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Scenario Planning for Decarbonization at Semen Indonesia: Strategies for Balancing Sustainability and Competitiveness

Andry Nugraha Sudana [1], Bambang Rudito [2], Socrates Rudy Sirait [3]

[1,2,3] *School of Business and Management, Institut Teknologi Bandung, Indonesia (andrysudana87@gmail.com)*

Abstract

The cement industry significantly contributes to global carbon emissions, accounting for around 7% of industrial emissions worldwide. PT Semen Indonesia (Persero) Tbk, commonly known as SIG, as Indonesia's leading cement producer, faces growing pressure to achieve decarbonization while maintaining business competitiveness amidst an oversupplied domestic market, rising costs, and emerging environmental regulations such as carbon taxes. This study aims to explore strategic scenario planning for Semen Indonesia to meet its 2030 decarbonization targets while ensuring business sustainability. The research begins with an extensive literature review covering decarbonization strategies, value chain analysis, Marginal Abatement Cost (MAC) framework, and scenario planning techniques. Internal and external analyses were conducted using SWOT and PESTLE frameworks to identify critical driving forces impacting Semen Indonesia's future. Scenario planning methodology was employed to develop plausible future scenarios, evaluating uncertainties and impacts related to technology adoption, regulatory shifts, market dynamics, and resource availability. Scenario analysis revealed that early investments in waste-to-energy technology, aggressive clinker factor reduction, and flexible adaptation to regulatory changes provide Semen Indonesia with the best pathway to remain competitive and sustainable. It offers practical recommendations for Semen Indonesia and provides insights for policymakers supporting the cement industry's transition toward net-zero emissions.

Keywords: Decarbonization, Cement Industry, Scenario Planning, Marginal Abatement Cost (MAC), PESTLE & SWOT Analysis.

INTRODUCTION

The cement industry contributes approximately 7% of global industrial carbon emissions and is the third-largest industrial energy consumer. About 60% of the CO2 emissions generated during cement production come from the decomposition of limestone (calcium carbonate), with the remaining 40% coming from fuel combustion and other energy-related activities. According to the International Energy Agency's (IEA) Reference Technology Scenario (RTS), global direct CO2 emissions from the cement industry are expected to rise by 4% in 2050, despite a projected 12% increase in production during that time (International Energy Agency, 2018).

The cement industry is characterized by a significant energy demand during its production process, accounting for approximately 30-40% of the total production cost (Mossie et al., 2025). It relies heavily on coal, particularly in Indonesia, contributing to greenhouse gas emissions. Efforts to reduce emissions have incurred significant costs over an extended period. On the other hand, the industry faces challenges in the Indonesian market, including intense competition that lowers profit margins, excess supply, rising fuel prices, and increasing costs of materials and labor.

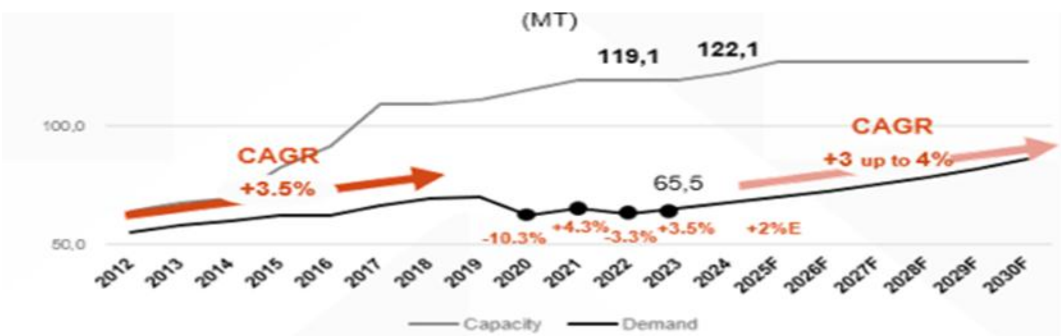

Figure 1. Indonesia domestic cement capacity vs demand (MT) (Source: Public Expose SIG, 2023)

The rising prices of raw materials and energy have a substantial influence on profitability. To uphold competitive pricing, the corporation must efficiently handle these costs. The Indonesian cement sector is currently facing a problem of excess supply, resulting in intense price competition among producers and putting pressure on profit margins (Aishanttya, 2021). Environmental concerns in cement manufacturing involve the ongoing issue of meeting legal standards and effectively controlling the environmental impact. This requires investment in sustainable practices and advanced technologies. The implementation of a carbon tax and trading system may become another challenge for the Indonesian cement industry, as it is one of the most significant contributors to carbon emissions. The industry must prepare and implement an appropriate strategy to anticipate the complex and multifaceted challenges and opportunities it faces.

As the largest cement producer in Indonesia, PT Semen Indonesia (Persero) Tbk, commonly known as SIG, faces pressure to balance its decarbonization efforts with business competitiveness amid industry challenges and the introduction of a carbon tax in Indonesia. SIG commits to achieving a long-term sustainability roadmap by 2030, which includes areas such as revenue generated from sustainable solutions, climate, circular economy, water, nature, and people and community. Regarding climate, SIG has targets in 2030 to reduce CO2 emission intensity from internal processes by 27% (2010-2030). The CO2 emission intensity from internal processes can be reduced by lowering the clinker factor and increasing the thermal substitution rate (TSR) (PT Semen Indonesia (Persero) Tbk, 2024).

In this article, we examine how SIG formulates the most feasible strategy to achieve carbon reduction targets while maintaining or improving market competitiveness in the Indonesian cement industry. Current and future national infrastructure projects, including the development of the new capital city, IKN Nusantara, present substantial prospects for expanding the demand for the domestic cement market. Expanding export markets provides a crucial chance to alleviate domestic market saturation and enhance earnings from international sales. Investing in innovative manufacturing technologies and sustainable practices can improve productivity, lower expenses, and comply with environmental standards, thereby offering a competitive advantage.

The study aims to contribute valuable insights into the integration of decarbonization initiatives into decision-making processes. The findings are expected to guide companies in formulating the most feasible strategy to achieve carbon reduction targets while maintaining or improving market competitiveness in the Indonesian cement industry. This study aims to answer the following research questions:

a. What are the key factors and driving forces for scenario planning for decarbonization in SIG?
b. What is the most feasible and viable scenario planning for the decarbonization strategy to achieve the SIG carbon reduction target by 2030 and promote business sustainability?
c. What is the implementation plan for this scenario?

LITERATURE REVIEW

Value Chain of Cement Industry

According to Imbabi, Carrigan, and McKenna (2012), the cement production process consists of several critical stages, each contributing to the overall value chain (Imbabi et al., 2012). Each stage of the value chain contributes to total energy consumption as follows:

1. Quarrying (7%): The process begins with the extraction of raw materials such as limestone and clay from the quarry. This stage accounts for about 7% of the total energy consumption in the cement production process.
2. Raw Milling: The raw materials are transported to the raw mill, where they are ground into a fine powder to create the raw meal necessary for clinker production.
3. Pyroprocessing (85%): The raw meal then enters the kiln system, passing through a cyclone tower with a pre-calciner. Pyroprocessing, which includes calcination and clinker formation, is the most energy-intensive stage, consuming approximately 85% of the total energy, with about 50% of that energy coming from the calcination process itself. In the kiln, the raw meal undergoes high-temperature processing to form clinker.
4. Clinker Cooling: After exiting the kiln, the clinker is rapidly cooled in the clinker cooler to preserve product quality and recover heat.
5. Clinker Storage: The cooled clinker is stored in silos until it is needed for grinding.

6. Grinding (5%): In the cement mills, clinkers are ground together with additives, such as gypsum, to produce cement. This stage accounts for about 5% of total energy consumption.
7. Transportation (3%): The finished cement is transported to distribution points or directly to customers. Transportation accounts for around 3% of the energy use in the cement production value chain.

During cement production, fuel is the most significant contributor to energy cost estimation, accounting for 36% of the total cost of cement production. Electricity contributes approximately 18% of the total cost of cement production. Additionally, thermal energy accounts for approximately 88% of the total energy demand in cement production, while electrical energy accounts for 12%, as shown in Figure 2 (Raharjo, 2024).

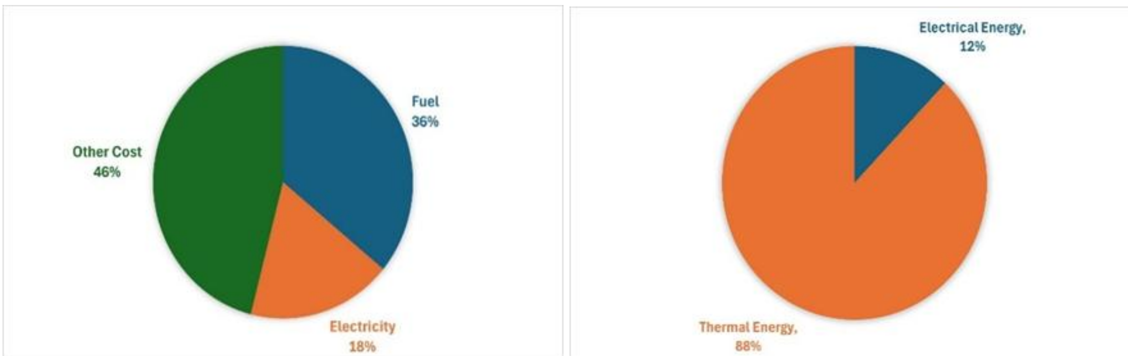

Figure 2. Cost Structure and Energy Demand for Cement Production (Source: Raharjo, 2024)

Decarbonization Strategy in Cement Production

Standard decarbonization methods encompass enhancing energy efficiency, reducing the clinker-to-cement ratio, utilizing alternative fuels, and employing renewable energy sources. These techniques not only improve the ability of cement companies to recover quickly and compete effectively but also support the overall objective of sustainable development. Several strategies may be implemented, which include:

1. Reduction of clinker usage: Clinker production is highly energy-intensive and accounts for the majority of emissions in cement production. Substituting clinker with alternative materials, such as fly ash, metal slag, or calcined clay, can significantly reduce emissions.
2. Decarbonization of heat and utilization of alternative fuels: Transitioning from traditional fossil fuels to alternative and renewable energy sources for kiln operation can decrease CO2 emissions. This includes the use of biofuels and waste materials as part of a broader waste recycling business.
3. Carbon capture, utilization, and Storage (CCUS): Capturing and storing or reusing CO2 emissions from cement production processes is another critical strategy. This not only helps in reducing emissions but can also be used in producing aggregates or other construction materials (Tau, 2023).
4. Supplementary Cementitious Materials and Innovations in Cement Formulation: Utilizing materials that can replace traditional cement components to reduce the carbon footprint of the overall manufacturing process is a growing area of focus. This includes innovations in creating low-binder cement and reusable concrete modules.
5. Circular economy and recycling: Circular solutions, such as recycling cement and concrete materials for new construction, are emerging as vital for reducing the industry's carbon footprint. This approach includes using demolished concrete in new constructions and developing technologies for the reuse of entire buildings (Heincke et al., 2023).

The technological options for decarbonizing the cement industry can be primarily divided into four groups: energy efficiency measures, the use of alternative fuels and raw materials, reducing clinker factors, and carbon management (Elango et al., 2023).

Marginal Abatement Cost (MAC)

The Marginal Abatement Cost (MAC) framework is a critical tool for evaluating the cost-effectiveness of various technologies and strategies aimed at reducing carbon dioxide (CO_2) emissions within the cement industry. MAC curves plot the cost (in USD per ton of CO_2 reduced) against the potential volume of emissions abated (in million tons of CO_2). In the cement sector in India, as illustrated by Kartheek Nitturu, the MAC for each technological option in the cement industry can be described as follows:

1. Energy Efficiency Measures.

   These include interventions such as waste heat recovery, efficient grinding systems, optimization of auxiliary power, and the use of energy-efficient electrical equipment. These measures often have negative abatement costs, meaning they both reduce emissions and save costs.

2. Renewable Energy (RE), Alternative Fuels, and Raw Materials.

   Measures such as the use of Refuse-Derived Fuel (RDF), biomass, and renewable energy sources will increase the Thermal Substitution Rate (TSR) in kilns, contributing to significant emission reductions at low or moderate abatement costs.

3. Reduction in Clinker Factor.

   Strategies like substituting Ordinary Portland Cement (OPC) with materials like fly ash, slag, and LC3 (Limestone Calcined Clay Cement) reduce the need for clinker, thereby decreasing CO_2 emissions. Reducing the clinker ratio to 85% in OPC is identified as a significant opportunity; however, it incurs higher costs compared to energy efficiency initiatives.

4. Carbon Capture, Utilization, and Storage (CCUS) and Carbon Offsets.

   Technologies such as Carbon Capture and Storage (CCS) and Carbon Capture and Utilization (CCU), along with carbon offset initiatives like afforestation, represent some of the highest-cost options but are crucial for achieving deep decarbonization beyond the limits of energy efficiency and material substitution.

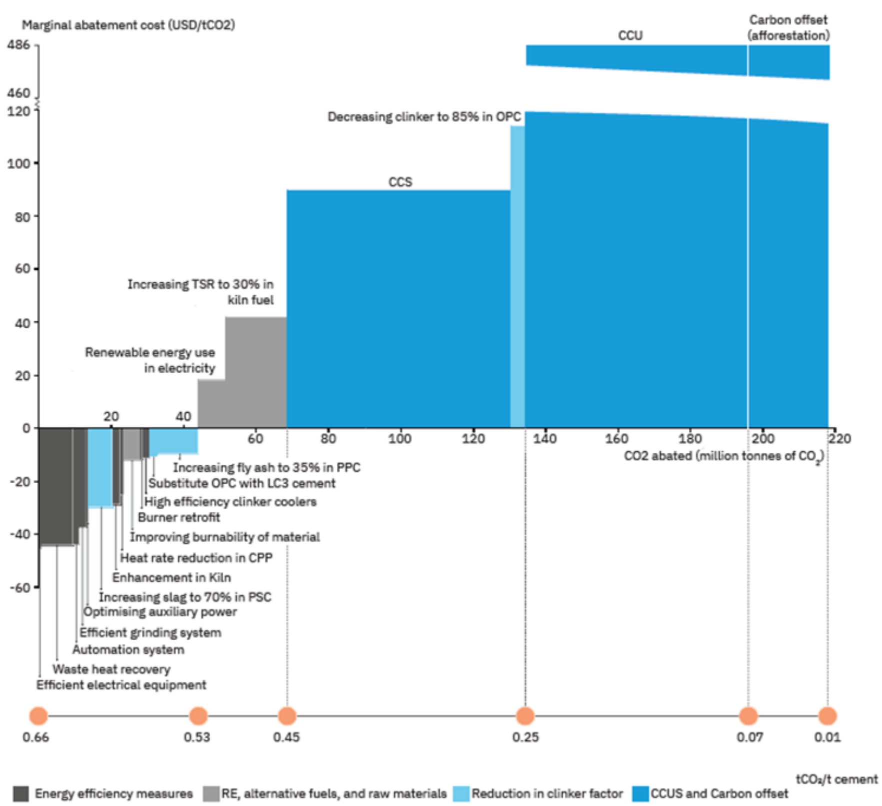

Figure 3. Decarbonization Technology MAC (Kartheek Nitturu, 2023)

The MAC curve highlights that low-cost and negative-cost measures should be prioritized first, as they deliver financial savings while cutting emissions. High-cost interventions, although expensive, will be necessary for achieving net-zero targets as the industry exhausts cheaper abatement opportunities.

The study's findings in Canada revealed that negative Marginal Abatement Costs (MACs), which represent cost savings achieved by reducing emissions, were identified for biomass and municipal solid waste (MSW) fuel switching options. In contrast, hydrogen and electrification offered the highest CO2 reductions but came with high positive MACs due to the high costs associated with these technologies. Additionally, market share analyses suggest Refused Derived Fuel (RDF) / Municipal Solid Waste (MSW) and biomass will dominate low-cost decarbonization pathways. At the same time, hydrogen and electrification will only penetrate deeply with technological advancements and supportive policies. Moreover, regional differences such as energy prices and fuel mixes significantly impact the MAC and effectiveness of each technology (Clark et al., 2024).

Scenario Planning

Scenario planning is a practical strategic planning tool for medium- to long-term planning under uncertain conditions, helping to navigate and sharpen strategies, stay focused on the unexpected, and keep a lookout for the right direction and on the right issues. Scenario planning is not only a planning instrument but also an effective tool for learning. By exploring various potential futures and considering a wide range of possibilities, the organization can formulate robust strategies that are resilient to change. Scenario planning emphasizes creative thinking and allows for a deeper understanding of risks and opportunities, ensuring that decision-makers are better equipped to respond to a dynamic environment (Bandhold, 2003).

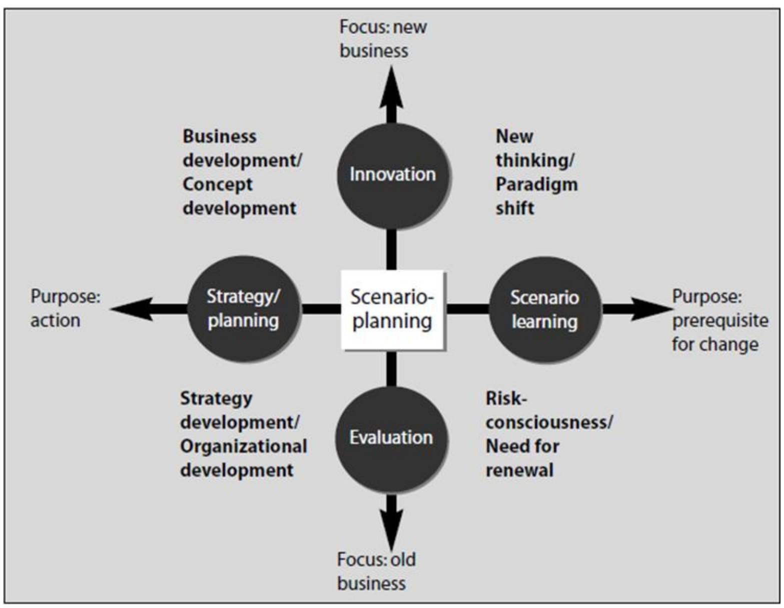

Figure 4. Different Purposes and Different Focuses of Scenario Planning (Source: Lindgren & Bandhold,2003)

According to Garvin, D.A., and Levesque, L.C. (2006), scenario planning is a structured method that organizations use to foresee multiple plausible futures. It aims to enable better strategic decision-making by expanding the mental models of decision-makers and preparing them for a range of uncertainties. Scenario planning helps to draw a summary from a variety of options and observe several uncertainties. These attributes are particularly suitable for medium- and long-term business strategies. The application of scenario planning can be used widely. It can be used to produce a product, provide a source of ideas and business concepts, and evaluate the current strategy.

PESTLE Analysis

A PESTLE analysis examines the key external factors that influence the organization. It can be applied in various scenarios and guides leadership in strategic decision-making (CIPD, 2025). Additionally, PESTLE analysis is a risk management method used to plan strategies that will be implemented to understand the potential impacts on a specific company or project. This analysis is also used to calculate follow-up actions with appropriate business considerations. The PESTLE analysis itself comprises six external factors: Political, Economic, Social, Technological, Legal, and Environmental.

SWOT Analysis

SWOT Analysis is a methodological approach used to assess the Strengths, Weaknesses, Opportunities, and Threats associated with an organization, plan, project, program, individual, or any business operations. The SWOT Analysis is the most frequently used strategic planning instrument for evaluating the internal and external variables of any firm. This is regarded as an excellent framework for planning and managing organizational resources to achieve specific goals within a designated timeframe (CR & Praveena, 2023).

METHOD

The research design is structured to achieve the research objective through a comprehensive and systematic process. The initial step involves setting the research objective, which serves as the guiding framework for all subsequent stages. Data collection is conducted by using both primary and secondary sources.

Primary data is gathered through in-depth interviews to provide insight directly from key stakeholders and subject matter experts. Secondary data is obtained from a thorough literature review, analysis of company and industry reports, government policies, and consultations with experts, to support the primary findings.

The internal and external analyses were conducted using the SWOT and PESTLE frameworks to identify critical driving forces that will impact SIG's future. A scenario planning methodology was employed to develop multiple plausible future scenarios, evaluating uncertainties and impacts related to technology adoption, regulatory shifts, market dynamics, and resource availability.

The final phase involves translating the scenario insights into a detailed implementation plan, outlining specific strategic initiatives and actionable steps aligned with the research objective. This structured, multi-method approach ensures a comprehensive understanding of the research, facilitating strategic decision-making.

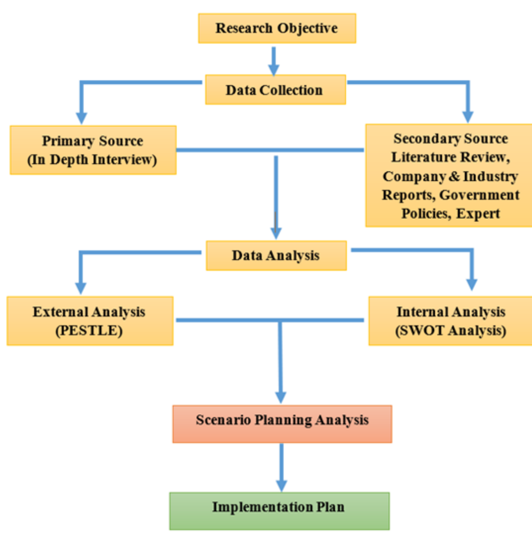

Figure 5. Research Design (Source: Author's Analysis)

Data Collection Method

This study will utilize in-depth interviews as the primary data collection method. The interview questions are semi-structured to allow flexibility in exploring topics in depth based on the interviewee's responses. The respondents will be asked to provide specific information for scenario planning.

Interviews were conducted to identify critical uncertainties and their impact on achieving the SIG decarbonization target by 2030, which informed the proposal of multiple scenarios in the scenario planning process. Semi-structured interviews were conducted with several stakeholders within the organization, including a leader in the SIG Sustainability Office, as well as representatives from Asset Management, Group Restructuring, and Tax. Additionally, interviews were conducted with renewable energy developers and environmental advisors from external parties to obtain diverse perspectives and generate thorough data.

The analysis of secondary data involves examining existing information collected from various sources, such as company and industry reports, literature reviews, and government policies. Additionally, internal factors, including project cost, employee numbers, licenses, and company strategies, were also considered to develop a thorough analysis.

RESULTS AND DISCUSSION

Business Environment Analysis

A SWOT analysis provides comprehensive insights into the company's current position and potential obstacles it may face, as well as various opportunities that can be leveraged to enhance business sustainability. SIG is positioned in the growth quadrant, which aligns with its quadrant position, indicating a favorable situation for the company. The company has the strength to seize the existing opportunities. The strategy that must be pursued is to support aggressive growth policies.

A PESTLE analysis is used to evaluate the macroeconomic factors influencing the implementation of the green transition initiative within Indonesia's cement industry. In terms of the political aspect, Indonesia has set a target to achieve net-zero emissions (NZE) by 2060 or earlier, however, depending on the availability of international support and advancements in green technology. Indonesia updated its Nationally Determined Contribution (NDC) in 2022, strengthening its emission reduction targets. The Energy Transition Roadmap aims to phase out coal and increase renewable energy contributions to at least 23% of the national energy mix by 2025, encouraging investment in solar, wind, hydro, and geothermal energy.

The introduction of a carbon tax (IDR 30,000 per ton of CO_2 emissions) and carbon trading systems to incentivize emission reductions. The carbon tax has been regulated in the Indonesian Minister of Finance Regulation No. 81/2024 and is planned to be implemented initially for the power sector in 2025, pending further delays. The Indonesia Stock Exchange launched the Indonesia Carbon Exchange (IDX Carbon) on September 26, 2023.

Several regulations have been issued to promote the green industry transformation, such as the Presidential Regulation No. 35/2018 on Acceleration of Waste-to-Energy Projects provide Government support and electricity tariff incentives, Government Regulation No.78/2019 which regulates full or partial exemption from Corporate Income Tax for companies that make significant investments in sustainable projects, and introduction of green industry standard for cement industry and other heavy industry sectors that set caps on the energy used to produce one ton of product, however the above initiatives are still in the early stage (Satria & Usman, 2024).

The availability of green bonds and sustainability-linked loans has a significant impact on decarbonization in Indonesia's cement industry. Major cement companies, such as SIG, can access green financing mechanisms to fund initiatives like renewable energy installations (e.g., Solar PV) and Waste Heat Recovery Systems (WHRS). Additionally, facilities loans from multilateral development banks such as the Asian Development Bank (ADB) and the World Bank, under climate finance initiatives, are accessible to support capital-intensive decarbonization technologies.

In terms of social aspects, public awareness of climate change and sustainability is increasing, especially in Southeast Asia. According to a survey conducted, nearly 60% of Southeast Asians believe their lives will be affected by climate change within the next 10 years (Seah, Southeast Asia Climate Outlook: 2024 Survey Report).

The waste-to-energy technology presents significant opportunities for decarbonization in the cement industry, addressing both the waste management issue and the challenge of reducing emissions. The use of Refused Derived Fuel (RDF) as a substitute for coal offers substantial efficiencies in cement production.

Table 1. Indonesia Cement Industry Macro Environment Analysis (Source: Author's Analysis)

Dimensions	**Parameters (External Factors to Consider)**	**Variables (Factors affected within the industry)**	**Importance to the organization**
Political	Government policies & regulations, political stability, global trade agreements, and restrictions	Indonesia's Net-Zero (NZE) target. Indonesia's Nationally Determined Contribution (NDC) targets encompass both unconditional and conditional objectives. Sectoral NDC Targets. Industry Incentives (Kementerian Perindustrian). Building Code for Green Building) Carbon Border Adjustment Mechanism for imported cement.	Medium – *Continue to monitor the political changes situation and their impact on industry and business development.*
Economic	Investment Costs, Financial Incentives, and Market Demand for Eco-Friendly Materials.	Green bonds/loan facilities. Technology & Alternative Fuel Price. Tax exemption for the purchase of highly efficient machinery. Carbon Trading	Medium – *Leverage financing by seeking partnerships with local and international institutions.*
Social	Public awareness and consumer preferences, social pressure (from NGOs, investors, and communities), and the workforce.	Public/consumers shifted behaviors. ESG compliance. The human capital capacity.	Medium – *Increase public awareness by improving the marketing strategy to be ESG-oriented.*
Technological	Availability of green technologies (carbon emissions reduction), energy efficiency, and alternative fuel and energy sources.	Carbon Capture Storage (CCS) Refused Derived Fuel (RDF). Alternative Energy Sources.	High – *Seeking new technology adoption to improve the efficiency and cost of production, to be more competitive*
Legal	Environmental Regulations, Financial Regulation, Environmental Standards Compliance	Carbon Tax. ISO 14001. SNI 2049:2015 on Portland Cement. Government Regulation No. 22 of 2021 on Environmental Protection and Management.	High – *Monitor and assess the new regulation to identify potential penalties or opportunities for future mitigation.*
Environmental Factors	Climate change, resource depletion, and waste management.	Alternative cement raw materials. Waste Management and Alternative Energy Sourcing Strategy.	Medium – *Adopt waste management for alternative fuels as it will increase efficiency. Asses the potency of waste*

Dimensions	Parameters (External Factors to Consider)	Variables (Factors affected within the industry)	Importance to the organization
			management business to generate other revenue and improve circular economy

Scenario Planning Analysis

Scenario planning for SIG will be conducted through 5 stages: 1. Orientation; 2) Exploration; 3) Scenario and Narrative Creation; 4) Option Consideration; 5) Integration. Each stage will be analyzed as follows:

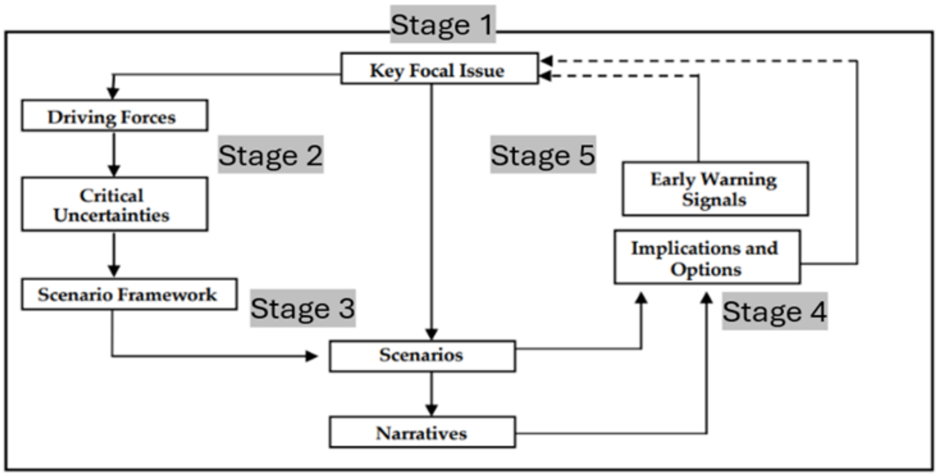

Figure 6. Factors or Variables in Scenario Planning (Source: (Garvin & Levesque, 2005))

Stage 1: Orientation

In the first stage, this study identified key focal issues as follows:

1. How can SIG achieve the decarbonization target in 2030?
2. What kind of strategies for SIG to achieve its 2030 decarbonization target while remaining competitive in the market?

Stage 2: Exploration

This stage involves an in-depth analysis of internal and external factors that shape the possible future of SIG's decarbonization strategy. Based on the company's business environment, literature review, and subsequent data collection from in-depth interviews, the driving forces were identified in five aspects (Political/Legal, Economic, Social, Technological, and Environmental), as described in Table 2.

Table 2. Driving Force to achieve SIG decarbonization target (Source: Author's Analysis)

No	Factors	Driving Forces	Explanation
1	Political / Legal	1. Government regulations and policies on energy transition and carbon emissions.	1. Cement production is highly carbon-intensive. Government regulation and policies significantly influence the decarbonization strategy. The Nationally Determined Contribution (NDC) to achieve Net Zero Emissions by 2060, the Indonesian Carbon Tax and Carbon Market, the Moratorium on restrictions on new cement plants, and regulations or instructions

		2. National and global political stability	for using Non-OPC Cement (green cement) in Construction work all play significant roles in influencing SIG's decarbonization target. 2. SIG is a state-owned company that the national political stability will significantly influence. Global geopolitics, such as the Russia-Ukraine war, impact the volatility of coal prices as the primary fuel in the cement production process.
2	Economic	1. Market demand for low-carbon cement products. 2. Fuel Prices (coals) 3. Financing & access to green investment	1. SIG, as the leading cement company in Indonesia, needs to maintain its competitiveness and capitalize on emerging opportunities, such as non-OPC cement (also known as green cement). 2. Coal is a primary fuel source to heat the kiln during the clinker production process. 3. Access to green financing and investment may benefit SIG in funding the green project, making it financially viable.
3	Social	Awareness of green cement products	Awareness of the climate change issue can lead to a rapid increase in demand for green cement in the market.
4	Technological	Technological Advancement	Technological choices determine the level of carbon reduction and ultimately impact the product cost.
5	Environmental	1. Waste Management 2. Climate change	1. Waste management can help SIG to provide alternative fuel from waste and supplementary cementitious material (alternative clinker materials). 2. As a major contributor to carbon emissions, the cement industry is under pressure to reduce its carbon emissions. Climate change will impact not only the regulatory framework and market demand but also the continuous business operation.

To identify the level of uncertainty associated with the driving forces, semi-structured interviews were conducted to gather the respondents' opinions on the driving forces that pose the most significant uncertainties for SIG to achieve its decarbonization target within the next 5 years, along with their scoring levels, as shown in Table 4.

Table 3. Driving forces scoring (Source: Author's Analysis)

No	Rank	Score
1	First choice	3
2	Second choice	2
3	Third choice	1
4	No choice	0

Table 4. Driving Force with level of uncertainties based on interview respondent (Source: Author's Analysis)

Driving forces	ES	OP	FA	AB	NH	DI	RA	DM	Total
Government regulation and policies	3	3	3	3	0	3	0	3	**18**
National and Global political stability	0	0	0	0	3	0	3	0	**6**

Market demand for low-carbon cement products	0	0	0	0	0	0	0	2	**2**
Fuel Prices (coals)	0	0	0	0	0	0	0	0	**0**
Financing & access to green investment	1	1	0	1	1	2	2	0	**8**
Awareness of green cement products	0	0	1	0	0	0	0	0	**1**
Technological Advancement	2	2	2	2	2	1	1	1	**13**
Waste Management	0	0	0	0	0	0	0	0	**0**
Climate change	0	0	0	0	0	0	0	0	**0**

Based on the results of semi-structured interviews, the respondents also identified the level of impact of driving forces on the SIG decarbonization target, as shown in Table 5.

Table 5. Driving Force with level of impact based on interview respondent (Source: Author's Analysis)

Driving forces	ES	OP	FA	AB	NH	DI	RA	DM	Total
Government regulation and policies	3	3	3	3	3	3	0	2	**20**
National and Global political stability	0	0	0	0	0	0	3	0	**3**
Market demand for low-carbon cement products	0	0	0	1	0	0	0	0	**1**
Fuel Prices (coals)	0	0	0	0	0	0	0	0	**0**
Financing & access to green investment	1	1	1	0	1	2	2	1	**9**
Awareness of green cement products	0	0	0	0	0	0	0	0	**0**
Technological Advancement	2	2	2	2	3	1	1	3	**16**
Waste Management	0	0	0	0	0	0	0	0	**0**
Climate change	0	0	0	0	0	0	0	0	**0**

The total scoring for impact and uncertainties is categorized based on the level of priorities, with the highest score reflecting the highest priority and the lowest score reflecting the lowest priority. The category itself consists of high, medium, and low, as shown in Table 6.

Table 6. Driving Force Scoring (Source: Author's Analysis)

No	Level	Score
1	High	>12
2	Medium	6-12
3	Low	0-6

The total scoring for the level of uncertainties and the impact of the driving forces, as shown in Table 2, will be combined into the critical uncertainties matrix, which combines both impactful and uncertainty factors, as shown in Table 7.

Table 7. Priority of driving force based on impact and uncertainties (Source: Author's Analysis)

Driving Force	**Uncertainties**		**Impact**	
	Score	**Level**	**Score**	**Level**
Government regulation and policies	18	High	20	High
Technological Advancement	13	High	16	High
Financing & access to green investment	8	Medium	9	Medium
National and Global political stability	6	Medium	3	Low
Market demand for low-carbon cement products	2	Low	1	Low
Fuel Prices (coals)	0	Low	0	Low
Awareness of green cement products	1	Low	0	Low
Waste Management	0	Low	0	Low
Climate change	0	Low	0	Low

Based on the interviewees' responses regarding the driving forces to achieve the SIG decarbonization target, it can be determined that government regulation and policies, as well as technological advancements, are the critical uncertainties and the most influential forces.

Level of Uncertainties

Level of Impact	**Low**	**Medium**	**High**
High			• Government regulation and policies • Technological Advancement
Medium		Financing & access to green investment	
Low	• Market demand for low-carbon cement products • Fuel prices (coals) • Awareness of green cement products • Waste management • Climate change	National and Global political stability	

Figure 7. Degree of Uncertainties (Source: Author's Analysis)

Stage 3: Scenario and Narrative Creation

Based on the results of the interview and internal and external analysis, the scenario development for this study is presented in a 2x2 Matrix that combines the two highest-impact and uncertain factors: technological advancement or adoption and Government policies for green transition, as shown in Figure 7.

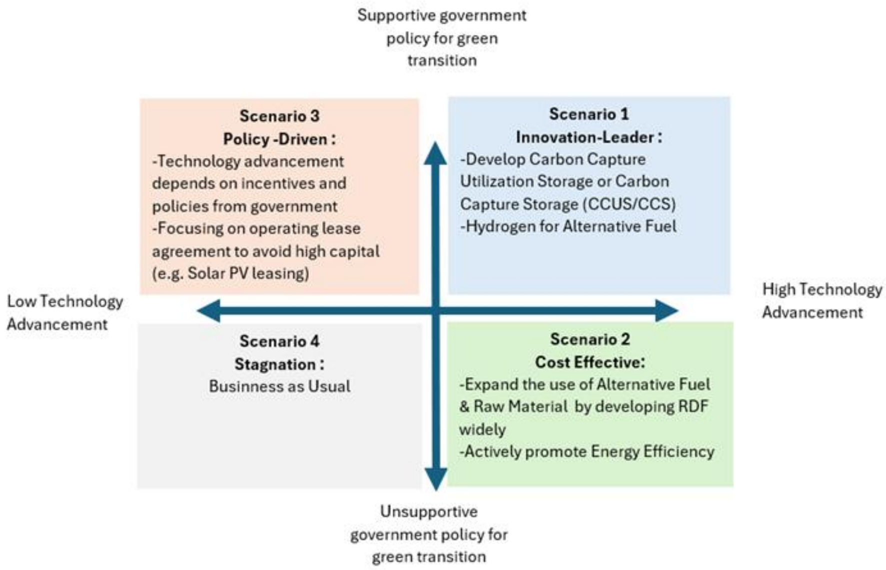

Figure 8. Scenario Alternatives (Source: Author's Analysis)

In reference to Figure 8, this study developed 4 (four) scenario alternatives:

Scenario 1: Innovation Leader

Key driving forces: Rapid technology adoption and supportive policies for green transition

In this scenario, SIG operates in an environment where the policy supports decarbonization in the cement industry, while technological advancements are rapidly progressing. The policies that support the green transition in the cement industry include new tax incentives for low-carbon innovations, a carbon tax and trading system, a moratorium on restrictions on new cement plants, and regulations or guidelines for using Non-OPC Cement (green cement) in construction.

Technological adoption in the cement industry plays a significant role in the decarbonization effort. Carbon Capture Utilization and Storage (CCUS), hydrogen as an alternative to fossil fuels, and renewable energy integration, such as solar PV for electricity, are key components. Despite its potential to drastically cut its emissions, high capital investment in R&D and technology deployment is required. Additionally, decarbonization using hydrogen, CCUS, and solar PV is considered to have a high marginal abatement cost (MAC), where the cost of achieving each incremental reduction in emissions is expensive, consequently making the cement production cost significantly higher. To achieve the net-zero emission target in the cement industry using these advanced technologies, robust R&D is needed to lower the MAC to a commercially viable level. In the long term, both hydrogen and CCUS offer the potential for the most significant annual carbon emissions reduction when fully deployed.

Scenario 2: Cost Effective

Key driving forces: High level of technological adoption in the unsupportive policies for green transition

In this environment, the government policies and regulations are considered unsupportive for decarbonization, and the level of technology adoption is considered high. The unsupportive government policies may eliminate the cost savings from adopting new technologies. The Indonesian government plans to revise the National Energy Policy, lowering the renewable energy achievement target from 23% in 2025 to 19–21% by 2030 (IESR, 2024). The delay in carbon tax implementation and limited incentives for decarbonization indicate that the energy transition effort in Indonesia has not progressed beyond the consolidation stage. The lack of political commitment, as well as unsupportive regulations and governance, are factors hindering the energy transition in Indonesia, despite significant progress in the cost competitiveness of low-carbon technology and fuels. Moreover, renewable energy projects are still considered high risk, which affects their low bankability.

The market forces, including the increase in sustainable products and the requirements for ESG initiatives to access green financing, drive SIG to adopt several technology options for decarbonization in the cement industry. Since there are limited incentives and regulatory support, it is imperative to choose cost-effective technology to produce cement products. The cost-effective technology option can be indicated by the lower or negative Marginal Abatement Cost (MAC). Based on a literature review and interview, the use of RDF technology to replace coal in cement production may lower the production cost of cement. Another technology option is energy efficiency, for example, Waste Heat Recovery Power Generation (WHRG), which captures and utilizes the heat energy released from cement production to generate electricity. This reduces energy consumption, enhances efficiency, and lowers carbon emissions.

Scenario 3: Policy-Driven

Key driving forces: Compliance with regulations and the utilization of incentives that support decarbonization, but limited technology adoption.

A strong regulatory framework with policies that promote sustainability and decarbonization triggers a policy-driven scenario. On the other hand, technological adoption is slow due to infrastructure, resources, and financial limitations. The focus is on compliance rather than innovation to avoid penalties from government-imposed regulations while maintaining competitiveness in the market.

In this scenario, the adoption of technology will depend on the government's incentives to fund decarbonization, accompanied by moderate progress in reducing carbon emissions. An example of this scenario is the implementation of regulations in Indonesia that support waste management, thereby increasing the availability of alternative materials to replace clinkers in cement production. Another example of this scenario is the introduction of a carbon tax and trading system; consequently, SIG needs to comply with the regulations by moderately reducing carbon emissions so that penalties can be minimized.

Scenario 4: Stagnation

Key driving forces: minimal regulatory support for decarbonization, and the adoption of technology is limited.

Minimal regulatory support and slow technology adoption drive this scenario. SIG operates using conventional methods, relying on fossil fuel (coal) and clinker as raw materials. The price of coal will also influence decision-making. The low price of coal compared to other resources will significantly contribute to the production cost, resulting in a lower pricing strategy in the market. As the cement market is price-sensitive and lacks government incentives to adopt green technology, this option may be an effective way to increase market share by focusing on a lower pricing strategy compared to competitors in the market.

In the long term, this scenario may pose several risks, including dependence on coal prices and vulnerability to carbon pricing and regulatory changes. For instance, the carbon tax introduced in Law No. 7 of 2021, with a rate of IDR 30,000/ton CO_2 (approximately \$2/ton CO_2), is considered one of the lowest globally (World Bank, 2023). Therefore, paying carbon tax penalties could be viewed as an option rather than developing new technology that increases production costs. The additional cost for new technology could be even higher than paying carbon tax penalties.

Stage 5: Integration

In this stage, the early warning signals will be identified. These signals indicate that a scenario is beginning to unfold. These signals help SIG to monitor the uncertainties and identify the opportunities to implement the strategy earlier than the competitors, as described in Table 8.

Table 8. Early Warning Signals for Each Scenario (Source: Author's Analysis)

Driving Factors	Indicators	Scenario Innovation Leader	Scenario Cost Effective	Scenario Policy-Driven	Scenario Stagnation
Regulatory and policy	Indonesia National Energy Policy	Unsupportive policy, as the government revised its renewable energy achievement target from 23% in 2025 to 19–21% by 2030.	SIG needs to implement cost-effective technology to meet the high demand for sustainable products while maintaining a limited commitment within the policy framework.	Incremental adoption of technology to comply with the 2030 energy policy.	Limited support to develop new technology for decarbonization.
	Carbon Tax and Trading	The implementation of a carbon tax, planned for 2025 or later, and carbon trading/offset in 2023, may trigger the advancement of technologies such as carbon capture, utilization, and storage (CCUS) and hydrogen.	The implementation of a carbon tax planned for 2025 or later will benefit the adoption of RDF by reducing the carbon tax payable.	SIG must comply with the implementation of a carbon tax planned for 2025 or later; thus, incremental adoption of technology needs to be in place to avoid penalties from the tax.	Payment of carbon tax may be considered rather than developing new technologies, which require a high capital cost.
	Government Incentives	The current regulatory framework has yet to effectively incentivize overseas partners to invest in carbon capture, utilization, and storage (CCUS) and hydrogen.	Presidential Regulation No. 35/2018 on the Acceleration of Waste-to-Energy Projects will benefit the utilization of RDF and Waste Heat Recovery in the cement production sector. Government Regulation No. 78/2019 provides incentives, including a corporate income tax reduction for sustainable projects, as well as exemption from import duty and Value Added Tax (VAT) borne by the Government for sustainable projects, such as RDF and Waste Heat Recovery projects.	The process of applying for tax incentives requires numerous supporting documents, including feasibility study reports, environmental certifications, and technical audits. Additionally, some regions have regulations that complicate the utilization of incentives resulting from policy implementation.	Incentives for the Domestic Market Obligation (DMO) policy, at $70 per ton for the National Electric Company and $90 for the industry, may hinder the green transition in the cement industry.

Driving Factors	Indicators	Scenario Innovation Leader	Scenario Cost Effective	Scenario Policy-Driven	Scenario Stagnation
			Furthermore, the application of these incentives needs to be optimized since there is no clear specific regulation to implement this incentive broadly.		
Technology adoption	Technology feasibility & readiness	CCUS and Hydrogen technology are at the development stage	The cement industry considers RDF and waste heat recovery to be mature for application.	Limited adoption of technology is due to the choice of technology being based on the incentive from the government.	Conventional technology in cement production primarily focuses on coal.
	Access to raw materials for new technology	High initial costs for electrolyzers as a raw material for hydrogen.	Municipal waste for RDF is cheaper than coal.	The renewable energy provider in the operating lease agreement provides the raw materials.	Limited technology adoption
	Marginal Abatement Cost (MAC)	Highest MAC	Lower or negative MAC	Moderate MAC	Limited technology adoption
	Potential Financing	Blended financing models combining a government grant and a private sector instrument	Global financial institutions, such as the Asian Development Bank, the World Bank, or the Danish Energy Agency, to finance RDF. Sustainability link loan Expansion into the waste management business, particularly through RDF production, presents a strategic opportunity not only to support decarbonization goals but also to generate additional revenue streams for SIG in the future.	Utilize carbon markets and green bonds, and partner with solar leasing firms in Indonesia.	Investment in the coal phase-out activity, both locally and internationally.

Business Solutions

To navigate those scenarios, SIG requires adaptive business solutions based on analysis from four key scenarios, implications & options, and early warning signals that align with policy and regulatory frameworks and technological advancements. The detailed business solutions are described as follows:

What are the key factors and driving forces for scenario planning for decarbonization in SIG?

Based on analysis from the exploration stage in scenario planning, nine driving forces have been identified as driving forces for scenario planning:

1. Government regulations and policies on energy transition and carbon emissions.
2. National and Global political stability
3. Market demand for low-carbon cement products
4. Coal prices
5. Financing & access to green investment
6. Awareness of green cement products
7. Technological advancement
8. Waste management
9. Climate Change

What is the most feasible and viable scenario planning for the decarbonization strategy to achieve the carbon reduction target and promote business sustainability?

To achieve the decarbonization target while maintaining or increasing competitiveness in 2030, SIG requires adaptive business solutions that align with the regulatory framework and technological adoption. Based on early warning signs, including the government's policy to delay the implementation of a carbon tax, initially scheduled for 2022, the decision to lower the renewable energy achievement target from 23% in 2025 to 19–21% by 2030, and limited incentives for decarbonization in the cement industry, indicate an unsupportive policy and regulatory environment for decarbonization in the cement industry.

In terms of technological advancement, SIG needs to consider lower or negative Marginal Abatement Cost (MAC) technologies to remain competitive and maintain its leadership in the Indonesian market. The use of alternative fuels, such as RDF, with lower MAC technologies can be the best solution for competitiveness in the intense market with a low-margin type of industry. Based on these perspectives, implementing a cost-effective scenario by utilizing RDF is considered the most feasible scenario for decarbonization in the short- to mid-term strategy.

What is the implementation plan for this scenario?

PT Solusi Bangun Indonesia (SBI), a subsidiary of PT Semen Indonesia, has been involved in the development of a Refuse Derived Fuel (RDF) facility in Indonesia. The first trial was conducted at the SBI Narogong Plant in 2016, serving as the basis for the RDF facility design at the Cilacap plant. In cooperation with the Central Java Province Government, Cilacap Regency, the Ministry of Environment and Forestry, the Ministry of Public Works, and the Government of Denmark, SBI, as the pioneer of the first RDF facility in Indonesia, officially commenced operations in 2020. The potential for implementing the RDF facility at other plants is considerable, as shown in Figure 9.

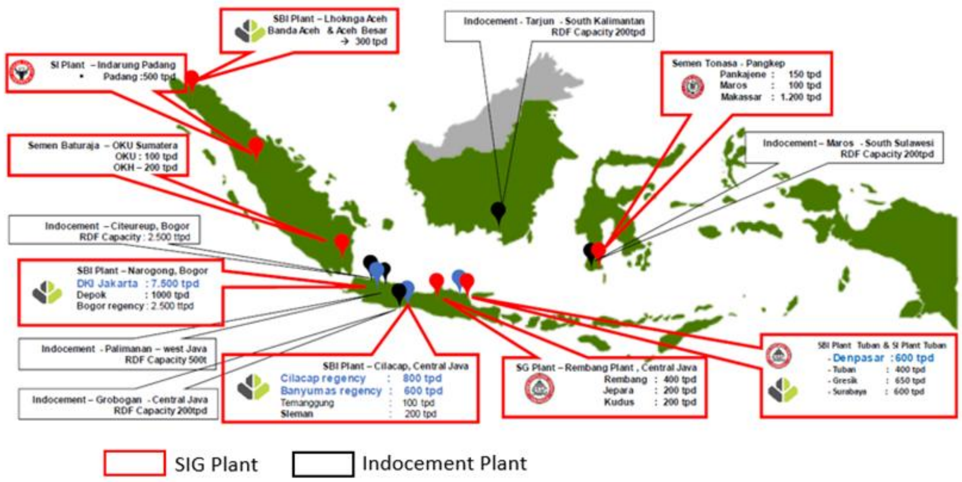

Figure 9. Map of potential future development of RDF (Source: Lilik Raharjo, 2024)

The success story in the Cilacap plant can be replicated in other plants operated by SIG. The replication itself consists of four phases to assess technical, environmental, and financial aspects.

Discussion

This study enriches the existing literature by providing a strategic tool in a more practical business context, bridging the gap between technical feasibility and strategic application in a rapidly changing environment. The findings in this study align with the Marginal Abatement Cost (MAC) literature, which promotes negative or lower MAC technology options as the most feasible alternatives for decarbonizing the cement industry or heavy industry in the short to mid-term period.

CONCLUSION

This study addressed the challenge of balancing sustainability targets in 2030 and competitiveness in PT Semen Indonesia (Persero) Tbk (SIG) by formulating a strategy for decarbonization using a scenario planning approach. The SIG decarbonization target is to reduce CO2 emission intensity from internal processes by 27% between 2010 and 2030. Through a comprehensive analysis, both internal and external factors were examined using PESTLE, SWOT analysis, and the Scenario Planning Framework. It was identified that the cement industry in Indonesia faces several challenges, such as market oversupply, increasing operational costs, and intense market competition with low profit margins. However, there are also several opportunities driven by ESG-focused market trends, government infrastructure projects, and technology advancements in low-carbon cement production.

The driving forces are further investigated in terms of the uncertainties and impact on the key focal issues. The most significant driving force that has an impact and introduces uncertainties to the key focal issue is government regulation and policies related to decarbonization in the cement industry. Based on the results of the interview, combining internal and external analysis, the scenario development for this study involves combining the two highest impact and uncertainties, resulting in four scenarios: Innovation Leader, Cost Effective, Policy-Driven, and Stagnation. Based on early warning signals analysis for each scenario, the implementation of a cost-effective scenario by utilizing RDF is considered the most feasible scenario for decarbonization in the short-term to mid-term strategy.

Managerial Implication

Based on the findings, it is recommended that SIG prioritize the following actions:

1. Accelerate RDF adoption: Expand RDF facilities across operational sites by collaborating with local governments and waste management companies to secure sustainable RDF supply, thereby increasing the Thermal Substitution Rate (TSR) and reducing dependency on coal.
2. Enhance operational efficiency: Continue upgrading production processes to maximize energy efficiency and reduce clinker factors, aligning with international best practices to lower carbon emissions.
3. Enhanced the marketing strategies for low-carbon cement (PCC) to increase awareness of the green cement product in both local and export markets.
4. Integrate ESG metrics into core strategy: ESG reporting and target achievements must be integrated into the business units' Key Performance Indicators (KPIs) to enhance investor confidence, foster stakeholder engagement, and ensure regulatory compliance.
5. Proactively prepare for carbon market readiness: develop internal capabilities for carbon trading and carbon tax management by establishing a task force in SIG to monitor developments and design corporate carbon strategies.
6. Partnership with international institutions that can leverage and support the adoption of green technologies, such as the World Bank, International Finance Corporation (IFC), and Asian Development Bank (ADB). These institutions may reduce the investment risk and subsidize the green premium by lowering the cost of capital for green projects.

Additionally, in the more unpredictable, uncertain, and rapidly changing decarbonization environment, scenario planning offers significant strategic value for SIG's leadership to anticipate multiple feasible futures, develop flexible and resilient strategies, enhance risk management, and align internal stakeholders by providing a structured, collaborative process for evaluating risks and opportunities.

Government support is essential in achieving the decarbonization target in the cement industry and heavy industries. This study proposes several policies based on its findings, including providing incentives and implementing fiscal and non-fiscal policies that support decarbonization in industry. These policies could include tax incentives for adopting green technology, which is currently a gray area, and setting emission targets for each sector. The implementation of carbon tax and carbon trading frameworks with a clear, gradual roadmap that aligns with sector readiness is also becoming a key factor. Furthermore, waste management regulations, such as waste sorting regulations and landfill tipping fees, need to be strengthened to support decarbonization efforts.

Limitation and Future Research

Even though this study provides a strategic framework for decarbonization in the Indonesian Cement Industry through scenario planning, several areas remain open for further investigation to strengthen the analysis. A quantitative assessment of technology adoption for each scenario, such as RDF development, could be developed based on the region and location of the plants or facilities to provide a detailed and accurate calculation.

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