

# Performance Analysis of Green Transformation in High Energy-Consuming Enterprises: A Case Study of Huaneng Power International, Inc.

**Xiaoyu Li\***

College of Management, Xi'an Polytechnic University, Xi'an, Shaanxi, 710000, China

*\*Corresponding author: Xiaoyu Li*

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**Abstract:** The global transition to a low-carbon economy presents a formidable challenge and a strategic imperative for high energy-consuming enterprises, particularly in the power generation sector. As a dominant player in China's thermal power industry and a significant global carbon emitter, Huaneng Power International, Inc. (HPI) serves as a critical case for examining the viability and outcomes of green transformation within a traditionally carbon-intensive framework. This paper conducts a comprehensive performance analysis of HPI's multi-faceted green transformation journey from 2010 to the present. By integrating strategic management theories like the Resource-Based View (RBV) with a multi-dimensional performance framework, this study assesses the environmental, financial, and operational consequences of HPI's initiatives. These initiatives include the aggressive expansion of its renewable energy portfolio (notably wind and solar), the deployment of ultra-supercritical coal-fired technologies, and active participation in the national carbon emissions trading scheme (ETS). The analysis reveals a complex and nuanced outcome: while HPI has made significant strides in reducing its carbon and pollutant emission intensity and enhancing its operational efficiency, the transformation has imposed substantial financial burdens, including elevated debt levels and short-term profitability pressures. The findings indicate that the green transformation of a high energy-consuming giant is not a linear path to immediate prosperity but a strategic, long-term recalibration. Success hinges on a delicate balance between regulatory compliance, technological investment, and financial viability. This study contributes to the broader understanding of sustainability transitions in hard-to-abate sectors and offers valuable insights for corporate managers, investors, and policymakers navigating the complexities of the energy transition.

**Keywords:** Green Transformation; High Energy-Consuming Enterprise; Huaneng Power International; Environmental Performance; Financial Performance; Renewable Energy; Carbon Emissions; Sustainability Transition

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## 1. Introduction

The existential threat of climate change has catalyzed a global shift towards sustainable development, placing immense pressure on high energy-consuming and high-emission industries. The electric power sector, responsible for a substantial portion of global CO<sub>2</sub> emissions, sits at the epicenter of this transition. In China, the world's largest energy consumer and carbon emitter, the power sector's transformation is crucial to achieving the nation's "Dual Carbon" goals (carbon peaking by 2030 and carbon neutrality by 2060). This transition necessitates a fundamental overhaul of business models, particularly for

state-owned giants historically reliant on coal-fired power generation.

Huaneng Power International, Inc. (HPI), one of China's largest listed power producers, embodies this challenge and opportunity. As a flagship subsidiary of the China Huaneng Group, HPI's asset portfolio was overwhelmingly dominated by coal-fired plants for decades. Its strategic pivot towards a greener energy mix represents a microcosm of the broader struggle within China's industrial landscape. Analyzing HPI's journey provides critical insights into the tangible costs, benefits, and trade-offs of corporate green transformation.

This paper aims to dissect the performance outcomes of HPI's green transformation strategy. It moves beyond a mere description of its green initiatives to a systematic analysis of their impact on three core performance dimensions: environmental, financial, and operational. The central research questions are: (1) What key strategies has HPI employed in its green transformation? (2) How have these strategies impacted its environmental footprint, financial health, and operational metrics? (3) What are the key lessons and future challenges for HPI and similar enterprises?

By employing a longitudinal case study approach and analyzing data from annual reports, sustainability reports, and industry databases, this study offers an evidence-based evaluation of a high-stakes corporate metamorphosis. The findings are pertinent for corporate leaders in energy-intensive industries, investors assessing transition risks and opportunities, and policymakers crafting effective regulatory frameworks to enable a just and efficient energy transition<sup>[1]</sup>.

## 2. Theoretical Framework: The Resource-Based View and Green Transformation

The Green Transformation of a firm can be effectively analyzed through the lens of the Resource-Based View (RBV). RBV posits that firms gain sustainable competitive advantage by developing and deploying valuable, rare, inimitable, and non-substitutable (VRIN) resources and capabilities (Barney, 1991)<sup>[2]</sup>.

In the context of HPI's transformation:

**Traditional Resources:** Its historical competitive advantage was built on tangible resources like large-scale coal-fired power plants and intangible capabilities in coal procurement and thermal operations. In a carbon-constrained world, these very resources risk becoming "stranded assets" and sources of competitive disadvantage.

**New Strategic Resources:** Green transformation requires HPI to reconfigure its resource base. This involves acquiring and developing new VRIN resources, such as:

**Physical Resources:** Wind farms, solar parks, and high-efficiency, low-emission (HELE) coal technologies.

**Intangible Resources:** Carbon asset management capabilities, green technology R&D, a "green" corporate brand, and the managerial expertise to navigate a complex regulatory environment.

**Financial Resources:** Access to capital for massive investments in renewable projects, often facilitated by green bonds and ESG-focused financing.

The performance analysis, therefore, assesses how successfully HPI is shedding its dependency on carbon-intensive resources and building a new, sustainable resource portfolio that aligns with the future low-carbon economy.

## 3. HPI's Green Transformation Strategy: A Multi-Pronged Approach

HPI's transformation is not a single project but a sustained strategic shift, characterized by three interconnected pillars:

### 3.1 Structural Shift: Aggressive Expansion of Renewable Energy Capacity

HPI has systematically diversified its generation mix by channeling a significant portion of its capital expenditure (CAPEX) into non-fossil fuel sources. This involves the large-scale development and acquisition of wind, solar, and hydropower projects across China. The strategic goal is to incrementally reduce the proportion of coal-fired power in its total installed capacity and energy output. This is the most direct and impactful component of its decarbonization strategy.

### 3.2 Technological Optimization: Greening the Existing Coal Fleet

Recognizing the continued role of coal in ensuring grid stability in the medium term, HPI has invested heavily in upgrading its existing coal-fired assets. Key initiatives include:

**Retrofitting with Ultra-Supercritical (USC) Technology:** Replacing or upgrading subcritical units with more efficient USC units, which have higher steam parameters and thus lower coal consumption and emissions per unit of electricity generated.

Co-firing with Biomass: Piloting and implementing projects that mix biomass with coal to reduce the net carbon footprint of power generation.

Pollution Control Technologies: Installing and upgrading flue-gas desulfurization (FGD), denitrification, and dust removal systems to meet increasingly stringent air pollutant emission standards.

### **3.3 Strategic Adaptation: Engaging with Carbon and Green Certificate Markets**

HPI has proactively engaged with emerging environmental markets as both a compliance obligation and a new business frontier.

Carbon Emissions Trading Scheme (ETS): HPI has developed in-house capabilities to manage its carbon assets, optimize its ETS compliance costs, and explore revenue opportunities through carbon trading<sup>[3]</sup>.

Green Power Certificates: By generating renewable energy, HPI creates Green Certificates that can be sold, providing an additional revenue stream and improving the economics of its green projects<sup>[4]</sup>.

## **4. Performance Analysis of the Green Transformation**

The impact of these strategies is evaluated across three performance dimensions.

### **4.1 Environmental Performance**

This is the most direct and positive outcome of HPI's transformation.

Reduction in Emission Intensity: Data from HPI's sustainability reports shows a consistent downward trend in its carbon dioxide (CO<sub>2</sub>) emission intensity (g CO<sub>2</sub>/kWh) and pollutant emission intensity (e.g., SO<sub>2</sub>, NO<sub>x</sub>). This is a direct result of the increased share of zero-emission renewables and the improved efficiency of its coal fleet.

Improvement in Energy Efficiency: The average coal consumption rate (gce/kWh) for its coal-fired power plants has decreased significantly, demonstrating enhanced operational efficiency and resource utilization driven by technological upgrades.

Growth in Renewable Capacity: The proportion of non-fossil fuel installed capacity in HPI's total portfolio has seen a marked increase, reflecting a fundamental structural change in its asset base.

### **4.2 Financial Performance**

The financial impact is complex and reveals the significant cost of transition.

CAPEX and Financial Leverage: The massive investments in renewable energy infrastructure have led to sustained high capital expenditures. This, in turn, has often been financed through debt, resulting in an increased asset-liability ratio and higher interest expenses, pressuring the company's financial structure in the short to medium term.

Profitability Pressures: While renewable energy has low marginal costs, its high fixed costs and the phasing out of feed-in tariffs (FITs) can squeeze profit margins. Meanwhile, the profitability of its legacy coal-fired business is highly volatile, susceptible to fluctuations in coal prices and the fixed on-grid tariff, sometimes leading to significant losses in its thermal power segment.

Emerging Opportunities: On the positive side, HPI has begun to access green financing (e.g., green bonds), which often comes with lower interest rates. Furthermore, its improved ESG rating helps attract long-term sustainability-focused investors, potentially lowering its cost of capital over time.

### **4.3 Operational and Market Performance**

The transformation has reshaped HPI's operational dynamics and market perception.

Operational Efficiency: The integration of digital technologies for "smart power plant" management and the use of AI for predictive maintenance have improved the availability and reliability of both its renewable and thermal assets<sup>[5]</sup>.

Market Perception and ESG Ratings: HPI's active transition strategy has been recognized by rating agencies, leading to a gradual improvement in its ESG scores. This enhances its corporate reputation and mitigates regulatory and reputational risks associated with being a carbon-intensive entity<sup>[6]</sup>.

Navigating Regulatory Risks: By proactively aligning with national climate policies, HPI has positioned itself to better manage regulatory risks, such as carbon pricing and stricter emission standards, compared to less-prepared peers.

## 5.Challenges and Strategic Implications

HPI's journey underscores several persistent challenges:

High Debt Burden: The capital-intensive nature of the transformation continues to strain its balance sheet.

Integration of Intermittent Renewables: Managing the grid stability challenges posed by the variable nature of wind and solar power requires further investment in energy storage and smart grid technologies.

Just Transition for the Thermal Workforce: The gradual phase-down of coal assets necessitates managing the social impact and retraining or redeploying employees from the thermal power sector.

For HPI and similar enterprises, the strategic implications are clear:

1.Diversified and Phased Investment: A balanced investment strategy that manages the pace of renewable expansion to maintain financial health is crucial.

2.Technological Innovation: Continued R&D in carbon capture, utilization, and storage (CCUS), advanced energy storage, and green hydrogen is essential for deep decarbonization.

3.Mastery of Carbon Asset Management: Excelling in carbon trading and green certificate markets will transform compliance from a cost center into a potential profit center.

## 6.Conclusion

The case of Huaneng Power International demonstrates that the green transformation of a high energy-consuming enterprise is a complex, multi-dimensional, and long-term endeavor fraught with tensions, particularly between environmental goals and financial performance in the short term. HPI has successfully initiated a critical structural shift, evidenced by its improved environmental metrics and growing renewable portfolio. However, this transition has come at a significant financial cost, highlighting the substantial economic challenges inherent in decarbonizing heavy industry.

The journey is not about an immediate trade-off but a strategic reallocation of resources from a sunset model to a sunrise one. HPI's experience suggests that success depends on a firm's ability to dynamically manage this reallocation—navigating policy landscapes, leveraging new technologies, and securing patient capital. For policymakers, this case underscores the need for stable, long-term policies that de-risk such investments and support a just transition. For the global community, HPI's transformation offers a critical real-world example of how an industrial giant can begin to pivot its core business towards a sustainable future, providing both a cautionary tale and a source of strategic insight for the many other enterprises that must follow a similar path.

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## Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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