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Study on Carbon Accounting and Emission Reduction Pathways of the Cement Industry in Liaoning Province

Feng Liu*,Zihan Zhao,Jingya Wang

University of Science and Technology Liaoning, 114051, Anshan, China

KEYWORDS

Carbon accounting;

Cement;

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ABSTRACT

The cement industry is a crucial basic raw material sector for national economic development, as well as a key area of energy consumption and carbon dioxide (CO_2) emissions. Taking the cement industry in Liaoning Province as the research object, this study systematically conducts research on carbon accounting and emission reduction pathways based on CO_2 emission data from fossil fuel combustion and production processes during 2000-2022. The accounting results indicate three key findings: the total industrial emissions present a three-stage characteristic of "fluctuating growth - peak - decline"; the emission structure has shifted from "combustion-dominated" to "balanced dual sources"; the emission reduction effect of combustion emissions is significant, while process emissions have become a bottleneck due to rigid constraints. Based on the accounting results, corresponding emission reduction policies are proposed. The research findings can provide data support and reference for the low-carbon transformation of the regional cement industry.

INTRODUCTION

Global climate change stands as one of the most pressing challenges confronting the world today. As the primary greenhouse gas, controlling carbon dioxide (CO_2) emissions is crucial for addressing this challenge [1]. Cement, as an indispensable core raw material for construction projects and infrastructure development, has played an irreplaceable role in the process of industrialization. However, carbon emissions from the cement industry remain persistently high, making it one of the most concerning sectors in terms of CO_2 emissions [2]. Emissions from cement, glass, and other industries account for approximately 50% of total industrial CO_2 emissions [3], making it a key carbon source in the industrial sector. The European Union's Carbon Border Adjustment Mechanism (CBAM) officially took effect in October 2023 and is currently in the transition period. It aims to ensure that imported goods pay the same carbon price as products within the EU, initially covering six categories of commodities: steel, cement, aluminum, electricity, hydrogen, and fertilizers. This initiative has reshaped global trade rules and is forcing the cement industry to accelerate its low-carbon transition [4].

The cement industry serves as a critical basic raw material sector for China's national economic development, while also being a key area of energy consumption and carbon dioxide (CO_2) emissions. China's cement output has remained above 2 billion tons for many consecutive years, with both its output and consumption accounting for over 50% of the global total [5], resulting in substantial energy consumption and CO_2 emissions①.Therefore, achieving low-carbon development in the cement industry is vital for comprehensive emission reduction [6]. It is estimated that CO_2 emissions from China's cement industry account for approximately 80% of those in the building materials industry and over 10% of the national total CO_2 emissions, making it a key sector for China's carbon reduction efforts②.Guided by the "dual carbon" goals (peaking carbon

①See National Carbon Market Information Network. https://www.cets.org.cn/zjsj/6512.jhtml.
②See Ministry of Ecology and Environment of the People's Republic of China.https://www.mee.gov.cn/zcwj/zcjd/.

* Corresponding author. E-mail address:liufeng63@126.com

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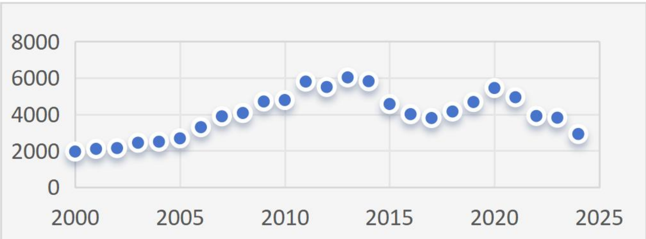
emissions before 2030 and achieving carbon neutrality before 2060), China has clearly articulated its targets. As an important basic industry of the national economy, the emission reduction progress of the cement industry directly affects the pace of achieving the country's "dual carbon" goals. Since 2021, with the decline in demand for cement products, China's cement output has shown a downward trend, and the contradiction of excess cement production capacity has become more prominent. In response, China has introduced a series of policy measures.

In January 2024, the Ministry of Ecology and Environment of the People's Republic of China issued the Opinions on Promoting the Implementation of Ultra-Low Emissions in the Cement Industry, proposing key tasks such as optimizing and adjusting the industrial structure, steadily advancing the ultra-low emission transformation of existing enterprises, coordinating the synergistic reduction of pollution and carbon emissions in the cement industry, and strengthening the whole-process refined environmental management.

In June 2024, the National Development and Reform Commission and other relevant departments issued the Special Action Plan for Energy Conservation and Carbon Reduction in the Cement Industry, setting the following targets by the end of 2025: controlling cement clinker production capacity at around 1.8 billion tons; ensuring that the proportion of production capacity meeting the benchmark energy efficiency level reaches 30%; completing the technological transformation or phasing out of production capacity below the baseline energy efficiency level; and reducing the comprehensive energy consumption per unit of cement clinker by 3.7% compared with 2020. During 2024—2025, the implementation of energy conservation and carbon reduction transformations and the renewal of energy-consuming equipment in the cement industry are expected to achieve energy savings of approximately 5 million tons of standard coal and reduce CO_2 emissions by around 13 million tons.



Source: Juhui Data Network（https://www.gotohui.com/）.

Fig.1. Cement Output of Liaoning Province (2000-2022)

As a core province of China's old industrial base in Northeast China, Liaoning Province, relying on its abundant limestone resources and improved industrial system, has become an important cement production base in North China. Its annual cement output is shown in Figure 1.

From the perspective of regional development needs, Liaoning Province is in a critical stage of transformation and upgrading as an old industrial base. As a traditional high-energy-consuming industry, the green transition of the cement industry is an important part of the optimization of the regional industrial structure. Currently, the cement industry in Liaoning Province is facing multiple challenges: on the one hand, backward production capacities such as traditional shaft kilns and wet-process kilns still remain, and the energy-saving transformation of advanced dry-process kiln production lines has not yet fully covered all enterprises; on the other hand, the substitution rate of new energy is less than 10%, coal remains the main energy source, and carbon emission intensity remains persistently high. Against this background, conducting targeted carbon accounting, tapping into emission reduction potential, and designing emission reduction pathways adapted to regional characteristics have become key initiatives to promote the green transition of Liaoning Province’s cement industry and support the achievement of regional "dual carbon" goals.

Building on this foundation, this study takes the cement industry in Liaoning Province as the research object and constructs a carbon accounting system. By comparing and analyzing advanced domestic and foreign emission reduction technologies and policy experiences, combined with Liaoning Province’s resource endowments and industrial foundation, emission reduction pathways are designed from dimensions such as technological upgrading, energy substitution, and policy guarantees. This research can provide data support for Liaoning Province to formulate precise emission reduction policies for the cement industry, as well as theoretical reference and practical experience for the green transition of high-energy-consuming industries in China’s old industrial bases in Northeast China.

As a prerequisite and foundation for precise emission reduction, carbon accounting is a core technical method to identify carbon emission sources and quantify emission reduction potential. Currently, China’s carbon accounting system for the cement industry has been formed with the Guidelines for Compiling Provincial Greenhouse Gas Inventories and the Guidelines for the Accounting Methods and Reporting of Greenhouse Gas Emissions from Cement

Production Enterprises as the core. However, regional-level accounting still suffers from insufficient refinement. Cement enterprises in Liaoning Province exhibit a distribution characteristic of "wide dispersion with partial concentration," and enterprises of different scales vary significantly in production processes, energy structures, and environmental protection facilities. Generic accounting methods struggle to accurately reflect the actual carbon emission situation of the regional industry, leading to a lack of precise data support for the formulation of targeted emission reduction policies.

1.Theoretical Basis

Cement production is a resource- and energy-intensive manufacturing process, accounting for approximately 12% to 15% of total industrial energy consumption, while cement production contributes 5% to 8% of global anthropogenic carbon dioxide (CO_2) emissions [7]. The emission sources included in the accounting and reporting of greenhouse gas emissions from cement production are: fossil fuel combustion emissions and process emissions [8]. In this study, CO_2 emissions from Liaoning's cement industry are calculated in accordance with the carbon accounting methods provided in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) [9] and its revised version (IPCC, 2019) [10].

1.1.Fossil Fuel Combustion Emissions

Since the National Bureau of Statistics has not disclosed data on fossil fuel combustion emissions specifically for cement, this study estimates such data based on the fossil fuel consumption data of the non-metallic mineral products industry published by the Bureau. The non-metallic mineral products industry covers multiple sub-sectors including cement, glass, and ceramics, among which cement accounts for the largest proportion of carbon emissions. Therefore, this study uses the fossil fuel consumption data of the non-metallic mineral products industry as a proxy for cement-specific data in the accounting process.

(1) Calculation Formula.The CO_2 emissions from fuel combustion activities refer to the sum of CO_2 emissions generated by the combustion of various fuels during the accounting and reporting period of an enterprise, which is calculated in accordance with Formula (1).

$$E_{\text{combustion}} = \sum_{i=1}^{n} AD_i \times EF_i \qquad (1)$$

Where:

$E_{combustion}$ refers to the net CO_2 emissions generated from the combustion of fossil fuels consumed during the accounting and reporting period, with the unit of tonne of carbon dioxide (tCO_2).

AD_i refers to the activity level of the i-th type of fossil fuel during the accounting and reporting period, with the unit of gigajoule (GJ).

EF_i refers to the carbon dioxide (CO_2) emission factor of the i-th type of fossil fuel, with the unit of tonne of carbon dioxide per gigajoule (tCO_2/GJ).

i refers to the type of fossil fuel consumed on a net basis.

The activity level (AD_i) of the i-th type of fossil fuel during the accounting and reporting period is calculated in accordance with Formula (2).

$$AD_i = NCV_i \times FC_i \qquad (2)$$

Where:

NCV_i is the average net calorific value of the i-th type of fossil fuel during the accounting and reporting period, with the unit of gigajoule per tonne (GJ/t) for solid or liquid fuels, and gigajoule per 10,000 cubic meters (GJ/10,000 Nm^3) for gaseous fuels;

FC_i is the net consumption of the i-th type of fossil fuel during the accounting and reporting period, with the unit of tonne (t) for solid or liquid fuels, and 10,000 cubic meters (10,000 Nm^3) for gaseous fuels.

The carbon dioxide emission factor of fossil fuels is calculated in accordance with Formula (3).

$$EF_i = CC_i \times OF_i \times \frac{44}{12} \qquad (3)$$

Where:

CC_i is the carbon content per unit calorific value of the i-th type of fossil fuel, with the unit of tonne of carbon per gigajoule (tC/GJ);

OF_i is the carbon oxidation rate of the i-th type of fossil fuel, with the unit of percent (%).

1.2.Process Emissions

The carbon dioxide emissions resulting from the decomposition of carbonates corresponding to clinker exclude those generated by the decomposition of carbonates associated with the dust from the kiln stack (kiln inlet) and bypass exhaust dust, as well as the carbon dioxide emissions from the calcination of non-fuel carbon in the raw meal.

The carbon dioxide emissions during cement production are mainly derived from the carbon produced by the decomposition of carbonates and a small amount of organic carbon in the raw meal during high - temperature calcination, and such emissions can be considered approximately proportional to the cement output.

$$E_{\text{process}} = 0.525Ac \qquad (4)$$

Among them, 0.525 is the default process emission factor issued by the Cement Sustainability Initiative (CSI), with the unit of tonne of carbon dioxide per tonne of clinker (tCO_2/t clinker). This default factor assumes a calcium oxide (CaO) content of 65% in clinker and accounts for carbon dioxide emissions generated from the decomposition of magnesium carbonate. Ac refers to the output of cement clinker, with the unit of tonne (t).

2.Calculation Results

2.1.Results of fossil fuel combustion emission calculations

After calculation, the CO_2 emissions from fossil fuel combustion in Liaoning Province's cement products industry are shown in Table 1.

As it can be seen from Table 1:

(1) The overall emission trend shows a "three-stage" characteristic: fluctuating growth followed by a decline.

• Stage 1 (2000-2008): Slow fluctuation with modest growth. The total emissions fluctuated from 13.5153 million tonnes in 2000 to 25.6894 million tonnes in 2008, with an average annual growth rate of approximately 8.5%. A phased trough occurred in 2002 (12.1559 million tonnes), followed by rapid growth during 2004-2007, reflecting the capacity expansion and increased energy consumption of the cement products industry during this period.

• Stage 2 (2009-2013): Rapid surge to a historical peak. The total emissions increased from 24.7188 million tonnes in 2009 to 44.6815 million tonnes in 2013, with an average annual growth rate of about 15.8%—the highest rate across the entire period. The historical peak was reached in 2013 (44.6815 million tonnes), an increase of 80.8% compared to 2009. The main driving factors were the explosive growth in coke consumption and the steady rise in coal consumption.

• Stage 3 (2014-2022): Sustained decline and gradual stabilization. The total emissions decreased from the 2013 peak to 20.2238 million tonnes in 2022, with an average annual decline rate of approximately 8.2%. A precipitous drop occurred during 2015-2016, followed by slight fluctuating recovery in 2017-2020 and another slow decline after 2021. The overall trend of "decline followed by stabilization" reflects the restrictive effects of tightened environmental policies (e.g., the "dual carbon" goals and capacity regulation) on high-energy-consuming industries.

(2) The energy structure is centered on "coal + coke," with an extremely low proportion of clean energy.Coal and coke are the dominant energy sources, accounting for over 80% of total emissions. Coal has been the largest emission source throughout the period, with its share consistently ranging between 50% and 70% from 2000 to 2022. It reached a peak in 2013 (28.3852 million tonnes, accounting for 63.5%) and gradually decreased after 2016 (17.6939 million tonnes in 2022, accounting for 87.5%). Coke is the second-largest emission source with significant volatility: its share was 5%-8% during 2000-2008, surged rapidly in 2009-2013, and plummeted to below 5% after 2016, which is related to production process optimization and the use of alternative energy sources.

(3) Other energy sources account for a low proportion, with some categories phased out.Liquid fuels (crude oil, gasoline, kerosene, diesel oil, and fuel oil) collectively account for less than 10% of total emissions. Crude oil contributed moderately during 2000-2003 (1.3307 million tonnes in 2000) but was basically phased out after 2005. Fuel oil accounted for 2%-4% during 2001-2013 and dropped to below 2% after 2016.The proportion of clean energy such as natural gas is extremely low, nearly zero (≤0.0124 million tonnes) during 2000-2008. It grew slowly after 2009, reaching 0.2551 million tonnes in 2022, accounting for only 1.3%, reflecting the slow progress of clean energy substitution in the industry. Indirect emissions from electricity account for 3%-5%, peaking at 1.0571 million tonnes in 2021, with an overall slow upward trend, which is associated with the improvement in the industry's electrification level.

(4) The energy structure has shifted from "coal + coke" dual-driver to "coal-dominated"

single-driver.Before 2013, coal and coke together accounted for 80%-90% of total emissions, forming a dual-driver pattern. After 2016, the share of coke plummeted while the share of coal rose to over 85%, making the energy structure even more homogeneous. Insufficient clean energy substitution has become a bottleneck for emission reduction.

Year	Coal	Coke	Crude Oil	Gasoline
2000	1065.06	76.78	133.07	4.59
2001	1026.22	75.69	143.07	2.16
2002	981.22	128.92	1.09	3.33
2003	1086.06	48.10	3.53	2.11
2004	1635.23	71.77	0.15	3.54
2005	1721.08	100.44	0.00	4.45
2006	1729.27	157.36	0.63	5.32
2007	2167.90	195.88	2.48	11.67
2008	2167.90	195.88	2.48	11.67
2009	1853.61	369.52	1.78	11.96
2010	2276.56	658.32	0.00	24.80
2011	2173.57	661.38	0.18	36.27
2012	2811.11	1099.32	0.88	25.48
2013	2838.52	1229.93	1.12	25.62
2014	2430.05	1016.28	1.00	20.65
2015	2028.85	891.31	0.00	12.99
2016	1592.68	61.75	0.00	18.90
2017	1713.17	51.19	0.00	2.93
2018	1713.17	51.19	0.00	2.93
2019	2056.81	40.03	0.00	4.47
2020	2136.07	33.31	0.00	5.21
2021	2075.24	39.28	0.00	4.25
2022	1769.39	39.42	0.00	4.22

Table.1.CO_2 Emissions from Fossil Fuel Combustion in Liaoning Province' s Cement Products Industry (Unit: 10,000 tonnes)

Year	Kero-sene	Diesel Oil	Fuel Oil	Natural Gas	Electr-icity
2000	0.16	11.64	44.54	0.03	15.66
2001	0.13	9.78	79.07	0.03	16.23
2002	1.61	9.57	74.13	0.08	15.66
2003	0.22	16.10	85.29	0.10	18.85
2004	1.23	24.49	89.19	0.41	36.76
2005	1.04	33.13	95.43	0.41	39.21
2006	1.92	29.60	103.26	0.96	43.12
2007	1.39	41.98	87.60	1.24	58.80
2008	1.39	41.98	87.60	1.24	58.80
2009	1.01	53.93	113.41	3.96	62.69
2010	0.85	63.81	73.21	11.36	74.61
2011	0.19	85.94	81.67	32.86	91.91
2012	0.00	130.68	80.18	60.68	90.93
2013	0.06	175.60	79.93	25.51	91.86
2014	0.03	22.97	81.51	34.18	94.29
2015	0.66	51.39	48.73	26.16	52.90
2016	0.03	45.20	50.32	12.32	60.19
2017	0.00	39.04	44.20	10.32	68.03
2018	0.00	39.04	44.20	10.32	68.03
2019	0.00	39.54	67.63	18.57	74.17
2020	0.00	43.45	54.19	21.13	97.78
2021	0.01	43.49	49.34	28.41	105.71
2022	0.12	49.14	37.38	25.51	97.19

Table.2. Continued

2.2.Process emission results

After calculation, the process CO_2 emissions of Liaoning Province' s cement products industry are shown in Table 3.

Year	Process Emissions	Year	Process Emissions
2000	1026.31	2012	2889.48
2001	1103.26	2013	3165.73
2002	1126.52	2014	3055.80
2003	1280.86	2015	2398.05
2004	1310.26	2016	2105.76
2005	1407.35	2017	1993.41
2006	1729.25	2018	2181.85
2007	2043.93	2019	2455.64
2008	2139.06	2020	2859.68
2009	2470.04	2021	2592.93
2010	2512.56	2022	2053.25
2011	3044.87		

Table.3. Process CO_2 Emissions of Liaoning Province' s Cement Products Industry (Unit: 10,000 tonnes)

As it can be seen from Table 2, the process emissions increased from 10.2631 million tonnes in 2000 to 20.5325 million tonnes in 2022, with a cumulative growth of 99.97% (nearly doubling). This reflects the "rigid growth" attribute of process emissions, which is directly driven by capacity expansion. There was no consecutive negative growth for more than 3 years throughout the period; even during the period of tightened emission reduction policies (after 2013), the characteristic of "rebound after decline" persisted. This highlights the strong correlation between process emissions and production scale — substantial emission reduction can only be achieved when there is a significant contraction in output or revolutionary optimization of production processes.

The underlying reasons are as follows: Firstly, the strength of cement is highly dependent on clinker (a product of calcium carbonate decomposition), and there are technical bottlenecks in raw material substitution (the current upper limit of waste residue substitution ratio is approximately 50%), making it impossible to completely decouple from calcium carbonate. Secondly, the potential for process-based emission reduction is limited: the new dry-process technology has become the mainstream (accounting for over 90%), and the emission reduction potential of traditional processes has been basically exhausted, while next-generation low-carbon technologies (such as electrochemical calcination and carbon capture) are still in the R&D stage. Thirdly, the production capacity base is large. Even if output declines, idle capacity may lead to a cycle of "overcapacity → illegal production → emission rebound."

3.Carbon Emission Reduction Pathways for the Cement Industry in Liaoning Province

3.1.Accelerate Clean Energy Substitution and Promote Energy-Saving Technology Upgrades

(1) Increase the Proportion of Clean Energy Utilization.In the current fossil fuel combustion emissions of Liaoning's cement products industry, coal accounts for as high as 87.5%, while clean energy such as natural gas accounts for only 1.3%. Although combustion emissions have dropped significantly between 2013 and 2022, there remains enormous potential for clean energy substitution. In the short term (2023-2025), priority should be given to promoting natural gas as a substitute for coal in core production processes such as rotary kilns and drying systems, aiming to increase the share of natural gas in total energy consumption to 5%-8%. In the medium to long term (2026-2030), leveraging Liaoning's local advantages in renewable energy development such as wind and solar power, pilot projects for electricity-driven calcination technologies (e.g., electric kilns) should be launched to gradually reduce reliance on fossil energy and fundamentally optimize the energy structure.

(2) Promote Upgrades of Energy-Saving Technologies.The rapid growth of combustion emissions from 2000 to 2013 was closely linked to low energy efficiency. Despite improvements after 2016, the energy consumption per unit product remains higher than the national advanced level. It is necessary to vigorously promote high-efficiency combustion systems (e.g., low-nitrogen burners) to improve fuel combustion efficiency, and popularize waste heat recovery and utilization technologies such as waste heat power generation at kiln tails to fully tap energy potential. Through this series of energy-saving technology upgrades, combustion emissions will be further reduced.

3.2.Strengthen New Raw Material Substitution and Enhance Technological Empowerment

(1) Large-Scale Application of Raw Material Substitution.Process emissions have risen from 43.16% in 2000 to 50.38% in 2022, becoming a bottleneck in emission reduction. The core reason is that limestone remains the dominant raw material, with insufficient substitution by industrial waste residues. The admixture ratio of industrial waste residues such as fly ash, slag, and steel slag should be increased. Meanwhile, pilot projects for new low-carbon raw materials that do not rely on cement clinker should be promoted in segmented fields such as precast components, with gradual expansion of application scope upon technological maturity.

(2) Break Through Bottlenecks in Process Innovation.Currently, the proportion of new dry-process cement production technology in Liaoning's cement products industry has exceeded 90%. The emission reduction potential of traditional processes has been basically exhausted, while process emission intensity remains at a high level. Existing processes need to be optimized and upgraded, including the upgrading of precalciner systems and the adoption of low-temperature calcination technologies to reduce the temperature required for calcium carbonate decomposition and minimize process emission losses. In addition, increase investment in cutting-edge technologies such as carbon capture, utilization, and storage (CCS), and select large-scale cement enterprises for pilot projects. It is expected that large-scale application of CCS technology will be achieved by 2030, enabling a reduction rate of over 30% per plant.

Construct a "low-cost, high-emission-reduction" technology combination system, and promote the implementation of various technologies in priority order:

High priority: Popularize mature technologies such as natural gas substitution for coal, waste heat recovery and utilization, and industrial waste residue substitution for clinker.

Medium priority: Promote advanced technologies such as new dry-process optimization and low-nitrogen burners, as well as pilot projects for alkali-activated cementitious materials (the former optimizes combustion emissions, while the latter achieves significant process emission reduction in pilot fields).

Medium-low priority: Layout cutting-edge technologies such as electric kiln calcination, renewable energy coupling, and large-scale CCS application to lay the foundation for long-term deep emission reduction.

3.3.Combine Rigid Constraints with Flexible Measures to Improve Policy Mechanisms

(1) Strengthen Rigid Constraints.Improve the emission accounting system by incorporating the dual indicators of "combustion emission intensity + process emission intensity" into environmental assessments, preventing enterprises from achieving emission reduction targets merely by reducing production while neglecting emission intensity optimization. Strictly implement production capacity control policies, prohibit new cement production capacity, and promote a linked mechanism of "production capacity replacement + off-peak production" to ensure stable emission reduction effects.

(2) Improve Incentive Mechanisms.Establish fiscal subsidy policies: Provide enterprises with a subsidy of 50-100 yuan per ton of CO_2 reduced for emission reduction projects such as natural gas substitution, high admixture ratio of waste residues, and CCS technology application to lower their emission reduction costs. Offer financial support by setting up special loans for low-carbon technologies to reduce the financing threshold and costs of technological transformation. Encourage cross-industry cooperation between cement enterprises and steel enterprises to realize the synergistic utilization of raw materials such as steel slag and form a joint force for emission reduction.

3.4.Guide Synergistic and Healthy Development of Demand

(1) Optimize the Terminal Demand Structure.Promote low-carbon cement products such as high-performance concrete, precast components, and fiber-reinforced cement products. These products have superior performance and can reduce cement consumption per unit project. Mandate the use of a certain proportion of low-carbon cement products in infrastructure projects such as transportation and municipal engineering, integrate cement emission reduction with green buildings and new urbanization construction, and guide terminal demand toward low-carbon transformation.

(2) Curb Ineffective Demand.Resolutely phase out outdated production lines , as these lines are inefficient and high-emission. Their elimination will avoid the "inefficient production - high emission" cycle caused by overcapacity. Guide industry integration, increase industry concentration through mergers and acquisitions, reduce emission costs per unit product via large-scale production, and enhance the overall emission reduction capacity of the industry.

Conclusion

Based on the IPCC Guidelines for National Greenhouse Gas Inventories and China's carbon accounting standards for the cement industry, this study calculates carbon emissions using statistical data of Liaoning Province's cement industry from 2000 to 2022 and explores potential emission reduction pathways. The core conclusions are as follows: The total carbon emissions of Liaoning's cement industry have shown a "fluctuating downward" trend, with emissions decreasing in recent years; however, structural contradictions persist. Accounting results indicate that process emissions and fossil fuel combustion emissions are the primary sources of carbon emissions. Based on these findings, this study puts forward targeted measures, including accelerating the replacement of clean energy, promoting the upgrading of energy-saving technologies, advancing the substitution of new raw materials, strengthening technological empowerment, enforcing rigid constraints, improving incentive mechanisms, and guiding the coordinated and healthy development of market demand.

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