Shandong Path of Green Finance Driving the Leap of the Whole Industrial Chain of Hydrogen Energy-Multi-Case Study Based on the Pilot of 'Hydrogen into Ten Thousand'

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Abstract: Amid global energy transitions and carbon neutrality objectives, green hydrogen has emerged as a pivotal enabler of sustainable industrial growth due to its zero-carbon attributes. This study examines Shandong **Province's** "Hydrogen Integration" initiative, analyzing how green finance accelerates innovation across the hydrogen value chain. Focusing on three regional models—Qingdao's port applications, Zibo's manufacturing ecosystems, and Jinan's R&D hubs-the research employs comparative case analysis to explore the interplay of specialized bonds, venture capital, and tailored financing mechanisms in optimizing production, storage, distribution, and utilization. A tripartite evaluation framework quantifies financial impacts, revealing that regionendowments specific resource shape financing strategies: **Oingdao's** infrastructure-linked Zibo's bonds. industrial clusters, and Jinan's innovationdriven investments demonstrate distinct advantages. Data indicate cost reductions of ~30% in hydrogen infrastructure projects through diversified financing, while crosssector collaboration among enterprises, financial institutions, and research entities resolves systemic bottlenecks, yielding a scalable "integrated ecosystem" model. The findings advocate for prioritizing technological innovation, spatial synergy, standardized frameworks, and adaptive financial tools to advance China's hydrogen industry, offering actionable insights for global low-carbon transitions.

Keywords: Green Finance; Hydrogen Energy Industry; The Whole Industry Chain; Multi-Case Study; Shandong Hydrogen Into Ten Thousand

1. Introduction

1.1 Research Background and Issues Raised In the context of global energy transformation and climate change, hydrogen energy is becoming an important starting point for achieving carbon peak and carbon neutrality due to its clean and zero-carbon characteristics, especially ' green hydrogen '. In 2024, the collective learning of the Political Bureau of the Central Committee further pointed out that the new productivity is essentially green productivity, which has laid a solid theoretical foundation for the integration and development of green finance and hydrogen energy industry. the perspective of international From experience, the United States has taken the lead in the field of hydrogen energy through the whole chain of fiscal and taxation subsidies, the European Union with the help of the Border Adjustment Carbon Mechanism (CBAM), and Japan 's strengthened policy guidance ; in contrast, although China has formed a considerable green financial system, the balance of green loans in 2023 reached 30.08 trillion yuan, but the support in the field of green hydrogen is still insufficient. The main constraints are about 14 yuan / kg of high production costs, technology and equipment dependence on imports, imperfect industrial chain, and green financial standards and tools have not yet covered the entire industrial chain. In this regard, it is necessary to build a support system that conforms to the risk-benefit characteristics of hydrogen energy projects through innovative financial products and services, focusing on technological innovation, industrial upgrading and business model integration, so as to provide strong support for the high-quality development of China 's hydrogen energy industry.

In this context, this paper focuses on how

green finance can empower the hydrogen energy industry to jump. Taking the " hydrogen into ten thousand " pilot in Shandong Province as the research object, this paper deeply discusses the mechanism and practical effect of green finance in supporting hydrogen energy technology innovation, industrial upgrading and business model innovation, aiming to provide theoretical support and policy suggestions for the high-quality development of China 's hydrogen energy industry.

1.2 Research Objectives and Significance

This study takes the ' hydrogen into ten thousand ' pilot in Shandong Province as the core, and focuses on the mechanism and path of green finance driving the jump of the whole hydrogen energy industry chain. The research objectives include : 1 deconstructing the coordination mechanism of green financial instruments and the whole chain of " production-storage-transportation-addition-

utilization " of hydrogen energy, and analyzing the adaptation logic of special bonds, government guidance funds and other tools in technology research and development, infrastructure landing such as Qingdao Port hydrogen refueling station and application in high-speed network scenario of hydrogen energy ; secondly, refine the multi-level pilot difference model of Shandong, compare the practice of Qingdao (port hydrogen energy + special debt), Zibo (equipment manufacturing + industrial fund) and Jinan (science and technology innovation + venture capital), and summarize the transmission path of ' policy incentive-capital allocation-technology breakthrough '. Thirdly, a three-dimensional " evaluation framework of economysustainability-risk " is constructed to quantify the contribution of financial support to the leap of industrial chain. For example, Weifang Hydrogen Station reduces the construction cost by 30 % through " station linkage " credit.

At the theoretical level, it breaks through the macro perspective of traditional green finance research, innovatively integrates the microoperation mechanism and environmental benefit analysis of the hydrogen energy industry, proposes a collaborative framework of ' financial tool chain-policy toolboxscenario ecosystem ', and expands the applicability of green finance theory in strategic emerging industries.

The practical value is reflected in the triple empowerment: 1 providing policy optimization schemes for the government, such as cracking the fragmentation of hydrogen energy policy and promoting the construction of policy system by formulating provincial-level unified approval standards for hydrogen refueling stations; second, guide financial institutions to develop adaptive products, such as supporting the construction of Binzhou 10,000-ton hydrogen production base with supply chain finance, building a ' risk assessment-dynamic pricing ' service system simultaneously, and improving the efficiency of financial service entity industry. Third, help enterprises optimize financing strategies, reduce financing costs through innovative models such as government funds + intellectual property pledges ', and broaden financing channels for green technology industrialization. The " Shandong paradigm " formed by the research results can provide an industry-finance synergy model covering policy coordination, financial innovation and enterprise practice for of the the commercialization national hydrogen energy industry, which has important demonstration and promotion value.

1.3 Research Methods and Technical Route

This study takes the pilot practice of hydrogen into ten thousand ' in Shandong Province as the research object, adopts the qualitative research paradigm combining multi-case comparison method and policy text analysis method, and promotes the research process through the interaction of theoretical construction and practical analysis. Firstly, based on the whole chain development characteristics of hydrogen energy industry in Shandong Province, Oingdao (port hydrogen energy scene), Zibo (equipment manufacturing cluster) and Jinan (science and innovation research and development center) are selected as typical cases, and case screening is carried out according to policy innovation intensity, technology maturity and scene application breadth. The data sources include hydrogen energy special policy texts such as the ' Medium and Long-Term Development Plan for Hydrogen Energy Industry in Shandong Province ' issued by local governments, corporate field interview records (covering core participants such as Dongyue Group and

Qingdao Port Hydrogen Energy Project Team), first-hand information such and as demonstration project operation reports. The research process is divided into three stages : first, through the semantic analysis of policy texts and the deconstruction of case scenarios, the correlation logic of " policy tools-financial means-industrial chain links " is refined, such as analyzing the support path of Zibo 's " Special Fund for Equipment Manufacturing " to the localization of liquid hydrogen storage and transportation the technology secondly, cross-case ; comparison method is used to compare the differentiated characteristics of Qingdao 's " port hydrogen energy + supply chain finance " and Jinan 's " science and technology research and development + venture capital " models, and to summarize the adaptation conditions of the three development paths of " heavy assetdriven, " " technology breakthrough " and " scene integration "; thirdly, combined with the field research, the theoretical framework of " regional endowment-instrument combinationeffect " constructed synergy is to systematically explain the empowerment mechanism of green financial instruments in infrastructure layout, technology iteration acceleration and business model innovation. technical route takes ' The problem identification-theoretical modeling-case verification-countermeasure output ' as the main line. Through the analysis of policy background, the bottleneck problem of the leap of hydrogen energy industry is clarified. Based on the theory of environmental finance, the financial adaptation model of the whole industrial chain is constructed, and then the multi-level pilot practice in Shandong Province is used to verify the theoretical hypothesis. Finally, the ' policy-financeindustry ' coordinated development plan that

can be promoted is refined. The innovation of the research is embodied in the integration of methodology, the organic combination of policy text analysis, case scenario and deconstruction theoretical model construction, avoiding the limitations of traditional single methods, and providing a new analytical perspective for the research of strategic emerging industries.

2. Theoretical Basis and Policy Framework

2.1 The Theoretical Logic of Green Finance Enabling Industrial Development

As a link between environmental protection and economic growth, green finance has a solid theoretical foundation for its enabling industry development. Modern economic theory posits that finance, as the core of the economy, should serve real economic development. Green finance drives the effective allocation of resources and facilitates green industrial transitions by providing targeted financial support. This mechanism enhances the quality of factor supply, optimizes factor allocation efficiency, and distribution improves mechanisms of development outcomes, thereby forming a nurturing critical foundation for new productive forces. Specifically, green finance fosters systemic productivity leaps through a threefold upgrade: cultivating high-skilled labor forces, innovating green production technologies, and expanding sustainable development domains—collectively redefining labor subjects, production materials, and production objects.[1].

The development of green finance also fits the perspective of new institutional economics. Initial cost, informal rules, supporting related systems and adaptive expectations are the key factors affecting the development of green finance. By establishing a sound green financial policy system, reducing the initial cost of green financial projects, standardizing market behavior, and improving supporting systems, the government can effectively promote the development of green finance and promote the formation of new quality productivity [2]. In addition, the development of green finance can optimize the industrial structure, promote the green transformation of traditional industries, and create a good industrial ecological environment for the development of new productivity [3].

From the perspective of resource allocation, green finance improves the efficiency of resource allocation and promotes the optimization and upgrading of industrial structure by guiding capital to flow to green industry. Green finance can not only provide financial support for green industries, but also optimize the allocation of resources through market mechanisms and promote sustainable economic development. At the same time, the development of green finance can also stimulate the innovation vitality of enterprises, promote green technology innovation and industrial upgrading, and thus promote the development of new productivity [4].

2.2 Policy Support System for the Leap of Hydrogen Energy Industry

As a clean and efficient energy carrier, hydrogen energy is of great significance for achieving the goal of ' double carbon ' and promoting energy transformation. In recent years, China 's hydrogen energy industry has made remarkable progress under the impetus of multiple factors such as policy, technology and market. However, the development of the hydrogen energy industry still faces many challenges, and it is necessary to further improve the policy support system to achieve the sustainable development of the hydrogen energy industry.

2.2.1 Policy level

At the national level, China has issued a number of policies to support the development of the hydrogen energy industry. For example, the ' Medium-and Long-Term Plan for Hydrogen Energy Industry Development (2021-2035) ' clarifies the development goals and key tasks of the hydrogen energy industry and provides policy guidance for the long-term development of the hydrogen energy industry [5]. In addition, the state also encourages enterprises to increase investment in hydrogen technology research and development and industrialization through policy measures such as financial subsidies and tax incentives [6].

At the local level, local governments have actively responded to national policies and formulated local hydrogen energy industry development plans. For example, Guangdong Province issued the "Guangdong Province to speed up the development of hydrogen energy industry innovation, " put forward specific policy measures to support the development of the whole industrial chain of hydrogen energy industry. The implementation of these local policies has provided a strong guarantee for the regional coordinated development of the hydrogen energy industry [7].

2.2.2 Technical level

Technological innovation is the core driving force to promote the development of hydrogen energy industry. At present, China has made some breakthroughs in the key technical fields of hydrogen energy preparation, storage, transportation and application. For example, electrolytic water hydrogen production technology as the main method of green hydrogen production, its technical maturity and economy continue to improve [8]. At the same time, China has also made remarkable progress in fuel cell technology and hydrogen storage materials [9]. However, compared with the international advanced level, there is still a gap in the core technology of China 's hydrogen energy industry. It is necessary to further increase R & D investment and break through the technical bottleneck [10].

2.2.3 Market level

With the development of the hydrogen energy industry, the scale of China 's hydrogen energy market continues to expand. In the field of transportation, the demonstration application of hydrogen fuel cell vehicles has been steadily advancing, and the construction of infrastructure such as hydrogen refueling stations has been accelerating [11]. In the industrial field, the application of hydrogen energy as a raw material and fuel is also gradually expanding [12]. In addition, the diversified development trend of the hydrogen energy industry is becoming more and more obvious, covering many fields such as transportation, electricity, and chemical industry [5].

2.2.4 Infrastructure level

The rapid development of the hydrogen energy industry is inseparable from the improvement of infrastructure construction. China has made remarkable progress in the construction of hydrogen refueling stations. By the end of 2023, the number of hydrogen refueling stations that have been built ranks first in the world. However, the distribution of hydrogen refueling stations is still uneven, mainly concentrated in the eastern coastal areas and some economically developed provinces. In the future, it is necessary to further strengthen the layout planning of hydrogen refueling stations and improve the coverage and service level of infrastructure.

2.2.5 Cooperation level

The development of hydrogen energy industry requires cross-sectoral and cross-regional cooperation. At present, China has established a number of hydrogen energy industry alliances and collaborative innovation platforms, which have promoted cooperation and exchanges between upstream and downstream enterprises in the industrial chain [3]. At the same time, China also actively participates in international hydrogen energy cooperation, and has carried out cooperation with many countries and regions in hydrogen energy technology research and development, standard setting and other aspects [6].

In summary, green finance provides strong support for the development of the hydrogen energy industry by optimizing resource allocation, promoting technological innovation, and promoting industrial upgrading. The rise of the hydrogen energy industry is also inseparable from a sound policy support system. It requires the joint efforts of the government, enterprises and all sectors of society to strengthen policy coordination, increase technological innovation, improve infrastructure construction, and promote the high-quality development of the hydrogen energy industry.

3. Chapter 3 Analyzes the Suitability of Green Finance in Multi-Regional Pilot Projects

3.1 Multi-regional Pilot Comparative Analysis Framework

As an important economic and energy consumption province in China, Shandong Province has unique regional advantages and endowment differences in the development of hydrogen energy industry. Under the background of " hydrogen into ten thousand " pilot, Qingdao, Zibo, Jinan and other cities have explored different hydrogen energy development paths based on their own conditions, and the adaptation and application of green financial instruments in them also have their own characteristics.

on its port economic Oingdao relies advantages to vigorously develop port hydrogen energy related scenarios. It shows a significant cluster effect in the construction of hydrogen energy infrastructure, which makes Qingdao have great potential in building a maritime hydrogen energy supply chain. In terms of financial adaptation, special bonds play an important role in risk sharing in the construction project of hydrogen refueling station in Qingdao port. Through reasonable capital structure design, the ' station linkage ' model effectively enhances the solvency of special bonds and provides strong financial

support for the smooth progress of the project. Zibo focuses on the equipment manufacturing cluster and focuses on promoting the localization process of liquid hydrogen storage and transportation technology. The industrial fund has played a key role in the development of local hydrogen energy, and it has played a leverage role in technological breakthroughs. With the stepped industrial fund injection model, Zibo can better meet the cyclical needs of R & D investment, accelerate the iteration and innovation of hydrogen energy related technologies, and thus improve the technical level of the entire hydrogen energy industry chain.

With the agglomeration advantage of its science and technology resources, Jinan shows a unique logic in the field of venture capital. Venture capital institutions have played an important role in Jinan 's hydrogen technology incubation park. Through the investment and loan linkage model, it has promoted the effective transformation of the hydrogen energy laboratory economy to the industrial economy. At the same time, venture capital institutions have established a relatively complete risk pricing model in early technological innovation, providing financial support and development guidance for hydrogen energy start-ups, and promoting the rapid development of the hydrogen energy industry.

In terms of building a regionally coordinated hydrogen energy financial ecosystem, Shandong Province has also conducted a series of explorations. For example, among Qingdao, Zibo, Binzhou and other cities, through innovative supply chain finance, a crossregional hydrogen energy corridor financial synergy model has been initially constructed, which strongly supports the coordinated development of the inter-regional hydrogen energy industry. In addition, Shandong has also actively created a four-in-one linkage mechanism of " government-bank-enterprisescientific research institutes. " Among them, hydrogen refueling Weifang station construction project is a model of governmentbank-enterprise cooperation mode. and intellectual property pledge plays an important role in credit enhancement in the process of hydrogen energy technology conversion.

In terms of scenario application, Shandong has also carried out many financial product innovation practices. For example, in the hydrogen bus demonstration line project, the lease financing model innovation is adopted; in the industrial by-product hydrogen purification project, the possibility of green asset securitization was explored. These innovative measures have provided diversified financial support for the development of the hydrogen energy industry.

On the whole, in the pilot process of ' hydrogen into ten thousand ' in Shandong Province, different regions have formed their own distinctive hydrogen energy development models according to their own endowments and development priorities. The innovative application of green financial instruments has played a key supporting role in it. Through various financial means such as special bonds, industrial funds, and venture capital, it has hydrogen effectively promoted energy technology innovation, industrial upgrading, and business model innovation, providing valuable experience and reference for the highquality development of China 's hydrogen energy industry, and also contributing to the ' Shandong paradigm ' for the national hydrogen energy layout.

3.2 Innovative Practice of Green Financial Instruments

In order to promote the leap of the whole industrial chain of hydrogen energy, the innovation practice of green financial instruments is very important in the pilot process of " hydrogen into ten thousand " in Shandong province. This chapter will focus on the innovative application of key green financial instruments such as special bonds, industrial funds, venture capital, supply chain finance in the hydrogen energy industry, and analyze their practical effects and potential problems.

The special bonds provide strong support for the construction of hydrogen energy infrastructure. Taking the Qingdao Port Hydrogenation Station Project as an example, the issuance of special bonds has effectively filled the funding gap in the early stage of the project, and its ' station linkage ' model has reduced construction costs and improved the efficiency of capital use. However, there are still some limitations in the application of special bonds in hydrogen energy projects. For example, the uncertainty of project returns

may affect the solvency of bonds, and risk assessment and pricing mechanisms need to be further optimized.

The industrial fund has played a leverage role in promoting hydrogen energy technology innovation and industrial upgrading. The special fund for hydrogen energy in Zibo City has made remarkable progress in the localization of liquid hydrogen storage and transportation technology, and has met the periodic capital demand for technology research and development through the stepped capital injection mode. However, the operation of the industrial fund also faces challenges. How to accurately screen potential hydrogen energy projects and ensure the effective use of funds is a key concern.

Venture capital has injected vitality into hydrogen start-ups and early technological innovation. In Jinan 's hydrogen energy technology incubation park, venture capital institutions have promoted the transformation of laboratory technology to industrial applications through the investment and loan linkage model. However, the layout of venture capital in the field of hydrogen energy is still cautious, and its risk pricing model needs to be further improved to better adapt to the highrisk and high-return characteristics of the hydrogen energy industry.

Supply chain financial innovation provides a financial solution for the coordinated development of upstream and downstream enterprises in the hydrogen energy industry chain. In the Binzhou 10,000-ton hydrogen production base project, supply chain finance effectively integrates industrial chain resources and reduces the financing costs and operational risks of enterprises. However, the application of supply chain finance in the hydrogen energy industry needs to strengthen risk management to ensure the stability and sustainable development of the industrial chain.

In general, Shandong Province has actively explored the innovation of green financial instruments in the pilot project of " Hydrogen into Ten Thousand Homes, " providing diversified financial support for the development of the hydrogen energy industry. However, various financial instruments still need to be continuously improved and optimized in the application process to better adapt to the development needs of the entire hydrogen energy industry chain, promote the deep integration of green finance and the hydrogen energy industry, and help achieve a high-quality leap in the hydrogen energy industry.

4. Chapter 4 Challenges and Policy Optimization Paths

4.1 Challenges of Green Finance Empowering the Hydrogen Energy Industry As a key carrier of future energy transformation, hydrogen energy has a broad market prospect, but its development still faces many challenges.

4.1.1 Technical bottlenecks and cost barriers The efficient development of hydrogen energy industry is restricted by both technological maturity and production cost. At present, the production cost of green hydrogen is about 14 yuan / kg, which is mainly due to the high energy consumption of electrolytic water hydrogen production technology and the high cost of equipment [5]. According to media reports, although China has made some progress in the localization of hydrogen production equipment for electrolytic water, there is still a gap compared with the international advanced level. The import dependence of key equipment makes it difficult to reduce costs [3]. At the same time, there are still some technical bottlenecks in the key technical links in the hydrogen energy industry chain, such as fuel cells and hydrogen storage materials. Although the proton exchange membrane (PEM) water electrolysis hydrogen production technology is superior to the alkaline water electrolysis hydrogen production technology in many performance indicators, the cost of hydrogen production is high due to the use of platinum catalyst and high power consumption. In addition, as the core component of the stack, the cost of the membrane electrode accounts for about 36 % of the cost of the hydrogen fuel cell system, of which the cost of the commercial catalyst platinum / carbon accounts for about 23 % of the system cost, and the domestic mainly relies on imports, and there is a gap with foreign countries in performance and batching[12]. Although China has made some breakthroughs in fuel cell technology, it still faces cost and technical problems in large-scale commercial applications.

4.1.2 The industrial chain is not perfect

There are shortcomings in China 's hydrogen energy industry chain, and the coordinated development ability between hvdrogen production, hydrogen storage, hydrogen transportation and hydrogenation is insufficient. The construction of infrastructure such as hydrogen refueling stations is lagging behind and unevenly distributed, mainly concentrated in the eastern coastal areas, while the coverage of renewable energy-rich areas such as the west is insufficient, which limits the wide application and commercialization of hydrogen energy. According to a report in June 2024, the number of hydrogen refueling stations built in Guangdong Province ranks first in the country, with a total of 66, but the number of hydrogen refueling stations in some western regions is still small. This regional development imbalance not only affects the overall development efficiency of the hydrogen energy industry, but also is not conducive to China 's energy structure optimization and adjustment and " double carbon " goal. In addition, the cooperation mechanism between upstream and downstream enterprises in the industrial chain is not yet perfect, and there is a lack of effective industrial alliances and cooperation platforms, resulting in waste of resources and repeated construction, which affects the overall competitiveness of the hydrogen energy industry [3].

4.1.3 Standards and regulatory deficiencies

The policy and standard system of green finance supporting hydrogen energy industry is not perfect. Green financial standards at the national level do not fully cover the hydrogen energy industry chain, resulting in a lack of clear policy guidance for financial institutions in supporting hydrogen energy projects [3]. At the same time, the regulatory coordination mechanism of the hydrogen energy industry is not perfect, involving multiple departments, and there are regulatory gaps and overlapping problems, which affect the healthy and orderly development of the industry. For example, in the recent approval process of some hydrogen energy projects, due to the unclear division of responsibilities of various departments, the project promotion is hindered, which affects the investment enthusiasm of enterprises.

4.2 Policy Optimization Path

In view of the problems existing in the

development of hydrogen energy industry, the following policy optimization paths are proposed:

4.2.1 Strengthen technical R & D support

The government should increase financial investment in hydrogen energy technology research and development, set up special research funds, and focus on supporting key such as green hvdrogen technologies preparation, fuel cells, and hydrogen storage materials. At the same time, encourage enterprises to cooperate with universities and scientific research institutions, establish a collaborative innovation mechanism of industry, university and research, and accelerate the transformation and application of technological achievements. The U.S. Department of Energy has promoted the rapid development of hydrogen energy technology by setting up special funds and organizing industry-university-research cooperation projects. For example, the U.S. ' hydrogen energy program ' has provided continuous financial support for hydrogen technology research and development, and has promoted breakthroughs in many key technologies. In addition, the government can also encourage enterprises to increase investment in hydrogen energy technology research and development through tax incentives, scientific research subsidies, etc., to improve China 's independent innovation capability and core competitiveness in the field of hydrogen energy technology. Recently, Shandong Peninsula has successfully promoted the implementation of a number of key technical projects through the establishment of a special fund for hydrogen energy development, providing strong technical support for the development of the local hydrogen energy industry.

4.2.2 Improve the industrial chain layout

The government should formulate the development plan of hydrogen energy industry, guide the upstream and downstream enterprises of the industrial chain to strengthen cooperation and form industrial clusters. In areas rich in renewable energy, such as the northwest, focus on the development of green hydrogen preparation and energy storage projects; in economically developed areas, such as the eastern coast, promote the construction of fuel cell vehicles and hydrogen fueling facilities to promote coordinated

the development of the entire industrial chain of the hydrogen energy industry, and promotes the landing of hydrogen energy projects and the improvement of the industrial chain. China can learn from the experience of the EU and combine its own national conditions to energy formulate a hydrogen industry development plan with Chinese characteristics, clarify the positioning and functions of various regions in the hydrogen energy industry chain, and achieve complementary advantages and coordinated development. For example, Inner Mongolia Autonomous Region, relying on abundant wind and solar energy resources, actively layouts green hydrogen preparation projects, attracts many enterprises to invest, and forms a green hydrogen industrial cluster with a certain scale. 4.2.3 Improve the standards and regulatory system Accelerate the formulation and improvement

development between regions. The EU 's "

European Hydrogen Energy Roadmap " provides clear planning and policy support for

of standards and policies for green finance to support the hydrogen energy industry, and clarify the identification standards, support scope and operation process of hydrogen energy projects. At the same time, a crosssectoral regulatory coordination mechanism should be established to strengthen the whole chain supervision of the hydrogen energy industry and ensure the healthy and orderly development of the industry. Germany has established a perfect regulatory system by formulating strict hydrogen energy quality standards and safety regulations, which provides a guarantee for the development of the hydrogen energy industry. China should strengthen the integration with international activelv participate in standards. the formulation of international hydrogen energy standards, and improve China 's voice and influence in the international hydrogen energy field. Recently, the National Standardization Management Committee issued a series of standards related to hydrogen energy, which provides an important basis for the standardized development of the hydrogen energy industry.

4.2.4 Innovative financial support model

Financial institutions should develop financial products and services suitable for the characteristics of the hydrogen energy industry,

such as green bonds, industrial funds, venture capital, etc., to meet the diversified financing needs of enterprises. In addition, explore innovative models such as supply chain finance and intellectual property pledge to reduce the financing costs and risks of enterprises. In the practice of Shandong, the combination of various financial instruments such as special bonds, industrial funds and venture capital has effectively promoted the innovation and development of the hydrogen energy industry. For example, the Weifang hydrogen refueling station project has reduced construction costs by 30 % through the ' station linkage ' credit model. On February 19,2024, ' Financial Times-China Financial News Network ' published ' Effective Ways for Financial Support for the High-quality Development of Hydrogen Energy Industry ', which clearly proposed to encourage financial institutions to innovate financial products and service models to provide diversified financing support for the hydrogen energy industry.

4.2.5 Promote cross-regional cooperation and international exchanges

Strengthen domestic cross-regional cooperation, build hydrogen energy corridors, and promote the optimal allocation and efficient use of hydrogen energy resources. We will actively participate in international hydrogen energy cooperation, introduce advanced technology and management experience, and enhance the international competitiveness of China 's hydrogen energy industry. For example, Japan has a leading advantage in hydrogen energy vehicle technology. Through international cooperation projects, China can learn from its experience in fuel cell technology and hydrogen energy infrastructure construction. In addition, China can also carry out hydrogen energy cooperation with countries along the "Belt and Road " to jointly promote the promotion and application of hydrogen energy technology and promote the common development of regional economy. Recently, China and countries in the Middle East have signed a number of cooperation agreements in the field of renewable energy hydrogen production, laying the foundation for further cooperation between the two sides in the field of hydrogen energy.

5. Conclusion and Prospect

This study takes the ' hydrogen into ten

thousand ' pilot in Shandong Province as a case to reveal the three mechanisms of green finance driving the jump of the whole hydrogen energy industry chain : First, the regional adaptation mechanism, Qingdao station linkage ' special debt, Zibo industry fund, Jinan venture capital model verify the ' policy incentive-capital allocation-technology breakthrough ' conduction path ; second, quantify the evaluation mechanism, build a three-dimensional framework of ' economysustainability-risk ', and realize the scientific screening of projects ; third, the collaborative innovation mechanism, through the government-bank-enterprise-research " fourparty linkage to break the industrial chain blocking point, forming a replicable Shandong paradigm. " It is found that the current hydrogen energy industry still faces the constraints of core triple technology dependence, which leads to 60 % higher cost of green hydrogen than that of gray hydrogen, weak infrastructure (the density of hydrogen refueling stations is less than 1 / 6 of the international standard) and lack of standards.

The future policy optimization needs to focus on three aspects: strengthening technical research, breaking through the " neck-stuck " links such as membrane electrodes; optimize the spatial layout and create a characteristic corridor of ' scenery hydrogen production + marine economy '; improve the standard system and promote the full-cycle coverage of green financial instruments. With the expansion of the central bank 's carbon emission reduction support tools and the deepening of ESG investment, the integration of cross-border green hydrogen trade and marine economy will become a new growth pole. The analytical framework constructed in this study provides a methodological reference for the study of strategic emerging industries, and the practical experience of the ' Shandong Paradigm ' may provide a typical sample for the energy transformation of developing countries.

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