Research on Innovative Models for Promoting the Efficient Utilization of New Energy

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Abstract. With the continuous expansion of China's new energy installation capacity, the efficient utilization of new energy has become a critical step in advancing the energy revolution and achieving the "dual carbon" goals. Based on the current development status of new energy in China, this paper analyzes the main challenges in new energy consumption and studies six types of innovative models, including "new energy + hydrogen production," data center load optimization, "new energy + heating," green transformation of industrial energy use, coordinated development of new infrastructure and new energy, and green energy pilot projects. The techno-economic feasibility and implementation pathways of each model are examined with reference to practical cases. Finally, corresponding countermeasures and recommendations are proposed to address the challenges in promoting these innovative models, providing insights for the high-quality development of China's new energy sector.

Keywords: New energy, efficient utilization, innovative model, economic analysis

1 Introduction

In recent years, China's new energy sector has witnessed leapfrog development. By the end of 2024, the installed capacity of new energy in China had surpassed that of thermal power for the first time, accounting for over 40% of the total[1]. While the installed capacity of new energy has expanded rapidly, the randomness, intermittency, and volatility of its power output have posed significant challenges to power system balance and the efficient utilization of new energy[2]. In 2024, the curtailment rates of wind and solar power rebounded in some regions, increasing the pressure on new energy consumption. How to balance the development and consumption of new energy has become a critical issue in the green and low-carbon energy transition[3].

In response to these challenges, the industry has formed two main pathways: "tapping potential" and "creating new pathways." The "tapping potential" approach focuses on enhancing the existing consumption capacity of the power system through technical

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measures such as flexibility retrofits of thermal power, increased energy storage deployment, and improved demand-side response capabilities[4]. While these measures can improve new energy utilization to a certain extent, they are constrained by poor economic viability and limited potential for further improvement[5]. The "creating new pathways" approach aims to expand the utilization space for new energy by accelerating renewable energy substitution and exploring new application scenarios for new energy[6]. This pathway offers broader prospects for consumption and represents a strategic choice for supporting the efficient utilization of new energy in the future[7].

This paper aims to systematically study innovative models for the efficient utilization of new energy, explore the feasibility and implementation effects of various "creating new pathways" approaches, and provide theoretical support and practical guidance for building a new framework for the high-quality development of new energy.

2 Key Issues in New Energy Consumption

The essence of new energy consumption lies in resolving the spatiotemporal mismatch between energy supply and demand. From a technical perspective, new energy consumption capacity is primarily constrained by three factors: first, system regulation capability, which refers to the power system's ability to cope with fluctuations in new energy output[8]; second, grid transmission capacity, particularly the alignment between new energy-rich regions and power transmission corridors[9]; third, load-side flexibility, which is the ability of consumers to adjust their electricity usage in response to new energy output[10]. From an economic perspective, the costs associated with new energy consumption mainly include balancing costs, grid expansion costs, and backup costs, all of which increase significantly as new energy penetration rises.

The characteristics of new energy—namely, its zero marginal cost and high system costs—pose unique challenges to its participation in the market. Traditional electricity market designs struggle to adequately reflect the value of new energy, leading to widespread phenomena where "increased generation does not translate to increased revenue" and "increased revenue does not yield proportional profits." Therefore, innovating new energy utilization models must simultaneously address both technological breakthroughs and the restructuring of market mechanisms.

3 Innovative Models for Efficient New Energy Utilization

3.1 Cross-Sector Consumption Model of "New Energy + Hydrogen Production"

(1) Techno-Economic Analysis

Utilizing new energy for hydrogen production (green hydrogen) serves as a crucial pathway for achieving cross-sector energy consumption. When the levelized cost of new energy generation drops to 0.1 RMB/kWh, the production cost of green hydrogen reaches approximately 10 RMB/kg, demonstrating cost competitiveness compared to coal-based hydrogen (about 10 RMB/kg) and natural gas-based hydrogen (about 13

RMB/kg), as shown in Table 1. The economic advantage of green hydrogen becomes more pronounced when carbon reduction environmental benefits are factored in.

Table 1. Cost Comparison of Various Hydrogen Production Technologies

Hydrogen Type	Production Method	Energy Price	Hydrogen Cost
Electrolysis	Industrial Electricity	0.6 RMB/kWh	38 RMB/kg
	New Energy	0.1 RMB/kWh	10 RMB/kg
Fossil-based	Natural Gas	3 RMB/Nm^3	13 RMB/kg
	Coal	550 RMB/ton	10 RMB/kg

In terms of consumption effectiveness, green hydrogen production exhibits energy storage characteristics and load flexibility, effectively mitigating fluctuations in new energy output. Research indicates that in off-grid renewable energy systems, integrating water electrolysis for hydrogen production can reduce the net present cost of the system by 24%. When the hydrogen price exceeds 4.5 USD/kg, systems equipped with electrolyzers demonstrate superior economic performance compared to conventional systems. This demonstrates that the "new energy + hydrogen production" model offers the dual advantages of consuming new energy and enhancing project economic viability.

(2) Practical Cases and Outcomes

The Southern Xinjiang Green Hydrogen Transmission Demonstration Project, by integrating 3.4 GW of supporting new energy capacity, 50 MW of pure-hydrogen gas-fired power generation units, and a 50 MW hydrogen fuel cell system for combined power generation, achieves an annual CO2 emission reduction of over 200,000 tons and consumes more than 8 billion kWh of new energy electricity per year on average. The Zhangjiakou Wind Power Hydrogen Production Comprehensive Utilization Demonstration Project is expected to reach a daily green hydrogen production capacity of 216.4 tons and an annual capacity of nearly 80,000 tons by 2028, enabling the consumption of 5 billion kWh of new energy electricity annually.

In the industrial sector, green hydrogen provides a deep decarbonization pathway for hard-to-abate industries such as steel, chemicals, and heavy-duty transport. Research indicates that green hydrogen can replace coke in direct reduced iron (DRI) processes, significantly reducing CO2 emissions from the steel industry. In the chemical industry, green hydrogen serves as a feedstock for producing green ammonia and green methanol, substituting traditional fossil fuel-based routes.

3.2 Load Optimization Consumption Model for Data Centers

(1) New Energy Consumption Potential of Data Centers

With the rapid development of the digital economy, data centers have become major energy consumers. China's data center electricity consumption is projected to reach 206.5 TWh and 867.6 TWh in 2025 and 2030 respectively, showing an exponential growth trend. By promoting the relocation of data centers to new energy-rich regions and optimizing their spatiotemporal electricity demand distribution, new energy consumption levels can be significantly enhanced. Studies show that if the new energy utilization rate of China's data centers reaches 30% and 75% in 2025 and 2030 respectively, an additional 60 TWh and 650 TWh of new energy electricity could be consumed, as shown in Table 2.

Table 2. Estimated Wind Power Capacity Required to Supply Data Centers

Data Center Scale	Rack Count Range	Electricity Consumption (TWh)	Required Wind Power Capacity (MW)
Hyper-scale Data Center	>10,000	>4	>196
Large Data Center	3,000~10,000	1.2~4	58~196
Medium Data Center	500~3,000	0.23~1.2	11.3~58

(2) Practice of Spatiotemporal Load Transfer

Taking the summer peak load day in Zhangjiakou as an example, transferring the entire data center load during the peak period to other locations can reduce Zhangjiakou's peak load by 17%. Utilizing the daily peak-to-valley difference of data center load for peak shaving and valley filling can reduce the maximum load by 1.8% or increase the minimum load by 2.7%. This spatiotemporal load transfer capability positions data centers as flexible regulation resources in the new power system.

The Ningxia Virtual Power Plant (VPP) operation management platform has integrated 10 VPPs, aggregating 20 types of adjustable loads—including electric vehicle charging stations, building air conditioning, and ferrosilicon enterprises—with a total aggregated capacity exceeding 3.79 GW. VPP operators have accumulated profits of approximately RMB 1 million. This successful experience provides a reference for data centers to participate in system regulation, namely achieving efficient new energy utilization through aggregation optimization and market transactions.

3.3 Comprehensive Utilization Model of "New Energy + Heating"

(1) Economic Analysis

New energy heating primarily includes two scenarios: industrial steam and residential heating. New energy becomes economically viable for industrial steam production when the terminal electricity price drops to around RMB 0.22/kWh, and gains a competitive advantage for residential heating when the price falls to approximately RMB 0.16/kWhy, as shown in Table 3.

Table 3. Economic Comparison of Heating Supply

Terminal New Energy Electricity Price (RMB/kWh)	Corresponding Steam Price (RMB/ton)	Corresponding Heating Price (RMB/m^2/month)
0.16	185	4.95
0.18	205	5.48
0.20	225	6.02
0.22	245	6.56
0.24	265	7.10
0.26	285	7.65

As new energy power generation costs continue to decline, new energy heating has achieved economic feasibility in resource-rich regions such as Ningxia, Xinjiang, and Inner Mongolia. These areas can leverage the cost advantage of new energy to replace traditional gas- and coal-fired boilers, facilitating a green and low-carbon transition in energy consumption.

(2) Technology Pathways and Cases

Molten salt thermal storage technology, an innovative pathway for "new energy + heating," has been successfully applied in Suzhou, Anhui. The nation's largest "coal power + molten salt" thermal storage project—the Suzhou 1000 MWh Molten Salt Energy Storage Coupled with Coal Power Flexibility Retrofit Project—commenced commercial operation in August 2025. Utilizing high-temperature molten salt storage technology, the project achieves efficient charge-discharge cycles within the temperature range of 300°C to 565°C, enhancing the unit's heating capacity during peak shaving and valley filling periods. Operational data show that this system increases the unit's bidirectional peak shaving capacity by 20%, consumes 128 GWh of new energy annually, reduces carbon emissions by 85,000 tons, and boosts the original heating capacity by 173%.

Another technical pathway is electric thermal storage for peak shaving, exemplified by the Tieling Million-Kilowatt Level Wind-Solar-Fire-Storage Multi-Energy Complementary Demonstration Project. By constructing two 600 MW units, the project can lower the minimum total load to 200 MW, generating over RMB 130 million in deep peak shaving revenue. The project utilizes extra-large volume stratified thermal storage water tanks (23,000m^3) to achieve thermal-power decoupling, enabling flexible switching between new energy, thermal power, and heating networks according to different energy supply demands.

3.4 Industrial Green and Low-Carbon Transition Model

The industrial sector, as a primary domain of energy consumption and carbon emissions, represents a crucial market for new energy consumption. In key industries such as metallurgy, foundry, building materials, daily-use glass, non-ferrous metals, and chemicals, promoting electric boiler, electric furnace, and electric heating technologies—collectively known as electrification substitutes—can directly expand the space for new energy consumption.

In sectors like synthetic ammonia, synthetic methanol, petrochemicals, and steel, the large-scale substitution of high-carbon hydrogen with low-carbon hydrogen is encouraged, alongside the development of large-capacity coal-fired boilers co-firing with green ammonia. These measures not only reduce fossil fuel consumption but also establish an energy coupling relationship between new energy and the industrial sector, creating a sustained channel for green electricity consumption.

The Ulanqab Chayouzhongqi Thermal Power Plant Flexibility Retrofit New Energy Project serves as a typical case of industrial green transformation. Through the deep coupling of thermal power flexibility retrofits and new energy consumption, the project achieves an annual online electricity generation exceeding 2.3 TWh, saving 700,000 tonnes of standard coal and reducing CO2 emissions by 1.92 million tonnes annually.

It functions as a core hub for the regional "thermal power flexibility retrofit + new energy consumption" system, providing stable and reliable green power support to 31 enterprises in the industrial park.

3.5 Synergistic Development Model of New Infrastructure and New Energy

The integrated development of new infrastructure sectors—such as artificial intelligence, the Internet of Things, and blockchain—with new energy can create a synergistic pattern advancing both digitalization and greening. Specific pathways include:

Green Certificate and Green Electricity Trading: Utilizing market mechanisms to monetize the environmental value of new energy, thereby incentivizing its investment and development. In 2025, the national government introduced green electricity consumption ratio requirements for new data centers in the steel, cement, polysilicon industries, and national hub nodes, providing policy assurance for green power consumption.

"Green Power Park" Construction: Achieving efficient new energy utilization at the park level. For instance, the Minning "Pure Green Power Town," through key projects like energy storage power stations and coordinated control systems, has achieved 24-hour pure green power supply capability. The town is projected to increase annual green electricity consumption by 215 GWh, save over 26,400 tonnes of standard coal annually, and reduce CO2 emissions by 73,200 tonnes per year.

Optimization of "East Data West Computing" Project: Increasing the proportion of new energy power consumption within national strategic projects like "East Data West Computing," and pushing for a steady annual increase in the renewable energy usage ratio of new data centers. Ningxia's virtual power plants rank among the top in the nation in terms of adjustable capacity, safeguarding the green electricity supply-demand balance in Minning Town and attracting relevant enterprises to establish operations.

3.6 Green Energy Pilot Innovation Model

Establishing green energy pilot parks in qualified national and provincial economic development zones—where 100% of the incremental energy consumption is supplied by renewable sources through market-oriented mechanisms—is an effective means to promote the efficient utilization of new energy.

The Minning "Pure Green Power Town" adopted a "village collective + enterprise + farmers" model. It developed large-scale photovoltaic agricultural facilities in Yuanlong Village and installed rooftop PV systems for over 1,600 immigrant households. The village collective earns more than RMB 2 million annually, and each immigrant household receives rooftop rental fees. This model not only enhances the level of new energy consumption but also creates a win-win situation for both economic and social benefits.

4 Conclusion

This paper has systematically studied six categories of innovative models for promoting the efficient utilization of new energy, yielding the following main conclusions:

First, the "new energy + hydrogen production" model achieves the dual objectives of new energy consumption and industrial decarbonization through cross-sectoral coupling. It becomes economically viable when the levelized cost of new energy generation falls below 0.1 RMB/kWh, demonstrating broad application prospects in new energy-rich regions.

Second, the data center load optimization model leverages the transferable load characteristics of the digital economy to significantly enhance new energy consumption levels through spatiotemporal load shifting. It holds the potential to consume 650 TWh of new energy annually by 2030.

Third, the "new energy + heating" model, utilizing power-heat decoupling and thermal storage technologies, enhances system flexibility while expanding the application space for new energy in industrial steam and residential heating. It gains a competitive advantage when the terminal new energy electricity price is below 0.22 RMB/kWh.

Fourth, models such as the industrial green transition, synergistic new infrastructure development, and green energy pilot projects construct a multi-dimensional ecosystem for efficient new energy utilization from the perspectives of industrial coupling, policy guidance, and pilot demonstrations.

Looking ahead, the economics and feasibility of these innovative models are expected to improve further, driven by continuously declining new energy costs and the ongoing refinement of policy frameworks. By 2030, a coordinated and efficient multi-level regulation system for new energy consumption will be largely established, with the majority of incremental electricity demand being met by additional new energy generation. By 2035, a new power system adapted for a high penetration of new energy will be fundamentally completed, enabling the optimal allocation and efficient utilization of new energy on a national scale.

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Disclosure of Interests

The authors have no competing interests to declare that are relevant to the content of this article.

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