change has become a major challenge of the 21st century, driving a global transition toward low-carbon energy to reduce greenhouse gas emissions, with a target of Net Zero Emissions (NZE) by 2050. The mining sector, particularly coal, faces significant transition risks, such as declining coal demand, rising operational costs, and social and environmental impacts due to increasingly stringent emission reduction policies. PT ABC, as a major coal producer in Indonesia, must adapt by shifting to renewable energy, reducing its dependence on coal, and managing transition risks while seizing opportunities for energy diversification. **Methods:** This study analyzes the transition risks faced by PT ABC, focusing on the impact of global climate policies, fluctuations in international carbon prices, and the shift toward renewable energy on the company's financial performance. **Findings:** The analysis shows that the company needs to reduce emissions by approximately 993,478 tons of CO_2eq per year to meet Indonesia's emission reduction targets in the Enhanced Nationally Determined Contributions (ENDC), with an additional annual cost of around IDR 29.8 billion at a carbon price of IDR 30,000 per ton. If carbon prices increase, costs could reach IDR 140.5 billion or IDR 198.7 billion by 2030. This study identifies four main transition risks: government policy changes, carbon price fluctuations, declining coal demand, and the implementation of a carbon tax. **Conclusion:** To mitigate financial and operational impacts, PT ABC needs to adopt environmentally friendly technologies, diversify investments in renewable energy, and improve energy efficiency. These risk mitigation efforts are expected to reduce negative impacts and support the company's operational sustainability amid the global energy transition. **Novelty/Originality of this article:** By quantifying emission reduction costs and potential carbon price impacts, it offers insights into strategic measures for coal companies adapting to the low-carbon transition.

KEYWORDS: transition risk; carbon emissions; mining sector; renewable energy; emission trading system (ETS).

1. Introduction

Climate change has now become one of the world's major challenges, with tangible impacts such as rising global temperatures, increased frequency of natural disasters, and ecosystem degradation. Mitigation efforts to address climate change have become a global priority, one of which is the transition to more environmentally friendly and low-carbon energy sources. The Paris Agreement sets a global target of Net Zero Emissions (NZE) by 2050, requiring countries to reduce their dependence on fossil fuels and shift towards renewable energy sources such as wind, solar, and hydrogen. This transition aims to curb greenhouse gas (GHG) emissions, which are the primary cause of global warming (Jonek-Kowalska, 2024; Reyseliani et al., 2024). The energy sector, which has long relied on fossil

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fuels, is a key focus due to its significant contribution to global carbon emissions (Aslam et al., 2024; Sun et al., 2024).

The coal mining sector faces significant transition risks, which can be classified into three main categories: economic, social, and environmental. Economic risks include declining revenue due to reduced global coal demand, increased operational costs to meet sustainability standards, and potential loss of market share in international coal markets (Palea et al., 2024). Social risks arise from reduced coal mining activities, which can lead to structural unemployment in communities dependent on the mining sector. Mine closures or production cuts can cause broader social disruptions, such as labor migration, poverty, and social instability if there is no effort to ensure a just and inclusive transition. Therefore, it is crucial to design policies that can provide support to affected communities (Subramaniam et al., 2024; Sun et al., 2024). Environmental risks are also a major issue, as the coal mining sector contributes to air pollution, water contamination, and land degradation. With increasing pressure from stricter environmental regulations, mining companies must better manage these negative impacts. Effective environmental management will be a key factor in maintaining operational permits and reducing carbon footprints (Chu et al., 2024). Additionally, the energy transition offers opportunities for the mining sector to diversify into more environmentally friendly industries, such as renewable energy and energy storage technologies, which can help mitigate negative environmental impacts (Sun et al., 2024; Xue et al., 2024).

In Indonesia, energy investments are projected to grow by 35% to 120% by 2040, driven by the transition to renewable energy as a priority agenda for reducing carbon emissions (Bakhsh et al., 2024). Studies show that policies related to carbon emission reductions can have a material impact on economic sustainability. These impacts are evident in changes in lending and investment patterns, particularly for projects prioritizing low-carbon energy or environmentally friendly technologies (Subramaniam et al., 2024). This presents both challenges and opportunities for the energy and mining sectors, especially in developing countries, to adapt to increasingly stringent environmental policies (Chu et al., 2024). Large-scale investments in the energy sector are putting pressure on fossil fuel-dependent companies to diversify their businesses (Sun et al., 2024).

PT XX is one of Indonesia's largest coal producers. With increasing global pressure to transition to clean energy, Bumi Resources faces significant challenges in reducing its reliance on coal as its primary revenue source. The company has begun taking steps to adapt to global trends, including exploring coal bed methane (CBM) as a cleaner and more efficient alternative energy source. This move is expected to reduce the environmental impact of mining operations and open opportunities for energy diversification (Palea et al., 2024; Sun et al., 2024). This study aims to analyze the transition risks faced by the mining sector, particularly PT XX. It is expected to provide recommendations for managing transition risks and leveraging existing opportunities. An integrated approach will offer valuable insights for mining companies to address these challenges more effectively (Chu et al., 2024; Sun et al., 2024). This research is also expected to contribute to the literature on transition risk mitigation strategies in the mining sector and provide useful guidance for fair and sustainable energy policies.

The environment, as defined in Law No. 32 of 2009 in Indonesia, encompasses the unity of space that includes all objects, forces, conditions, and living organisms, including humans and their behavior, which influence nature, the continuity of life, and the welfare of humans and other living beings. Environmental science, as an interdisciplinary field, studies the interaction between humans and the environment, aiming to understand the impact of human activities on ecosystems and manage these systems sustainably (Strange et al., 2024).

Sustainability is a core principle that emphasizes the balance between economic success, environmental preservation, and social responsibility. In the corporate context, this approach is implemented through the circular economy concept, which aims to reduce waste and maximize resource efficiency, thereby supporting significant carbon emission reductions and achieving sustainable development goals (Palea et al., 2024). In the mining

sector, sustainability serves as a guideline for managing natural resources efficiently to meet current needs without compromising the needs of future generations. The adoption of environmentally friendly technologies in mining operations is also a key strategy in achieving this goal (Xue et al., 2024). Overall, sustainability in the energy context emphasizes efficient resource management, the adoption of green technologies, and the reduction of negative environmental impacts, collectively supporting balanced and sustainable economic development (Adom, 2024).

Environmental economics is a branch of economics that focuses on the relationship between economic activities and the environment. This approach seeks to internalize the negative environmental impacts, such as pollution and natural resource exploitation, into economic decision-making. In the context of the energy transition, environmental economics provides a framework for promoting renewable energy and reducing dependence on fossil fuels, which are the primary causes of carbon emissions and climate change (Shang et al., 2024). In the mining sector, environmental economics highlights the importance of transitioning to more environmentally friendly practices through the adoption of clean technologies and sustainable waste management. Studies on the mining industry in China reveal that Environmental Information Disclosure has a positive impact on green transformation, although there are challenges in implementation due to regulatory and technological limitations (Zhang et al., 2024). Strategies such as energy diversification and economic structure optimization have proven effective in reducing the negative impacts of fossil fuel-based energy consumption, especially in developing countries heavily reliant on coal as a primary energy source (Chong et al., 2023). Environmental economics provides a crucial foundation for understanding the dynamics of the energy transition, particularly in the mining sector, by emphasizing the importance of innovation, stringent regulations, and international collaboration to address complex environmental challenges. This strategy supports the development of policies that are not only environmentally friendly but also promote inclusive and sustainable long-term economic growth.

The mining sector, which often relies on fossil fuels, contributes significantly to global carbon emissions, both from extraction processes, mineral processing, and the transportation of mined materials. In the context of the energy transition, reducing carbon emissions is a top priority to achieve decarbonization targets and environmental sustainability (Xue et al., 2024). Carbon emission mitigation in the mining sector includes diversifying energy sources by utilizing renewable energy, such as solar and wind power, to replace fossil fuels in mining operations. The adoption of low-carbon technologies, such as electric vehicles for mine transportation, has also shown positive results in reducing operational carbon footprints (Gan & Zhao, 2024).

The carbon market is a market instrument designed to reduce greenhouse gas emissions by assigning economic value to carbon emissions through the trading of carbon credits. The carbon market is divided into two types: voluntary carbon markets, which involve entities not legally required but willing to demonstrate sustainability commitments, and mandatory carbon markets, which operate under specific policies such as the European Union Emissions Trading Scheme (EU ETS). Both types of markets encourage companies to adopt low-carbon technologies and sustainability strategies, as well as increase climate data transparency, which in turn reduces energy transition risks (Palea et al., 2024; Sun et al., 2024; Xu et al., 2024).

The Emission Trading System (ETS) is a market mechanism that allows companies to buy and sell carbon emission allowances, aiming to efficiently reduce greenhouse gas emissions. The ETS acts as an economic instrument that motivates companies to reduce carbon emissions by providing financial incentives for those who successfully reduce emissions below set limits (Xu et al., 2024). The carbon market through ETS emphasizes the "cap-and-trade" principle, which sets a limit or quota on carbon emissions that can be traded among companies complying with emission regulations. One of the largest examples of ETS is the EU ETS, which covers various industrial sectors in Europe and has significantly reduced emissions over the past few decades (Palea et al., 2024). Globally, ETS is increasingly recognized as an important tool for achieving decarbonization and Net Zero

Emissions (NZE) targets, particularly in the transition to clean and low-carbon energy. In addition to providing flexibility for companies, ETS also supports global efforts to mitigate climate change by reducing carbon emissions in a measurable and controlled manner (Aydin et al., 2024). However, the implementation of ETS also faces challenges, such as carbon price fluctuations that can affect market stability and difficulties in setting the appropriate emission quota levels (Sun et al., 2024). Therefore, strengthening and monitoring the ETS system is crucial to ensure its success in reducing the impacts of climate change.

On the other hand, carbon taxes are environmental policies that set a price on carbon emissions, based on the "polluter pays" principle, which requires emitters to pay for the environmental damage they cause. Carbon tax policies can encourage innovation in environmentally friendly technologies, improve energy efficiency, and support more effective reductions in greenhouse gas emissions (Wang et al., 2024; Yuan et al., 2024). These two instruments, carbon markets and carbon taxes, work synergistically to accelerate the transition to a low-carbon economy and achieve global decarbonization goals.

The energy transition refers to the shift from fossil fuel use to cleaner and renewable energy sources, such as solar, wind, and biomass. This process is at the core of global efforts to reduce carbon emissions, slow global warming, and achieve environmental and economic sustainability, as mandated by the 2015 Paris Agreement (Bakhsh et al., 2024). In addition to mitigating climate change impacts, the energy transition also aims to enhance energy security by diversifying energy sources and reducing dependence on fossil fuels (Kartal et al., 2024). Risk management is crucial to help companies, such as PT XX, identify and manage the potential negative impacts of this transition. Through systematic risk management, companies can reduce exposure to threats and seize opportunities in the shift toward renewable energy.

Environmental, Social, and Governance (ESG) refers to an integrated approach to assessing company performance based on three main aspects: environmental, social, and governance. On the environmental dimension, ESG evaluates how companies manage their ecological impacts, including natural resource management, carbon emission reductions, and efforts to reduce pollution and environmental damage (Aydin et al., 2024). On the social side, ESG focuses on a company's responsibility toward employees, local communities, and consumers, encompassing human rights protection, social justice, and community well-being (Xie & Bui, 2024). Meanwhile, governance pertains to aspects of transparency, managerial integrity, and the quality of corporate decision-making, including the implementation of fair policies, anti-corruption measures, and high accountability (Xue et al., 2024). The comprehensive application of ESG principles can enhance a company's reputation, attract sustainability-focused investors, and reduce long-term risks associated with climate change and social instability. In the mining sector, ESG implementation is increasingly important for managing environmental risks, improving community relations, and ensuring regulatory compliance (Shang et al., 2024; Wang et al., 2024).

Risk management is a systematic approach to identifying, evaluating, and managing risks that can affect organizational objectives. In the mining sector, risk management is essential for addressing uncertainties arising from the energy transition, such as regulatory changes and market volatility. This process involves risk identification, impact analysis, mitigation planning, and continuous monitoring to ensure operational continuity (Sun et al., 2024). The first stage is risk identification, which includes threats from internal and external factors, such as natural disasters and stricter environmental policies (Xu et al., 2024). Next, risk evaluation is conducted by assessing the likelihood and impact of risks on the company, where technologies such as machine learning can improve risk evaluation accuracy (Subramaniam et al., 2024). After that, mitigation strategies are developed with a focus on resource diversification, adoption of low-carbon technologies, and the application of Environmental, Social, and Governance (ESG) principles to reduce risks and enhance global competitiveness (Carr-Wilson et al., 2024). Finally, risk monitoring and control are carried out to ensure the effectiveness of strategies and policy adjustments if necessary (Xue et al., 2024). Integrated risk management also emphasizes collaboration among

stakeholders to create opportunities for innovation and sustainable growth (Bandpey et al., 2024). To address climate change challenges, mining companies need to understand and manage two main types of risks: physical risks, which are related to the direct impacts of climate change on operations, and transition risks, which are associated with the shift toward a low-carbon economy and increasingly stringent regulations.

Physical risks in the mining sector refer to threats arising from climate change, such as extreme temperatures, heavy rainfall, floods, and other natural disasters, which can damage mining infrastructure, disrupt supply chains, and increase operational and remediation costs (Klein et al., 2022). Additionally, climate change worsens the quality of water and soil around mining sites, increasing pollution risks and the potential for litigation related to ecosystem damage (Xu et al., 2024). Physical risks also affect transportation infrastructure and energy supply, with extreme weather events such as storms and droughts disrupting the distribution of mined materials and causing commodity price volatility (Bandpey et al., 2024). To address this, many mining companies are adopting technology-based mitigation strategies, such as predictive tools to monitor environmental conditions, and implementing Environmental, Social, and Governance (ESG) principles to support operational sustainability (Xue et al., 2024).

Meanwhile, transition risks encompass economic, social, and technological challenges arising from the shift from fossil fuels to low-carbon energy. The mining sector faces these risks due to its reliance on critical minerals such as lithium and cobalt, which are needed for clean energy technologies. Global demand for these minerals is expected to increase, adding pressure to supply chains and slowing the global energy transition (Aydin et al., 2024; Carr-Wilson et al., 2024). These risks also involve regulatory uncertainty, market fluctuations, and challenges in maintaining economic competitiveness amid stringent decarbonization policies (Aydin et al., 2024; Gan & Zhao, 2024). The social impacts of energy transition risks are significant, particularly in communities dependent on fossil fuels for their livelihoods. The concept of "just transition" becomes crucial to ensure the energy transition is carried out fairly by providing economic and social support to affected groups, such as miners and local communities. The closure of coal mines without adequate planning can lead to social losses, including unemployment and economic inequality in mining regions, as seen in case studies in Australia (Aydin et al., 2024; Xie & Bui, 2024). Transition risk mitigation strategies combine technology and governance based on Environmental, Social, and Governance (ESG), where data-driven predictive technologies, such as real-time monitoring, enable more accurate risk identification and effective mitigation measures. The application of ESG frameworks not only reduces transition risks but also opens opportunities for green investments that support long-term economic sustainability (Aydin et al., 2024; Gan & Zhao, 2024). However, transition risks also create uncertainty in mining sector investments and operations, with geopolitical tensions and political risks in mineral-producing countries further complicating dynamics and hindering investments in clean energy technologies (Özkan et al., 2024).

Climate change risks have become a major concern in the mining sector due to their significant impacts on operations, the environment, and infrastructure. Changes in rainfall patterns, rising temperatures, and natural disasters such as floods or droughts can damage mining facilities, pollute water, and cause environmental degradation (Klein et al., 2022). Climate change impacts also affect transportation infrastructure and increase operational costs, such as road damage and mineral processing facility disruptions due to higher temperatures and hydrological changes (Klein et al., 2022). Additionally, social impacts such as job losses in mining regions can occur (Benita & Gaytán-Alfaro, 2024). Beyond physical risks, climate change also influences policies and regulations governing the mining sector. Major mining-producing countries face pressure to reduce carbon emissions, impacting the sustainability of fossil fuel-based mining operations and triggering transition risks, such as increased regulatory costs and market pressure to shift to more environmentally friendly resources (Xie & Bui, 2024). This can reduce the competitiveness of mining companies and affect investments in low-carbon technologies needed to support the energy transition (Xu et al., 2024). Effective mitigation strategies involve the adoption

of environmentally friendly technologies and data-based management to reduce physical risks, such as the use of artificial intelligence and data-driven predictive models. Enhanced transparency through Environmental, Social, and Governance (ESG) frameworks also helps mining companies address climate change challenges. The mining sector must integrate climate change risk mitigation into business strategies, including investments in low-carbon technologies and adaptation to new environmental policies, to ensure operational sustainability (Tao & Chao, 2024).

Risk mitigation in the mining sector is a crucial step to reduce the negative impacts of operational activities, regulatory changes, and increasingly complex environmental and social challenges. Mitigation strategies include the adoption of environmentally friendly technologies, resource diversification, and the implementation of Environmental, Social, and Governance (ESG)-based governance. This approach helps mining companies reduce risks related to regulations and market changes, while opening opportunities for green investments to support long-term economic sustainability (Aslam et al., 2024; Shang et al., 2024; Wang et al., 2024). One of the main challenges is the global energy transition, which involves the use of critical minerals such as lithium, cobalt, and rare earth elements, which can pose high supply risks and environmental impacts due to mining activities. Therefore, mitigation strategies include supply chain diversification and the use of more efficient mining technologies to reduce carbon footprints and other environmental impacts (Bandpey et al., 2024; Niu et al., 2024). The application of ESG also enhances corporate transparency and accountability in addressing risks, with a focus on operational efficiency and the management of environmental impacts and community relations (Xie & Bui, 2024; Xue et al., 2024). Additionally, risk mitigation involves careful planning for regulatory changes and market dynamics, such as carbon pricing policies and incentives for investments in low-carbon technologies, which encourage companies to adapt to global market needs and meet sustainability targets (Bandpey et al., 2024; Xie & Bui, 2024). This integrated and collaborative approach is essential to ensure economic, social, and environmental sustainability in addressing the challenges of the energy transition and global climate change.

Green investment refers to the allocation of funds to projects or activities that support environmental sustainability, such as renewable energy, energy efficiency, and carbon emission reductions. In the mining sector, green investment plays a key role in supporting the energy transition and mitigating climate change risks by promoting the adoption of low-carbon technologies and more sustainable resource management. Research shows that mining companies that integrate green investment into their strategies can reduce their dependence on fossil fuels and enhance their competitiveness in markets increasingly focused on sustainability (Bandpey et al., 2024; Shang et al., 2024). Additionally, green investment opens opportunities for green financing, which can reduce financial risks associated with emission reduction policies and carbon price fluctuations (Wang et al., 2024). With increasingly stringent environmental regulations and growing demand for renewable energy, the mining sector needs to invest in environmentally friendly technologies to address energy transition challenges more effectively and sustainably.

2. Methods

The approach used in this research is transition risk analysis, which focuses on the impact of climate policy changes, carbon price fluctuations, and the transition to renewable energy on the financial performance of PT XX. This research integrates national and global regulatory factors, such as Indonesia's Enhanced Nationally Determined Contributions (ENDC), which sets carbon emission reduction targets until 2030. This approach aims to understand how global and domestic policies addressing climate change can affect the operations and business strategies of companies in the mining sector. Additionally, the analysis also considers the dynamics of the international carbon market, which influences carbon prices and, in turn, can increase the company's operational costs. The data sources used in this research are secondary data, including PT XX sustainability reports for the

period 2020-2023, as well as various literature related to global climate policies and carbon markets. Furthermore, data related to Indonesian government policies, particularly those concerning carbon emission reduction policies, and international carbon prices are also used to analyze how carbon price fluctuations can affect the company's operational costs. This data is crucial for identifying external factors that can influence the financial risks borne by the company.

The analysis in this research is conducted through several stages. The first stage is the identification of transition risks, where risks affecting the company's operations and financial performance are identified and classified. These risks include changes in government policies related to carbon emission reductions, global carbon price fluctuations, and the decline in coal demand due to the shift toward renewable energy. After risk identification, the next step is the assessment of the impact and probability of each risk, using predetermined impact and probability scales. This assessment helps measure the severity of the impact and the likelihood of each risk, enabling the company to plan appropriate mitigation measures. Subsequently, a calculation of financial risks related to the additional costs the company must bear, particularly concerning the purchase of carbon quotas through the Emission Trading System (ETS) mechanism, is conducted. This research also includes a sensitivity analysis, which aims to measure how carbon price fluctuations and carbon emission reduction policies affect the company's operational costs.

3. Results and Discussion

3.1 Risk analysis

The global energy transition toward cleaner and low-carbon systems not only brings opportunities but also poses significant risks for the mining sector. Adaro, as one of Indonesia's largest coal producers, is at the center of this major shift. With global dependence on coal declining due to stricter environmental policies and increasing demand for renewable energy, the sector faces significant challenges in maintaining operational sustainability and relevance in the global energy market. Through this case study, the analysis will cover the assessment of the company's financial performance amid declining coal demand, the social impacts felt by communities around the mines, and the steps taken by PT Adaro to improve operational efficiency and diversify its portfolio into renewable energy. Additionally, the integration of Environmental, Social, and Governance (ESG) principles into PT Adaro's business strategy will also be evaluated to see how well the company is adapting to global energy policy changes that increasingly support sustainability.

3.1.1 Risk identification

The identification of transition risks in the mining sector, particularly for PT XX, is based on various factors, including low-carbon emission policy assumptions, the Polluter Pays Principle, and international carbon trading mechanisms. Low-carbon emission policies affect the company's economic activities with direct implications for financial conditions, especially through the implementation of carbon taxes for emissions exceeding the reduction targets set by Indonesia's Enhanced Nationally Determined Contribution (ENDC). Additionally, international carbon trading through the Emission Trading System (ETS) scheme is also a key factor in this risk scenario. The main factor influencing transition risks is Indonesia's commitment to transitioning to a low-carbon economy in line with the ENDC. In this context, emissions from the mining sector, including PT XX, are increasing by about 5% annually, creating pressure to adjust emission reduction targets. Furthermore, the government's target to reduce emissions with international investment support of 15.5% in the energy sector presents additional challenges for the company. Significant changes due to emission reduction targets include increased operational costs (CAPEX and OPEX), fluctuations in carbon buying and selling prices, potential profit declines, and the risk of

stranded assets. This impacts the company's resilience in facing the dynamics of transition policies.

Transition risks are channeled through micro and macroeconomic channels. At the micro level, changes in cost structures, carbon price fluctuations, and stranded assets can reduce company profitability. Meanwhile, at the macro level, inflation, interest rates, employment levels, and public purchasing power become important indicators affecting the company's stability amid carbon transition pressures. Financial risk identification includes credit, market, liquidity, and operational risks. With the transition policies, PT XX faces potential difficulties in maintaining cash flow, managing debt, and ensuring operational sustainability amid regulatory and global carbon market pressures.

3.1.2 Exposure mapping

The approach used in this analysis is bottom-up, which refers to the method of collecting data and information directly from sources owned or controlled by the company, such as vehicle emissions and others, where carbon emissions are calculated based on operational data available at the company level. This method was chosen because it provides a more accurate picture of the mining sector's contribution to greenhouse gas (GHG) emissions generated by PT XX, focusing on emission sources that can be directly measured. In this case, the analysis focuses on Scope 1, which includes the calculation of GHG emissions directly from the company's operational activities. Emission sources considered include the use of fossil fuels such as diesel, biodiesel, pertamax, and coal used in mining operations and other activities. This is important because emissions from these sources are directly related to the company's activities and have a significant impact on total emissions. The data required is obtained from Tier 2, which is publicly available data through PT XX Sustainability Report. This report provides emission data that can be used to validate and estimate the carbon impact generated by the company.

In risk classification, various categories of risks arising from policy changes related to carbon emission reductions are identified, including credit risk, market risk, liquidity risk, and operational risk.

3.1.2.1 Credit risk

Credit risk will be affected by this transition, particularly related to PT XX ability to meet its financial obligations. Regulatory changes requiring the company to reduce carbon emissions or invest in environmentally friendly technologies can increase operational costs. If the company cannot effectively manage these additional costs, it may affect liquidity and its capacity to pay debts. Additionally, changes in coal demand due to green energy policies and the transition to renewable energy can impact company revenue, potentially reducing its ability to meet financial obligations. Investors and financial institutions funding the company may also assess credit risk higher if the company does not adapt to market and regulatory changes, thereby increasing borrowing costs or reducing access to financing.

3.1.2.2 Market risk

Market risk in the mining sector will be significantly affected by the transition to a low-carbon economy. The decline in global coal demand due to increased climate change awareness and the growth of renewable energy can affect coal commodity prices and sales volumes. With reduced demand, PT XX may face declining coal prices, impacting company revenue and profitability. Additionally, this demand shift can lead to higher price volatility in the global coal market, exacerbating market uncertainty. This can also affect the company's relationships with partners and customers, who are increasingly focused on sustainability and carbon emission reductions.

3.1.2.3 Liquidity risk

PT XX's liquidity risk may be affected by the need to pay additional costs arising from transition policies, such as carbon taxes or investments in emission reduction technologies. If the company cannot generate sufficient revenue to cover these additional expenses, it may face difficulties in meeting short-term financial obligations. Additionally, liquidity risk increases if PT XX cannot obtain new financing or must pay higher interest on loans due to increased credit risk. Declining coal demand and falling commodity prices can reduce the company's cash flow, worsening dependence on external financing.

3.1.2.4 Operational risk

Operational risk in the mining sector is heavily influenced by the transition to a low-carbon economy, particularly related to increased operational costs due to the adoption of environmentally friendly technologies and emission reduction policies. PT XX may need to make significant investments to upgrade infrastructure and adopt more efficient technologies, which can impact daily operations. Additionally, stricter regulations on carbon emissions and environmental management can add operational complexity, such as the need to comply with new standards or face technical challenges in existing mining operations. If the company cannot efficiently adapt to these changes, it may disrupt productivity and operational reliability, leading to unexpected additional costs.

Each type of risk is considered relevant because policy changes supporting the transition to a low-carbon economy can affect financial stability, operational costs, and the overall sustainability of the company. Therefore, this risk analysis includes the potential impacts of emission reduction policies that may affect various aspects of PT XX operations.

3.3 Risk quantification

In analyzing the transition risks faced by PT XX, risk quantification is conducted to assess the impact of the transition to a low-carbon economy on PT XX, particularly related to carbon emission reduction policies that will affect the company's future operational costs. This analysis uses emission scenarios and carbon pricing adjusted to Indonesia's ENDC policy for the energy sector, which is expected to reduce emissions by 15.5% by 2030, as well as the potential additional costs the company must bear in facing the carbon tax policy implemented by the government. This quantification aims to provide an overview of the financial impact of emission reductions that PT XX must follow to meet national policy targets.

3.3.1 Scenario analysis

The main component used in this scenario analysis is the total carbon emissions of PT XX in 2020, recorded at 2,244,133 tons of CO_2eq per year, as the baseline emission value for future emission calculations according to the sustainability reports published by PT XX for 2020-2023. Based on Indonesia's ENDC policy, the energy sector's emission reduction target of 15.5% by 2030, equivalent to a 1.29% annual reduction, has been set. To achieve this target, PT XX needs to gradually reduce emissions each year. With an average annual emission increase of 5.54%, the company faces significant challenges in aligning with the emission reduction targets set by the government. Table 4.1 shows the emission projections and the impact of carbon taxes based on Indonesia's ENDC until 2030.

Table 1. Emission projections and carbon tax impact based on Indonesia's ENDC until 2030

Year	BAU emissions +5.54% (CO_2eq in tons)	ENDC (-15.5% by 2030, equivalent to 1.29% per year) (CO_2eq in tons)	CO_2eq difference (tons)	Carbon pricing (Assumed price IDR30,000 per ton CO_2eq)
2018	2,244,133	2,244,133	-	-
2019	2,272,054	2,215,184	56,870	1,706,093,014
2020	2,522,847	2,186,608	336,239	10,087,162,141
2021	2,358,766	2,158,401	200,365	6,010,945,807
2022	2,569,578	2,130,557	439,020	13,170,614,370
2023	2,902,956	2,103,073	799,883	23,996,487,550
2024	3,063,780	2,075,943	987,836	29,635,089,786
2025	3,233,513	2,049,164	1,184,349	35,530,481,948
2026	3,412,650	2,022,730	1,389,920	41,697,607,289
2027	3,601,711	1,996,636	1,605,074	48,152,227,672
2028	3,801,245	1,970,880	1,830,366	54,910,969,033
2029	4,011,834	1,945,455	2,066,379	61,991,369,373
2030	4,234,090	2,215,184	2,018,906	60,567,187,092
Average emission increase			993,478	29,804,325.775

(PT XX, 2024)

Table 1 shows that to align with Indonesia's ENDC emission reduction targets by 2030, PT XX must reduce emissions by an average of 993,478 tons of CO_2eq per year. This will require the company to pay carbon tax costs of IDR 29.8 billion per year, assuming a price of IDR 30,000 per ton of CO_2eq. If the company fails to meet this target, these additional costs will become a significant financial burden, affecting cash flow and profitability. Therefore, the company needs to implement effective mitigation measures, such as adopting environmentally friendly technologies, to reduce emissions and avoid high carbon tax costs and associated financial risks.

3.3.2 Sensitivity analysis (carbon price)

In this analysis, carbon price sensitivity is tested to estimate its impact on the additional costs PT XX must bear related to purchasing emission quotas through the Emission Trading System (ETS). Based on carbon prices in the international market, the China National ETS carbon price is recorded at 12.57 USD or around IDR 200,000 per ton of CO_2eq, while the Korea ETS carbon price is at 6.30 USD or around IDR 100,000 per ton of CO_2eq, assuming an exchange rate of IDR 15,900.

Table 2. Sensitivity analysis based on China and Korea ETS carbon prices

Year	BAU emissions +5.54% (CO_2eq in tons)	ENDC (-15.5% by 2030, equivalent to 1.29% per year) (CO_2eq in tons)	CO_2eq difference (tons)	Carbon pricing (Assumed price IDR100,000 per ton CO_2eq)	Carbon pricing (Assumed price IDR200,000 per ton CO_2eq)
2018	2,244,133	2,244,133	-	-	-
2019	2,272,054	2,215,184	56,870	5,686,976,712	11,373,953,424
2020	2,522,847	2,186,608	336,239	33,623,873,805	67,247,747,609
2021	2,358,766	2,158,401	200,365	20,036,486,024	40,072,972,048
2022	2,569,578	2,130,557	439,020	43,902,047,901	87,804,095,802
2023	2,902,956	2,103,073	799,883	79,988,291,832	159,976,583,664
2024	3,063,780	2,075,943	987,836	98,783,632,621	197,567,265,241

2025	3,233,513	2,049,164	1,184,349	118,434,939,825	236,869,879,651
2026	3,412,650	2,022,730	1,389,920	138,992,024,297	277,984,048,594
2027	3,601,711	1,996,636	1,605,074	160,507,425,573	321,014,851,146
2028	3,801,245	1,970,880	1,830,366	183,036,563,443	366,073,126,887
2029	4,011,834	1,945,455	2,066,379	206,637,897,910	413,275,795,820
2030	4,234,090	2,215,184	2,018,906	201,890,623,640	403,781,247,281
Average emission increase			993,478	99,347,752,583	198,695,505,167

(PT XX, 2024)

Table 2 shows the calculation of additional costs the company must pay if emissions exceed the reduction targets set by Indonesia's ENDC. Assuming BAU emissions increase by 5.54% annually, the company will face an emission deficit that must be purchased through the ETS scheme. For example, in 2019, with a carbon price of IDR 100,000 per ton of CO_2eq, the company must pay around IDR 5.69 billion to purchase carbon exceeding the target, or IDR 11.37 billion if the carbon price is IDR 200,000 per ton of CO_2eq. Over time, the costs to be incurred increase, reaching IDR 236.87 billion in 2025 and IDR 403.78 billion in 2030. The average annual emission increase generated by PT XX is 993,478 tons of CO_2eq, meaning the company must allocate annual costs to purchase carbon through the ETS scheme, with average costs ranging from IDR 99.35 billion to IDR 198.70 billion per year, depending on the applied carbon price. This highlights the importance for the company to consider better emission reduction strategies to reduce dependence on purchasing emission quotas and avoid significant costs due to global carbon price fluctuations.

3.3.3 Sensitivity analysis (BAU emission reduction)

In this analysis, two different scenarios are used to measure the potential emission deficit and additional costs arising from the inability to meet the emission reduction targets set by Indonesia's ENDC. Table 3 shows the calculations related to the BAU emission scenario increasing by 1.5% and its impact on the carbon costs the company must pay.

Table 3. Sensitivity analysis of 1.5% BAU emission increase

Year	BAU emissions +1.5% (CO_2eq in tons)	ENDC (-15.5% by 2030, equivalent to 1.29% per year) (CO_2eq in tons)	CO_2eq difference (tons)	Carbon pricing (Assumed price IDR 200,000 per ton CO_2eq)
2018	2,244,133	2,244,133	-	-
2019	2,272,054	2,215,184	56,870	11,373,953,424
2020	2,522,847	2,186,608	336,239	67,247,747,609
2021	2,358,766	2,158,401	200,365	40,072,972,048
2022	2,569,578	2,130,557	439,020	87,804,095,802
2023	2,902,956	2,103,073	799,883	159,976,583,664
2024	2,946,500	2,075,943	870,557	174,111,380,438
2025	2,990,698	2,049,164	941,534	188,306,815,754
2026	3.035.558	2,022,730	1,012,829	202,565,752,037
2027	3.081.092	1,996,636	1,084,455	216,891,069,454
2028	3.127.308	1,970,880	1,156,428	231,285,666,511
2029	3.174.218	1,945,455	1,228,762	245,752,460,644
2030	3.221.831	2,215,184	1,006,647	201,329,440,098
Average emission increase			702,584	140,516,764,422
Average emission deficit			702,584	per ton CO_2eq
Emission deficit purchase			140,516,764,422	IDR/ton CO_2eq

(PT XX, 2024*)*

The sensitivity analysis of the 1.5% BAU emission reduction scenario shows significant financial impacts if the company fails to achieve the expected emission reduction targets. In this scenario, the company must face an emission deficit of 702,584 tons of CO_2eq per year. This deficit arises because the company's emissions exceed the reduction targets set by Indonesia's ENDC, which requires a 15.5% reduction by 2030. To cover this deficit, the company can purchase carbon quotas through the Emission Trading System (ETS). Based on calculations with a carbon price of IDR 200,000 per ton of CO_2eq, the cost the company must bear to purchase this emission deficit is estimated at around IDR 140.52 billion per year. This figure shows that the inability to meet emission reduction targets can lead to significant financial burdens.

Table 4. Sensitivity analysis of 2% BAU emission increase

Year	BAU emissions +2% (CO_2eq in tons)	ENDC (-15.5% by 2030, equivalent to 1.29% per year) (CO_2eq in tons)	CO_2eq difference (tons)	Carbon pricing (Assumed price IDR200,000 per ton CO_2eq)
2018	2,244,133	2,244,133	-	-
2019	2,272,054	2,215,184	56,870	11,373,953,424
2020	2,522,847	2,186,608	336,239	67,247,747,609
2021	2,358,766	2,158,401	200,365	40,072,972,048
2022	2,569,578	2,130,557	439,020	87,804,095,802
2023	2,902,956	2,103,073	799,883	159,976,583,664
2024	2,961,015	2,075,943	885,072	177,014,336,478
2025	3,020,235	2,049,164	971,072	194,214,331,296
2026	3,080,640	2,022,730	1,057,911	211,582,115,775
2027	3,142,253	1,996,636	1,145,617	229,123,318,822
2028	3,205,098	1,970,880	1,234,218	246,843,652,596
2029	3,269,200	1,945,455	1,323,745	264,748,914,557
2030	3,334,584	2,215,184	1,119,400	223,880,040,817
Average emission increase			736,108	147,221,697,145
Average emission deficit			736.108	per ton CO_2eq
Emission deficit purchase			147.221.697.145	IDR/ton CO_2eq

(PT XX, 2024)

In the scenario where the company's BAU emissions increase by 2% annually, the company may experience a larger emission deficit compared to lower emission reduction scenarios. Based on calculations, the emission deficit reaches 736,108 tons of CO_2eq per year. To cover this deficit, the company must purchase additional emission quotas through the Emission Trading System (ETS), with an estimated average cost of IDR 147.22 billion per year, assuming a carbon price of IDR 200,000 per ton of CO_2eq. This figure shows that the company's inability to achieve emission reductions at a minimum of 2% will increase the financial burden of purchasing carbon quotas. The smaller the emission reduction target set, the higher the costs incurred to meet carbon quota needs, which can lead to greater dependence on the ETS scheme. Therefore, the company needs to consider setting more ambitious and consistent emission reduction targets in line with sustainable mitigation policies to reduce dependence on carbon quota purchases and support the achievement of sustainability goals more effectively.

3.4 Risk profile

In this Risk Profile section, there are two main components that describe the extent to which the company can manage risks related to CO_2eq emission reductions in different scenarios. The company's Risk Appetite refers to the level of emission reduction considered acceptable in business operations without causing excessive financial or operational

impacts. In this case, the company demonstrates the capacity to reduce emissions at a level of 1.5% from BAU, resulting in an emission deficit of 702,584 tons of CO_2eq per year with an average potential deficit payment of IDR 140.52 billion per ton of CO_2eq/year. This deficit can be covered by purchasing carbon quotas from the market, but with a more moderate emission reduction level, the company can still manage the additional costs arising from carbon purchases.

On the other hand, Risk Tolerance reflects the limits or level of emission reduction the company can accept before the financial or operational impacts become too high. At a 2% emission reduction level from BAU, the company will face an emission deficit of 736,108 tons of CO_2eq per year with an average potential deficit payment of IDR 147.22 billion per ton of CO_2eq/year, slightly higher than the Risk Appetite scenario. This indicates that the company has the tolerance to bear higher costs, but with the consequence of increased expenditure on carbon quota purchases, which can affect cash flow and operational efficiency. These two components, Risk Appetite and Risk Tolerance, provide a clear picture of how the company plans and assesses its capacity to manage risks related to emission reductions while balancing sustainability and operational continuity.

3.5 Risk management

Risk management is a crucial process in identifying, assessing, and mitigating risks that can affect organizational goals, especially in facing the challenges of transitioning to a low-carbon economy. For PT XX, these risks are primarily related to government policy changes, global carbon price fluctuations, energy demand, and the implementation of carbon taxes, each of which can significantly impact the company's operations and finances. In transition risk management, an impact scale is used to measure the extent of a risk's influence on the company, particularly in terms of carbon emissions and carbon quota purchase costs. This scale identifies various impact levels based on the emission deficit generated and the carbon quotas needed. These impacts can significantly affect the company's finances and operations. Table 5 explains the impact criteria based on emission deficit, carbon quota purchase costs, and their impact on the company:

Table 5. Impact scale

Impact scale	Impact criteria	Emission deficit (tons CO_2eq/year)	Carbon quota purchase cost
1	Very low	0 - 50,000	< IDR10 Billion
2	Low	50,001 - 100,000	IDR10 - 25 Billion
3	Moderate	100,001 - 300,000	IDR25 - 50 Billion
4	High	300,001 - 500,000	IDR50 - 75 Billion
5	Very high	500,001 - 736,108	> IDR75 Billion

(PT XX, 2024)

In addition to impact, it is important to assess the likelihood of a risk occurring. The probability scale helps the company determine how likely a risk is to occur within a relevant time frame. Table 6 is the Probability Scale, which classifies risks based on their likelihood of occurrence:

Table 6. Probability scale

Probability scale	Probability	Description
1	Almost impossible	Very low likelihood of occurrence (less than 5%) and nearly impossible within the relevant timeframe.
2	Rarely occurs	Low likelihood of occurrence (5%-20%), but still possible, though infrequent.
3	Likely to occur	Moderate likelihood of occurrence (20%-50%), with a reasonable chance of happening, but not certain.
4	Quite frequent	High likelihood of occurrence (50%-80%), occurs often or almost certain if triggering factors exist.

5	Almost certain	Very high likelihood of occurrence (80%-100%), nearly guaranteed within the relevant timeframe.

(PT XX, 2024)

Table 7 identifies four main transition risks that could potentially affect the company, along with their probability of occurrence, impact, and mitigation strategies that can be implemented to reduce the impact of these risks.

Table 7. Transition risk management in the mining sector

No	Risk triggering	Transition risk	Risk description	Probability	Impact	Risk rating	Risk mitigation	Residual risk		
								Probability	Impact	Risk rating
1	Indonesia's commitment to the Paris Agreement as outlined in ENDC	Policy changes by the government	Government policies requiring carbon emission reductions may lead to increased operational costs.	4 (Quite frequent)	5 (Very high)	20 (Extreme)	a. Adoption of environmentally friendly technology b. Planning for carbon tax management and emission restrictions.	4 (Quite frequent)	3 (Moderate)	12 (Medium)
2		Global carbon price fluctuations	Global carbon price fluctuations may increase the cost of purchasing carbon quotas through the ETS scheme.	3 (Likely to occur)	4 (High)	12 (Medium)	a. Managing reserve funds for carbon quota purchases b. Diversifying investments in renewable energy sectors c. Introducing energy efficiency initiatives to reduce dependency on carbon quota purchases.	2 (Rarely occurs)	4 (High)	8 (Medium)
3		Changes in energy demand	Declining coal demand and transition to renewable energy reduce revenue, impacting liquidity.	3 (Likely to occur)	3 (Moderate)	9 (Medium)	Diversification of revenue sources, investment in renewable energy, and operational cost savings.	2 (Rarely occurs)	2 (Low)	4 (Low)

4	Implementation of Carbon Tax	The implementation of a carbon tax will increase operational costs, reducing profit margins.	4 (Quite frequent)	4 (High)	16 (High)	Improving operational efficiency and renewable energy use, conducting research on emission reduction technologies.	3 (Likely to occur)	3 (Moderate)	9 (Medium)

(PT XX, 2024)

4. Conclusions

This study presents an in-depth analysis of the transition risks faced by PT XX, focusing on the challenges arising from global climate policy changes, international carbon price fluctuations, and the shift toward renewable energy. As one of Indonesia's largest coal mining companies, PT XX faces several major risks that could significantly impact its financial and operational performance. These risks include changes in Indonesian government policies related to carbon emission reductions, volatile carbon prices in the international market, declining coal demand driven by the global transition to renewable energy, and the increasingly stringent implementation of carbon taxes.

The analysis results indicate that if PT XX fails to meet the emission reduction targets set in Indonesia's Enhanced Nationally Determined Contributions (ENDC), the company risks facing substantial additional costs, particularly related to the obligation to purchase carbon quotas through the Emission Trading System (ETS) scheme. Projection calculations show that the annual cost of purchasing carbon quotas could exceed IDR200 billion by 2030, depending on the prevailing carbon prices in the global market. Therefore, to mitigate the financial and operational impacts arising from the inability to meet emission targets, the company needs to design and implement more sustainable mitigation strategies. These strategies should include the adoption of more efficient low-carbon technologies and investments in renewable energy development.

PT XX should accelerate the adoption of environmentally friendly technologies and improve operational efficiency across the entire mining value chain. These steps will reduce dependence on coal and mitigate risks related to carbon price fluctuations and the implementation of carbon taxes. Additionally, the company should develop a more robust strategic plan to meet more ambitious carbon emission reduction targets and leverage opportunities in green financing and sustainable investments. PT XX should also establish closer partnerships with stakeholders at the national and international levels to ensure alignment with global climate change and energy transition policies, as well as to take advantage of existing incentives and policy support to accelerate the transition toward a sustainable low-carbon economy.

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The author solely conducted all aspects of this research, including conceptualization, data collection, analysis, interpretation, and manuscript writing. All findings and conclusions presented in this study are the author's responsibility.

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