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Scenario Planning of Carbon Emission Reduction Effort to Support Net Zero Emission Program by Implementing Good Mining Practices at PT Borneo Indobara

Riadi Simka Pinem*, Yudo Anggoro
Institut Teknologi Bandung, Indonesia
Email: riadi_pinem@sbm-itb.ac.id

Abstract

This research examines the identification of emission sources and the development of greenhouse gas (GHG) reduction strategies, focusing on Scope 1 emissions at *PT* Borneo Indobara (*PT* BIB). The study is vital for helping *PT* BIB manage potential costs from carbon taxes and rising fuel prices, especially with the Indonesian Government's upcoming Biofuel B40 mandate. Despite existing regulations such as *Law No. 7/2021* and *President Regulation No. 98/2021*, policy implementation in the mining sector remains uncertain. Using PESTEL analysis, Pareto analysis, and scenario planning, the research identifies that overburden haul trucks, large excavators, and coal-hauling trucks are the primary sources of CO_2 emissions at *PT* BIB. Four future scenarios—*Bridge to The Future*, *Black Gold Renaissance*, *Decarbonize or Disappear*, and *Stranded Policy*—were developed to explore various emission reduction pathways, with potential CO_2 reductions ranging from 10% to 60%. The findings offer strategic recommendations for *PT* BIB to reduce emissions and adapt to regulatory changes by integrating policy and technology solutions aligned with good mining practice.

Keywords: Green-houses gasses, National Determined Contribution, Transformative scenario planning, PESTEL industry analysis, Economic Carbon Value, Deductive method.

INTRODUCTION

The global issue of climate change increase awareness of nations around the globe to control GHG emissions, to measure it and set a limit for emissions in each nation (Althor et al., 2016; Rehan & Nehdi, 2005). One of the mechanisms to reduce the GHG emissions is applied carbon tax and carbon trading markets in many countries (Haites, 2018; Tsai, 2020). GOI set a target for Enhanced National Determined Contribution (ENDC) for carbon dioxide (CO_2) emissions reduction around 32% unconditional or 912 million-ton CO_2eq for all industrial sectors (Tekmira ESDM, 2024) and 41% with conditional in 2030 which target to reach net zero emissions in 2050. GHG emission reduction target set by government for energy sector estimated around 358 million-ton CO_2eq (Tekmira ESDM, 2024).

PT BIB is one of the biggest surface coal mining companies nationally in Indonesia and burned a lot of fossil fuel in its operation every year that reach more than 200 million liters/year. A lot of heavy equipment is deploying by PT BIB's mine contractors that using fossil fuel as main energy and emitted

GHG to the atmosphere such as Carbon Dioxide (CO_2) and Methane (CH_4). The emissions intensity and profile of emission number varies from one company to another, mainly due to unique characteristics of each mine such as stripping ratio, overburden & coal hauling distance, production level, coal type, coal seam profile, mine depth and mining techniques. PT BIB are in a growing phase which the ultimate target would be 54 million tons starting in 2026 and beyond. PT BIB has strong commitment and intention to manage its CO_2 emission and need to show that CO_2 emission per ton of coal produced in the longterm plan would be declined by doing carbon management. Carbon management could be implemented by reducing fossil fuel consumption, equipment electrification, increase biodiesel composition for mining equipment and revegetation in the mining area or outside mining area to increase carbon absorption or removal from the atmosphere. Currently there is no road map at PT BIB regarding GHG emission reduction and it will be critical and become very urgent to prepare it to anticipate carbon tax/trading in the future. Corporations also expect shareholder activism to grow in coming years, and this is supported by the growth of organizations (Schulte Roth & Zabel, 2014).

Carbon tax is going to be implemented in Indonesia after issuance of policy and regulation by GOI such as Law No 7 year 2021 regarding Tax Harmonization, President Regulation No 98 year 2021 regarding Economic Carbon, Ministry of Environment regulation No 21 year 2022 regarding guideline of implementation carbon economic value, Ministry of Energy and Mineral Resources (MEMR) No 22 year 2019 regarding Guideline to do emission inventories and mitigate of GHG in energy sector and Regulation of Financial Authority (OJK) No 51 year 2017 regarding requirement for public companies to develop sustainability report covering energy and emission. PT BIB burned huge fossil fuel every day in its operation and emitting GHG so it would hit significantly to the cost, reputation, negative campaign caused by the issues and policy implementation. PT BIB need to manage its emission of carbon and effort to absorb its emission to make the net balance as low as possible. The carbon dioxide (CO_2) emission reduction would give positive impact to the company with no additional cost to its operation once carbon tax and carbon trading implemented in the next coming years.

Due to that problematic issues, Researcher proposes to develop alternatives solution in this study to answer research questions such as (i) what is the list of the source's greenhouse gases emission in operational area and what is the baseline/actual of PT BIB carbon emission in the current condition, (ii) what list of scenario planning initiatives PT BIB can do to improve emission reduction as part of responding and adapting to the global issues and national policy /regulation once it will be implemented, (iii) what feasible programs could be implemented by PT BIB to improve its business process to support net zero emissions in term of investment benefit, operating cost,

business operation and strategic factors and will the company able to support net zero emission and how is the road map.

One relevant study by Rafi (2022) discussed the increasing pressure on mining companies to reduce their greenhouse gas (GHG) emissions due to evolving policies and regulations, focusing on the risks that mining companies face if they fail to implement emission reduction measures. However, the study primarily focuses on the broader implications of GHG regulation and policy on the mining sector, rather than providing specific, actionable recommendations for individual companies to manage their emissions. While the study highlights the urgency of reducing emissions, it lacks a detailed, practical framework for companies to follow in managing their carbon footprints and navigating regulatory requirements, particularly in the context of carbon taxes and trading systems.

In contrast, another study by Schulte Roth & Zabel (2014) explored shareholder activism in driving environmental sustainability in corporate governance, including in the mining sector. The study argued that shareholder expectations would play a significant role in motivating companies to adopt sustainable practices. However, it did not provide a clear roadmap or strategies for companies to reduce their carbon emissions in response to these growing expectations and regulations. It focused more on the macroeconomic and governance aspects of corporate environmental responsibility, neglecting the practical steps that mining companies need to take to reduce their carbon emissions effectively.

The research objectives are to predict PT BIB's carbon emissions profile throughout its life of mine, estimate the potential costs related to carbon tax and trading mechanisms, and assess the economic feasibility of capital expenditures required to reduce emissions. This research aims to provide PT BIB with a roadmap to reduce emissions, optimize operational costs, and enhance the company's reputation. The benefits of this study include helping PT BIB avoid future financial penalties associated with carbon tax, improving its environmental impact, and positioning the company favorably in the eyes of stakeholders, investors, and regulatory bodies. The study is expected to contribute to the development of a sustainable and cost-effective strategy for PT BIB to meet national and global environmental goals while ensuring long-term business viability.

RESEARCH METHOD

The researcher uses mix method research by doing it in staging such as first stage the research will be approached through quantitative method by deploying pareto chart analysis to show the figure how big and how realistic the effort can be done to reduce certain amount of carbon dioxide (CO_2) emission from each business process, analyses the results, then builds on the results to explain them in more detail with qualitative research using PESTEL external analysis and finally use Kahane's transformative scenario planning

method (Creswell & Creswell, 2017). The data were collected and analyzed have to support to answer research's questions and meeting the objectives regarding emission reduction at PT BIB as stated in the introduction.

To know better the baseline or existing GHG emission at PT BIB, primary data were collected and analyze using quantitative method. Researcher gathers all fuel consumption for the last five years since 2020-2024 from all activities such as excavation activities, hauling activities for overburden and coal, hauling activities for coal from run of mine (ROM) stockpile to the port destination, support activities at mine area for road maintenance and working area preparation, coal crushing and preparation activities, coal transshipments from jetty loading to the mother vessels anchorage, employees transportation activities and other activities that consume fuel. This quantitative data will be used to estimate future fuel consumption and GHG emission would be generated until life of mine of PT BIB. The other primary data were collected and used by researcher that source from interview with key actors involve actively at PT BIB business process who considered have deep knowledge of net zero emission, have power and influence to make transformation in their respective company. The interview question is designed with list of questions which consider the most important thing required to fulfil scenario planning element. The secondary data were collected and use source from regulations related to the CO_2 emission, company's annual report, company's sustainability report, journals, papers, internet information and long-term mine planning document such as feasibility study also environment impact analysis document. To commence of reviewing the amount of actual GHG at PT BIB, researcher grouping the activities become several activities from the biggest source of emission to the least source of emission.

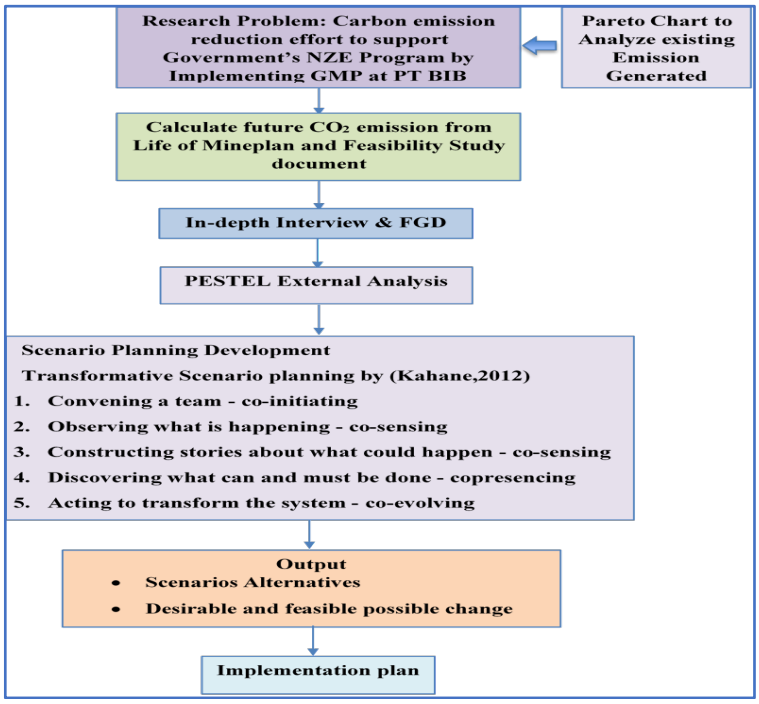

Figure 1. Conceptual framework (source: Author's analysis)

This classification of CO_2 emission into specific activities will be useful to estimate the possibility and the level of difficulty of the electrification program for the mine equipment because the size of equipment significantly varied in each activity. Pareto Chart able to figure it clearly and the incremental amount of CO_2 emission reduction can be easily estimated. Pareto chart analysis was used to figure it to show the amount of emission each activity and incremental percentage of its emission. The figure will be used to do in-depth interview with key actors to open mind and ask their view of the impact also uncertainty to reduce the emission in each of mine business process activities.

PESTEL analysis was utilized to create list of questions for in-depth interview with key actors to ask their view of which focal issue, what external driving forces in politic, economic, social, technology, environment and legal (PESTEL) that would be contributed in the most uncertainty and most impactful to the emission reduction. Those focal issue, driving forces and uncertainty obtained from PESTEL analysis would be used as an input for creating scenario planning.

RESULTS AND DISCUSSION

Analysis

Five steps of scenario planning were used to gradually transform actors' understandings, relationships, intentions and actions (Garvin & Levesque, 2005). The transformation ripples out from the credible and influential individual leaders as key actors in the organization as whole system to the scenario team (Chermack, 2022).

Step 1: Convening a team from across the whole system (co-initiating)

The researcher did in-depth interview with several key actors who involved and considered have power, influence, understanding regarding the net zero emission and their top management role as decision maker around PT BIB operation such as Chief Executive Officer (CEO) role, Chief Operating Officer (COO) role, President Directors of mining services companies and investors from mining services company (Chermack, 2011).

Step 2: Observing what is happening known also as co-sensing

Several important points are gathered from this step such as current efforts in their company regarding CO_2 emission reduction, what driving forces factors that could become the highest impact and what could become the highest uncertainties that would affecting decarbonization in the PT BIB's operation.

Current Effort of CO_2 Emission Reduction in the Company's operation (Gallego-Álvarez et al., 2015);

a. Transition from Generator Set Utilization to electrification at mine operation
b. Electric Vehicles (EV) Trial Implementation for Coal Hauling from Run of Mine to the Port
c. The company collaborate and partnered with PLN to secure 10 MVA of renewable energy capacity and committed to purchasing Renewable Energy Certificates (REC)
d. Trial to use of electric equipment for operations support activities
e. Digital monitoring and optimization, development of a real-time emissions dashboard using digital tools
f. Engagement with Contractors, PT BIB is working closely with contractors to plan gradual replacement of diesel equipment with electric equipment
g. Industry collaboration, including cooperation with equipment suppliers to develop cost-effective and durable EV technology
h. Setting up specific key performance indicators (KPI) and contract agreement for mining services regarding CO_2 emission reduction target.

Significant challenges that would affecting the effort in CO_2 emission reduction initiatives at mining industry are;

a. High investment costs of low-carbon technologies
b Technology scarcity and innovation
c Extreme weather that can disrupt
d Availability of electricity surplus
e Workforce transition & development
f. Economic readiness
g. Lack of law implementation

operational processes and operational safety	problems, regulation support, government support and policies

The driving forces with *highest impact* that affecting the effort in CO_2 emission reduction initiatives at mining industry are;

1) Politic & Legal
   a. Government's support and regulation
   b. National energy policy
   c. Political will and commitment
   d. Longterm policy stability & policy certainty
2) Technology
   a. Availability of big size equipment with EV technology
   b. Battery technology
3) Economic
   a. Capital investment in EV & infrastructure
   b. Economic incentive and fiscal policy
   c. Operational cost saving
4) Social
   a. Stakeholder pressure and expectation
5) Environment
   a. Reputation and brand value

The driving forces with *highest Uncertainties* that affecting the effort in CO_2 emission reduction initiatives at mining industry are;

1) Politic or Legal
   a. Regulatory and policy uncertainty
   b. Shifting political commitment and priorities
   c. Lack of incentives gaps in policy
   d. Geopolitical and external policy
2) Technology
   a. Reliability and readiness of electrification technology
   b. Pace of technology development
   c. Hybrid technology or full electrification pathways
3) Economic
   a. High capital expenditure and stranded assets
   b. Cost competitiveness of electrification
   c. Access to financing
   d. Lack of economic incentives
4) Social
   a. Stakeholders and customers expectation
   b. Workforce readiness and skills transition
   c. Leadership commitment

5) Environment

Evolving environment standard raise uncertainty about future regulatory requirement

Step 3 Constructing stories about what could happen (as co-sensing)

The Researcher uses deductive method of scenario planning in this final project with selection of two highest uncertainties from information that respondents thought were essentials to affect the direction of CO_2 emission reduction program in the next coming years (Kahane, 2012). The two keys considered as the most uncertainties were gathered through focus group discussion and in-depth interview involving all key decision makers and key actors in the organizations which actively work inside PT BIB's mining concession. The first key uncertainty is whether technology readiness (battery lifespan, faster charging time and charging infrastructure scalability) would be high (quick) or low (slow) in readiness. The second key uncertainty is whether the government will be issued supportive policies or unclear/delayed policies for the mining business to create robust plan and enable the acceleration of decarbonization specifically at PT BIB's mine operation.

The researcher creates four possible scenarios from deductive method of scenario planning using matrix two by two (2 x 2) of two keys uncertainties and exploring the significant challenges posed in each scenario;

Scenario 1: Bridge to The Future (Accelerated electrification)

This condition would be possible with high readiness or maturity of technology in the electric heavy equipment particularly battery technology suitable for mining operation such as battery lifespan, fast charging time, big battery capacity to eliminate frequent charging in every working shift. Government's support would be required to accelerate the CO_2 emission reduction by clear implementation of economic carbon value, incentive for decarbonization efforts by companies and reduce or eliminate import duties for electric heavy equipment for mining industry. The outcome of this scenario is emission reduction minimum 60% after 2032 until 2036 at PT BIB's mine operation that come from the area of all coal hauling activities, all light vehicles will be electrified, all mine support equipment (lighting tower, pumps, motor graders, dozers, compactors), all port facilities, 45% of big excavators and 50% big hauler trucks will be electrified and including all facilities at mine area.

Scenario 2: Black Gold Renaissance (Policy-Driven Grid Reliance)

This condition would be possible if there is certainty or supportive regulation/policy issued and implemented by government with detail how the policy will be implemented, the mechanism, the timeline and implementation of sanction for non-compliance activities conducted by companies. Government's support would be required to accelerate the CO_2 emission

reduction by clear implementation of economic carbon value, incentive for decarbonization efforts by companies and reduce or eliminate import duties for electric heavy equipment for mining industry even though technology advancement is still underperforming. The outcome of this scenario is emission reduction would be achieved in the range of 40% - 45% of emission reduction by 2035 at PT BIB's mine operation that come from the area of all coal hauling activities, all light vehicles will be electrified, all mine support equipment (lighting tower, pumps, motor graders, dozers, compactors) will be electrified, all port facilities, 35% of big excavators, 20% big hauler trucks and including all facilities at mine area.

Scenario 3: Decarbonize or Disappear (Fragmented Transition)

This condition would be possible with high readiness or maturity of technology in the electric heavy equipment particularly battery technology suitable for mining operation such as battery lifespan, fast charging time, big battery capacity to eliminate frequent charging in every working shift. Technology advancement condition but do not get support by government with policy, regulation delays/lagging and unclear for its implementation for mining business such as delay implementation of economic carbon value, high import tariff and National Determine Contribution (NDC) as promised by 2030 to the global communities do not put as high priority anymore. The outcome of this scenario is emission reduction would be achieved in the range of 20% - 30% of emission reduction by 2035 at PT BIB's mine operation that come from the area of all coal hauling activities, all light vehicles will be electrified, 50% mine support equipment (lighting tower, pumps, motor graders, dozers, compactors) will be electrified, all port facilities, 5% of big excavators, 10% big hauler trucks and including all facilities at mine area.

Scenario 4: Stranded Legacy (Stranded Assets and Cost Overruns)

This condition would be the worst scenario for decarbonization with low technology advancement and unclear policies or regulations from government to support the CO_2 emission reduction. The outcome of this scenario is emission reduction implementation will be adopted very minimum only through efficient operation and fuel saving program in the operation with improving equipment productivity, reduce distance for hauling of material, improving road surface, turn-off the idle engine of equipment, etc. This operational improvement in fuel saving will give maximum 10% of emission reduction by 2036. This scenario will greatly impact to high operating cost with the price increase trend of biofuel B40 implemented by government starting in 2025 and gradually increase in the next coming years. This significant increase of fossil fuel demand will also potentially impact the scarcity of biofuel B40 and B50 in the market since all mining companies have obligation or mandate to use it. Meanwhile, the supply of biofuel from the palm oil industries is predicted will not match with the demand and lack of fuel will

impact the equipment standby (stranded) because of no fuel available to be used.

Stranded assets could possibly happen if the buyers or customers have a concern regarding sustainability and GHG (Bos & Gupta, 2019; Semieniuk et al., 2022; Wilkins, 2018). Coal sales could be decline due to declining of customers demand as the result of they do not want to buy the coal product that considered as dirty product or not implemented sustainable practices in its mine operation.

Step 4 What can and must be done known also as co-presence

Each scenario above will commence gradually effective starting in 2026 or this year until 2036 where PT BIB's mining license will be expired. Those four scenarios that analyze using deductive methodology of scenario planning would be commenced from 2026 – 2036 with detail explanation of each scenario are below;

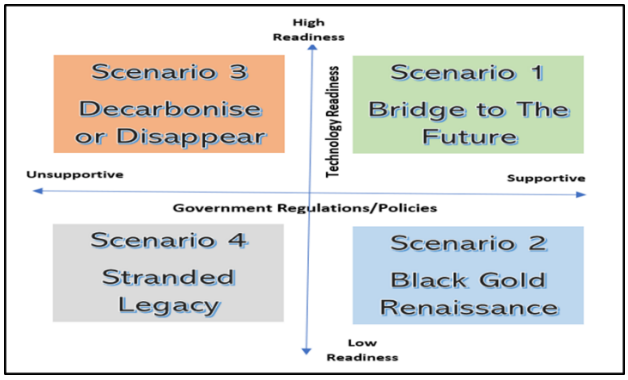

Figure 2 Scenario planning of CO_2 emission reduction at PT BIB

Scenario 1: Bridge to The Future

Government regulation could significantly accelerate the adoption of high readiness of technologies by creating financial incentives to minimizing the risk of investment, accelerated payback period, implementation of emission cap regulation, refundable tax credits and aligning market with decarbonization (carbon market). Escalation of carbon tax or carbon price directly incentivize industries to adopt low CO_2 emission technology to avoid penalties. Easing tariffs of import electric heavy equipment technology can directly reduce costs and encourage adoption and making it easier for mining companies to invest in high readiness technologies.

Supportive policies and regulations will act as force multipliers for high readiness technologies, bridging gaps between innovation and market feasibility.

Table 1. CO_2 emission reduction and finance measured until 2035

Year	Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Total CO_2 Emission	kTon CO_2 eq	820	751	954	905	916	1,044	879	881	766	546	8,462

Year	Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Total CO_2 Emission Reduction Plan	kTon CO_2 eq	91	205	347	403	458	522	569	571	496	353	4,015
Fuel Saving Occurred	kLiter	33,686	75,849	128,411	149,321	169,655	193,315	210,911	211,297	183,807	130,908	1,487,161
Cost Reduction from Carbon Tax @Rp 30/kg	Rp (Billions)	2.73	6.14	10.40	12.09	13.74	15.66	17.08	17.12	14.89	10.60	120.46
Fuel Consumption Cost Saving @Rp 13,500/liter	Rp (Billions)	455	1,024	1,734	2,016	2,290	2,610	2,847	2,853	2,481	1,767	20,077

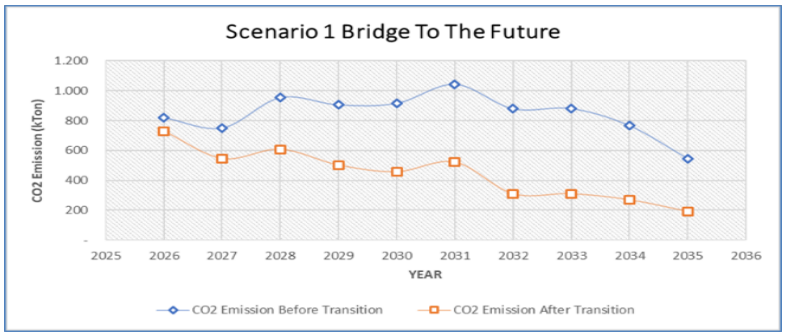

Figure 3 Significant carbon dioxide (CO_2) emission reduction successfully achieved

Scenario 2: Black Gold Renaissance

From previous explanation of the scenario 1, it could be seen that government regulation and policies have strong position to force companies to adopt low CO_2 emission technology even though the technologies are not yet cost effective or scalable in implementation. Supportive policies without parallel technology readiness create a transition gap and this gap will affect companies face compliance burdens but lack of feasible solution in term of technology readiness.

This gap of readiness for suitable electric heavy equipment technology at mining operation need to be bridged with hybrid technology as transition phase until suitable low carbon emission technology viable and available in the market.

Table 2. CO_2 emission reduction and finance measured until 2035

Year	Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Total CO_2 Emission	kTon CO_2 eq	820	751	954	905	916	1,044	879	881	766	546	8,462
CO_2 Emission Reduction Plan	kTon CO_2 eq	81	114	238	312	410	467	417	418	363	259	3,078
Fuel Saving Occurred	kLiter	29,815	42,166	88,044	115,523	151,883	173,064	154,361	154,644	134,524	95,809	1,139,833

Cost Reduction from Carbon Tax @Rp 30/kg	Rp (Billions)	2.42	3.42	7.13	9.36	12.30	14.02	12.50	12.53	10.90	7.76	92.33
Fuel Cost Saving @Rp 13,500/liter	Rp (Billions)	403	569	1,189	1,560	2,050	2,336	2,084	2,088	1,816	1,293	15,388

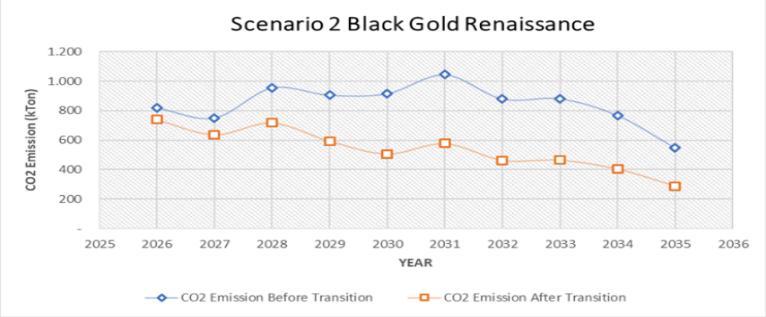

Figure 4. Carbon dioxide (CO_2) emission reduction with scenario 2

Scenario 3: Decarbonize or Disappear

Unclear government regulation or policies create a trap where high readiness technologies remain under-utilized although its potential to accelerate CO_2 emission reduction. High upfront investment in low carbon emission technologies become risky if policies are unclear or delayed and as the impact companies may delay or scale back the investment of carbon emission technologies. Policies certainty is required to scale up the technology deployment massively throughout the business.

Unclear and inconsistent government regulation create significant barriers to adopt high readiness CO_2 emission reduction although it is available in the market. Companies will treat investment as options and delay commitments until policy clarity emerges in order to avert risk. Unclear regulation regarding carbon pricing or emission caps, will affect the low emission technology struggle to compete with polluting technology that usually cheaper. Companies will prioritize short-term compliance and advantage over longterm innovation and perpetuating reliance on fossil fuels.

Table 3. CO_2 emission reduction and finance measured until 2035

Year	Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Total CO_2 Emission	kTon CO_2 eq	820	751	954	905	916	1,044	879	881	766	546	8,462
CO_2 Emission Reduction Plan	kTon CO_2 eq	58	79	128	158	227	259	271	272	236	168	1,856
Fuel Saving Occurred	kLiter	21,377	29,414	47,303	58,522	84,065	95,788	100,457	100,641	87,548	62,352	687,466
Cost Reduction from Carbon	Rp (Billions)	1.73	2.38	3.83	4.74	6.81	7.76	8.14	8.15	7.09	5.05	55.68

Tax @Rp 30/kg												
Fuel Cost Saving @Rp 13,500/liter	Rp (Billions)	289	397	639	790	1,135	1,293	1,356	1,359	1,182	842	9,281

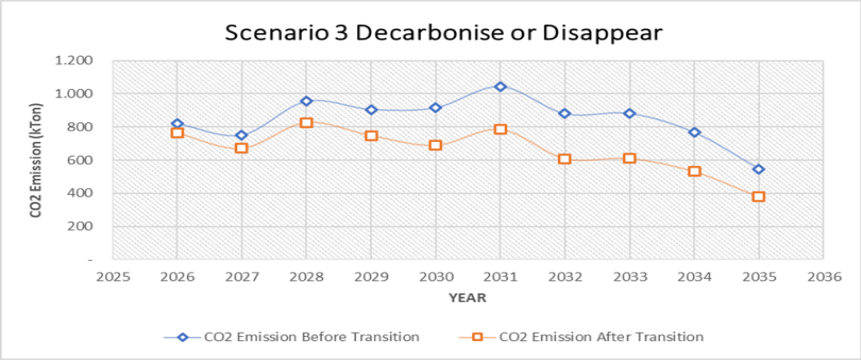

Figure 5. Carbon dioxide (CO_2) emission reduction with scenario 3

Scenario 4: Stranded Legacy

Unclear government regulation or policies and low readiness of low emission technology will create reinforcing cycle that hindering effort of company in reduction CO_2 emission. The ambiguity of government regulation or policies will amplify the risk for companies in deploying the low carbon emission technology, meanwhile low readiness of technology will make government hesitate to implement the strict regulations or policies. This interdependency shows that low readiness of low carbon emission and unclear (uncertainty) of government regulation cannot progress in isolation condition.

Table 4. CO_2 emission reduction and finance measured until 2035

Year	Units	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Total
Total CO_2 Emission	kTon CO_2 eq	820	751	954	905	916	1,044	879	881	766	546	8,462
CO_2 Emission Reduction Plan	kTon CO_2 eq	52	59	75	78	97	110	93	93	81	58	796
Fuel Saving Occurred	kLiter	19,179	21,731	27,634	28,965	35,892	40,898	34,461	34,525	30,033	21,390	294,709
Cost Reduction from Carbon Tax @Rp 30/kg	Rp (Billions)	1.55	1.76	2.24	2.35	2.91	3.31	2.79	2.80	2.43	1.73	23.87
Fuel Cost Saving @Rp 13,500/liter	Rp (Billions)	259	293	373	391	485	552	465	466	405	289	3,979

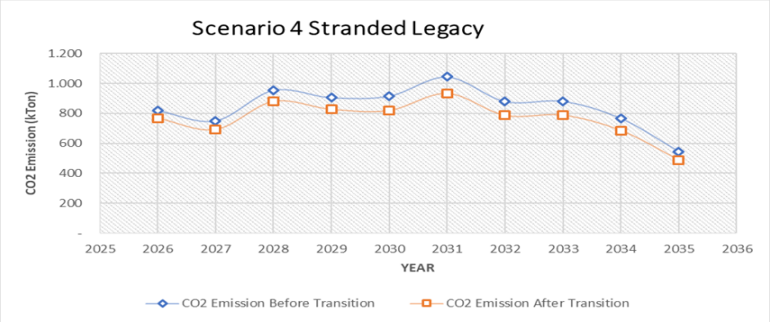

Figure 6. Carbon dioxide (CO_2) emission reduction with scenario 4

Step 5 Acting to transform the system (co-creating and co-evolving)

The Researcher brought together team of key decision makers in the system, constructed scenarios about what could happen and The Researcher is part of the system. The Researcher have conclusion about what will do to deal with the opportunities and challenges pose by those scenarios. The Researcher has systemic understanding, cross system relationship, system aware intentions and produced intended outputs of the CO_2 emission reduction project. Through this result, The Researcher could help to enable key decision actors who together have the capacity to transform the system to take wiser action to do so. Fundamentally, The Researcher has opened a way for the key decision makers to get unstuck and move forward, collaboratively and creatively to deal with these problematic situations.

Business Solution

It could be concluded from the information gathered during interview or FGD that all key decision makers have big concern about CO_2 emission reduction in their respective company. There are two biggest uncertainties identified to accelerate emission reduction namely technology readiness and government regulations. Solution to the problematic regarding high CO_2 emission face by PT BIB is transition from diesel combustion engine into electric heavy equipment (electrification). Three scenarios developed by researcher can be considered as options to reduce CO_2 emission through electrification with different impact of emission reduction such as (a) Scenario 1, Accelerated Electrification, (b) Scenario 2, Policy-Driven Grid Reliance and (c) Scenario 3, Fragmented Transition. Those three scenarios for the CO_2 emission reduction could be implemented started in 2026 and the differences between each other are the aggressiveness of electrification stage.

Table 5. Propose implementation plan for decarbonization at PT BIB

Scenarios	2026	2027	2028	2029	2030-2031	2032-2036
		10% big excavators	20% big excavators	30% big excavators	35% big excavators	45% big excavators
		15% big	20% big	25% big	25% big	50% big

Scenarios	2026	2027	2028	2029	2030-2031	2032-2036
		haulers	haulers,	haulers	haulers	haulers
Scenario 1 Accelerated Electrification	25% mine support fleets 25% hauling truck 50% Light Vehicles 100% Port Operation facilities	50% mine support fleets 50% hauling truck 100% Light Vehicles 100% Port Operation facilities	60% mine support fleets, 75% hauling truck, 100% Light Vehicles 100% Port Operation facilities	80% mine support fleets 85% hauling truck 100% Light Vehicles 100% Port Operation facilities	100% mine support fleets 100% hauling truck 100% Light Vehicles 100% Port Operation facilities	100% mine support fleets 100% hauling truck 100% Light Vehicles 100% Port Operation facilities
Scenario 2 Policy-Driven Reliance	15% mine support fleets 25% hauling truck 50% Light Vehicles 100% Port Operation facilities	35% mine support fleets 45% hauling truck 100% Light Vehicles 100% Port Operation facilities	15% big excavators 5% big haulers, 55% mine support fleets, 60% hauling truck, 100% Light Vehicles 100% Port Operation facilities	25% big excavators 10% big haulers 80% mine support fleets 75% hauling truck 100% Light Vehicles 100% Port Operation facilities	35% big excavators 15% big haulers 100% mine support fleets 100% hauling truck 100% Light Vehicles 100% Port Operation facilities	35% big excavators 20% big haulers 100% mine support fleets 100% hauling truck 100% Light Vehicles 100% Port Operation facilities
Scenario 3 Fragmented Transition	10% mine support fleets	10% mine support fleets 35%	10% mine support fleets, 55%	20% mine support fleets, 75%	50% mine support fleets, 100%	5% big excavators 10% big haulers 50% mine support fleets 100%

Scenarios	2026	2027	2028	2029	2030-2031	2032-2036
	15% hauling truck 50% Light Vehicles 100% Port Operation facilities	hauling truck 100% Light Vehicles 100% Port Operation facilities	hauling truck, 100% Light Vehicles 100% Port Operation facilities	hauling truck, 100% Light Vehicles 100% Port Operation facilities	hauling truck, 100% Light Vehicles 100% Port Operation facilities	hauling truck 100% Light Vehicles 100% Port Operation facilities

Those three scenarios would give benefit for the company to avoid additional cost incur due to carbon tax once the regulation implemented and also benefit by eliminating of fossil fuel consumption through electrification. Summary of potential benefit could be obtained with this transition process from fossil fuel to electrification are as below;

Table 6. Summary of potential benefit from fossil fuel into electrification 2026-2035

Impact of Transition	***Unit***	***Scenario 1***	***Scenario 2***	***Scenario 3***
Total CO_2 emission reduction from 2026-2035	Ton CO_2eq	4 million-ton CO_2eq	3.08 million-ton CO_2eq	1,86 million-ton CO2eq
Carbon tax reduction @ Rp 30,000/ton	Rp (Billion)	Rp 120.5 Billion	Rp 92.33 Billion	Rp 55.68 Billion
Fuel consume eliminated	Liters	1.4 Billion	1.14 Billion	0,69 Billion
Cost reduction for fuel @ price Rp 13,500/liters	Rp (Billion)	Rp 20 Trillion	Rp 15.39 Trillion	Rp 9.28 Trillion
Total Potential Benefit	**Rp (Trillion)**	**Rp 20.2 Trillion**	**Rp 15.48 Trillion**	**Rp 9.34 Trillion**

CONCLUSION

Based on Pareto analysis and scenario planning, PT BIB's main sources of CO_2 emissions were identified, enabling prioritization of decarbonization actions through four future scenarios: Bridge to The Future (high technology and regulatory support, 60%+ reduction), Black Gold Renaissance (strong policy but limited technology, 40–45% reduction), Decarbonize or Disappear (advanced technology but weak regulation, 20–30% reduction), and Stranded Legacy (limited support, up to 10% reduction). These scenarios provide a structured framework for PT BIB to make strategic decisions in the face of regulatory and technological uncertainties. It is recommended that PT BIB continuously monitor technological and policy developments, invest in research and development of emission-reducing technologies, and collaborate with regulatory bodies to ensure effective and adaptive emission reduction strategies. Future research should focus on testing these strategies in real-world

operations and expanding the analysis to include Scope 2 and 3 emissions for a more comprehensive approach to carbon management.

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