

THE IMPACT OF GREEN INNOVATION STRATEGY ON COMPETITIVE ADVANTAGE IN THE NEW ENERGY INDUSTRY: THE MEDIATING ROLE OF RESOURCE EFFICIENCY

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Abstract: This study offers valuable insights into the role of green innovation strategies in fostering competitive advantage in the new energy industry, with resource efficiency serving as a key mediating mechanism. While prior research has often emphasized the direct outcomes of green innovation, few studies have explored how green innovation strategies -through technological, process, product, and sustainable business model innovation-enhances operational efficiency and strategic positioning. In response to mounting environmental pressures and industrial transformation, this study develops a comprehensive model grounded in Resource-Based Theory and the theory of competitive advantage to examine the indirect and direct effects of green innovation strategies on competitive advantage. Based on survey data from 455 Chinese new energy firms, structural equation modeling using SPSS and AMOS reveals that green innovation strategies significantly improves RE, which in turn reinforces a firm's competitive advantage. Furthermore, green innovation strategy also exerts a direct impact on competitive advantage, with resource efficiency acting as a partial mediator. These findings underscore the strategic value of green innovation strategy not only as a sustainability measure but also as a driver of long-term business performance through resource optimization.

Keywords: Green Innovation Strategy, Resource Efficiency, Competitive Advantage, New Energy Industry, Structural Equation Modeling

Introduction

As the global shift toward sustainable energy accelerates, firms in the new energy sector-including solar, wind, hydrogen, battery storage, and EV infrastructure-face mounting pressure to align innovation with environmental goals. In this context, green innovation strategies (GIS) have become essential for achieving both sustainability and competitive advantage (Liao & Liu, 2021; Qiu et al., 2020). GIS integrates technological, process, product, and business model innovations aimed at minimizing environmental impact, improving efficiency, and enhancing product differentiation (Wang et al., 2021). Given rising resource constraints and growing stakeholder expectations, GIS plays a vital

role in securing long-term value and resilience (Orazalin, 2020). Although research links GIS to improved firm performance (Shahzad et al., 2020), the mechanisms behind this relationship remain underexplored. In particular, the role of resource efficiency (RE)-the ability to optimize energy and material use, reduce waste, and streamline operations—has not been fully addressed. RE offers a tangible path through which GIS can deliver strategic outcomes, particularly in capital-intensive sectors like new energy (Demirel & Kesidou, 2019). However, most studies focus on single innovation types and rarely consider their combined impact through the lens of resource utilization.

To fill this gap, this study proposes an integrated model examining how GIS-across four innovation dimensions-affects competitive advantage, with RE as a mediator. Competitive advantage is defined in terms of market differentiation, cost leadership, revenue growth, and stakeholder trust. Using survey data from 545 Chinese new energy firms and structural equation modeling, this study explores how sustainability-driven strategies lead to strategic gains. The findings contribute to both academic understanding and practical insights for firms navigating environmentally sensitive, innovation-driven markets.

Research Objectives

1. To examine the effect of green innovation strategy on the competitive advantage of firms in the new energy industry.
2. To examine the effect of green innovation strategy on firms' resource efficiency.
3. To examine the effect of resource efficiency on the competitive advantage of firms in the new energy industry.
4. To examine the mediating role of resource efficiency in the relationship between green innovation strategy and competitive advantage.

Literature Review

Theory of Competitive Advantage and Resource-Based Theory

The theory of competitive advantage suggests that firms can outperform competitors by offering superior value through differentiation or achieving cost leadership through operational efficiency. In the new energy industry, green innovation strategies (GIS) support both approaches by enabling firms to develop eco-friendly technologies, improve processes, and implement sustainable business models, thus enhancing customer loyalty and market differentiation (Wang et al., 2021). GIS also helps firms meet regulatory demands, reduce environmental impact, and capitalize on opportunities in rapidly evolving sectors like solar, wind, hydrogen, and battery storage (Qiu et al., 2020). Complementing this, the Resource-Based Theory (RBT) argues that sustained competitive advantage arises from valuable, rare, inimitable, and non-substitutable resources, with GIS serving as such a resource. Resource efficiency -the optimization of energy, materials, and processes to minimize waste

and costs-plays a key role in this framework, acting as a mediator through which GIS enhances competitive advantage by improving both economic and environmental outcomes (Zameer et al., 2020).

Green Innovation Strategies

Green innovation strategies (GIS) have become essential in sustainability-driven industries, particularly in the new energy sector. Although widely discussed in the literature, GIS remains a broad concept encompassing environmentally conscious innovations aimed at minimizing ecological harm while improving firm performance. These innovations may include new or enhanced technologies, processes, products, and business models designed to reduce pollution, optimize resource use, and promote environmental sustainability (Rahman, 2023). GIS often overlaps with terms like environmental innovation, eco-innovation, and sustainable innovation, all driven by regulatory pressure, market demands, and stakeholder expectations (Le, 2022; Shahzad et al., 2020). In practice, GIS involves activities such as energy-efficient production, sustainable product design, eco-friendly materials, waste reduction, and the adoption of circular economy principles, particularly relevant in the new energy sector where innovation is central to addressing climate challenges (Demirel & Kesidou, 2019).

In this study, GIS is conceptualized as a multidimensional construct, incorporating technological, process, product, and business model innovations, aligning with prior frameworks. This framework enables a comprehensive analysis of how different forms of innovation contribute to firm outcomes. Notably, the effectiveness of GIS often depends on its integration with resource efficiency-the optimized use of energy, materials, and operational capacity. Efficient resource utilization not only reduces costs but also enhances a firm's environmental credibility and long-term competitiveness (Zameer et al., 2020). This study aims to address the gap in the literature by exploring how GIS, through its various dimensions, influences competitive advantage, both directly and indirectly, through resource efficiency, using empirical data from firms in the new energy sector.

Green Innovation Strategy and Green Innovative Competitive Advantage (GICA)

Green Innovative Competitive Advantage (GICA) reflects a firm's ability to achieve superior performance through environmentally driven innovation initiatives. According to the resource-based theory (RBT), organizations that effectively develop and deploy internal capabilities-such as green technologies and sustainable processes-can build long-term competitive advantage (Zameer et al., 2020). Green innovation strategies (GIS), including process, product, and service innovations, enable firms to reduce environmental impact, lower costs, and respond to stakeholder demands, thereby strengthening their strategic market position (Xu et al., 2023). By adopting GIS, firms not only improve operational efficiency but also differentiate themselves in competitive markets through green branding, eco-design, and sustainable production, which collectively contribute to GICA.

Firms that leverage GIS to align with social and environmental priorities-such as pollution control, eco-labeling, and sustainability-focused communication-can also enhance their reputational

capital and innovation capabilities (Awan et al., 2021). These initiatives often result in first-mover advantages and better responsiveness to green consumer demands (Kumar et al., 2021). While previous studies have affirmed the link between green innovation and competitiveness, few have systematically examined how different GIS components—green process, product, and service innovation—jointly influence GICA, especially in the context of sustainability-driven industries. This study seeks to fill that gap by exploring the direct impact of GIS on GICA within the new energy sector, providing insights into how green strategies contribute to sustained strategic advantage.

Green Innovation Strategy and Resource Efficiency

Green innovation strategies (GIS) play a critical role in enhancing a firm's ability to utilize resources more efficiently. According to the resource-based theory (RBT), firms can gain sustainable advantages by developing internal capabilities that reduce input usage while maintaining or improving output quality (Demirel & Kesidou, 2019). GIS, through technological, process, and product innovation, enables companies to reduce energy consumption, minimize material waste, and streamline operations (Zameer et al., 2020). These improvements contribute directly to resource efficiency (RE), which reflects the firm's ability to produce more with fewer resources and less environmental impact.

Implementing GIS also drives eco-efficient practices such as recycling, cleaner production, and optimized supply chain management. These practices reduce operating costs and increase environmental compliance, further reinforcing the firm's sustainability performance (Takalo & Tooranloo, 2021). Abu Seman et al. (2019) highlight that green innovation efforts are often linked to improvements in material reuse, pollution mitigation, and energy-saving technologies, all of which are key dimensions of RE. Despite the established theoretical connection, empirical studies exploring GIS as a direct antecedent of RE—especially in new energy sectors—remain limited. This study addresses this gap by investigating how the adoption of green innovation strategies affects resource efficiency, thereby laying the foundation for improved competitive outcomes in sustainability-driven industries.

Green Innovative Competitive Advantage (GICA) and Resource Efficiency

Resource efficiency (RE) is increasingly recognized as a vital contributor to achieving green innovative competitive advantage (GICA). Rooted in the resource-based theory, RE reflects a firm's ability to optimize the use of energy, materials, and processes to reduce costs and environmental impact while maintaining productivity (Demirel & Kesidou, 2019). Firms that achieve higher RE are better equipped to implement green innovations effectively, which, in turn, strengthens their ability to differentiate from competitors through eco-friendly products, efficient operations, and sustainable branding (Zameer et al., 2020).

Studies have shown that RE supports the development of unique, hard-to-imitate capabilities that are essential for sustaining competitive advantage (Taylor et al., 2018). By reducing dependency on non-renewable resources and improving cost structures, firms can reinvest in innovation and adapt more rapidly to environmental and market changes. Furthermore, RE enhances customer and

stakeholder perception, reinforcing green credibility and trust (Khan et al., 2021). Despite these advantages, empirical research directly linking RE to GICA remains limited, particularly in the new energy sector. This study therefore aims to bridge this gap by analyzing how improvements in resource efficiency contribute to building and sustaining green innovative competitive advantage.

Methodology

This study employed a structured quantitative design to examine the relationships among Green Innovation Strategy (GIS), Resource Efficiency (RE), and Competitive Advantage (CA) within the new energy industry. Constructs were measured using established multi-item scales from prior literature, evaluated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree), following standard practices in environmental and strategic management research (Hayat & Qingyu, 2024; Liao & Liu, 2021; Madhavan et al., 2022).

The final questionnaire was distributed to employees in firms across various segments of China's new energy industry, including solar photovoltaic, wind energy, hydrogen energy, energy storage, EV infrastructure, and smart grid/energy internet. Using both online and offline channels, a stratified random sampling method ensured balanced representation across firm types and job roles. Of the 950 questionnaires distributed, 578 were returned, and after removing incomplete or invalid responses, 455 valid cases were retained, yielding an effective response rate of 78.7%. Among the respondents, 38.5% were engaged in environmental or sustainability management, 29.0% in R&D, 17.8% in middle management, 10.5% in other roles, and 4.2% held senior management positions. Regarding tenure, 37.4% had worked at their current company for 1–3 years, followed by 25.7% with less than one year, 20.0% for 4–6 years, 12.3% for 7–10 years, and 4.6% for more than ten years.

In terms of firm characteristics, private enterprises accounted for 40.9% of the sample, followed by joint ventures (25.3%), state-owned enterprises (14.3%), foreign-funded firms (13.2%), and others (6.4%). Sector-wise, firms were mainly engaged in solar photovoltaic (22.2%) and new energy vehicles (20.2%), with notable representation in wind energy (17.4%), hydrogen (15.4%), energy storage (13.2%), and smart grid-related technologies (9.5%). Regarding size, 43.5% of firms had 100–499 employees, 26.8% had 500–999, 15.6% had more than 1,000, and 14.1% had fewer than 100. In terms of firm age, 35.8% were established within the past three years, 29.0% between three and five years, 25.3% between six and ten years, and 9.9% had operated for more than a decade. The diversity of respondents' roles, tenure, firm size, and industry background provides a solid foundation for exploring the relationships among green innovation strategies, resource efficiency, and competitive advantage. Data were analyzed using SPSS 26.0 and AMOS 24.0.

To test the proposed model, a two-step structural equation modeling (SEM) approach was adopted, as recommended by Anderson and Gerbing (1988). First, confirmatory factor analysis (CFA) was performed to evaluate reliability, convergent validity, and discriminant validity (Hayat & Qingyu,

2024). All reliability indicators met accepted thresholds. Second, covariance-based SEM was conducted to test the hypothesized relationships among GIS, RE, and CA. Model fit was assessed using standard indices, including RMSEA, CFI, TLI, and χ^2/df , ensuring the robustness and validity of the structural model.

Results

The structural equation modeling results indicate a good model fit ($\chi^2/df = 2.480$, IFI = 0.882, TLI = 0.870, CFI = 0.881, RMSEA = 0.057), supporting the overall validity of the proposed framework. Green Innovation Strategy (GIS) has a significant positive effect on Resource Efficiency (RE) ($\beta = 0.506$, $p < 0.01$) and directly enhances Competitive Advantage (CA) ($\beta = 0.310$, $p < 0.01$). Additionally, RE significantly influences CA ($\beta = 0.494$, $p < 0.01$), confirming its mediating role. These results suggest that firms adopting green innovation strategies can improve operational efficiency, which in turn contributes to superior market performance. The findings highlight the strategic value of integrating resource efficiency into green innovation efforts to build and sustain competitive advantage in the new energy industry.

Table 1: Estimation of the baseline structural model

item	Main Effect
Model fit	Model 1
χ^2/df	2.480
IFI	0.882
TLI	0.870
CFI	0.881
RMSEA	0.057
GIS→RE	0.506**(7.672)
GIS→CA	0.310**(5.068)
RE→CA	0.494**(6.791)

Note: *Sig at 0.05 level, **Sig at 0.01 level, ***Sig at 0.001 level

The structural equation modeling (SEM) results support the proposed framework and confirm the hypothesized relationships among Green Innovation Strategy (GIS), Resource Efficiency (RE), and Competitive Advantage (CA). GIS has a significant direct effect on CA ($\beta = 0.31$) and an even stronger effect on RE ($\beta = 0.59$), while RE also positively influences CA ($\beta = 0.49$), confirming its mediating role. All first-order constructs under GIS-Technological Innovation, Process Innovation, Product-related Innovation, and Sustainable Business Model Innovation-demonstrate strong standardized factor loadings (≥ 0.70), indicating solid construct validity. Likewise, RE is effectively captured through

Energy Efficiency, Material and Waste Efficiency, Supply Chain Optimization, and Production Cost Reduction, with all loadings exceeding 0.70. CA is measured through Market Differentiation, Cost Leadership, Revenue Growth, and Customer and Stakeholder Trust, each showing strong reliability (≥ 0.72). Overall, the model fits the data well and highlights the critical role of resource efficiency in translating green innovation into competitive advantage within the new energy sector.

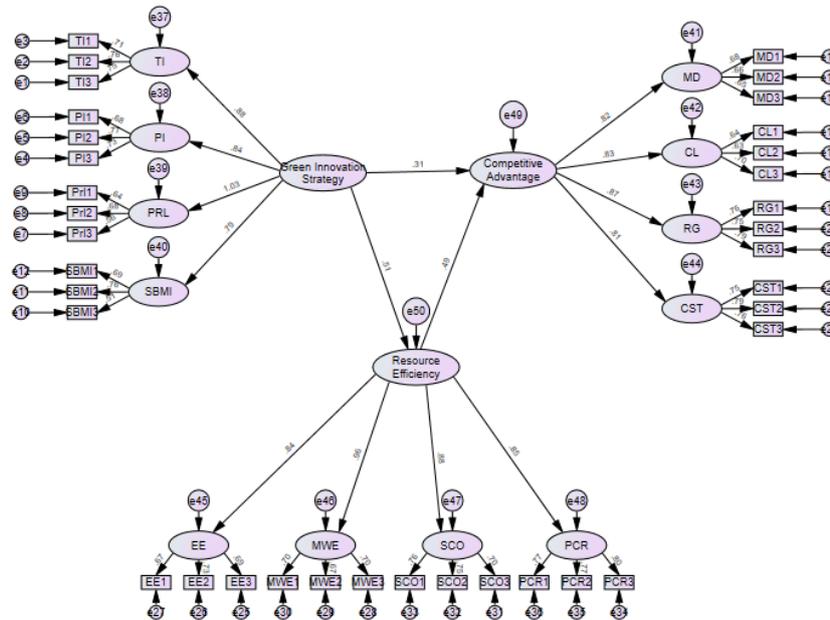


Figure 1: Structural Equation Modeling

Source: This study compiles

The mediation effect was assessed using the bootstrap method in AMOS 26, with 5,000 resamples and a 95% confidence level. A bias-corrected confidence interval (BC CI) was used to determine significance; if the interval does not include zero, the effect is considered significant. The nature of mediation was further evaluated by examining whether the direct effect remained significant; if so, it indicates partial mediation; otherwise, full mediation.

In this study, Green Innovation Strategy (GIS) significantly influenced Competitive Advantage (CA) through Resource Efficiency (RE), with an indirect effect of 0.209 and a 95% BC CI of [0.137, 0.311], excluding zero. This confirms that RE significantly mediates the GIS–CA relationship. The direct effect (0.259, CI = [0.142, 0.406]) also remained significant, indicating a partial mediation effect.

Table 2: Mediation Effect Summary

Pathway	Effect Type	Estimate	Lower	Upper	p-value
GIS→RE→CA	Indirect Effect	0.209	0.137	0.311	0.000
GIS→CA	Direct Effect	0.259	0.142	0.406	0.000
Total Effect	Total Effect	0.468	0.357	0.620	0.000

Discussion

The findings of this study support the theoretical framework grounded in the Resource-Based Theory (RBT) and Competitive Advantage Theory. Results confirm that Green Innovation Strategy (GIS) has a significant positive effect on both Resource Efficiency (RE) and Competitive Advantage (CA), validating H1 and H2. Firms adopting GIS—through technological upgrades, process optimization, green product innovation, and sustainable business models—tend to improve resource utilization and operational efficiency (Demirel & Kesidou, 2019). Moreover, GIS directly enhances CA (H3), indicating that environmental innovation contributes not only to sustainability goals but also to market differentiation, cost leadership, and stronger stakeholder engagement. These findings are consistent with Hayat and Qingyu's (2024) view of sustainable competitive advantage and align with the empirical evidence of Zameer et al. (2020) regarding the strategic impact of green initiatives.

Additionally, the significant path from RE to CA (H4) reinforces the role of efficiency as a key mechanism for translating innovation into performance gains. Firms that effectively manage energy and material use are more likely to achieve competitive outcomes, affirming RE as a strategic resource under RBT. The mediation analysis further shows that RE partially mediates the relationship between GIS and CA (H5), suggesting that while GIS directly contributes to competitive advantage, its impact is amplified through improvements in resource efficiency. Overall, the results highlight that green innovation strategies yield the greatest value when coupled with operational efficiency. For firms in the new energy industry, this underscores the importance of aligning innovation initiatives with resource-focused practices to maximize long-term competitive benefits.

Conclusion

This study concludes that Green Innovation Strategy (GIS) positively influences firms' Competitive Advantage (CA), both directly and indirectly through Resource Efficiency (RE). By adopting innovations in technology, processes, products, and business models, firms not only enhance sustainability but also improve operational efficiency and market positioning. Resource efficiency plays a key mediating role, translating green innovation into tangible strategic benefits. These findings underscore that, in the new energy industry, the effectiveness of green strategies depends not only on innovation itself but also on how well firms optimize their resource use. The study provides practical guidance for businesses and policymakers, emphasizing the importance of integrating innovation with efficiency-driven practices to achieve long-term competitiveness in environmentally conscious markets.

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