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Exploration on the Development Ideas of Hydrogen Energy Industry in State-owned Enterprises

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Abstract: As the core carrier of global energy transition and a key support for China's "dual carbon" strategy, hydrogen energy has become an important part of the national energy system. As the "national team" and "chain leader" in the development of the hydrogen energy industry, state-owned enterprises play an irreplaceable role in technological breakthroughs, ecological construction, and scenario demonstration. Based on the perspective of the entire hydrogen energy industrial chain and combined with the layout practices of state-owned enterprises, this paper systematically analyzes the strategic positioning and development status of state-owned enterprises in the hydrogen energy industry, deeply explores core challenges such as technological bottlenecks, cost pressures, institutional constraints, and insufficient coordination, and proposes targeted development ideas from four dimensions: technological innovation, industrial chain integration, market-oriented transformation, and policy connection. The feasibility of the path is verified through typical cases. The research holds that state-owned enterprises need to take technological independence as the core, industrial chain coordination as the support, market-oriented mechanisms as the driving force, and policy standards as the guarantee to realize the high-quality development of the hydrogen energy industry and provide strategic support for China's energy structure transformation.

Keywords: State-owned Enterprises; Hydrogen Energy Industry; Development Ideas; Industrial Chain Coordination; Technological Innovation.

1. Introduction

Driven by the global "carbon neutrality" wave, hydrogen energy has become a key path to break the dependence on fossil energy and realize energy structure transformation due to its characteristics of cleanliness, low carbon, high energy density, and wide application scenarios. China's *Medium and Long-Term Development Plan for the Hydrogen Energy Industry (2021—2035)* clearly lists hydrogen energy as a strategic emerging industry, and the *Energy Law* implemented in 2025 further establishes the legal energy status of hydrogen energy, laying a institutional foundation for industrial development. Data shows that in 2024, China's hydrogen energy production and consumption scale exceeded 36.5 million tons, the capacity of renewable energy-based hydrogen production accounted for more than half of the world's total, and the number of hydrogen refueling stations reached 542, ranking first in the world.

As the core carrier of national strategy implementation, state-owned enterprises shoulder a dual mission in the development of the hydrogen energy industry: on the one hand, to ensure energy security and promote the independent controllability of key core technologies; on the other hand, to lead industrial upgrading and build a sustainable industrial ecology. By the end of 2024, 47% of central enterprises had been involved in hydrogen energy-related businesses, forming a number of leading enterprises such as Sinopec, China Energy Investment Corporation (CEIC), and Dongfang Electric Corporation. Significant progress has been made in green hydrogen production, equipment manufacturing, and scenario application. However, state-owned enterprises also face prominent problems such as "bottleneck" core technologies, high green hydrogen costs, and insufficient flexibility in institutional mechanisms, which restrict the large-scale development of the industry.

Based on this, this paper, focusing on the functional positioning of state-owned enterprises and combining the characteristics of each link of the entire hydrogen energy industrial chain ("production-storage-transportation-application-R&D"), constructs a systematic development framework by analyzing the current industrial development situation and challenges, providing reference for state-owned enterprises to address development dilemmas and give play to their leading role, and helping China's hydrogen energy industry transition from "pilot demonstration" to "large-scale commercialization".

2. Strategic Positioning and Development Status of Hydrogen Energy Industry in State-owned Enterprises

2.1. Policy Environment Supports Accelerated Industrial Layout

China has formed a three-level policy system of "national planning + local policies + legal guarantees", providing a favorable environment for state-owned enterprises to participate in the hydrogen energy industry. At the national level, the *Medium and Long-Term Development Plan for the Hydrogen Energy Industry (2021—2035)* clarifies the strategic position of hydrogen energy in the energy system and proposes the goal of building a diversified hydrogen production system and an entire industrial chain layout. At the local level, Jiangsu, Beijing, Guangdong and other regions have issued special policies, with the highest subsidy for a single project reaching 20 million yuan, forming three major industrial clusters in the Yangtze River Delta, Pearl River Delta, and Beijing-Tianjin-Hebei region. At the legal level, the *Energy Law* implemented in 2025 first incorporates

hydrogen energy into the energy category, breaking the institutional barrier of being managed as a chemical product previously. The continuous release of policy dividends has promoted state-owned enterprises to increase investment in the hydrogen energy industry. Only in 2023-2024, the investment in hydrogen energy demonstration projects led by central enterprises exceeded 50 billion yuan [1].

2.2. Initial Formation of the Entire Industrial Chain Layout

State-owned enterprises have formed a comprehensive layout in all links of the hydrogen energy "production-storage-transportation-application-R&D", presenting a development pattern of "central enterprises leading and local state-owned enterprises coordinating" (see Table 1). In the hydrogen production link, Sinopec's Xinjiang Kuqa project with an annual output of 20,000 tons of green hydrogen has become a domestic benchmark; CEIC has laid out "wind-solar hydrogen production + hydrogen-based fuel synthesis" projects in Inner Mongolia and Ningxia to promote large-scale green hydrogen production. In the storage and transportation link, Sinopec launched the Beijing-Inner Mongolia hydrogen transmission pipeline demonstration project, and the 90MPa hydraulic drive compressor developed by Sinopec Machinery leads the industry; Guofu Hydrogen Energy ranks among the top in the market share of hydrogen storage cylinders. In the refueling link, Sinopec has built 144 hydrogen refueling stations and operates 7 "hydrogen corridors", becoming the enterprise with the most operating hydrogen refueling stations in the world. In the application link, Dongfang Hydrogen Energy has provided more than 500 hydrogen-powered vehicles for more than 20 routes, with the maximum mileage of a single vehicle exceeding 400,000 kilometers; CEIC has jointly built a 2,400-kilowatt hydrogen-powered shunting locomotive with CRRC Group, filling the gap in hydrogen energy application in heavy-haul railways [2].

Table 1. Layout of State-owned Enterprises in Each Link

Industrial Chain Links	Representative State-owned Enterprises	Core Achievements
Hydrogen Production	Sinopec, CEIC	Xinjiang Kuqa 20,000 tons/year green hydrogen project; 5MW alkaline water electrolysis hydrogen production test platform
Hydrogen Storage	Sinopec Machinery, Guofu Hydrogen Energy	Mass production of 90MPa hydrogen storage compressor and high-capacity hydrogen storage cylinder
Hydrogen Transportation	Sinopec	Beijing-Inner Mongolia hydrogen transmission pipeline demonstration project
Hydrogen Refueling	Sinopec, China Energy Construction	144 hydrogen refueling stations; "hydrogen corridor" layout
Hydrogen Application	Dongfang Hydrogen Energy, CEIC	Application of more than 500 hydrogen-powered vehicles; hydrogen-powered shunting locomotive
R&D	Dongfang Hydrogen Energy, China Energy Construction Hydrogen Energy Research Institute	270kW fuel cell system; megawatt-level PEM hydrogen production system

2.3. Strategic Positioning: "Ballast Stone" and "Pacemaker" for Industrial Development

State-owned enterprises assume three core roles in the hydrogen energy industry: first, the "ballast stone" for national energy security, ensuring the diversification of energy supply by laying out green hydrogen projects to replace fossil energy; second, the "pacemaker" for core technologies, relying on R&D resources to tackle "bottleneck" technologies such as electrolyzers and fuel cells. Dongfang Hydrogen Energy's R&D investment intensity has exceeded 50% in the past three years, successfully developing a 270kW fuel cell single-machine system; third, the "builder" of industrial ecology, giving play to the role of "chain leader" in the industrial chain to integrate upstream and downstream resources. Sinopec launched a 5 billion yuan hydrogen energy industry fund and took the lead in establishing the Central Enterprise Green Hydrogen Production, Storage and Transportation Innovation Consortium. This strategic positioning determines that state-owned enterprises must balance national strategies and market benefits, and play a leading role in technological breakthroughs and scenario demonstrations[3].

3. Core Challenges Facing the Development of Hydrogen Energy Industry in State-owned Enterprises

3.1. Insufficient Level of Core Technology Independence

China's hydrogen energy technology is generally in the "follower" stage, and state-owned enterprises still rely on imports for key materials and core components. In the field of fuel cells, the localization rate of core materials such as proton exchange membranes, catalysts, and carbon paper is less than 30%, and there is a significant gap between domestic products and international standards in terms of performance and durability. In the hydrogen production link, core components of PEM electrolyzers rely on imports, while alkaline electrolyzers have achieved localization but still have room for improvement in energy consumption control.[4] Although enterprises such as Dongfang Hydrogen Energy and Aerospace Science and Technology have made technological breakthroughs in 270kW fuel cell systems and hydrogen liquefaction systems, overall, the R&D forces of core technologies in state-owned enterprises are scattered, lacking cross-enterprise and cross-field collaborative innovation, and the technology conversion efficiency is not high, which restricts the improvement of industrial competitiveness.

3.2. Persistently High Green Hydrogen Costs

Cost disadvantage is a key factor restricting the large-scale development of hydrogen energy, and green hydrogen projects of state-owned enterprises generally face economic pressure. On the hydrogen production side, the current cost of green hydrogen is about 20-25 yuan/kg, 1.5-2 times that of gray hydrogen (10-18 yuan/kg). Even if the electricity price drops to 0.15 yuan/kWh, the cost of green hydrogen still needs to be 16 yuan/kg to be on par with blue hydrogen. On the storage and transportation side, the cost of gaseous storage and transportation by long-tube trailers is about 7.79 yuan/kg, which is sensitive to transportation distance; the energy consumption of liquid storage and transportation accounts for 30%-40% of the total energy of hydrogen, and the equipment investment is high. On the application side, the levelized driving cost of hydrogen fuel cell vehicles is about 37-43 US dollars per 100 kilometers, higher than the full-life cycle cost of electric heavy trucks. Cost pressure leads to state-owned enterprises' hydrogen energy projects relying on policy subsidies, lacking market-oriented profitability, and it is difficult to form a sustainable development model[5].

3.3. Significant Regional Differences in Technology Maturity

The development of hydrogen energy technology in state-owned enterprises is unbalanced in different links and regions, showing the characteristics of "strong application end, weak core end" and "strong eastern region, weak western region". In terms of technology maturity (see Table 2), links such as hydrogen refueling station construction and hydrogen-powered vehicle application have high maturity (over 80%), while the maturity of core technologies such as PEM electrolysis hydrogen production and solid-state hydrogen storage is less than 50%. In terms of regional distribution, technology application is intensive in the Yangtze River Delta and Pearl River Delta regions, while the technology conversion capacity in western regions rich in green hydrogen resources is weak.

Table 2. Maturity of Core Technologies in State-owned Enterprises

Technology Field	Maturity Score	Progress of Representative Enterprises
Alkaline Water Electrolysis for Hydrogen Production	75 points	Commissioning of CEIC's 5MW test platform
PEM Electrolysis for Hydrogen Production	48 points	Successful pilot test of Dongfang Hydrogen Energy's megawatt-level system
High-pressure Gaseous Hydrogen Storage	72 points	35MPa technology mature; 70MPa technology under development
Solid-state Hydrogen Storage	35 points	Laboratory stage; Shaanxi Hydrogen Energy's salt cavern hydrogen storage demonstration in progress
Fuel Cell Stack	68 points	Continuous improvement of power density; durability to be verified
Hydrogen Refueling Station Construction	85 points	Operation of 144 hydrogen refueling stations by Sinopec

4. High-quality Development Framework for Hydrogen Energy Industry in State-owned Enterprises

In response to the above challenges, combined with the strategic positioning of state-owned enterprises and the development laws of the hydrogen energy industry, a four-in-one development framework of "technological independence, industrial chain coordination, market-oriented transformation, and policy connection" is constructed to promote state-owned enterprises to transform from "scale expansion" to "quality and efficiency improvement"[6].

4.1. Focus on Technological Independence to Build an Innovation-driven System

4.1.1. Concentrate Efforts on Key Fields

State-owned enterprises should focus on the core links of the hydrogen energy industrial chain and concentrate resources to tackle "bottleneck" technologies. In the hydrogen production link, focus on tackling core materials (proton exchange membranes, catalysts) for PEM electrolyzers and energy efficiency optimization technologies for alkaline electrolyzers, with the goal of reducing electrolyzer costs to below 1,000 yuan/kW by 2030. In the storage and transportation link, accelerate the development of low-cost technologies such as pipeline hydrogen blending and organic liquid hydrogen storage, and promote the lightweight of high-pressure hydrogen storage cylinders and the reduction of energy consumption in liquid hydrogen storage and transportation. In the fuel cell link, improve the reliability and service life of core components such as membrane electrodes and bipolar plates, and promote the power density of fuel cell systems to exceed 3kW/L. Drawing on Dongfang Hydrogen Energy's "technology roadmap + dynamic adjustment mechanism" model, formulate a clear technology development plan to avoid the dispersion of R&D resources.

4.1.2. Innovate Collaborative R&D Mechanisms

Give play to the leading role of state-owned enterprises and build an innovation consortium of "leading enterprises + universities + research institutes". Promote mechanisms such as "task assignment based on open competition", "military order system", and "horse race system". For example, China Energy Construction Hydrogen Energy Company collaborated with top domestic universities to tackle flexible ammonia synthesis technology and successfully passed the scheme review. Rely on national-level innovation platforms such as the "14th Five-Year Plan" Race for Excellence Innovation Platform of the National Energy Administration and the Hydrogen Storage, Transportation and Refueling Equipment Technology Innovation Center to gather innovation resources and attract high-level talents. In the past three years, Dongfang Hydrogen Energy has attracted more than 1 billion yuan in investment and 13 technical experts

through innovation platforms. Establish a technology achievement sharing mechanism to break technical barriers between enterprises and improve the overall technical level of the industry.

4.2. Rely on Industrial Chain Coordination to Build Industrial Ecological Clusters

4.2.1. Give Play to the Role of "Chain Leader" to Integrate Resources

State-owned enterprises should rely on their own advantages to take the lead in building a collaborative ecology of the entire industrial chain. Upstream, focus on the construction of green hydrogen bases, expand the layout of renewable hydrogen production capacity relying on strategic regions such as "desert, Gobi, and desert" and "offshore areas". For example, China Energy Construction Songyuan Hydrogen Energy Industrial Park (green hydrogen-ammonia-alcohol integration) project, with a total investment of 29.6 billion yuan, will build the world's largest green hydrogen demonstration base. Midstream, strengthen equipment manufacturing capacity, promote the localization and large-scale production of core equipment such as electrolyzers, hydrogen storage cylinders, and compressors, and reduce manufacturing costs. Downstream, expand application scenarios, focusing on three major scenarios: industrial decarbonization (hydrogen metallurgy, green chemical industry), transportation field (hydrogen-powered heavy trucks, public transportation), and energy backup (distributed power generation). For example, HBIS Zhangxuan Technology's 1.2 million tons hydrogen metallurgy project reduces carbon emissions per ton of steel by 70%.

4.2.2. Promote Regional Coordination and Differentiated Layout

Optimize the regional layout of state-owned enterprises according to resource endowments and market demands. Western regions rich in energy resources focus on the development of green hydrogen production bases, such as wind-solar hydrogen production projects in Xinjiang and Inner Mongolia, to provide low-cost green hydrogen for the eastern region. Eastern economically developed regions focus on the layout of hydrogen energy application scenarios and equipment manufacturing, such as hydrogen-powered vehicle demonstrations in the Yangtze River Delta and hydrogen refueling station network construction in the Pearl River Delta. Central regions play a hub role in building hydrogen energy storage and transportation transit bases to realize "hydrogen transmission from west to east" and "hydrogen transportation from north to south". Avoid redundant construction between regions and form a regional collaborative pattern of "resource-manufacturing-application" linkage.

4.3. Take Market-oriented Transformation as the Driving Force to Stimulate Endogenous Vitality

4.3.1. Innovate Business Models

State-owned enterprises should get rid of dependence on policy subsidies and explore sustainable market-oriented business models. Promote the "green hydrogen + carbon trading" model to make up for the cost disadvantage of green hydrogen through carbon emission reduction benefits. For example, Jinnan Iron and Steel combined by-product hydrogen recovery with photovoltaic green electricity, reducing the cost per ton of steel by 120 yuan. Develop the "hydrogen energy + comprehensive energy service" model, integrating hydrogen refueling stations with charging stations, battery swapping stations, and gas stations to improve the profitability of single points. Explore the "energy performance contracting" model to provide green hydrogen supply services for steel and chemical enterprises and lock in long-term benefits.

4.3.2. Deepen Institutional Mechanism Reform

Optimize the internal management system of state-owned enterprises to adapt to the innovative development needs of the hydrogen energy industry. First, simplify the decision-making process, establish a rapid approval channel for hydrogen energy projects, and give project teams greater autonomy. Second, improve the incentive mechanism, expand the coverage of employee stock ownership and stock option incentives, focusing on R&D personnel and core technical backbones. Referring to Dongfang Hydrogen Energy's "product manager system", coordinate the entire life cycle of products from concept to commercialization. Third, strengthen market-oriented assessment, take market share, cost control, and technological advancement as core assessment indicators, and establish a employment mechanism of "ability-based promotion and demotion" to improve operational efficiency.

4.4. Take Policy Connection as the Guarantee to Optimize the Development Environment

4.4.1. Participate in the Construction of Standard System

State-owned enterprises should take the initiative to participate in the formulation of hydrogen energy standards to enhance industry discourse power. At the national level, promote the establishment of an energy attribute-based hydrogen standard system, covering safety specifications and technical parameters for all links of hydrogen production, storage, transportation, refueling, and application. At the industry level, take the lead in formulating group standards and enterprise standards. For example, Dongfang Hydrogen Energy's enterprise standard *Fuel Cell System* obtained the "leader" certificate, improving product competitiveness. At the international level, strengthen cooperation with international organizations and advanced countries, promote the internationalization of Chinese standards, and break trade barriers.

4.4.2. Strengthen Policy Advocacy and Coordination

State-owned enterprises should actively connect with government departments to strive for policy support and promote policy optimization. First, strive for financial support, obtain R&D subsidies through methods such as "task assignment based on open competition", and reduce the cost of technological breakthroughs. Second, promote policy coordination, suggest establishing a national hydrogen economy administration to coordinate multi-department supervision, unify approval standards and subsidy policies, and solve problems such as local protectionism and regional barriers. Third, strive for financial support, use tools such as green credit and carbon neutrality funds to reduce financing costs and provide capital guarantee for large-scale projects.

5. Case Analysis: Development Practice and Enlightenment of Shaanxi Hydrogen Energy Co., Ltd.

As a professional state-owned hydrogen energy platform in Shaanxi Province, Shaanxi Hydrogen Energy Co., Ltd. was established on December 28, 2022, with the strategic goal of "rooting in Yulin, developing Shaanxi, radiating the northwest, building a first-class enterprise, and creating a western hydrogen valley". Through the layout of the entire industrial chain, scenario-driven demonstration, and collaborative innovation, it has achieved rapid development in more than two years. In 2024, its hydrogen energy-related business revenue exceeded 3 billion yuan. Its development practice provides important enlightenment for state-owned enterprises to develop the hydrogen energy industry based on regional resource endowments.

5.1. Core Practices

5.1.1. Anchor Regional Advantages to Build an Entire Industrial Chain Layout

Based on Shaanxi Province's hydrogen energy resource endowment of "multi-source complementarity and entire chain connection", Shaanxi Hydrogen Energy Co., Ltd. has built an integrated layout of "production-storage-transportation-refueling-application". On the hydrogen production side, relying on the by-product hydrogen resources of Yulin's coal chemical industry, it has built a 150,000 Nm^3/h industrial by-product gas hydrogen production device with an annual output of 35,000 tons of high-purity hydrogen, and the ex-factory price of hydrogen is controlled within 10 yuan/kg. Simultaneously, it has laid out the Shaanxi-Inner Mongolia 30GW new energy hydrogen production project, with the first phase planning 2 million kilowatts of wind and solar installed capacity and an annual hydrogen production of 70,000 tons, promoting the gradual reduction of green hydrogen costs to below 15 yuan/kg. On the hydrogen storage side, it has jointly promoted the Yulin Jiaxian salt cavern hydrogen storage demonstration project with Tsinghua University, built a 40,000 cubic meter salt cavern hydrogen storage facility with a pressure of 30MPa, realizing low-cost, large-scale, and cross-seasonal hydrogen storage, and filling the domestic technical gap. On the hydrogen transportation side, it plans to build the first phase of the Shaanxi-Inner Mongolia hydrogen transmission pipeline project, connecting the Ordos green hydrogen base with the Yulin chemical industrial park, and extending to the Guanzhong urban agglomeration in the long term, reducing the hydrogen transmission cost to 0.8 yuan/kg·100km. On the hydrogen application side, focusing on Yulin's coal short-distance transportation scenario, it has put 100 49-ton hydrogen-powered heavy trucks into operation and built 5 supporting hydrogen refueling stations, forming a closed loop of "hydrogen production-hydrogen storage-hydrogen refueling-hydrogen application", with the maximum mileage of a single vehicle exceeding 400,000 kilometers[7].

5.1.2. Focus on Scenario Demonstration to Promote Market-oriented Implementation

Taking "scenario development driving industrial development" as the core idea, Shaanxi Hydrogen Energy Co., Ltd. has created four characteristic application scenarios. First, the hydrogen-powered heavy truck short-distance transportation scenario: it has opened 4 heavy truck "short-distance transportation" demonstration lines in Yulin Yushen Industrial Park, with an annual transportation volume exceeding 7 million tons, replacing diesel heavy trucks and reducing carbon dioxide emissions by more than 20,000 tons per year[8]. Second, the green hydrogen chemical replacement scenario: cooperating with CEIC Yulin Chemical, it uses green hydrogen for coal-to-methanol projects, with a single project reducing carbon dioxide emissions by more than 20 million tons per year. Third, the salt cavern hydrogen storage peak regulation scenario: using Yulin's salt cavern resources to store green hydrogen, providing cross-seasonal peak regulation services for the power grid, which can adjust the volatility of 10GW-level wind and solar power generation. Fourth, the intercity hydrogen energy logistics scenario: participating in the construction of the "Hancheng-Weinan-Xi'an" hydrogen corridor, putting 33 hydrogen-powered heavy trucks into operation to realize 260-kilometer one-way steel transportation, and promoting the expansion of scenarios from closed parks to intercity openness. Through scenario demonstration, Shaanxi Hydrogen Energy Co., Ltd. has formed a replicable commercial model, and the operating cost of hydrogen-powered heavy trucks is 15%-20% lower than that of diesel heavy trucks.

5.1.3. Deepen Collaborative Innovation to Tackle Technical Bottlenecks

Shaanxi Hydrogen Energy Co., Ltd. has built an innovation system of "enterprise-led, university-supported, and research institute-coordinated", united more than 20 scientific research institutions such as Xi'an Jiaotong University, Tsinghua University, and Northwestern Polytechnical University to form the Shaanxi Provincial Hydrogen Energy Industry Innovation Consortium, focusing on key technical breakthroughs such as salt cavern hydrogen storage, low-cost electrolyzers, and fuel cell durability. In the field of salt cavern hydrogen storage, it has broken through core technologies such as controllable cavity construction and high-pressure injection-production, forming a complete set of solutions for 40,000 cubic meter salt cavern hydrogen storage, with the injection-production rate increased to 5,000 m^3/h. In the field of electrolysis hydrogen production, it has jointly developed a megawatt-level alkaline electrolyzer with LONGi Hydrogen Energy, with the DC power consumption reduced to 4.087 kWh/Nm^3, reaching the advanced domestic level. In the field of fuel cells, it has cooperated with Xuqing Times to develop a 270kW fuel cell system, adapting to the needs of hydrogen-powered heavy trucks, with durability exceeding 10,000 hours. In the past three years, Shaanxi Hydrogen Energy Co., Ltd.'s R&D investment has accumulated more than 1.2 billion yuan, obtaining 68 patents, including 23 invention patents, and the technology conversion efficiency has reached 35%.

5.1.4. Innovate Institutional Mechanisms to Stimulate Endogenous Vitality

As a state-owned enterprise, Shaanxi Hydrogen Energy Co., Ltd. has actively explored market-oriented institutional mechanism reforms. First, implement "project-based" management, establish special working groups for key projects such as salt cavern hydrogen storage and hydrogen-powered heavy truck demonstration, endow the teams with autonomy in personnel, remuneration, and procurement, and directly link project benefits with team performance. Second, establish a collaborative incentive mechanism, sign technology achievement transformation agreements with cooperative universities and research institutes, agree on the profit sharing ratio, and R&D personnel can obtain 30%-50%

of the transformation benefits. Third, strive for fault tolerance and error correction policy support, be included in the pilot of fault tolerance and error correction for hydrogen energy industry investment in Shaanxi Province, and grant immunity for reasonable trial and error in technological innovation and scenario demonstration to reduce innovation risks. Fourth, innovate investment and financing models, initiate the establishment of a 5 billion yuan Shaanxi Provincial Hydrogen Energy Industry Fund to attract social capital participation, amplify the leverage effect of state-owned capital, and the fund has invested in 12 hydrogen energy industrial chain projects.

5.2. Experience and Enlightenment

The successful practice of Shaanxi Hydrogen Energy Co., Ltd. shows that state-owned enterprises need to grasp four keys to develop the hydrogen energy industry: first, accurately position based on regional resource endowments. State-owned enterprises should fully tap local characteristic resources such as energy, industry, and transportation to form a differentiated development path. Shaanxi Hydrogen Energy Co., Ltd. has quickly formed competitive advantages relying on Yulin's unique resources such as industrial by-product hydrogen, salt caverns, and short-distance transportation scenarios. Second, promote market-oriented implementation through scenario demonstration. The core of large-scale development of the hydrogen energy industry is to find sustainable application scenarios. State-owned enterprises should focus on rigid demand scenarios such as closed parks and professional logistics, accumulate data and reduce costs through demonstration operations, and then gradually expand to open scenarios. Third, build a collaborative innovation system to tackle technical bottlenecks. State-owned enterprises should give play to the role of "chain leader", integrate innovation resources of universities, research institutes, and upstream and downstream enterprises to form a joint force for tackling key problems, avoiding working alone. Fourth, deepen institutional mechanism reforms to stimulate vitality. State-owned enterprises need to break the constraints of traditional management models, and adapt to the innovative development needs of the hydrogen energy industry through flexible incentive mechanisms, decision-making mechanisms, and investment and financing mechanisms. This provides replicable experience for other state-owned enterprises, especially local state-owned enterprises, to address development dilemmas and achieve high-quality development.

6. Conclusion

The hydrogen energy industry is a strategic direction of China's energy transformation. As the core force of industrial development, state-owned enterprises shoulder the important mission of technological independence, industrial scale, and ecological construction. At present, state-owned enterprises have initially formed a layout in the entire hydrogen energy industrial chain, but they still face prominent challenges such as technological bottlenecks, cost pressures, institutional constraints, and insufficient coordination.

In the future, state-owned enterprises need to take technological independence as the core, concentrate efforts on key fields, and build a collaborative innovation system; take industrial chain coordination as the support, give play to the role of "chain leader", and build a regionally linked industrial ecology; take market-oriented transformation as the driving force, innovate business models and institutional mechanisms, and enhance endogenous vitality; take policy connection as the guarantee, participate in standard formulation, strive for policy support, and optimize the development environment. Through the implementation of the four-in-one development ideas, state-owned enterprises will effectively address development dilemmas, give full play to their leading role, promote China's hydrogen energy industry to transition from "pilot demonstration" to "large-scale commercialization", and provide solid support for the realization of the "dual carbon" goal and energy security.

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