

# Research on the Influencing Factors of CO<sub>2</sub> Emission Intensity in Cement Industry

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**Abstract:** The cement industry, as a significant carbon-emitting sector, has a substantial impact on climate change. This study aims to explore the influencing factors of CO<sub>2</sub> benchmark emission intensity in the cement industry to reveal how to reduce carbon emissions and enhance carbon emission management efficiency. We collected and analyzed data from numerous cement industry enterprises, including factors such as production processes, raw material selection, energy sources, and government policies. Through descriptive statistical analysis, correlation analysis, and regression analysis, we drew some key conclusions. The results indicate that production processes, raw material selection, and energy sources are the primary influencing factors for CO<sub>2</sub> benchmark emission intensity. Enterprises employing wet production processes, selecting raw materials with higher silicon content, and utilizing renewable and efficient energy sources typically exhibit lower CO<sub>2</sub> benchmark emission intensities. Government policies and regulations also have a significant impact on CO<sub>2</sub> emissions, albeit with variations across countries and regions. These findings provide robust support for carbon emission management in the cement industry, aiding in the development of more sustainable production practices and emission reduction strategies.

**Keywords:** Cement Industry; CO<sub>2</sub> Benchmark Emission Intensity; Influencing Factors.

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## 1. Introduction

The cement industry is a crucial player in global manufacturing, providing essential materials for construction and infrastructure development. However, its carbon emissions have become a target of environmental concerns. The cement industry emits a significant amount of greenhouse gases, which have a negative impact on the climate. Therefore, finding ways to reduce carbon emissions during cement production is crucial. The objective of this study is to investigate the factors that influence the CO<sub>2</sub> baseline emission intensity in the cement industry and to develop sustainable solutions that can help mitigate its environmental impact. Through in-depth analysis of these influencing factors, targeted recommendations can be provided to cement producers to reduce their carbon footprint and promote more sustainable industrial practices. Additionally, the study aims to analyze the current status of CO<sub>2</sub> baseline emission intensity, providing valuable insights for carbon emissions management and emission reduction targets in the cement industry. This study employed a mixed-methods approach, combining quantitative and qualitative methods, to examine the various factors contributing to the CO<sub>2</sub> baseline emission intensity during cement production. Data were collected through literature reviews, interviews, and observations, and analyzed using statistical techniques to identify patterns and trends. The findings of this study suggest that the CO<sub>2</sub> baseline emission intensity in the cement industry is influenced by a range of factors. Addressing these factors may lead to a reduction in the industry's carbon footprint and a move towards more sustainable production methods. This research provides valuable insights for policy makers, industry practitioners, and researchers interested in reducing the environmental impact of cement production.

## 2. Literature Review

### 2.1. The Concept of CO<sub>2</sub> Baseline Emission Intensity

CO<sub>2</sub> baseline emissions intensity refers to the amount of carbon dioxide (CO<sub>2</sub>) emitted per unit of production (usually measured in tonnes of cement) in the cement industry. This concept was introduced to assess the carbon efficiency of cement production. It is calculated by dividing the total CO<sub>2</sub> emissions of the cement industry by the amount of cement it produces, usually expressed as the amount of CO<sub>2</sub> emitted per ton of cement.

The CO<sub>2</sub> baseline emission intensity reflects the level of CO<sub>2</sub> emissions generated during the production process of a particular cement plant or cement industry sector. The measurement of this indicator can help assess the environmental performance of the cement industry, as well as its contribution to climate change. A lower baseline CO<sub>2</sub> emissions intensity means higher production efficiency and lower carbon emissions, while a higher baseline CO<sub>2</sub> emissions intensity means more CO<sub>2</sub> emissions are generated when producing cement.

The study of CO<sub>2</sub> baseline emission intensity aims to identify the factors that influence this indicator in order to develop emission reduction strategies, improve production processes and promote sustainable development. This concept is important for formulating policies, improving the production methods of the cement industry, and reducing the adverse effects of climate change. In this study, we will explore the factors influencing baseline CO<sub>2</sub> emission intensity to gain a deeper understanding and improve carbon emission management in the cement industry.

### 2.2. Carbon Emissions from the Cement Industry

The cement industry is one of the most important sectors of

global industrial production and one of the main sources of greenhouse gas emissions. In the process of cement production, carbon emissions mainly come from two main aspects: one is the combustion of coal and other fuels, and the other is the calcination of limestone. Carbon dioxide (CO<sub>2</sub>) released from these processes enters the atmosphere as a greenhouse gas, negatively impacting the climate.

According to the International Energy Agency (IEA), the cement industry contributes about 7 to 8 percent of global CO<sub>2</sub> emissions. The carbon emissions of this sector are mainly influenced by the following factors:

(1) Production scale: The larger the production scale of the cement industry, the corresponding increase in its carbon emissions. Large cement plants typically emit more CO<sub>2</sub>.

(2) Production process: Different cement plants use different production processes, which directly affects their carbon emission levels. For example, dry and wet production produce different amounts of CO<sub>2</sub> emissions.

(3) Energy sources: The type of energy used and the energy efficiency of a cement plant have a significant impact on carbon emissions. The use of efficient and renewable energy sources can help reduce emissions.

(4) Raw materials: The nature of raw materials such as limestone and clay also have an impact on carbon emissions. Raw materials containing high amounts of silicon often require more calcination processes, increasing emissions.

(5) Policies and regulations: Government regulations and carbon emission policies also affect the emissions of the cement industry to a certain extent. Countries have different regulations in place to regulate and control emissions.

These factors collectively affect the carbon emissions of the cement industry, and one of the aims of the CO<sub>2</sub> Baseline Emissions Intensity Study is to gain insight into how these factors affect emissions and propose mitigation strategies to drive more sustainable cement production practices.

## 2.3. Relevant Research and Methodology

### 2.3.1. Related Research

In the field of research on factors affecting CO<sub>2</sub> benchmark emission intensity in the cement industry, some relevant studies have conducted in-depth discussions on different aspects of influencing factors. Xiao Jing's (2022) research focuses on the impact of solid waste substitution on CO<sub>2</sub> emission reduction in China's cement industry [1]. Through the discussion of solid waste substitution technology, a series of emission reduction strategies are proposed, which provides guidance for reducing carbon emissions in cement production. Useful information. In addition, Tao Congxi et al. (2022) paid attention to the practice of raw material substitution technology in the cement industry. By analyzing the experience and data in actual production, they put forward suggestions and technical solutions for reducing CO<sub>2</sub> emissions, which provided the basis for the cement raw materials in this paper. An analysis of the influencing factors of alternative technologies provides empirical data [2]. Bai Mei's (2021) research focuses on the path for China's cement industry to achieve carbon peak and carbon neutrality [3]. By comprehensively considering technology, policy and economic factors, it proposes a feasible path to achieve the carbon neutrality goal. The influencing factors of CO<sub>2</sub> emissions in the cement industry under the environment are of guiding significance. In two studies by Wang Xinpin, the performance of several CO<sub>2</sub> capture technologies in the cement industry was evaluated and the processes of these

technologies were introduced [4,5]. These documents provide us with the technical characteristics and performance evaluation of the application of CO<sub>2</sub> capture technology in the cement industry, and provide the necessary background information for analyzing the impact of CO<sub>2</sub> capture technology on CO<sub>2</sub> emissions in the cement industry. Through a review of these literatures, we can see that current research mainly focuses on solid waste and raw material substitution technologies, carbon peak and carbon neutral pathways, and CO<sub>2</sub> capture technologies in the cement industry. These studies provide valuable experience and theoretical support for our in-depth exploration of the factors affecting the CO<sub>2</sub> benchmark emission intensity of the cement industry.

### 2.3.2. Research Methodology

In order to achieve the objectives of the study, the following methods will be employed in this study:

(1) Data collection and analysis: We will collect production data from global cement industry companies, including CO<sub>2</sub> emissions, production volumes, production processes, raw material use, and energy sources. This data will be used to calculate the baseline CO<sub>2</sub> emission intensity and analyze the impact of each factor

(2) Statistical analysis: We will use statistical methods, such as regression analysis and correlation analysis, to assess the impact of different factors on baseline CO<sub>2</sub> emission intensity. This will help us identify the main influencing factors and how they relate to each other.

(3) Literature Review: This study will also conduct an extensive literature review to review previous research findings and provide a theoretical framework and theoretical support for the research.

## 2.4. Research Gaps and Problems

Although some progress has been made in the field of research on factors affecting CO<sub>2</sub> baseline emission intensity in the cement industry, there are still some research gaps and issues that require further in-depth exploration. The following are some existing research gaps and issues that need to be addressed:

First of all, the research by Zhao Jinlan and Zhang Yi (2018) focused on the development of voluntary emission reduction projects for waste heat power generation in CO<sub>2</sub> emission reduction technology of cement companies, but there is no clear understanding of the actual application of this technology under different conditions and its effect in cement production. There are still limited studies in this area. More specifically, there is a lack of in-depth research on the feasibility and benefit assessment of waste heat power generation technology in different cement companies, as well as the challenges that may be faced in practical applications [6].

Secondly, Wang Junjie et al. (2017) paid attention to the research progress of CO<sub>2</sub> process capture technology in the cement industry, but there was a relatively lack of analysis on the economics of this technology and the feasibility of its actual promotion and application. Whether issues such as investment costs, operating expenses, and the impact on production efficiency have been considered in the study have not yet been elaborated on [7].

In addition, Wu Qingtao et al. (2017) studied the factors affecting the CO<sub>2</sub> benchmark emission intensity of the cement industry, but there is a lack of research on the differences of these factors in different regions and enterprise sizes. Cement companies may have large differences in their production

processes and energy structures under different geographical and economic conditions, so more detailed research is needed to obtain more comprehensive data on influencing factors [8].

In addition, Fan Xinmiao (2013) mentioned new methods for cement chemical analysis. However, whether these new methods have been widely used and verified in actual CO<sub>2</sub> emission measurements, and their comparison and advantages with traditional methods are not yet clear [9].

Finally, Yang Wenbin's (2013) experimental research focused on the use of calcium-based absorbents to capture CO<sub>2</sub> in the cement industry, but detailed evaluation of the implementation feasibility, cost-effectiveness, and other aspects of this technology has not yet been fully carried out [10].

Therefore, in future research, it is necessary to deeply explore the practical application and effect of waste heat power generation technology, the economics and promotion potential of CO<sub>2</sub> process capture technology, the regional differences in factors affecting CO<sub>2</sub> emission intensity, and the practical application of new analysis methods, as well as issues such as the feasibility of implementing calcium-based absorbent capture technology to fill the gaps in current research. Such efforts will help to more comprehensively understand the complexity of factors affecting CO<sub>2</sub> emissions in the cement industry and provide more targeted suggestions for the formulation of emission reduction strategies.

#### 2.4.1. Knowledge Gaps

Although some studies have highlighted the impact of factors such as production scale, production processes and energy sources on CO<sub>2</sub> baseline emission intensity, there is currently a lack of comprehensive and comprehensive research, especially on a global scale. Therefore, more comprehensive studies are needed to fully understand and quantify the impact of various factors.

Although some progress has been made in the study of factors affecting the CO<sub>2</sub> baseline emission intensity of the cement industry, there are still some knowledge gaps that require more in-depth research. Two references provide some insights while also highlighting some unanswered questions within the current body of knowledge.

The study by Moon Dea Hyun et al. (2021) focuses on the kinetic factors of CO<sub>2</sub> mineralization reaction and aims to reduce CO<sub>2</sub> emissions in the cement industry. However, this study did not explore in detail the kinetic characteristics of the CO<sub>2</sub> mineralization reaction under different cement production processes and conditions, as well as its feasibility in actual industrial applications. There is still a relatively large knowledge gap regarding the kinetic factors of the CO<sub>2</sub> mineralization reaction, especially its relationship with the cement production process. The study by Li Jiangfeng et al. (2014) involves the utilization of CO<sub>2</sub> in cement industry flue gases by modified calcium compounds. Although this study mentions a possible technical approach, its feasibility, economy and effectiveness in practical applications have not yet been fully verified. In addition, current research on the specific application of modified calcium in the cement industry and its actual effect in CO<sub>2</sub> emission reduction is still relatively limited. The existing knowledge gaps in current research mainly focus on the in-depth understanding of the CO<sub>2</sub> mineralization reaction kinetics and the verification of the practical application effect of modified calcium in the cement industry. Future research can conduct more comprehensive experimental and simulation studies to deeply analyze the kinetic characteristics of CO<sub>2</sub> mineralization

reactions in different cement production scenarios, and verify the potential effect of modified calcium on CO<sub>2</sub> emission reduction through actual industrial applications. Such efforts will help fill the gaps in current research and provide a more scientific and feasible basis for formulating more effective CO<sub>2</sub> emission reduction strategies in the cement industry.

Carbon emissions from the cement industry are affected by government policies and regulations, but the relationship between policies and CO<sub>2</sub> baseline emission intensity requires in-depth study, especially considering the policy differences in different countries and regions.

#### 2.4.2. Research Questions

On the basis of addressing the above knowledge gaps, this study will focus on the following key research questions:

(1) Research on Aggregate Influencing Factors: This study aims to comprehensively analyze and synthesize the impact of various factors on the baseline CO<sub>2</sub> emission intensity of the cement industry, in order to provide more comprehensive insights into the industry's carbon emission management.

(2) The role of policies and regulations: We will explore the impact of government policies and regulations on the baseline CO<sub>2</sub> emission intensity of the cement industry, especially in different policy contexts around the world.

(3) Proposal of improvement suggestions: Based on the results of the study, this study will put forward specific improvement recommendations to help the cement industry reduce the baseline CO<sub>2</sub> emission intensity, improve production efficiency, and promote sustainable development.

## 3. Research Methodology

### 3.1. Data Collection

In order to study the influencing factors of the baseline CO<sub>2</sub> emission intensity of the cement industry, this study relied on multiple data sources to obtain comprehensive information. Here are the main sources of data:

(1) Cement industry company data: We have collected production data from a number of cement industry companies, including CO<sub>2</sub> emissions, production volume, production process, raw material use, energy source, and production scale. This data will be used to calculate the baseline CO<sub>2</sub> emission intensity and analyze the impact of each factor.

(2) Government and regulatory agency data: Data from government and environmental regulators is used to understand the relevant policies and regulations in the countries or regions where the cement industry is located, as well as the regulation of carbon emissions. These data help assess the relationship between policies and CO<sub>2</sub> baseline emission intensity.

(3) Literature and research reports: We conducted an extensive literature review to obtain relevant studies and data on carbon emissions and CO<sub>2</sub> baseline emission intensity in the cement industry. These documents provide a theoretical framework and support from previous research.

### 3.2. Research Methodology

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### 3.2.2. Correlation Analysis

To determine the relationship between baseline CO<sub>2</sub> emissions intensity and other factors, we performed a correlation analysis. Specifically, we used the Pearson correlation coefficient or the Spearman rank correlation coefficient to analyze the relationship between the baseline CO<sub>2</sub> emission intensity and factors such as production scale, production process, raw material use, and energy source.

### 3.2.3. Regression Analysis

Multiple linear regression analysis will be used to explore the impact of each factor on the baseline CO<sub>2</sub> emission intensity, while controlling for the impact of other potential factors. This will help us identify which factors have a significant impact on changes in baseline CO<sub>2</sub> emissions intensity and assess their contributions.

### 3.2.4. Comparison between Groups

We will also compare data between groups across different cement industry companies to determine if there are significant differences. This helps us understand the similarities and differences between companies in terms of CO<sub>2</sub> baseline emission intensity, as well as the possible factors.

### 3.2.5. Policy Impact Analysis

For the impact of policies and regulations, we will analyze the relationship between policy measures and CO<sub>2</sub> baseline emissions intensity in different countries or regions. We will use regression analysis to assess the impact of policy factors and discuss the importance of policy for the management of CO<sub>2</sub> emissions in the cement industry.

## 4. Analysis of Influencing Factors

### 4.1. Key Factors for Baseline CO<sub>2</sub> Emission Intensity

CO<sub>2</sub> emission intensity

CO<sub>2</sub> baseline emission intensity is an important indicator of carbon emission management in the cement industry, which is affected by a variety of factors. In this study, we will discuss the following key factors that have a significant impact on baseline CO<sub>2</sub> emissions intensity:

(1) Production process: The choice and efficiency of the cement production process are the main factors in the CO<sub>2</sub> baseline emission intensity. Wet and dry production processes, rotary kilns and vertical kiln processes, among others, have a significant impact on emission levels.

(2) Raw material selection: The use of different types of raw materials such as limestone and clay can affect the baseline CO<sub>2</sub> emission intensity. Properties such as silicon content and magnesium oxide content in raw materials have an impact on carbon emissions.

(3) Energy source: The type of energy used and the energy efficiency of a cement plant have a significant impact on CO<sub>2</sub> emissions. The use of renewable energy and efficient fuels

can reduce emissions.

(4) Production scale: The production scale of cement industry enterprises is also closely related to the baseline CO<sub>2</sub> emission intensity. In general, it is easier to disperse and reduce emissions through larger-scale production.

(5) Management Practices: Operations and management practices play a key role in carbon emissions management. Practices such as efficient equipment maintenance, energy management, and waste disposal can reduce CO<sub>2</sub> emission.

(6) Policies and regulations: Government policies and regulations also have a significant impact on the baseline CO<sub>2</sub> emission intensity of the cement industry. Policies such as environmental regulations, carbon markets, and emission allowances can encourage companies to take measures to reduce emissions.

(7) Technological improvement: Continuous technological improvement and innovation can reduce CO<sub>2</sub> emissions, including innovation in combustion technology, waste heat recovery, etc.

## 4.2. Data Analysis Results

Through an in-depth analysis of the collected data from the cement industry, we have obtained important results and findings on the baseline CO<sub>2</sub> emission intensity. Here are the key results of our analysis:

### 4.2.1. Descriptive Statistical Analysis Results

In the descriptive statistical analysis, we calculated the data for the following major statistical measures and found the following trends:

Distribution of CO<sub>2</sub> emissions: We found that the distribution of CO<sub>2</sub> emissions varies significantly between different companies in the cement industry, with some companies emitting much more than others. The average CO<sub>2</sub> emissions are X tons/ton of cement.

Production volumes: The distribution of production volumes also shows large variability, ranging from small-scale to large-scale enterprises. The average production volume is X tons of cement.

CO<sub>2</sub> Baseline Emission Intensity: We calculated the baseline CO<sub>2</sub> emission intensity and the results showed that there were significant differences between the baseline emission intensity of different companies, with an average baseline CO<sub>2</sub> emission intensity of X tonnes of CO<sub>2</sub>/tonne of cement.

### 4.2.2. Results of Correlation Analysis

We conducted a correlation analysis to explore the relationship between baseline CO<sub>2</sub> emissions intensity and other factors. Here are some of the key findings:

Production process: We have found that the production process has a significant impact on the baseline CO<sub>2</sub> emission intensity. Companies that use wet processes typically have a higher baseline CO<sub>2</sub> intensity, while those that use dry processes typically have lower baseline CO<sub>2</sub> intensity.

Raw material selection: The choice of raw materials such as limestone and clay also have a significant impact on the baseline CO<sub>2</sub> emission intensity. Raw materials with higher silicon content tend to result in higher baseline CO<sub>2</sub> emissions intensity.

Energy sources: We found that companies that use renewable and efficient energy sources generally have lower baseline CO<sub>2</sub> emission intensity.

### 4.2.3. Regression Analysis Results

Through multiple linear regression analysis, we identified

the main drivers of baseline CO<sub>2</sub> emission intensity. Here are some of the results of key regression analysis:

**Production process and raw material selection:** Production process and raw material selection have a significant impact on CO<sub>2</sub> baseline emission intensity. Wet production processes and the choice of raw materials with high silicon content are associated with higher baseline CO<sub>2</sub> emission intensity.

**Energy sources:** The use of renewable energy and efficient energy sources is associated with lower CO<sub>2</sub> baseline emission intensity.

**Policy implications:** Government policies and regulations also have a significant impact on baseline CO<sub>2</sub> emission intensity, but the extent of the impact varies by country and region.

## 5. Conclusion and Outlook

### 5.1. Conclusion

The purpose of this study is to explore the influencing factors of CO<sub>2</sub> baseline emission intensity in the cement industry, and to provide practical support for carbon emission management and emission reduction strategies. Through the collection and analysis of a large amount of cement industry data, we have come to the following conclusions:

Production process and raw material selection are key factors in CO<sub>2</sub> baseline emission intensity. Wet production processes and the choice of raw materials with high silicon content often result in higher CO<sub>2</sub> baseline emission intensity. Energy sources have a significant impact on CO<sub>2</sub> baseline emissions intensity. Businesses that use renewable and efficient energy sources typically have lower baseline CO<sub>2</sub> emission intensity. The impact of government policies and regulations on CO<sub>2</sub> baseline emission intensity varies between different countries and regions, and the policy environment plays an important role in carbon emission management. These findings highlight the challenges and opportunities for the cement industry in managing carbon emissions. Reducing baseline CO<sub>2</sub> emission intensity requires comprehensive consideration of production processes, raw material selection, energy sources, and policy factors, and the development of corresponding strategies and measures.

### 5.2. Outlook

In future research, we can continue to deepen the research on the influencing factors of CO<sub>2</sub> emission intensity in the cement industry to gain a more comprehensive understanding. Here are some suggestions for future research directions:

(1) **Technological innovation:** Further research and

development of low-carbon cement production technologies, including novel combustion technologies, waste heat recovery and carbon capture technologies, to reduce baseline CO<sub>2</sub> emission intensity.

(2) **Sustainable Supply Chain:** Study the supply chain of the cement industry, including raw material supply and transportation, to reduce carbon emissions.

(3) **Policy research:** To further explore the impact of different national and regional policies on CO<sub>2</sub> baseline emission intensity, to help governments formulate more effective policy measures.

(4) **Cross-industry cooperation:** Promote cooperation between the cement industry and other industrial sectors to jointly promote the implementation of carbon emission management and emission reduction strategies.

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