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MODEL OF GREEN LOGISTICS IN THE INDUSTRIAL PROCESS AND PRODUCT USE (IPPU) IN THE CEMENT INDUSTRY TO REDUCE CARBON DIOXIDE EMISSIONS

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Abstract: In the current development of globalization, one of the industrial sectors that continues to grow every year is the cement industry because cement is the main material in the construction process. Research institutions state that cement contributes around 8% of the world's carbon dioxide (CO2) emissions and the largest comes from industrial processes and product use (IPPU) so that the concept of environmentally friendly logistics can be implemented to reduce CO2 emissions. This study uses the Dynamic System method. The results of the study show that the use of alternative raw materials and alternative fuels can reduce CO2 emissions generated from the cement production process. This is evidenced by the results of the first scenario, namely Business as Usual, which is 334.90 KgCO2, then decreased by 38.2% or to 207.02 KgCO2 in the second scenario, namely the use of alternative raw materials, and in the third scenario, namely the use of alternative fuels, it also decreased by 68.9% or to 100.88 KgCO2.

Keywords: *Cement Industry, Carbon Dioxide Emissions, Emission Mitigation, System Dynamics, Environmental Social Governance*

1. Introduction

In the current development of globalization, industry is one of the factors that has a wide-ranging impact on a country. Law Number 3 of 2014 on Industry is one of the government's efforts to regulate and facilitate the development of industry in Indonesia. One of the industrial sectors that continues to grow every year is the cement industry. This is happening alongside population growth, which leads to an increase in infrastructure in Indonesia, as cement is a primary material in the construction process (Chamsudi et al., 2021; Chamsudi, Suryobuwono, et al., 2022). The population growth each year continues to increase, which will affect the amount of cement production since cement is a primary material in infrastructure development.

The amount of cement production from 2015 to 2023 can be seen in the Table 1.

Table 1

Cement Production

Year	Cement production volume (million tons)
2015	59.1
2016	65.0
2017	69.1
2018	72.2
2019	73.9
2020	71.3
2021	73.0
2022	69.6
2023	68.2

Based on the data, the production of cement tends to increase every year, although there was a decline in cement production in 2023. With the development of the industrial sector, industry players must be wise about the impacts that will arise from the industrial activities themselves. The Chatham House Research Institute stated that cement is a source of CO2 emissions accounting for about 8% globally. Carbon dioxide emissions are partly caused by industrial processes and the use of products (IPPU). As a response to this issue, the concept of environmentally friendly logistics or green logistics can be implemented to reduce carbon dioxide emissions. In addition, the government, as the regulatory body, has established regulations regarding guidelines for CO2 emission reduction for the cement industry in Indonesia. The Minister of Industry Regulation Number 12 of 2012 concerning the CO2 Emission Reduction Guideline Map for the Cement Industry in Indonesia is a national planning document that outlines the targets, strategies, policies, and action plan programs aimed at reducing CO2 emissions from the cement industry in Indonesia over a period of 10 years. In the last 5 years since the implementation of this regulation, the mandatory specific CO2 emission reduction is 3% of what is produced per ton of cement.

In this research, the focus is on the use of alternative raw materials and alternative fuels in the cement production process. The use of alternative raw materials includes fly ash and bottom ash, which are waste products from coal combustion in the cement production process. For alternative fuel, Refuse Derived Fuel (RDF) is used. RDF is the result of processed waste that has been reprocessed into small granules, commonly referred to as waste chips. The implementation of environmentally friendly logistics is essential for a sustainable global future. As awareness of sustainable business practices increases, the principles of Environmental, Social, and Governance (ESG) are being increasingly adopted by companies worldwide. The ESG principles encourage companies to pay attention to environmental and social aspects, as well as good governance standards, in order to foster innovation and competitiveness while also mitigating risks that may arise in the future (Radyati et al., 2023).

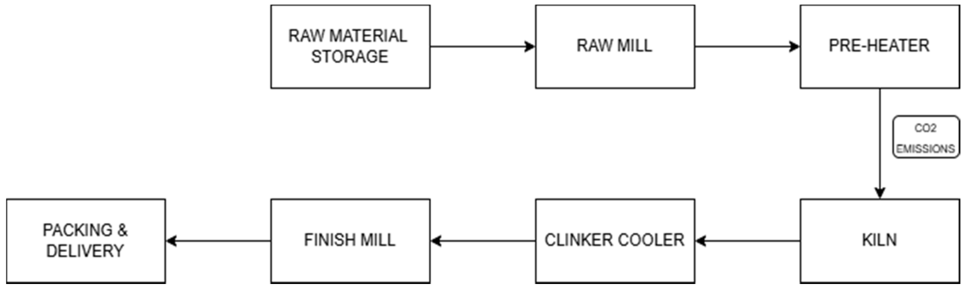

Fig. 1. Cement Production Process

In the cement processing (see Fig. 1), it begins with the storage of raw materials, specifically limestone, which then enters the raw mill stage, where the drying and grinding of the raw materials take place. Next, the raw materials proceed to the first heating process, commonly referred to as the pre-heater process. In this stage, the limestone is heated to separate the gas from the material itself (Aurellia & Safaruddin, 2021). The purpose of preheating is to reduce the high temperature difference in order to minimize the amount of energy used. After that, the semi-finished raw materials undergo a complete combustion process known as calcination or clinkering at a temperature of 1450°C in a rotating device called a rrotary kiln. After the combustion, the clinker is then cooled to a temperature of 100-200°C. Next, the clinker enters the finish mill stage, which involves grinding the clinker with a few percent of other mixed materials. The final stage of cement production is the packaging of the cement product. The cement products to be shipped can be in bulk or in bags.

In the cement industry, direct carbon dioxide emissions are generated from the following sources:

- Calcination or the burning process of raw materials
- Combustion of conventional and alternative fossil fuels
- Burning of fuel at power generation facilities

Thus, the research problem is “how to reduce carbon dioxide emissions in the cement production process?”.

2. Literature review

Green logistics is simply the way to minimize environmental impact and carbon footprint from logistics activities, such as production, storage, packaging, and delivery, as a sustainability solution involving various logistics stakeholders so that logistics resources can be utilized to the fullest (Lai & Wong, 2012; Seroka-Stolka, 2014; Zhang et al., 2020).

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According to the Law of the Republic of Indonesia Number 3 of 2014 concerning Industry. Industry encompasses all forms of economic activities that process raw materials and/or utilize industrial resources to produce goods that have added value or greater benefits, including industrial services. The term "cement" itself comes from the Latin word "caementum," which means adhesive material. Cement is an industrial product made from a mixture of raw materials, primarily limestone and clay, with the final result being a solid in the form of powder or bulk, regardless of the manufacturing process that will harden when mixed with water.

According to the World Bank, carbon dioxide emissions result from the burning of fossil fuels. This includes carbon dioxide produced during the consumption of solid, liquid, and gas fuels. Carbon dioxide (CO_2) emissions are one type of greenhouse gas emissions that contribute to global warming. A significant amount of carbon emissions is generated from manufacturing processes, transportation, and heating to produce electricity for the production of goods or services consumed (Aldersa et al., 2021).

3. Research method

The research method is using dynamic systems methodology. The method is used to analyze and understand the interrelated factors within a system (Chamsudi, Rahardjo, et al., 2022; Ferdiansyah et al., 2018). The focus of using dynamic system methods is to measure how each part of the system influences each other and changes over time. Before creating the dynamic system model, a causal loop diagram will be made to determine the variables that are interconnected with one another. The preparation of a cause-and-effect diagram based on the variables that have been collected by the author through literature studies that refer to Junianto et al. (2023). The cause-and-effect model diagram is a framework for thinking and can reveal the patterns of relationships that are formed. In the causal loop diagram, symbol B represents balancing or a balancing loop. Symbol B means that the connected variable will balance the other variable when a change occurs.

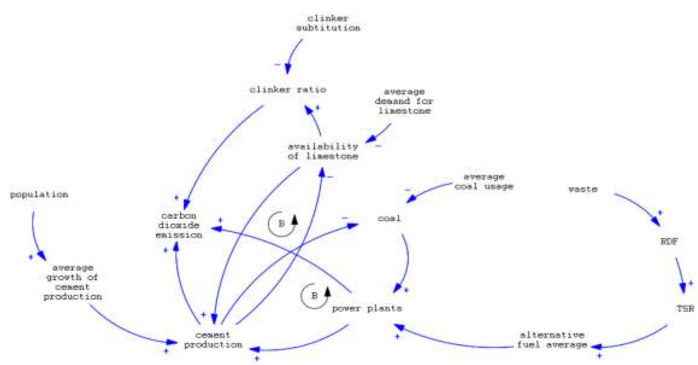

Fig. 2. Causal Loop Diagram

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4. Results and discussion

After conducting a variable analysis with a cause-and-effect diagram, a scenario has been developed to determine the dynamic system model. The first scenario is Business as Usual (1). The BAU scenario represents a condition of normal activities or actions without considering specific circumstances, especially in unusual situations that may have negative impacts. By applying the BAU condition, a comparison can be made between the policies currently in place and the policy scenario that will be created as a solution to the existing problems. Under business as usual (BAU) conditions, there are no efforts to reduce CO2 emissions in the cement production process. The second scenario involves the use of alternative raw materials in the cement production process. The application of alternative raw materials represents a mitigation scenario aimed at reducing carbon dioxide emissions in the cement industry. Solid waste from other industrial sectors, such as fly ash and bottom ash from coal combustion, can be used as alternative raw materials in cement production. The use of alternative raw materials as primary raw materials can affect the amount of limestone that will be used in cement production. Limestone that undergoes a burning process as the main raw material for cement production is called clinker. The amount of clinker used in cement production will influence the amount of CO2 emissions released during the limestone burning process.

The third scenario is the use of alternative fuels in the cement production process. (3). An alternative fuel that can be used for cement production is RDF or Refuse Derived Fuel. RDF is the result of processing waste that has been reprocessed into small granules, commonly referred to as waste chips. RDF can replace about 5-6% of the coal requirements in the cement production process. The Thermal Substitution Rate, or TSR, is the percentage of fuel needs that is substituted with alternative fuels in the cement production process. In the cement production process, coal is used as the main raw material in the kiln. The burning of fossil fuels will produce CO2 emissions. Therefore, these fossil fuels can be replaced with alternative fuels to reduce the CO2 emissions released during the cement production process.

Here is the stock flow diagram model based on the cause-and-effect diagram that has been created, along with the three scenarios that have been explained.

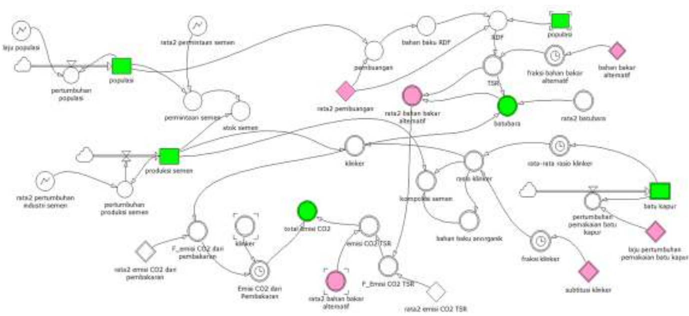

Fig. 3. Stock Flow Diagram

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Based on the stock flow diagram, the simulation results are presented in the following graph:

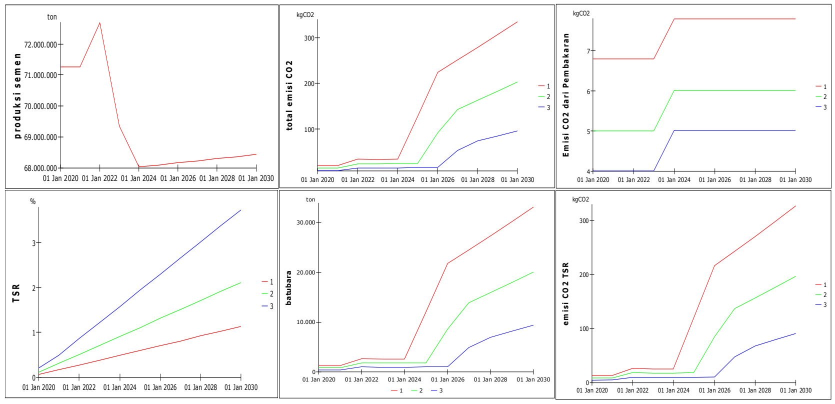

Fig. 4. Simulation result's of the use of alternative raw materials and fuels

The cement production graph in the top left shows that the growth in cement production has steadily increased each year from 2025 to 2030, despite a decline in production in 2024. In the graph, the Business as Usual scenario is marked with a red line (1), the alternative raw material usage scenario is marked with a green line (2), and the alternative fuel usage scenario is marked with a blue color. (3). The results show that the amount of CO2 emissions released each year has steadily decreased due to efforts to use alternative raw materials and alternative fuels in the cement production process. Furthermore, based on the results of the stock flow diagram simulation, it was found that the use of alternative raw materials in the cement production process can reduce the CO2 emissions generated from clinker combustion. The amount of CO2 emissions produced from the combustion of limestone into clinker with the use of alternative raw materials is lower than that from combustion without using alternative raw materials. This is evidenced by the simulation results, where under Business as Usual conditions, the CO2 emissions amount to 7.79 KgCO2, which then decreases to 6.01 KgCO2 in the scenario of using alternative raw materials. Meanwhile, in the use of alternative fuels, in the year 2030 under Business as Usual conditions, the CO2 emissions from TSR are 327.11 KgCO2, which then decreases in the third scenario to 95.87 KgCO2.

It can be seen in the graph of total CO2 emissions released from the cement production process in the second image at the top. The second and third line graphs show a trend of decreasing total CO2 emissions compared to the first scenario. Here is the total amount of CO2 emissions generated from the stock flow diagram simulation with the Business as Usual scenario, the alternative raw material usage scenario, and the alternative fuel usage scenario.

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Table 2
Simulation results of total CO2 emissions

Time	total emisi CO2 (kgCO2)
01 Jan 2020	{19,59; 13,75; 8,68}
01 Jan 2021	{19,73; 13,90; 8,80}
01 Jan 2022	{33,63; 23,58; 14,16}
01 Jan 2023	{32,67; 23,02; 13,93}
01 Jan 2024	{33,46; 23,98; 14,97}
01 Jan 2025	{127,80; 24,30; 15,23}
01 Jan 2026	{224,40; 92,12; 15,48}
01 Jan 2027	{251,10; 145,16; 54,88}
01 Jan 2028	{278,40; 165,11; 76,19}
01 Jan 2029	{306,33; 185,72; 88,26}
01 Jan 2030	{334,90; 207,02; 100,88}

The table shows that in 2030, the use of alternative raw materials and alternative fuels will reduce CO2 emissions generated from the cement production process, decreasing from 334.90 KgCO2 in the first scenario to 207.02 KgCO2, and in the third scenario, it will further decrease to 100.88 KgCO2. The results of the simulation represent an effort made in mitigating carbon dioxide emissions in the cement industry and can be achieved by 2030 through the management of raw materials and fuels in the cement production process. Based on these research findings, the implementation of environmentally friendly logistics, such as the use of alternative raw materials and fuels in the cement production process, will impact the principles of Environmental, Social, and Governance (ESG). In terms of environmental principles, by using alternative raw materials, the cement industry can utilize waste from other industries, thereby reducing environmental pollution. Alternative fuels used also play a role in preserving the availability of natural resources. The principle of social responsibility will be reflected in the cement industry when the application of environmental principles is carried out to the fullest. This proves that the cement industry cares about the negative environmental impacts that will affect the community. The principles of governance are also influenced by environmental and social principles. Good governance is a form of corporate accountability that enables sustainable business practices by producing innovative products and services that add value to environmental and social aspects.

5. Conclusion

The problem in the cement industry lies in the high CO2 emissions produced during the cement manufacturing process. In reducing CO2 emissions, this is achieved through the management of raw materials and fuels used in cement production. The research was conducted using dynamic system methods to understand the variables in the system that influence each other. The variables used to determine the total amount of CO2 emissions released during cement production are the amount of cement produced, TSR, the amount of coal used, the CO2 emissions generated from the combustion of limestone, and the CO2 emissions produced from the use of TSR through alternative fuels. The results of the simulation were obtained, where in the first scenario, Business as Usual, it amounted to 334.90 KgCO2, then decreased by 38.2% or 207.02 KgCO2 in the second scenario with the use of alternative raw materials, and in the third scenario, the use of alternative fuels also decreased by 68.9% or 100.88 KgCO2.

In this study, the technology used in the cement production process has not been taken into account, so this aspect can be considered in future research. In addition, the government is currently designing a roadmap for industrial decarbonization, which is the process of reducing carbon dioxide emissions produced by the industrial sector, so this can also be taken into consideration for future research.

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