# Research on the ESG Transformation Pathways and Strategies for Domestic High-Emission Enterprises under the Dual-carbon Goals

**Yancheng LIN, Shanshan SHI**

Faculty of Busines,Lingnan University(HongKong,999077,China)

**Abstract:** Transformation has evolved from passive compliance into a core strategic initiative for high-emission enterprises. This study selects nine sample firms covering three typical high-emission industries (power, steel and chemical industries), and adopts policy text analysis, multi-case comparison and grounded theory to explore how dual-carbon pressure affects corporate ESG transformation paths alongside internal adaptive capabilities. The results show that external transformation pressures mainly stem from carbon regulatory constraints, green market demand and carbon trading market volatility, while internal driving capabilities consist of carbon accounting capacity, green technology reserves, financial support and internal governance quality. At present, most high-emission enterprises suffer from mismatched external pressure and internal capacity, accompanied by prominent dilemmas including unclear carbon asset valuation, insufficient green technology application and non-standard ESG information disclosure. Moreover, significant industrial heterogeneity leads to differentiated ESG transformation strategies among high-carbon enterprises. Accordingly, this paper establishes an integrated theoretical framework of "dual carbon pressure-enterprise capability-ESG response" targeted at industrial differences. The findings complement existing theories on corporate green and ESG transformation under carbon neutrality constraints. Besides, they provide practical operational guidance for high-emission enterprises to break transformation bottlenecks and realize coordinated development of carbon reduction and corporate value growth, as well as valuable references for governments to formulate differentiated industrial green policies and optimize green financial supervision systems

**Keywords:** dual carbon target; high-emission enterprises; ESG transformation; differentiated transformation paths

**JEL Classification:** G18; Q54; Q56; Q58

## 1 Introduction

Global greenhouse gas emissions keep pushing climate risks upward, and all nations have accelerated the formulation of carbon reduction policies. In 2020, China formally put forward the strategic goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. This commitment serves as both China's international climate pledge and the core guideline for domestic industrial green upgrading. In 2026, the General Office of the State Council issued updated documents to raise standards for energy conservation and carbon reduction, clearly defining the power, steel and chemical sectors as core industrial emission reduction subjects. Statistical data confirms that the three industries, namely the electricity, steel and chemical industries, together contribute more than 70% of China's total industrial carbon emissions, making them the primary carriers for delivering dual-carbon tasks.

As an integrated evaluation system covering environmental, social and non-financial governance indicators, ESG has evolved from voluntary corporate social responsibility reporting to a mandatory strategic management

tool for high-emission firms. ESG is a comprehensive evaluation framework covering the environmental, social and governance dimensions. The environmental dimension takes carbon accounting and low-carbon technological renovation as core priorities under dual-carbon constraints, covering greenhouse gas control, resource recycling and pollution abatement. The social dimension focuses on employee rights protection, green supply chain management and community sustainable development. The governance dimension includes the setting of board ESG committees, climate risk management and standardized information disclosure mechanisms. Different from the traditional single shareholder value maximization logic, the ESG governance paradigm balances the reasonable demands of multiple stakeholders, and becomes a standardized management tool for high-emission enterprises to respond to carbon risks and rebuild long-term competitive advantages.

Nevertheless, a prominent disconnection exists between academic research and real corporate operations. Although China's "1+N" dual-carbon policy framework and multi-layer ESG disclosure rules have taken initial shape, most high-emission enterprises lack clear, industry-matched transformation roadmaps. Two critical research gaps remain unaddressed in existing literature. First, prior scholars rarely construct an integrated analytical framework to interpret the dynamic coupling between external institutional pressure and firms' heterogeneous internal resources. Second, few cross-industry multi-case comparative analyses have been carried out to classify heterogeneous transformation paths and their matching strategic systems. To fill these research gaps, this paper conducts grounded multi-case analysis based on nine representative listed firms across three high-emission sectors, and summarizes four typical ESG transformation modes with targeted implementation strategies.

Most existing ESG transformation literature adopts a single-dimensional analytical perspective, either overemphasizing the binding force of external policies or only discussing the supporting role of internal resource endowments. This paper integrates institutional theory and the resource-based view to build the "dual carbon pressure-enterprise capability-ESG response" analytical framework. The framework systematically clarifies the interactive mechanism between external carbon constraints and internal corporate capacity, supplementing theoretical interpretations of transformation driving logic.

In addition, most relevant studies rely on single-industry or single-case evidence, lacking horizontal comparative analysis of power, steel and chemical industries. Through standardized multi-case coding and cross-group comparison, this paper distinguishes four transformation paths with clear applicable boundaries. The findings remedy the defects of macro descriptive research and expand the application scope of corporate sustainable development theory under dual-carbon constraints.

Current research generally proposes one-size-fits-all transformation models for all high-emission enterprises. This paper designs differentiated strategic portfolios according to industrial attributes, profitability and R&D reserves of firms, which can resolve practical dilemmas such as ambiguous transformation directions and mismatched resource allocation, helping enterprises balance short-term transformation expenditures and long-term low-carbon value appreciation.

For government regulators, micro empirical evidence extracted from nine sample firms provides decision-making references for formulating categorized industrial green policies. Differentiated policy tools can replace unified carbon reduction standards, reduce the

transformation impact on different types of enterprises, and realize synergies between policy incentives and corporate low-carbon behaviors.

The remaining of this paper is organized as follows: Chapter 2 provides a literature review focusing on the driving factors and mechanics for ESG transformation. Chapter 3 details the research methodology for the study. Chapters 4 provides an in-depth analysis of nine sample companies from the three high-emission industries. Chapter 5 constructs an ESG strategy system based on the differentiated transformation pathways. The paper concludes with a Chapter 6.

## 2 Literature Review

### 2.1 Evolution of ESG Disclosure Systems and International Standard Comparison

China's ESG information disclosure framework has gone through four distinct development stages. The voluntary reporting phase lasted from 2003 to 2015, during which enterprises released environmental reports without mandatory regulatory requirements. The preliminary regulation stage covered 2016–2020, accompanied by the launch of China's green financial framework. The mandatory expansion stage (2021–2023) was driven by the dual-carbon goals, while the standardized construction stage began in 2024 after the release of national double-materiality disclosure guidelines. At present, CSI 180 and STAR 50 constituent stocks as well as central SOEs are required to publish ESG reports, yet data distortion, insufficient third-party verification and widespread greenwashing remain prominent practical problems [1].

Globally, two mainstream sustainable reporting systems form a complementary structure. The ISSB issued IFRS S1 and IFRS S2 based on financial materiality and the TCFD four-pillar framework, requiring full disclosure of Scope 1, 2 and 3 greenhouse gas emissions. The EU's CSRD and ESRS standards adopt the double-materiality principle, simultaneously demanding disclosure of corporate environmental externalities and climate financial risks [2]. GRI standards focus on multi-stakeholder impact evaluation, and have formed compatible reporting logic with ISSB norms to lower disclosure costs for multinational enterprises [3]. Comparative research proves that unified accounting standards can boost cross-border investor confidence, but gaps between nominal rules and actual implementation weaken policy effects. China's localized double-materiality system can provide unique experience for coordinating global disclosure standards [5].

### 2.2 Driving Factors and Mechanisms of Corporate ESG Transformation

The formation of corporate ESG transformation willingness and capacity is jointly determined by external institutional forces and internal resource conditions. Externally, three layers of pressure work together: rigid constraints from carbon trading and environmental inspections, normative pressure from green investor preferences, and imitation pressure within industrial competition [6,8]. Internally, senior management's environmental cognition, low-carbon technology stock and corporate financing scale determine the feasibility of green investment [7].

The ESG three-dimensional framework affects corporate operations through differentiated channels. The environmental dimension relies on energy-saving technological renovation to cut emission costs; the social dimension optimizes stakeholder relations to enhance operational resilience; the governance dimension improves long-term climate risk decision-making mechanisms. Coordination between internal and external drivers can simultaneously lift environmental and financial performance, a conclusion supported by multiple empirical studies [11].

### 2.3 Industry-Specific Research on High-Emission Sectors' Transformation Paths

Existing literature has formed segmented conclusions for power, steel and chemical industries. The low-carbon transition of the power industry centers on building a new energy system supported by wind, solar and CCUS equipment, while traditional thermal power firms face prominent stranded asset risks and short-term profit pressure [18]. The steel industry is restricted by severe blast furnace long-process carbon lock-in, and its transformation follows a three-stage logic: energy efficiency optimization in the short run, electric furnace popularization in the medium run, and hydrogen metallurgy breakthroughs in the long run. The sector's transformation is closely linked to downstream green steel procurement demand [13]. The chemical industry features diversified product structures and heterogeneous technical routes, relying on park circular symbiosis, green hydrogen substitution and high-value material expansion to complete systematic decarbonization [10].

Nevertheless, most existing studies only analyze a single industry and fail to conduct horizontal comparisons of transformation modes based on enterprises' resource endowments, lacking categorized strategic guidance for different types of firms.

### 2.4 Transformation Challenges and ESG Value Creation Logic

High-emission enterprises share universal transformation obstacles, including high commercialization costs of disruptive low-carbon technologies, insufficient cross-industry coordination mechanisms and incomplete internal ESG governance systems [20]. A series of empirical studies confirm the positive correlation between ESG performance and corporate value. Carbon emission trading pilot policies can significantly raise manufacturing firms' green total factor productivity; energy-intensive enterprises with high ESG ratings exhibit lower stock market volatility [21]. Optimized board structure and ESG-linked executive compensation can restrain corporate short-sighted behaviors and lift long-term environmental output [25]. McKinsey's five-channel value creation theory summarizes that standardized ESG management improves corporate competitiveness via revenue expansion, cost reduction, risk control, human resource optimization and high-quality investment allocation [23]. The above research lays a theoretical foundation for the case analysis and strategic design of this paper.

## 3 Research Aims and Methodology

### 3.1 Research Aims

China's dual-carbon strategic target contains two sequential core objectives: carbon peaking by 2030 and carbon neutrality by 2060. Carbon peaking means industrial carbon emissions reach a historical maximum value and then maintain a sustained downward trend, realizing decoupling between economic expansion and fossil energy consumption. Carbon neutrality requires enterprises to offset net carbon emissions within a fixed cycle via energy conservation, carbon sink afforestation and CCUS carbon capture technologies.

This paper sets three core research objectives. First, it deconstructs the dual driving system of ESG transformation, sorts three categories of external institutional pressure and four types of internal enterprise capacity, and analyzes their dynamic coupling logic to explain firms' transition from passive compliance to active low-carbon strategic layout.

Second, based on nine cross-industry sample enterprises, this paper identifies four

typical ESG transformation paths, and clarifies the trigger conditions, resource dependence, industrial adaptability and potential risks of each path via comparative case coding.

Third, this study constructs a multi-dimensional ESG strategic system matching differentiated transformation paths, and designs targeted strategic portfolios covering technological innovation, organizational governance, information disclosure and stakeholder collaboration.

### 3.2 Research Methodology

This study employs a mixed qualitative research framework integrating multiple case analysis, comparative research and textual analysis as its core methodological toolkit. Additionally, the study defines high-emission enterprises via three unified standards. First, industrial classification standard: enterprises belonging to thermal power, steel, petrochemical and other high-carbon statistical sectors. Second, emission intensity standard: enterprises whose carbon output per unit value is significantly higher than the industrial average level. Third, regulatory inclusion standard: key emission control entities incorporated into the national carbon emission trading market.

Such enterprises share four common industrial characteristics: fossil energy-locked production equipment with high transformation sunk costs; capital and technology-intensive renovation demands; extensive carbon spillover effects along upstream and downstream industrial chains; ESG transformation involves systematic upgrades of technology, assets and organizations rather than simple terminal pollution treatment.

A mixed qualitative study is carried out as follows: First, a theoretical sampling strategy is applied to select nine representative A-share listed firms spanning the power, steel and chemical sectors, with multi-source data including annual statements, ESG disclosures and industrial policy archives (2022–2024) triangulated to ensure empirical reliability; key observation indicators centering on ESG governance frameworks, carbon neutrality targets, low-carbon capital outlays and third-party ESG ratings are constructed for cross-firm evaluation. Second, multi-dimensional comparative analysis is conducted from cross-industry, intra-industry and financial correlation perspectives to unpack sectoral transformation disparities, firm-type strategic heterogeneities and the financial underpinnings of decarbonization investments. Complementarily, dual textual coding procedures are implemented: policy document coding identifies tiered green regulatory instruments under the dual-carbon agenda, while content analysis of corporate ESG reports and executive addresses decodes firms' latent low-carbon strategic orientations embedded in public disclosure discourse.

## 4 Industrial Background and Overview of Case Enterprises

### 4.1 Comparative Analysis of Transformation Background Across Three Industries

Power, steel and chemical industries contribute over 70% of China's total industrial carbon emissions, while their technical-economic characteristics lead to differentiated transformation logic. The power industry's carbon emissions mainly derive from coal combustion, with the core contradiction between national energy supply security and low-carbon asset upgrading. Its mainstream transformation path relies on wind-solar incremental expansion and functional transformation of stock coal-fired generating units.

The steel industry suffers from severe long-process carbon lock-in. Its transformation follows a progressive route: short-term energy efficiency optimization, medium-term electric furnace popularization and long-term hydrogen metallurgy technological breakthrough, and is closely linked to downstream green steel procurement demand.

The chemical industry features complex product chains and diversified carbon sources covering fuel, production process and purchased thermal power. Its transformation depends on three parallel approaches: green electricity/hydrogen substitution, bio-based raw material upgrading and industrial park circular symbiosis, with huge cross-industry collaborative emission reduction space.

**4.2 Overview of Nine Case Enterprises**

Three typical listed enterprises are selected from each high-emission industry as research samples:

Power industry: Datang Power Generation (structural reshaping representative), GD Power Development (compliance governance benchmark), Huaneng Power International (pioneer of global transition bonds).

Steel industry: Baoshan Iron & Steel (technological breakthrough leader), HBIS Group (value chain synergy practitioner), Valin Steel (compliance-oriented local SOE).

Chemical industry: Wanhua Chemical (process innovation leader), Hualu Hengsheng (park circular economy model), Sinopec (full industrial chain integrated enterprise).

All nine sample enterprises continuously released complete ESG or social responsibility reports from 2022 to 2024, providing consistent and comparable data support for cross-case comparative analysis.

**4.3 Identification and Characterization of Four Typical ESG Transformation Paths**

**4.3.1 Technology Breakthrough Path**

**4.3.1.1 Path Characteristics and Driving Mechanism**

The core logic of the technology breakthrough path is to realize source decarbonization via sustained high-intensity R&D investment and disruptive low-carbon process innovation, replacing passive terminal pollution control and constructing long-term industrial green competitive barriers.

Endogenous driving forces include management's long-term low-carbon strategic cognition, stable operating cash flow supporting large-scale R&D expenditure and mature internal innovation organizational systems. Exogenous driving forces consist of tightening industrial energy intensity limits, inter-firm green technology competition and national low-carbon demonstration project subsidies. The primary restriction of this path lies in long R&D cycles and high technical trial risks, which is only applicable to industry leaders with stable long-term profitability.

**4.3.1.2 In-Depth Case Analysis: Baosteel and Wanhua Chemical**

Baosteel and Wanhua Chemical are typical representatives of the technology breakthrough path. Both firms maintain sustained large-scale R&D investment even during industrial profit downturns, forming positive cycles of technological innovation and ESG performance improvement. Table 1 and Table 2 display their core profitability indicators from 2022 to 2024.

Table 1 Analysis of Profitability Factors of Baosteel

| Baosteel | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 3677.78 | 3445.00 | 3221.16 |
| Net Profit Attributable to Parent (CNY bn) | 121.87 | 119.44 | 73.62 |
| Weighted Average ROE (%) | 6.33 | 6.01 | 3.65 |
| Cash Flow from Operating Activities (CNY bn) | 447.20 | 253.00 | 277.40 |
| Total R&D Investment (CNY bn) | 31.68 | 34.19 | 37.79 |

Source: Baosteel Corporation's 2022-2024 Annual Report

Table 2 Analysis of Profitability Factors of Wanhua

| Wanhua Chemical | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1655.65 | 1753.61 | 1820.69 |
| Net Profit Attributable to Parent (CNY bn) | 162.34 | 168.16 | 130.33 |
| Weighted Average ROE (%) | 22.75 | 20.42 | 14.29 |
| Cash Flow from Operating Activities (CNY bn) | 363.40 | 268.00 | 300.50 |
| Total R&D Investment (CNY bn) | 34.20 | 40.81 | 45.50 |

Source: Wanhua Chemical's 2022-2024 Annual Report

As shown in Table 1, Baosteel's profitability declined continuously from 2022 to 2024 under cyclical industry pressure, yet its annual R&D expenditure maintained steady growth and reached CNY 3.779 billion in 2024. The firm took the lead in putting a million-ton hydrogen-based shaft furnace into operation at Zhanjiang base, realizing milestone zero-carbon metallurgy technological breakthroughs. Meanwhile, Baosteel built an industrial AI intelligent manufacturing platform to precisely control production energy consumption, achieving a 6.1% year-on-year decline in carbon emission intensity in 2024. It has maintained CDP Climate A- Leadership rating and ranked first in China's listed firms' dual-carbon evaluation for three consecutive years.

Table 2 reflects Wanhua Chemical's stable profitability resilience. Its 2024 R&D investment hit CNY 4.55 billion, maintaining a year-on-year growth rate over 11%. The enterprise relies on iterative optimization of core MDI and TDI production processes to reduce unit energy consumption, while deploying photovoltaic, offshore wind and nuclear power projects to expand green electricity supply. Wanhua independently realized the industrialization of POE and high-end new materials, opening up new low-carbon growth curves beyond traditional polyurethane business. Table 3 further sorts out the two firms' comprehensive ESG rating performance.

Table 3 ESG Rating Performance Analysis of Two Companies

| Company | Rating / Honor | 2022 | 2023 | 2024 |
|---|---|---|---|---|
| Baosteel | S&P CSA Rating | Unavailable | Top 5% globally in industry | Top 5% globally in industry |
| Baosteel | S&P / Moody's / Fitch Rating | A-/A2/A+ | A-/A2/A+ | A-/A2/A |
| Baosteel | Central SOE ESG Pioneer Index | Ranked 4th | Included | Included |
| Baosteel | China Listed Company Dual Carbon Leadership | Excellent (Ranked 1st) | Excellent (Ranked 1st) | Excellent (Ranked 1st) |
| Baosteel | CDP Climate Change Rating | Unavailable | Leadership level (A-) | Leadership level (A-) |
| Baosteel | Fortune World's Most Admired Companies | Included | Included (No.1 in Metals) | Unavailable |
| Wanhua Chemical | Global Top 50 Chemical Companies Ranking | 17th | 18th | 16th |
| Wanhua Chemical | Lianhe Credit Rating | AAA/Stable | AAA/Stable | AAA/Stable |
| Wanhua Chemical | China Listed Company Dual Carbon Leadership | Unavailable | Excellent (Ranked 1st) | Unavailable |
| Wanhua Chemical | Central SOE ESG Pioneer 100 Index | Unavailable | Four-and-a-half-star level | Unavailable |
| Wanhua Chemical | ESG Best Practice / Pioneer Award | Included | Included | Included |

Source: Baosteel, Wanhua Chemical's 2022-2024 Annual Report, ESG Report

### 4.3.2 Structural Reshaping Path

#### 4.3.2.1 Path Characteristics and Driving Mechanism

The structural reshaping path refers to fundamental strategic adjustment of corporate asset portfolios, which drastically reduces the proportion of high-carbon thermal power assets and expands large-scale zero-carbon wind and photovoltaic layout, realizing complete redefinition of enterprises' profit composition and market positioning.

Endogenous constraints include massive upfront capital expenditure, short-term asset impairment risks and talent structure adjustment pressure. Exogenous supporting conditions cover national new energy industrial policies, continuous cost reduction of wind-solar equipment and diversified green & transition bond financing channels. This path is the dominant transformation mode for large traditional power conglomerates.

#### 4.3.2.2 In-Depth Case Analysis: Datang Power Generation

Datang Power Generation is the typical sample of the structural reshaping path. Table 4 displays its financial performance from 2022 to 2024.

Table 4 Analysis of Profitability Factors of Datang

| Datang | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1168.28 | 1224.04 | 1234.73 |
| Net Profit Attributable to Parent (CNY bn) | -4.07 | 13.67 | 45.06 |
| Weighted Average ROE (%) | -6.21 | -1.03 | 10.44 |
| Cash Flow from Operating Activities (CNY bn) | 204.60 | 212.40 | 261.20 |

Source: Datang's 2022-2024 Annual Report

In 2022, surging coal prices caused Datang a net loss of CNY 407 million, but the enterprise still persisted in large-scale new energy investment. Driven by continuous asset layout adjustment, its net profit rebounded sharply to CNY 4.506 billion in 2024, with wind and photovoltaic sectors becoming core profit contributors. Table 5 lists its core ESG operational indicators.

Table 5 ESG Rating Performance Analysis of Datang

| Evaluation Dimension | 2022 | 2023 | 2024 |
|---|---|---|---|
| Clean Energy Installed Capacity (%) | 33.10 | 37.75 | 40.37 |
| Coal Consumption for Power Supply (g/kWh) | Unavailable | 294 | Unavailable |
| Ultra-low Emission Units Capacity (%) | Unavailable | 98.8 | Unavailable |
| Included in ESG Index | Unavailable | Central SOE ESG Pioneer 100 Index | Central SOE ESG Pioneer 100 Index |
| SSE Information Disclosure Rating | Unavailable | Unavailable | A rating |
| Listed Company Honor | Unavailable | Unavailable | Golden Bull Award "Golden Information Disclosure Award" |

Source: Datang's 2022-2024 Annual Report, ESG Report

From 2022 to 2024, Datang's clean energy installed capacity ratio rose from 33.10% to 40.37%. Meanwhile, the firm promoted the three linked transformations of energy-saving, flexibility and heating renovation for coal-fired units, balancing national energy supply stability and low-carbon asset upgrading. Digital intelligent inspection systems further reduced operational energy consumption, and the enterprise obtained Grade A information disclosure rating on the Shanghai Stock Exchange in 2024.

### 4.3.3 Value Chain Collaborative Path

#### 4.3.3.1 Path Characteristics and Driving Mechanism

The core feature of the value chain collaborative path is to extend the boundary of corporate ESG governance to upstream and downstream industrial chains, and realize systematic low-cost emission reduction via full-life-cycle

carbon footprint management, green supply chain assessment and industrial park circular symbiosis.

Endogenous advantages include integrated industrial layout and stable long-term operating cash flow. Exogenous incentives originate from ISSB and GRI Scope 3 disclosure mandatory requirements, downstream green procurement standards and national circular economy policy subsidies. Collaborative emission reduction can effectively lower the marginal decarbonization cost compared with independent enterprise technological renovation.

#### 4.3.3.2 In-Depth Case Analysis: Hualu Hengsheng, HBIS and Sinopec

Three enterprises from chemical, steel and full-chain energy industries are selected as samples of the value chain collaborative path. Table 6, Table 7 and Table 8 respectively present their profitability data.

Table 6 Analysis of Profitability Factors of Hualu

| Hualu | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 302.45 | 272.60 | 342.26 |
| Net Profit Attributable to Parent (CNY bn) | 62.89 | 35.76 | 39.03 |
| Weighted Average ROE (%) | 25.58 | 12.81 | 13.05 |
| Cash Flow from Operating Activities (CNY bn) | 69.99 | 47.15 | 49.68 |

Source: HBIS's 2022-2024 Annual Report

Table 7 Analysis of Profitability Factors of HBIS

| HBIS | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1434.70 | 1227.44 | 1216.17 |
| Net Profit Attributable to Parent (CNY bn) | 13.95 | 10.84 | 7.07 |
| Weighted Average ROE (%) | 2.64 | 1.72 | 0.93 |
| Cash Flow from Operating Activities (CNY bn) | 92.35 | 112.10 | 96.78 |

Source: HBIS's 2022-2024 Annual Report

Table 8 Analysis of Profitability Factors of Sinopec

| Sinopec | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 33181.00 | 32122.15 | 30745.62 |
| Net Profit Attributable to Parent (CNY bn) | 670.82 | 604.63 | 503.13 |
| Weighted Average ROE (%) | 8.57 | 7.59 | 6.19 |
| Cash Flow from Operating Activities (CNY bn) | 1163.00 | 1615.00 | 1494.00 |

Source: Sinopec's 2022-2024 Annual Report

Hualu Hengsheng relies on coal chemical flexible co-production platforms to build internal park material and energy circulation systems, maintaining an asset-liability ratio below 30% for a long time, and extends industrial chains to high-value new energy materials to reduce unit carbon intensity. HBIS raised the procurement proportion of top five strategic suppliers to 82.72% in 2024, and developed low-carbon automotive steel to realize downstream collaborative emission reduction. Sinopec owns a full oil-gas-chemical industrial chain, with 2024 operating cash flow reaching CNY 149.4 billion to support cross-industry low-carbon layout. Table 9 summarizes the three firms' ESG governance and rating conditions.

Table 9 ESG Rating Performance Analysis of Three Companies

| Evaluation Dimension | Hualu Hengsheng | HBIS | Sinopec |
|---|---|---|---|
| ESG Report Disclosure | Continuously published, available on parent company Hualu Holding's official website | 2023 ESG report disclosed simultaneously with annual report | Continuously publishes sustainability reports |
| ESG Rating (2024) | Industry leading level | Huazheng B, Wind BB | Mid-to-upper level among mainstream ratings |
| Governance Structure | Incorporated into parent Hualu Holding's ESG management system | Established ESG management structure at the board level | Established a Sustainable Development Committee |
| Information Disclosure Rating | Unavailable | SSE Information Disclosure A rating (2024) | Received A rating for many consecutive years |
| ESG Improvement Measures | Parent company set up an ESG report section, subsidiaries disclose on an annual basis | Starting from 2024, preparing more detailed ESG reports and disclosing simultaneously with annual reports | First time developing a market value management system, incorporating ESG considerations |

Source: Hualu Hengsheng, HBIS, Sinopec's 2022-2024 Annual Report, ESG Report

### 4.3.4 Compliance-Oriented Path

#### 4.3.4.1 Path Characteristics and Driving Mechanism

The compliance-oriented path takes meeting regulatory carbon market settlement and stock exchange ESG disclosure rules as primary objectives. Enterprises under this path focus on constructing standardized carbon accounting ledgers and perfecting ESG reporting systems, and adopt low-risk, short payback-period energy-saving renovation as major transformation measures.

External rigid constraints include carbon quota compulsory fulfillment and listed firms' disclosure supervision requirements. Internal characteristics include limited R&D budget, fluctuating profitability and incomplete long-term low-carbon strategic layout, which makes this path the mainstream starting mode for most local state-owned high-emission enterprises.

#### 4.3.4.2 In-Depth Case Analysis: Valin Steel, GD Power, Huaneng International

Valin Steel, GD Power and Huaneng International are three compliance-oriented sample enterprises. Table 10, 11, 12 list their financial indicators respectively.

Table 10 Analysis of Profitability Factors of Valin

| Valin | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1686.36 | 1644.65 | 1446.84 |
| Net Profit Attributable to Parent (CNY bn) | 63.78 | 50.78 | 20.31 |
| Weighted Average ROE (%) | 13.42 | 9.87 | 3.81 |
| Cash Flow from Operating Activities (CNY bn) | 94.57 | 52.73 | 57.78 |

Source: Valin Steel's 2022-2024 Annual Report

Table 11 Analysis of Profitability Factors of Guodian

| Guodian | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 1946.74 | 1809.98 | 1791.82 |
| Net Profit Attributable to Parent (CNY bn) | 28.21 | 56.08 | 98.31 |
| Weighted Average ROE (%) | 6.07 | 11.83 | 18.59 |
| Cash Flow from Operating Activities (CNY bn) | 377.40 | 425.80 | 556.40 |

Source: Guodian Electric Power's 2022-2024 Annual Report

Table 12 Analysis of Profitability Factors of Huaneng

| Huaneng | 2022 | 2023 | 2024 |
|---|---|---|---|
| Revenue (CNY bn) | 2467.24 | 2543.96 | 2455.50 |
| Net Profit Attributable to Parent (CNY bn) | -73.87 | 84.45 | 101.35 |
| Weighted Average ROE (%) | -18.50 | 11.25 | 13.14 |
| Cash Flow from Operating Activities (CNY bn) | 325.20 | 455.00 | 505.30 |

Source: Huaneng International's 2022-2024 Annual Report

Valin Steel released its first complete sustainability report in 2024 in response to Shenzhen Stock Exchange rules, and adjusted the board committee structure to add ESG management functions. GD Power maintained stable profit growth year by year, continuously optimizing standardized ESG disclosure mechanisms and retaining Grade A disclosure rating. Huaneng International, as the world's first issuer of transition bonds, complies with

dual A+H listing disclosure rules, and translates compliance advantages into low-cost green financing channels. Table 13 compares their ESG governance performances.

Table 13 ESG Rating Performance Analysis of Three Companies

| Evaluation Dimension | Valin Steel | GD Power | Huaneng Power International |
|---|---|---|---|
| ESG Report Disclosure | 5th annual sustainability report (released in 2024) | Continuously published social responsibility reports for many years | Continuously publishes sustainability reports |
| Governance Structure | Plans to rename the original Strategy Committee to Strategy and ESG Committee, no longer setting up a Supervisory Board | Established ESG management structure at the board level | Established a Sustainable Development Committee |
| ESG Rating | Ongoing progress | Mid-to-upper level within the industry | Mid-to-upper level among mainstream ratings |
| Information Disclosure Rating | SSE A rating (2024) | Continuously standardizes disclosure | Received A rating for many consecutive years |
| Regulatory Compliance Response | Starting from 2024, preparing more detailed ESG reports and disclosing simultaneously with annual reports | Responds to regulatory requirements such as HKEX | World's first transition bond issuer |

Source: Valin Steel, GD Power, Huaneng Power's 2022-2024 Annual Report, ESG Report

### 4.4 Cross-Case Comparative Analysis and Evolution Logic of Transformation Paths

The four transformation paths summarized in this paper are not mutually exclusive alternatives, but present clear progressive evolutionary relationships from basic to advanced levels. The compliance-oriented path is the essential foundation for all high-emission enterprises' ESG construction, completing standardized institutional frameworks and information disclosure systems. The value chain collaborative path represents the advanced evolution of compliance management, which reduces overall transformation costs through industrial upstream and downstream synergy. The structural reshaping path belongs to deep strategic adjustment via large-scale asset portfolio optimization. The technology breakthrough path is the top-tier transformation mode relying on proprietary low-carbon innovation to form irreplaceable industrial competitive barriers.

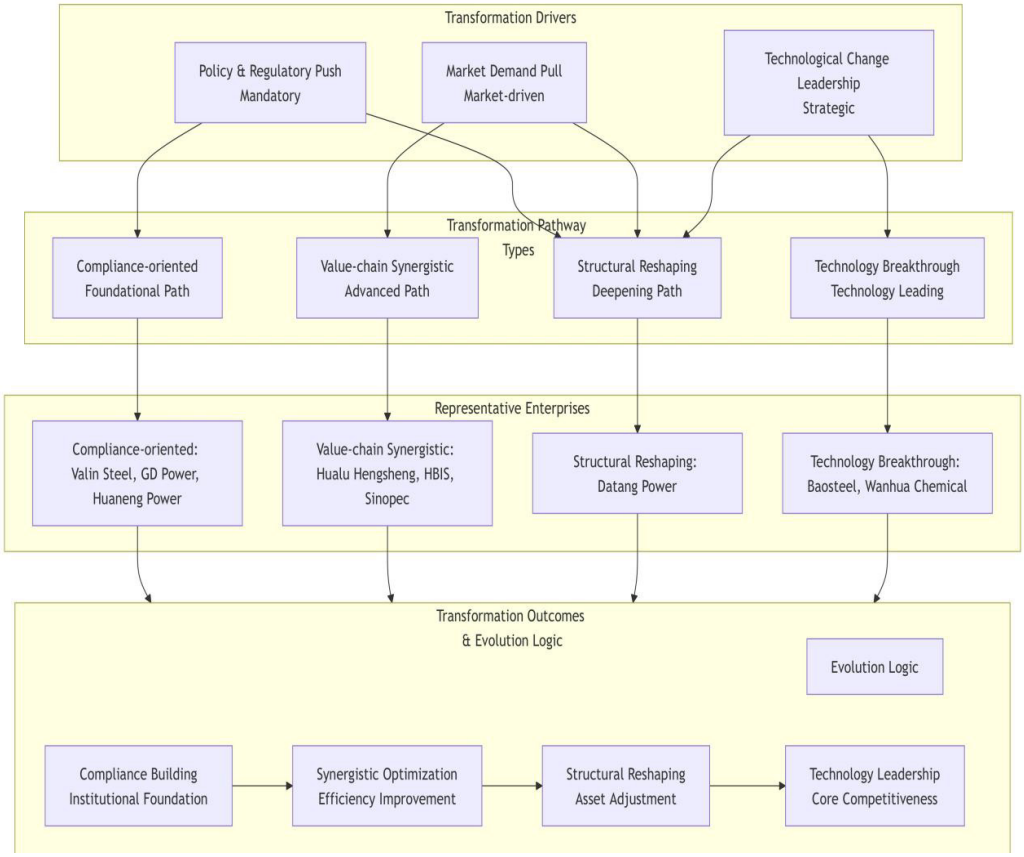


Figure 1 ESG Transformation Path Map

Industrial heterogeneity determines differentiated path matching rules. Steel and chemical industry leaders with sufficient R&D capacity tend to choose the technology breakthrough path, while mid-sized firms adopt value chain synergy strategies. Power enterprises generally take structural asset reshaping as the core transformation direction matched with compliance governance construction. Local small and medium high-emission enterprises with limited financial resources mostly start with the compliance-oriented path. In actual operational practice, most enterprises adopt mixed multi-path layouts with one dominant transformation mode.

## 5 Design of Differentiated ESG Strategic Systems Based on Transformation Paths

### 5.1 Four Core Strategic Dimensions

#### 5.1.1 Technological Innovation Strategy

Enterprises following different transformation paths hold differentiated technological investment priorities. Technology breakthrough firms need to maintain persistent high R&D intensity, carry out parallel layout of multiple low-carbon technical routes, and build industry-university-research collaborative platforms to disperse innovation risks, focusing on hydrogen metallurgy, CCUS and high-end green new material industrialization.

Structural reshaping power enterprises' technological investment concentrates on mature wind-solar storage equipment and coal-fired unit flexibility transformation, reducing trial-and-error costs of unproven cutting-edge technologies. Value chain collaborative firms prioritize park circulation technology and upstream-downstream coupled process renovation, sharing R&D expenditure via industrial alliance cooperation. Compliance-oriented enterprises only deploy mature short

payback-period energy-saving equipment to accumulate transformation funds before investing in disruptive low-carbon technologies.

**5.1.2 Corporate Governance and Organizational Change Strategy**

Governance mechanism design must match enterprises' dominant transformation path. Technology breakthrough firms establish independent R&D-ESG special committees, formulate long-term innovation incentive mechanisms, and bind executive compensation indicators with carbon intensity reduction and low-carbon patent output.

Structural reshaping enterprises build exclusive new energy investment decision groups and standardized high-carbon asset impairment evaluation systems to balance traditional thermal power and clean energy layout. Value chain collaborative enterprises extend ESG assessment mechanisms to supplier management, setting joint low-carbon working groups with upstream and downstream partners. Compliance-oriented enterprises prioritize perfecting board ESG functional departments and internal carbon accounting control procedures to fully satisfy regulatory bottom-line disclosure requirements.

**5.1.3 Information Disclosure and Stakeholder Communication Strategy**

Disclosure focus varies significantly among four types of enterprises. Technology breakthrough firms take quantified low-carbon patent data and demonstration project emission reduction effects as core disclosure content to convey long-term technical moat value to capital market investors.

Structural reshaping enterprises focus on releasing clean energy installed capacity proportion and new energy profit contribution indicators to display asset low-carbon optimization progress. Value chain collaborative enterprises emphasize full-life-cycle carbon footprint and supplier ESG assessment data to meet international standard Scope 3 disclosure demands. Compliance-oriented enterprises standardize all mandatory disclosure indicators first, and gradually add forward-looking carbon neutrality targets on the basis of meeting stock exchange supervision rules.

**5.1.4 Stakeholder Collaboration Strategy**

Stakeholder cooperation layouts correspond to transformation characteristics. Technology breakthrough enterprises cooperate with universities and research institutes to build joint low-carbon laboratories and share innovation costs. Structural reshaping power firms deepen coordination with local governments and green financial institutions to obtain new energy land and credit support. Value chain collaborative enterprises implement green supplier rating systems and jointly develop low-carbon products with downstream clients to build industrial sustainable alliances. Compliance-oriented enterprises maintain regular communication with regulators and institutional investors to mitigate climate compliance risks.

**5.2 Differentiated Strategic Combinations for Four Paths**

This study establishes four differentiated matched strategic portfolios corresponding to the four categorized corporate ESG transformation pathways derived from multi-case evidence, with clear scope of application delineated for each set of integrated strategies:

Technology breakthrough strategic portfolio: Composed of sustained high-intensity research and development input, R&D-centric ESG governance architecture, targeted disclosure of low-carbon technological achievements, and industry-university-research collaborative innovation mechanisms. This portfolio is designed for profitable industrial frontrunners that aim to build long-term differentiated green competitive moats via proprietary

decarbonization technologies.

Asset structural reshaping strategic portfolio: Integrated with large-scale investment in zero-carbon clean assets, dual-track risk governance covering both high-carbon legacy and emerging green assets, disclosure frameworks centering on energy mix metrics, and multi-stakeholder coordination with administrative authorities and financial intermediaries. It targets large incumbent energy conglomerates engaged in systematic asset portfolio decarbonization.

Value chain collaborative strategic portfolio: Incorporates industrial park circular economy retrofits, full-spectrum ESG oversight covering upstream and downstream supply chains, enterprise-wide full life-cycle carbon disclosure systems, and cross-factory synergy via industrial alliances. The strategic suite fits integrated steel and chemical enterprises possessing complete vertical industrial layouts.

Compliance-driven strategic portfolio: Centered on low-capital energy-saving technical renovations, standardized internal ESG control procedures, fundamental regulatory-mandated information disclosure, and routine communication mechanisms with institutional investors and industry regulators. This set of strategies applies to local state-owned enterprises constrained by insufficient financial resources that remain at the preliminary stage of low-carbon transition.

## 6 Conclusions and Implications

### 6.1 Main Research Conclusions

First, four typical categorized ESG transformation paths exist for domestic high-emission enterprises under dual-carbon constraints, namely technology breakthrough, structural reshaping, value chain collaboration and compliance orientation. The four paths follow a progressive development sequence, and enterprises' dominant transformation choice is jointly determined by industrial attributes, profitability and internal resource endowments.

Second, stable operating cash flow and sustained profitability constitute the fundamental financial foundation supporting all transformation modes. Technology breakthrough requires long-cycle continuous R&D expenditure; structural reshaping demands massive upfront new energy capital outlay; value chain synergy and compliance governance both rely on persistent environmental protection investment, and profit volatility will directly restrict enterprises' transformation depth.

Third, a positive feedback loop exists between ESG transformation performance and capital market feedback. Complete standardized low-carbon layout and high-quality information disclosure can lift corporate ESG ratings and reduce green financing costs, providing continuous financial support for subsequent low-carbon investment.

Fourth, industrial heterogeneity generates path differentiation effects. Power enterprises mainly adopt structural asset adjustment strategies; steel and chemical industrial leaders choose technological breakthrough paths, while mid-sized enterprises rely on industrial chain synergy; local small high-emission enterprises start transformation from compliance construction.

### 6.2 Theoretical Contributions

This paper integrates institutional theory and the resource-based view to construct the unified "dual carbon pressure-enterprise capability-ESG response" analytical framework, clarifying the interactive mechanism between external carbon regulatory pressure and enterprises' heterogeneous internal resources. Based on cross-industry multi-case comparative analysis, this study systematically distinguishes the characteristics, driving logic and applicable boundaries of four transformation paths, making

up for the research defects of single-industry and single-case literature, and expands the application scope of corporate sustainable governance theory under carbon neutrality targets.

**6.3 Practical Implications**

High-emission enterprises should abandon unified one-size-fits-all transformation templates and select matching dominant paths according to industrial positioning, R&D reserves and financial status. Industrial leaders with abundant funds can take the initiative to deploy forward-looking low-carbon technologies; large energy groups focus on clean asset substitution layout; integrated chain enterprises promote upstream-downstream collaborative emission reduction; profit-limited local enterprises prioritize compliance disclosure and short-cycle energy-saving renovation. All firms should establish long-term low-carbon investment budgets to balance short-term transformation costs and long-term green value appreciation.

From a policy design perspective, regulatory authorities should formulate differentiated industrial green policy portfolios tailored to the four categorized ESG transformation pathways identified in this research. Specifically, targeted R&D tax deductions and special subsidies for low-carbon demonstration projects shall be implemented for enterprises adopting the technology breakthrough path. For energy conglomerates pursuing asset structural reshaping, authorities may scale up the supply of green bonds and transitional credit facilities to ease capital expenditure pressures. For firms relying on industrial chain collaborative decarbonization, policymakers can support the construction of circular economy industrial zones and launch standardized green supply chain incentive frameworks. For local state-owned enterprises at the compliance-oriented transformation stage, systematic training programmes on carbon accounting specifications and normative ESG disclosure guidelines should be rolled out. Such tiered policy arrangements can eliminate one-size-fits-all rigid carbon emission reduction mandates imposed indiscriminately across all high-carbon industrial sectors.

**References**

[1] CUI X T. The Evolution and Future Trajectory of China's ESG Disclosure System[J]. Global Academic Frontiers, 2025, 3(2): 225-256.

[2] BAUMÜLLER J. IFRS Sustainability Disclosure Standards (ISSB)[J]. Zeitschrift für Corporate Governance, 2023(3): 132-137.

[3] TEIXEIRA S J. Comparative Research on GRI and ISSB Sustainable Reporting Standards[J]. International Journal of Current Science Research and Review, 2025, 8(10).

[4] SRESELI N, SRESELI R. Integration of Sustainability Reporting and IFRS[R]. Working Paper, 2024.

[5] POTHARLA S. Global Adoption and Implementation Effect of IFRS Standards[EB/OL]. SSRN Electronic Library, 2025.

[6] DONG C, DONG X C, JIANG Q Z, et al. ESG Rating Divergence, Financing Constraints and Corporate Green Innovation[J]. Chinese Journal of Population, Resources and Environment, 2024, 34(8): 103-113.

[7] DONG Y A, ZHAN J Y, PENG Y. The Influence of Executives' Green Cognition on ESG Rating Difference[J]. Journal of Guizhou University of Finance and Economics, 2025(3): 94-101.

[8] XU Z Y. Environmental Information Disclosure and Low-Carbon Transformation of Power Enterprises Under Dual-Carbon Goals[J]. Modern Management, 2025(15): 187-193.

[9] BLAGOVA I, ROMANISHINA T, KUSHELEV I, et al. ESG Transformation as Climate Risk Mitigation Tool[C]// E3S Web of Conferences. EDP Sciences, 2024, 548: 01006.

[10] ZHAO L L. Research on Green Transformation Paths of Chemical Enterprises Under Dual-Carbon Constraints[J]. Frontiers of Engineering Technology, 2025(1): 45-51.

[11] WU J Y. Coupling Relationship Between ESG Performance and High-Quality Development of Steel

Industry[J]. Management Science and Engineering, 2023, 12: 485-492.

[12] WANG J, FU Z S, YANG X L. Low-Carbon Development Path of Steel Industry Under Dual-Carbon Targets[J]. Metal World, 2025(1): 25-28.

[13] WANG X D, SHANGGUAN F Q, TIAN J L. Full-Process Low-Carbon Technology Routes for Steel Enterprises[J]. Journal of Engineering Science, 2023, 45(5): 853-862.

[14] CUI Z F, XU A J. Comparative Analysis of Deep Decarbonization Strategies in Global Steel Industry[J]. Journal of Engineering Science, 2022, 44(9): 1496-1506.

[15] XIE W Y. Construction of ESG Performance Evaluation System for Petrochemical Enterprises Based on AHP[J]. Frontiers of Economic Management, 2025(1): 33-39.

[16] ZHANG Y. Dynamic Evolution Game of Corporate Low-Carbon Transformation Under Carbon Tax Policy[R]. Industrial Economic Research Report, 2023.

[17] GONG Z X. Financial Risk Identification of Traditional Energy Enterprises Under Dual-Carbon Constraints: Evidence from Sinopec[J]. Modern Management, 2025(15): 228-232.

[18] ZHANG Y Z, ZHANG N, WU X Y. Coordination Model of Electricity-Hydrogen-Carbon for New Power Systems[J]. China Electric Power, 2021, 54(1): 1-8.

[19] LI X. Green Transformation Performance Evaluation of Huaneng Power[J]. Asia Pacific Economic and Management Review, 2025, 2(5).

[20] LAI E, WANG S. Mechanism Effect of Carbon Emission Trading on Transformation of High-Energy-Consuming Enterprises[J]. Asia Pacific Economic and Management Review, 2025, 2(6).

[21] ZHOU Z, MA Z, LIN X. Carbon Pilot Policy and Green Total Factor Productivity of Manufacturing Enterprises[J]. Frontiers in Environmental Science, 2022, 10: 984612.

[22] RAU P R, YU T. A Comprehensive Literature Review on Corporate ESG Research[J]. China Finance Review International, 2024, 14(1): 3-33.

[23] HENISZ W, KOLLER T, NUTTALL R. Five Ways ESG Creates Corporate Value[J]. McKinsey Quarterly, 2019(4): 1-12.

[24] SONG Z. Transformation Efficiency Evaluation of High-Carbon Manufacturing Industry[J]. Journal of International Relations and Regional Development, 2025(1).

[25] LI T T, WANG K, SUEYOSHI T, et al. Board Diversity, ESG Incentives and Corporate Environmental Performance[J]. Sustainability, 2021, 13(21): 11663.

**Author Biographies:**

Yancheng LIN, Master of Accountancy, Faculty of- Business, Lingnan University.

Shanshan SHI, Corresponding author, Faculty of Business, Lingnan University, Research Interests: PRC International Taxation; Taxation and Tax Planning; Taxation for Digital Economy; Transfer Pricing; Corporate Governance; ESG and Sustainability.