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Empowering a sustainable future: Quantitative evaluation and practical pathways of China's hydrogen energy industry policies

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Abstract

Hydrogen energy, a green, low-carbon secondary source, is pivotal to the global energy transition and a national strategy in China under the Dual Carbon goals. However, the sector faces weak innovation and imperfect standards. This study aims to assess policy performance to identify governance gaps and optimization pathways. This paper adopts the ROSTCM6 text-mining tool and the PMC index model to construct a comprehensive, quantitative framework. It evaluates eight Chinese hydrogen policies issued from 2021 to 2025 and benchmarks the highest-ranked domestic policy against those of three other countries. The evaluation results reveal notable hierarchical administrative disparities across China's hydrogen policies, coupled with insufficient coverage spanning the upstream, midstream, and downstream segments. Moreover, the enforceability of local policy measures remains generally weak. Critically, the country displays distinct deficiencies in specialized legislation and international multilateral coordination. The study confirms that, while China holds quantitative advantages, structural weaknesses in systemic coordination and legal foundation persist, which ultimately impede the high-quality development of the hydrogen industry. To optimize policy effectiveness, this paper suggests establishing a three-tier legal governance system, deepening international standard alignment, and innovating fiscal and regulatory instruments. These practical recommendations are vital for promoting industrial upgrading and securing national long-term energy interests.

Keywords: China's hydrogen energy industry policies, Comparative policy analysis, PMC index model, Policy evaluation, Policy modeling, Text mining.
JEL Classification: Q48; O25; C54.

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Contents

Contribution of this paper to the literature:
This study innovatively integrates ROSTCM6 text mining with the PMC index model to objectively evaluate China's hydrogen policies and conducts a novel cross-country comparison with South Korea, Australia, and South Africa, identifying structural legal gaps and proposing a three-tier governance framework and international cooperation pathways.

1. Introduction

In recent years, the focus of global energy governance has gradually shifted towards "decarbonization, diversification, and digitalization." From the G20 Energy Transition Dialogue to the advancement of the United Nations Sustainable Development Goals, reducing carbon emissions and building a green energy system have become global imperatives transcending developmental stages. As issues such as environmental pollution and resource contention under the traditional energy structure become increasingly prominent, hydrogen energy a secondary energy source with zero carbon emissions across its entire lifecycle is emerging as a key focal point for nations to overcome energy transition bottlenecks and achieve sustainable development. This is due to its cross-sector compatibility: it can facilitate decarbonization in industries like steel and chemicals, while also serving as a long-duration energy storage medium to integrate and accommodate wind and photovoltaic power.

Recognizing this trend, countries around the world are increasingly prioritizing the hydrogen energy industry. South Korea, for instance, has released the "Hydrogen Economy Development Roadmap" (Ministry of Trade Industry and Energy, 2019), which outlines clear targets for hydrogen refueling station deployment by 2030 and plans for the adoption of hydrogen fuel cell passenger vehicles. The roadmap further commits approximately 2.5 trillion Korean won in investments over the next five years to bolster the entire industry chain (Zhang, 2019); Meanwhile, leveraging its abundant renewable energy resources, Australia has launched the "Australia's National Hydrogen Strategy" (Australian Government, 2019), which prioritizes the development of green hydrogen production. The strategy includes plans to establish large-scale green hydrogen production bases in Queensland and Western Australia, with the aim of reducing the cost of green hydrogen to below AUD 2 per kilogram by 2030. Concurrently, through initiatives such as the "Hydrogen Export Hub" project, Australia is actively advancing the international trade of hydrogen energy (Australian Hydrogen Council, 2020); Building on its mineral resource advantages and industrial decarbonization needs, South Africa has introduced the "Hydrogen Society Roadmap for South Africa 2021" (Department of Science and Innovation, 2021), which aims to achieve the commercial application of hydrogen in the mining sector by 2035 (Scholvin, Black, & Robbins, 2024), Norway, aligning with its oil and gas industry transition needs, has released "The Norwegian Government's hydrogen strategy-towards a low emission society" (Norwegian Ministry of Petroleum and Energy & Norwegian Ministry of Climate and Environment, 2020) the strategy prioritizes the coordinated development of blue and green hydrogen production, and encourages enterprise participation in hydrogen projects through policy incentives such as tax relief and targeted subsidies. These multidimensional measures combining technological R&D, infrastructure development, pilot demonstrations, and policy incentives have established distinctive development pathways for the hydrogen energy industry in each country, offering diverse references for the growth of the global hydrogen sector (Arup, 2024).

As the world's largest developing country and energy consumer, China places high importance on the development of the hydrogen energy industry. It has incorporated hydrogen energy into policy documents such as the "14th Five-Year Plan for a Modern Energy System" (National Development and Reform Commission & National Energy Administration of the People's Republic of China, 2022a) and the "Medium and Long-Term Development Plan for Science and Technology Innovation in the Transport Sector (2021-2035)" (Ministry of Transport of the People's Republic of China & Ministry of Science and Technology of the People's Republic of China, 2022) clearly defining its strategic role in achieving the "dual carbon" goals. Since hydrogen energy technology was first included in the new energy R&D system under the "China's Science and Technology Special Action for Addressing Climate Change" (Ministry of Science and Technology of the People's Republic of China National Development and Reform Commission & Ministry of Foreign Affairs of the Peoples Republic of China, 2007) in 2007, hydrogen-related policies have gradually progressed from technological research to industrial implementation. In 2020, Foshan launched a project to promote 1,000 hydrogen fuel cell buses, marking the beginning of large-scale hydrogen transportation demonstrations. In 2024, the Ministry of Transport supported the State Power Investment Corporation in advancing research and development of hydrogen fuel cell systems for ships and establishing a hydrogen transportation operation platform. In 2025, the "Guiding Opinions on Promoting the Integrated Development of Transportation and Energy" (Ministry of Transport of the People's Republic of China, 2025) further proposed the construction of hydrogen production networks within transportation infrastructure, improving hydrogen storage, transportation, and refueling systems, and promoting the large-scale application of hydrogen-powered heavy-duty trucks and ships. The continuous refinement of policies provides institutional guarantees for breakthroughs in hydrogen technology, the cultivation of the industrial chain, and emission reductions in high-carbon sectors. This plays an irreplaceable role in helping China achieve its "dual carbon" goals and build a new energy system.

The quantitative evaluation and international benchmarking of hydrogen energy industry policies are crucial for transitioning policies from "framework guidance" to "targeted empowerment." While China's hydrogen energy policies have been introduced intensively, issues such as inconsistent standard systems and regional homogeneous competition have become prominent, making it urgent to optimize policy effectiveness through scientific evaluation. From a research logic perspective, first analyzing the intrinsic characteristics of policy texts using text mining tools, then quantifying policy effectiveness into objective indicators via the PMC index, and finally identifying shortcomings by comparing with international policy samples, can provide a multi-layered foundation comprising "data support, quantitative evidence, and empirical references" for policy optimization. However, existing research and practice still face unresolved challenges. For instance, when using ROSTCM6 for word segmentation and visual analysis of hydrogen policies, how can core variables that reflect the essence of the policies be accurately selected to avoid deviations in PMC model variable settings caused by semantic overlap or redundant information? Furthermore, focusing solely on the PMC quantitative evaluation of Chinese policies may not sufficiently reveal international gaps in areas such as goal coherence and measure feasibility. Additionally, when selecting international comparison samples, how can the stage-specific characteristics of China's hydrogen industry, where "technological breakthroughs and scenario demonstrations proceed in parallel" be effectively matched to avoid the dilemma of "misaligned benchmarking"? Addressing these questions directly determines whether policies can effectively resolve industrial pain points and is critical for China to seize opportunities and build differentiated advantages in the global hydrogen industry competition, highlighting the practical urgency and necessity of this research.

Based on this, the innovative value of this piece is concentrated in three aspects.

Methodologically, it deeply integrates ROSTCM6 text mining with the PMC index model. By constructing a core semantic map of policies to precisely screen evaluation variables, it avoids subjective assignment bias, thereby enhancing the objectivity and accuracy of the evaluation. In terms of research perspective, it breaks through the limitations of single-country studies. By selecting policies from South Korea, Australia, and South Africa for benchmarking against China's optimal policy, it covers diverse development pathways while aligning with the characteristics of China's industrial stage. This approach fills a research gap in precise international benchmarking. Regarding practical value, through quantitative evaluation and international comparison, it extracts policy optimization pathways tailored to China's national context. This provides empirical support for addressing industrial challenges such as insufficient innovation, lagging standards, and regional homogenization. Simultaneously, it offers a reference for other developing countries formulating hydrogen policies, thereby contributing to the coordinated development of the global hydrogen industry and supporting the achievement of China's "Dual Carbon" goals.

2. Literature Review

Scholarship on China's hydrogen energy industry policies has yielded multi-dimensional research findings, centering on three main dimensions: policy practice, research evolution, and technology application.

2.1. Policy Practice Dimension

First, in research on policy evolution characteristics and hierarchical differences, Yang (2025) examined 1,580 hydrogen energy industry policy documents issued at the national, provincial, and municipal government levels in China from 1995 to 2022. Using co-occurrence keyword analysis and Latent Dirichlet Allocation (LDA) topic modeling, she concluded that policies among governments at the same level exhibited a "progressive evolution" characteristic, with policy themes developing from macro to meso levels. However, the evolutionary linkage between national and local government policies was not strong. She also suggested future improvements should focus on enhancing policy coordination, among other aspects. Huang, Hu, and Huang (2021) employed methods such as bibliometrics, a two-dimensional classification combining policy tools and the industrial chain, and keyword content analysis. Their study pointed out that China's hydrogen energy industry is in a transitional phase from the formation stage to the growth stage. Policies are predominantly supply-oriented and environment-oriented, with an imbalanced regional distribution. Sun et al. (2023) systematically reviewed the development trajectory of both national and local hydrogen energy industry policies. They found that local policies are highly aligned with national planning, yet issues such as a lack of regional coordination and ambiguous industrial chain pathways persist.

Second, in research on industrial development pathways and policy recommendations, Zhang, Zhang, and Shen (2022) reviewed relevant domestic and international policies, literature, and cases. From the perspectives of technology, industry, and standards, they proposed pathways such as integrating hydrogen energy with oil and gas pipeline networks and advancing the standardization of green hydrogen. They emphasized the need to improve top-level design and establish strategic alliances. Zhang and Huang (2023) analyzed the current state of domestic and international developments in hydrogen energy industry policies, technology, and economics. They noted that China's hydrogen sector is currently dominated by gray hydrogen in the upstream, faces bottlenecks in storage, transportation, and related infrastructure in the midstream, and is still in the early stages of downstream application. They emphasized the need for differentiated development strategies that leverage regional resource advantages. Following their analysis of hydrogen energy industrial layouts, demonstration project implementations, and national policies across key countries and regions globally, Han et al. (2021) emphasized that policy planning must be grounded in the actual conditions of China's industry to avoid blind benchmarking.

Third, in research on international experience, Jia, Yuan, and Li (2022) argue that the European Union's comprehensive top-level design for the entire industry chain, legislative guarantees, and precision subsidy models hold significant referential value. Through a comparative analysis of hydrogen energy policies across more than ten countries including Germany, Adebisi (2025) distilled differentiated development pathways and focal points, thereby broadening the international perspective for the formulation of China's hydrogen energy policies. When analyzing domestic and international hydrogen energy industry policies, Zhang and Huang (2023) emphasized the reference value of the European Union's comprehensive industry chain support policies for China, highlighting the importance of international experience.

2.2. Research Evolution Dimension

To map out the evolutionary trajectory and assess the current status of hydrogen energy research in China, scholars primarily employ methodologies such as bibliometric analysis and industrial data analysis to reveal development patterns and core characteristics. Specifically, Li, Tan, and Chen (2024) systematically reviewed hydrogen energy research hotspots, annual publication trends, and their underlying policy drivers from 2013 to 2022 by integrating bibliometric analysis with scientific knowledge mapping. This approach offers a multi-faceted portrayal of the research evolution and developmental landscape of China's hydrogen energy sector over the past decade. Furthermore, research conducted by Han et al. (2021) and Huang et al. (2021) has provided additional insights into understanding the current state of China's hydrogen energy development from perspectives including the industrial chain and policy frameworks.

2.3. Technology Application Dimension

At the level of technological positioning and industrial chain application, scholars have formed multidimensional conclusions regarding the pain points and potential across the entire industry chain. Ma, Sun, Xue, Zhang, and Chen

(2023) approached from the perspectives of upstream production, midstream storage and transportation, and downstream application, pointing out that the cost of green hydrogen needs to drop to 2 USD/kg to achieve large-scale adoption, while midstream storage and transportation technologies are still in the exploratory phase, requiring a balanced consideration of technical, economic, and environmental benefits throughout the lifecycle. Aba, Sauer, and Amado (2024) compared hydrogen energy with electric energy in terms of technological maturity, energy return rate, and application scenario adaptability, concluding that hydrogen energy holds irreplaceable advantages in long-duration energy storage and industrial decarbonization. Hren et al. (2023) quantitatively assessed the environmental value and economic feasibility of replacing gray hydrogen with green hydrogen, emphasizing the need to optimize storage and transportation technologies, such as high-density hydrogen storage and low-loss transportation, to reduce environmental footprints. Additionally, Stetson and Wieliczko (2020) noted that breakthroughs in hydrogen technology rely on the development of advanced materials such as adsorbents and metal hydrides. Coupling hydrogen energy with multiple energy sources can effectively enhance grid resilience and reduce curtailment rates of wind and solar power, thereby further advancing the research framework for the technological application of hydrogen in the energy transition.

Although existing research has explored China's hydrogen energy industry policies, development pathways, and international experiences from multiple dimensions, covering core areas such as policy practice, research evolution, and technology application, and has laid a solid foundation for hydrogen energy industry studies, it still faces limitations in three key aspects. First, most studies remain at surface-level analyses, such as policy quantity statistics or keyword frequency listings. They fail to deeply deconstruct the intrinsic attributes of policy texts, such as core semantics and variable characteristics, using specialized tools like ROSTCM6 or VOSviewer. Consequently, policy evaluations often rely on qualitative descriptions, lacking objective and precise data support. Second, international experience draws primarily from developed economies like the EU and the United States, with limited research on hydrogen policies in emerging economies that share similar resource endowments or developmental stages with China, resulting in less targeted reference value. Third, few studies have deeply integrated text mining techniques with the PMC index model. They have not leveraged visualized analyses of policy text features—such as semantic network maps or core variable maps—to scientifically select and define the evaluation dimensions and specific indicators for the PMC model. This leads to subjective assignment biases during policy effectiveness assessments, making it difficult to objectively and comprehensively identify the strengths and weaknesses of policy design in areas such as goal coherence, measure feasibility, and coverage completeness.

Therefore, this piece takes eight Chinese hydrogen energy industry policies from 2021 to 2025 as its research sample. Firstly, it utilizes ROSTCM6 software to conduct systematic word segmentation and visual analysis of text features. By presenting the core semantic characteristics of policies through mapping, it selects and defines the variables for the PMC index model. Secondly, based on the PMC index, a quantitative evaluation of policy effectiveness is completed to precisely identify the strengths and weaknesses of different policies in aspects like goal setting and measure implementation. Finally, the policy text with the best quantitative result in China is selected for comparative analysis with hydrogen policies from representative countries such as South Korea, Australia, and South Africa. These three countries exemplify "legislation-driven," "resource-export-oriented," and "emerging-transition" models of hydrogen development, respectively, covering different developmental stages and pathways. They can provide differentiated references for China from dimensions such as legislation, industrial layout, and transition practices. Through this process, this piece aims to distill policy optimization experiences suited to China's national context, offering new theoretical support and practical pathways for the transformation of China's hydrogen energy industry policies from "framework guidance" to "targeted empowerment" and for constructing a hydrogen development system adapted to national conditions.

3. Data Sources and Research Methodology

3.1. Data Sources

The period from 2021 to 2025 represents a critical phase for the development of China's hydrogen energy industry and the construction of its policy system. Coinciding with the implementation cycle of the "14th Five-Year Plan," this period has seen both top-level designs, such as the "Medium and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035)" (National Development and Reform Commission & National Energy Administration of the People's Republic of China, 2022b) which outline specific development targets for 2025, and the intensive issuance of national and local-level policies covering technological innovation, infrastructure, financial support, and other areas, driving the industry's transition from its initial stages towards rapid development.

Therefore, the hydrogen energy industry policy texts analyzed in this piece are primarily sourced from the "PKULAW" database, focusing on official normative documents categorized as "Central Regulations" and "Local Regulations" issued between January 2021 and August 2025 to ensure the authority and policy nature of the sample. Using "hydrogen energy" and "Hydrogen Energy Source" as core search terms, combined with the phrase "hydrogen+fuel cell" for sentence-level matching, an initial collection of 585 documents related to the hydrogen energy industry was obtained. A systematic manual secondary screening was then conducted by first applying a dual set of rigid criteria to define the selection boundaries: in terms of policy nature, only normative documents such as laws, regulations, and official notices containing the four key elements of "issuing authority, development objectives, specific measures, and implementation timelines" were retained, while non-policy texts were excluded; regarding core relevance, only texts containing at least one complete paragraph or clause and explicitly covering at least two core content areas were kept. This was followed by a three-tier quality assurance process involving dual-person preliminary screening, expert secondary screening, and team final review. Finally, adhering to the principles of prioritizing authority, ensuring comprehensive geographical coverage, maintaining content relevance, and selecting samples with notable practical effectiveness, eight typical policy texts were identified, as listed in Table 1.

The representativeness of the sample is reflected in three aspects.

First, in terms of administrative hierarchy, the sample encompasses national-level (2 documents), provincial-level (3 documents), and municipal-level (3 documents) policies, fully covering the three-tier structure of policy formulation in China. At the national level, only two "guiding documents" were selected: the "Medium and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035)" and the "14th Five-Year Plan for a

Modern Energy System" (National Development and Reform Commission & National Energy Administration of the People's Republic of China, 2022a). The former formally incorporated hydrogen energy into the national energy strategy for the first time, clarifying development goals and technological pathways for the entire industrial chain, and serves as the fundamental reference for the hydrogen energy sector. The latter coordinates the synergistic development of hydrogen energy with other clean energy sources from a holistic perspective, aligning with the "Dual Carbon" goals. Together, these two documents comprehensively cover the key information regarding strategic positioning, overall framework, and core directions at the national level, with outstanding authority and guidance. Other national-level documents were excluded as they either serve as specific implementation rules for single domains or are interim work notices, often exhibiting issues of overlap or fragmentation in content. At the provincial level, Shandong (an industrial powerhouse in the east), Sichuan (a resource-rich province in the west), and Qinghai (a green electricity base in the northwest) represent three distinct hydrogen energy development models: industrial transformation in the east, resource utilization in the west, and green electricity integration in the northwest. These provinces cover the core regions of eastern, central, and western China, effectively reflecting the differentiated positioning of provincial policies across various regions. Policies from other provinces were largely excluded due to issues such as regional homogeneity. At the municipal level, policies from Shanghai (a demonstration hub for hydrogen transportation in the eastern coastal region), Wuhan (a core city for the hydrogen vehicle industry chain in central China), and Guangzhou (a pilot city for hydrogen infrastructure construction in the south) were selected, corresponding to three practical directions: transportation applications, industrial chain cultivation, and market-oriented operations. These cities cover key regions, including the eastern coast, central hubs, and southern special economic zones. Policies from other cities were excluded as they either lacked innovative measures or had short implementation cycles, failing to yield effective practical outcomes or demonstrate the unique value of local policies. Thus, these eight documents were ultimately selected as the sample.

Second, in terms of policy type, the sample includes "plans," "implementation schemes," "guidelines," and "notices," which correspond respectively to long-term strategic direction, specialized implementation pathways, developmental support orientation, and specific execution measures. This aligns with the diverse forms of hydrogen policies, spanning from top-level design to practical implementation, and covers the entire process from macro-level guidance to micro-level execution, thereby avoiding one-sidedness in the evaluation.

Third, in terms of content, the sample balances regional coverage with industrial chain relevance and focuses on the critical implementation period of 2022-2024. At the regional level, Eastern China is represented by Shanghai, Shandong, and Guangzhou, showcasing the commercialization pathways in economically developed areas; Western China is represented by Sichuan and Qinghai, reflecting the industrial chain layout in resource-rich regions; and Central China is represented by Wuhan, highlighting the application expansion in transportation hub cities. This ensures comprehensive coverage across different regions and developmental stages. At the industrial chain level, the selected documents explicitly cover all or key segments of the "production-storage-transportation-refueling-application" chain, with more specific policy content and clearer measures. By focusing on the critical implementation phase of hydrogen policies, the sample avoids issues of vagueness and low operability common in early pilot-stage policies. Ultimately, this ensures that the sample possesses authority, representativeness, and comprehensiveness, laying a solid data foundation for subsequent research.

Table 1. Hydrogen energy industry policy samples.

Serial No.	Year	Category	Issuing Authority	Policy Name
P_1	2022	Plan	National Development and Reform Commission, National Energy Administration	Medium and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035) (National Development and Reform Commission & National Energy Administration of the People's Republic of China, 2022b)
P_2	2022	Plan	National Development and Reform Commission, National Energy Administration	14th Five-Year Plan for a Modern Energy System
P_3	2023	Implementation Plan	Shanghai Municipal Transportation Commission, Shanghai Municipal Development and Reform Commission, Shanghai Municipal Economy and Information Technology Commission	Plan for the Promotion and Application of Hydrogen Energy in Shanghai's Transportation Sector (2023-2025) (Shanghai Municipal Transportation Commission Shanghai Municipal Development and Reform Commission & Shanghai Municipal Commission of Economy and Informatization, 2023)
P_4	2024	Implementation Plan	General Office of the People's Government of Sichuan Province	Action Plan of Sichuan Province for Further Promoting the Integrated Development and Application of the Whole Hydrogen Energy Industry Chain (2024-2027) (General Office of the People's Government of Sichuan Province, 2024)
P_5	2022	Implementation Plan	General Office of the People's Government of Shandong Province	the Carbon Peaking Implementation Plan of Shandong Province (People's Government of Shandong Province, 2022)

Serial No.	Year	Category	Issuing Authority	Policy Name
P_6	2022	Implementation Plan	Qinghai Provincial Development and Reform Commission, Qinghai Provincial Energy Administration	Three-Year Action Plan for the Development of Hydrogen Energy Industry in Qinghai Province (2022-2025) (Qinghai Provincial Development and Reform Commission & Qinghai Provincial Energy Administration, 2023)
P_7	2022	Guideline	Wuhan Municipal People's Government	Opinions of the Municipal People's Government on Supporting the Development of Hydrogen Energy Industry (People's Government of Wuhan Municipality, 2022)
P_8	2024	Notice	General Office of the People's Government of Guangzhou Municipality	Notice of the General Office of the People's Government of Guangzhou Municipality on Issuing Several Measures for Accelerating the High-Quality Development of Hydrogen Energy Industry (General Office of the People's Government of Guangzhou Municipality, 2024)

Note: This table lists 8 national and local hydrogen energy industry policies issued in China from 2022 to 2024. These policies cover national strategic plans, provincial and municipal implementation plans, guidelines, and specific supporting measures, forming the policy sample for quantitative evaluation in this study.

3.2. Research Methodology

The PMC (Policy Modeling Consistency) index model was first proposed by Mario Arturo Ruiz Estrada in 2011. Its theoretical foundation stems from the "Omnia Mobilis" hypothesis, which posits that variables within a policy system do not exist in isolation. Instead, they form a dynamic relational network through complex logical interactions, and each variable holds equal importance in policy evaluation (Ba & Luo, 2025). Based on this hypothesis, the PMC model overcomes the subjective limitations of traditional policy evaluation. Through its comprehensive process of "multi-input-output table assignment → secondary indicator quantification → primary indicator aggregation → comprehensive index calculation," it transforms policy texts from qualitative descriptions into quantitative assessments. The core function of the model is to measure the structural integrity, logical consistency, and implementation adaptability of policies. It not only precisely captures the coverage of policy provisions through the binary assignment of secondary indicators ("1" indicating satisfaction and "0" indicating non-satisfaction) but also visually presents the gap between policies and the "ideal state" through the mean calculation of primary indicators and index summation. This provides a quantifiable and comparable scientific basis for policy optimization. After its introduction to China, the model was first applied and validated in science and technology innovation policy research by Zhang and Geng (2015). Subsequently, scholars have extended its application to fields such as government data governance, artificial intelligence, and green development. Its advantages in mitigating subjective bias and comprehensively capturing the multidimensional characteristics of policies have established it as an important methodology within policy informatics, combining both theoretical rigor and practical guidance. For this piece, the rationale for the model's suitability lies in the following: The design of hydrogen energy industry policies must encompass the complete process from energy production to end-user applications, and assessing their comprehensiveness requires multidimensional evaluation. The PMC model, through its systematic framework of primary and secondary variables, can comprehensively cover key dimensions such as policy nature, timeliness, and content, thereby avoiding the one-sidedness inherent in single-indicator evaluations. Meanwhile, quantitative calculation transforms the qualitative content of policy texts into objective scores, addressing the pain point of subjective judgment bias in hydrogen policy assessment and providing a unified standard for horizontal comparison across policies of different levels and types.

This study constructs a research framework of "text feature extraction-variable screening- quantitative evaluation" for the quantitative assessment of hydrogen energy industry policies. The specific procedure is as follows: First, the texts undergo word segmentation, removal of stop words, and keyword extraction to filter out high-frequency core words such as "hydrogen energy," "energy," "development," "industry," "technology," and "application." Concurrently, social network analysis is employed to visualize the co-occurrence relationships of high-frequency words and the core semantic features of the policy texts through methods like semantic network maps and tag clouds. The top 20-30 high-frequency words (e.g., "development," "construction," "technology") directly provide textual support for determining the secondary variables of the subsequent PMC model, ensuring that the variable settings are highly aligned with the actual content of the policies. On this basis, with reference to the classic framework of the PMC Index Model and combined with the hydrogen energy industry's "secondary energy attribute, whole-industry-chain linkage demand, cross-field application characteristics, and the particularity of safety supervision", the evaluation variable system is determined. Compared with traditional energy policies, hydrogen energy industry policies need to cover the entire industrial process, connect multiple fields such as energy, transportation, and industry, and simultaneously address safety risks such as storage and transportation leakage and hydrogen refueling station operation that run through all links of the industry. Therefore, the design of first-level variables not only retains general dimensions such as policy nature and policy time effectiveness but also specifically strengthens the coverage of "policy content" for the whole industry chain, the adaptability of "policy binding force" to safety supervision, and the orientation of "policy focus" for technological innovation and scenario implementation. Finally, ten dimensions are determined: policy nature, policy time effectiveness, policy content, policy evaluation, policy perspective, policy binding force, policy focus, policy object, policy support, and policy disclosure. Second-level variables are determined based on high-frequency word characteristics and the decomposition of first-level variable dimensions (e.g., X3 "Policy Content" includes three second-level variables: "Technological R&D", "Industrial Application", and "Safety Management", corresponding to high-frequency words such as "technology", "R&D", "application", and "safety"). All second-level variables adopt the binary "0-1 assignment method" (assign 1 if the policy text clearly mentions and articulates the content, and 0 if it is not mentioned or ambiguously expressed). Subsequently, the score of each policy under each first-level variable is calculated as the average score of its subordinate second-level variables. The PMC composite index of each policy is then obtained by summing the scores of the first 10 variables, with the defect index (i.e., the difference between 9 and the PMC index) used for auxiliary evaluation. Based on the index range (0-9 points), policies are classified into five grades: Grade A (8-9 points, Excellent), Grade B (6-8 points, Good), Grade C (4-6 points, Satisfactory), Grade D (2-4 points, Average), and Grade E (0-2 points, Poor). Meanwhile, by plotting the PMC surface graph of each policy, the score differences among first-level variables are intuitively presented, with a particular focus on the performance of hydrogen energy-specific dimensions such as "Policy Content". Finally, combining the score ranking and the characteristics of the surface graph, the completeness and rationality of policy design are systematically evaluated, and the advantageous dimensions and areas for optimization of each policy are identified.

4. Empirical Research and Results Analysis

4.1. Variable Selection and Indicator Establishment

To ensure that the variables of the PMC index model have a significant impact on policy outcomes, an in-depth mining of the hydrogen energy industry policy text database was first conducted using the ROSTCM6 text analysis tool. With the assistance of a high-frequency word semantic network relationship diagram (as shown in Figure 1), nodes such as "hydrogen energy," "energy," and "development" and their interconnections can be visually presented, clearly reflecting the semantic links within policies centered on the core domains of the hydrogen energy industry. Based on this, a high-frequency word list was generated (as shown in Table 2) to anchor the direction for model indicator selection. The table reveals that "hydrogen energy" ranks at the forefront with a high frequency of 635 occurrences, while words such as "energy," "development," "industry," and "application" also appear frequently and are closely interrelated, reflecting the core orientation of the policies. Simultaneously, the frequent appearance of words like "safety," "facilitation," and "innovation" indicates the policies' emphasis on corporate entities, innovation-driven approaches, and safety assurance. Words such as "acceleration," "Priorities," and "enhancement" highlight the policies' concentration on strengthening the industrial foundation and achieving breakthroughs in critical areas. These findings provide direct evidence for the precise selection of subsequent model variables.

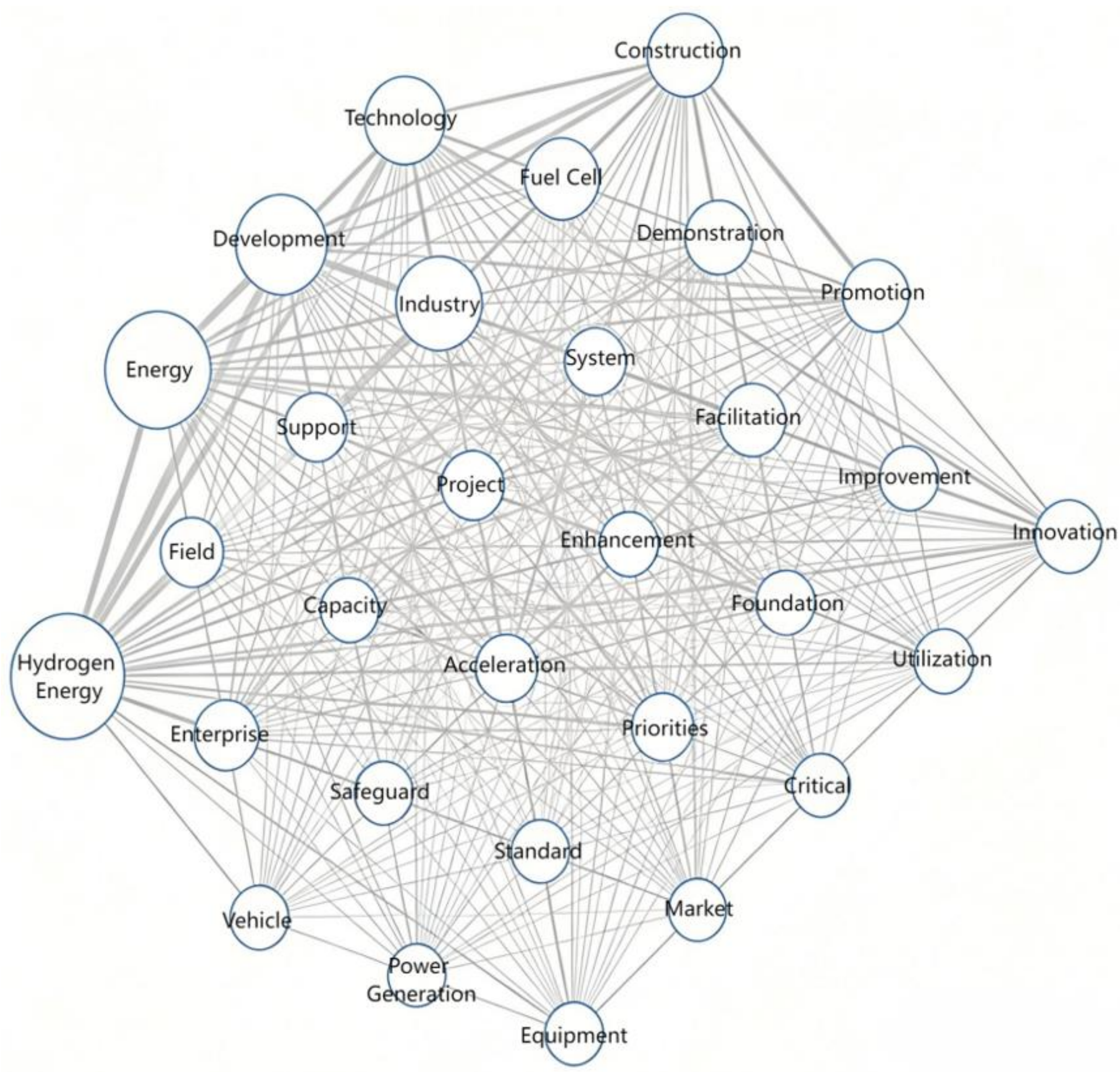

Figure 1. Semantic network relationship diagram of high-frequency words (Top 30) in Chinese hydrogen energy industry policy texts.

Note: This diagram visualizes the co-occurrence network of the top 30 high-frequency keywords extracted from China's hydrogen energy industry policy texts. Nodes represent key thematic words, and the lines indicate the co-occurrence relationships between them, reflecting the core focus and logical structure of policy attention.

Table 2. High-frequency word statistics of the Chinese hydrogen energy industry policy database (Top 50).

Word	Frequency	Word	Frequency	Word	Frequency	Word	Frequency	Word	Frequency
Hydrogen Energy	635	Safety	180	Acceleration	127	Critical	93	Electric Power	85
Energy	568	Facilitation	180	Priorities	127	Power Generation	93	Transportation	85
Development	417	Innovation	178	Foundation	107	Equipment	93	Management	84
Industry	380	Enterprise	158	Enhancement	105	Market	92	Layout	83
Application	332	Field	148	Utilization	103	Framework	91	Implementation	82
Technology	326	Project	145	Improvement	102	Standard	88	Region	81
Construction	280	Support	143	Capacity	98	Nation	88	Renewable	80
Fuel Cell	260	Strengthen	135	Proactive	97	R&D	87	Exploration	79
Demonstration	199	Conduct	132	Vehicle	97	Planning	86	Extension	79
Promotion	182	System	131	Safeguard	96	Green	86	Related	78

Note: This table presents the top 50 high-frequency keywords extracted from China's hydrogen energy industry policy texts, along with their occurrence frequencies. These words reflect the core policy concerns, key development directions, and focus areas in China's hydrogen energy industry policies.

When applying the PMC index model to evaluate hydrogen energy industry policies, constructing a classified variable evaluation indicator system is a crucial step. Building upon collected literature on PMC index evaluation studies and the results of the aforementioned analysis of hydrogen energy industry policy texts, this piece establishes a PMC index model evaluation indicator system for hydrogen energy industry policies, comprising 10 primary variables and 28 secondary variables (see Table 3). Among them, the primary variables—Policy Nature (X_1), Policy Timeliness (X_2), Policy Evaluation (X_4), Policy Perspective (X_5), Policy Binding Force (X_6), Policy Target (X_8), Policy Support (X_9), Policy Disclosure (X_{10}) and their affiliated secondary variables primarily draw on research by scholars such as Zhang and Geng (2015), Estrada (2011), Bu and Zhang (2023), Yong'an and Haituo (2017) and Cai, Chai, and Tian (2021). This aspect of the system focuses on evaluating the nature, timeliness, evaluation, perspective, binding force, target, support, and disclosure of policies. The establishment of the variables Policy Content (X_3) and Policy Focus (X_7) originates from the mining and analysis of hydrogen energy industry policy texts, aiming primarily at assessing the scientific nature, rationality, feasibility, and comprehensiveness of policy content. The specific indicators for their affiliated secondary variables are derived from the core variables extracted from the aforementioned high-frequency word statistics table. Following the completion of variable setting, this piece constructs an input-output table for hydrogen energy industry policies (as shown in Table 4).

Table 3. Evaluation indicator system of the PMC index model for hydrogen energy industry policies.

Primary Variable	Secondary Variable Code	Secondary Variable Name	Secondary Variable Evaluation Indicator	Scoring Criterion	Source
Policy Nature X_1	X_1:1	Forecast	Does the policy demonstrate predictive insights into the development trends of the hydrogen energy industry?	N:[0,1]	Zhang and Geng (2015)
	X_1:2	Regulation	Does the policy reflect regulatory considerations for activities related to the hydrogen energy industry?	N:[0,1]	
	X_1:3	Guidance	Does the policy exhibit a tendency to guide the development direction of the hydrogen energy industry?	N:[0,1]	
	X_1:4	Recommendation	Does the policy contain recommendatory content regarding the development of the hydrogen energy industry?	N:[0,1]	
	X_1:5	Description	Does the policy describe relevant circumstances of the hydrogen energy industry?	N:[0,1]	
Policy Timeliness X_2	X_2:1	Long-term (>5 years)	Does the policy address hydrogen energy industry planning for a period longer than 5 years?	N:[0,1]	Estrada (2011)
	X_2:2	Medium-term (3-5 years)	Does the policy address hydrogen energy industry planning for a 3 to 5-year period?	N:[0,1]	
	X_2:3	Short-term (<3 years)	Does the policy address hydrogen energy industry planning for a period shorter than 3 years?	N:[0,1]	
Policy Content X_3	X_3:1	Technology R&D	Does the policy address content related to technology R&D in the hydrogen energy industry?	N:[0,1]	High-frequency Word Statistics Table
	X_3:2	Industrial Application	Does the policy address content related to industrial applications in the hydrogen energy industry?	N:[0,1]	
	X_3:3	Safety Management	Does the policy address content related to safety management in the hydrogen energy industry？	N:[0,1]	
Policy Evaluation X_4	X_4:1	Clear Objectives	Do the policy objectives clearly specify development goals for the hydrogen energy industry?	N:[0,1]	Bu and Zhang (2023)
	X_4:2	Comprehensive Content	Is the policy content comprehensive and detailed, covering multiple aspects of the hydrogen energy industry?	N:[0,1]	
	X_4:3	Clear Authority and Responsibility	Does the policy clearly define the authority and responsibilities of relevant entities in the hydrogen energy industry?	N:[0,1]	
Policy Perspective X_5	X_5:1	Macro Perspective	Does the policy elaborate on the hydrogen energy industry from a macro-level perspective?	N:[0,1]	Cai et al. (2021)
	X_5:2	Micro Perspective	Does the policy elaborate on the hydrogen energy industry from a micro-level perspective?	N:[0,1]	
Policy Binding Force X_6	X_6:1	Penalty Mechanism	Does the policy contain content pertaining to penalties for non-compliance or violations within the hydrogen energy industry?	N:[0,1]	Yong'an and Haituo (2017)
	X_6:2	Governance System	Does the policy address content related to the governance system of the hydrogen energy industry?	N:[0,1]	

Primary Variable	Secondary Variable Code	Secondary Variable Name	Secondary Variable Evaluation Indicator	Scoring Criterion	Source
Policy Focus X_7	X_7:1	Technological Innovation	Does the policy highlight content related to technological innovation in the hydrogen energy industry?	N:[0,1]	High-frequency Word Statistics Table
	X_7:2	Industrial Promotion	Does the policy highlight content related to industrial promotion in the hydrogen energy industry?	N:[0,1]	
	X_7:3	Safety Assurance	Does the policy highlight content related to safety assurance in the hydrogen energy industry?	N:[0,1]	
Policy Target X_8	X_8:1	Enterprises	Does the policy address content related to hydrogen energy enterprises?	N:[0,1]	Cai et al. (2021)
	X_8:2	Research Institutions	Does the policy address content related to hydrogen energy research institutions?	N:[0,1]	
	X_8:3	Government Departments	Does the policy address content related to the role of government departments in the hydrogen energy industry?	N:[0,1]	
Policy Support X_9	X_9:1	Financial Support	Does the policy address content related to funding support for the hydrogen energy industry?	N:[0,1]	High-frequency Word Statistics Table
	X_9:2	Project Support	Does the policy address content related to support for hydrogen energy projects?	N:[0,1]	
Policy Disclosure X_{10}	/		Is the policy publicly disclosed?	N:[0,1]	Yong'an and Haituo (2017)

Note: This table constructs a multi-dimensional evaluation indicator system for hydrogen energy policies based on the PMC index model. All secondary indicators adopt a binary scoring standard of 0 or 1, where 1 means the corresponding content is involved in the policy, and 0 means it is not involved.

4.2. Constructing the Multi-Input-Output Table

To accurately assess the scientific rigor and completeness of hydrogen energy industry policies, it is first necessary to systematically deconstruct and quantitatively code the policy texts. Table 4, the Multi-input-output Table of the PMC Index Model for Hydrogen Energy Industry Policies, serves as the core analytical tool based on the PMC index model. It systematically records the alignment of eight hydrogen energy policy samples (P_1–P_8) with the established evaluation framework, which includes 10 primary variables such as Policy Nature (X_1) and Policy Timeliness (X_2) and their corresponding secondary variables. Following the research methodology of Estrada (2011), the table employs a binary coding system, where "1" indicates that a policy satisfies a given indicator and "0" indicates it does not. This coding lays the data foundation for the subsequent calculation of the PMC index, deficiency index, and policy grading.

Table 4. Multi-input-output table of the PMC index model for hydrogen energy industry policies.

Policy Code	X_1					X_2		
	$X_{1:1}$	$X_{1:2}$	$X_{1:3}$	$X_{1:4}$	$X_{1:5}$	$X_{2:1}$	$X_{2:2}$	$X_{2:3}$
P_1	1	1	1	1	1	1	1	1
P_2	1	1	1	1	1	1	1	1
P_3	1	1	1	0	1	0	1	1
P_4	1	1	1	1	1	1	0	1
P_5	1	1	1	1	1	1	1	1
P_6	1	1	1	1	0	1	0	1
P_7	1	0	1	0	1	0	1	1
P_8	1	1	1	0	0	0	1	1
	X_3					X_4		
	$X_{3:1}$	$X_{3:2}$	$X_{3:3}$			$X_{4:1}$	$X_{4:2}$	$X_{4:3}$
P_1	1	1	1			1	1	1
P_2	1	1	1			1	1	0
P_3	1	1	0			1	0	1
P_4	1	0	1			1	1	1
P_5	0	1	1			1	1	1
P_6	0	1	1			1	1	1
P_7	1	1	0			1	0	1
P_8	0	1	1			1	0	1
	X_5		X_6			X_7		
	$X_{5:1}$	$X_{5:2}$	$X_{6:1}$	$X_{6:2}$		$X_{7:1}$	$X_{7:2}$	$X_{7:3}$
P_1	1	1	1	0		1	1	1
P_2	1	1	1	0		1	1	1
P_3	1	1	0	1		1	1	0
P_4	1	1	0	1		1	0	1
P_5	1	1	0	1		0	1	1
P_6	1	1	0	1		0	1	1
P_7	1	1	0	1		1	1	0
P_8	1	1	0	1		0	1	1
	X_8					X_9		X_{10}

	$X_{8:1}$	$X_{8:2}$	$X_{8:3}$			$X_{9:1}$	$X_{9:2}$	
P_1	1	1	1			1	1	1
P_2	1	1	1			1	1	1
P_3	1	1	1			1	1	1
P_4	1	1	1			1	1	1
P_5	1	1	1			0	1	1
P_6	1	1	1			1	1	1
P_7	1	1	1			1	1	1
P_8	1	1	1			1	0	1

Note: This table presents the binary scoring results of all secondary indicators for the 8 selected hydrogen energy policies based on the PMC index model. The value of 1 means the corresponding indicator item is covered in the policy, while 0 means it is not covered.

4.3. Calculating the PMC Index

Quantitative analysis of policy texts using the PMC Index provides an objective and precise method for evaluating the completeness of the framework design and the adaptability during the practical implementation of hydrogen energy industry policies. A higher index score indicates stronger policy rationality and internal consistency. The specific calculation logic and grading determination rules are as follows:

First, the constructed "Multi-input-output Table of the PMC Index Model for Hydrogen Energy Industry Policies" serves as the primary data source. This table has completed the binary assignment for the eight hydrogen energy policy samples (P_1–P_8): according to Formula 1, for all secondary indicators under the 10 primary variables such as Policy Nature (X_1) and Policy Timeliness (X_2), a value of "1" is assigned if policy P meets the evaluation criteria for a given indicator, and "0" if it does not.

Second, following Formula 2, the value for each primary variable is calculated. In the formula, s or $s(P_{i,j})$ represents the number of secondary indicators under the i-th primary variable. This step yields the specific score of each policy across the 10 primary dimensions.

Finally, based on Formula 3, the scores of the 10 primary variables are summed directly to obtain the PMC Index for the corresponding policy, thereby completing the transformation from "qualitative description" to "quantitative assessment."

$$P_{i,j} \sim N(0,1) \qquad \text{(Formula 1)}$$

$$P_i = \left[\sum_{j=1}^{s} \frac{P_{i,j}}{s(P_{i,j})} \right] \quad i=1,2,3,\ldots,n \qquad \text{(Formula 2)}$$

$$\mathrm{PMC}_{\mathrm{index}} = \left[\begin{array}{l} P_1\left(\sum_{j=1}^{5}\frac{P_{1:j}}{5}\right) + P_2\left(\sum_{j=1}^{3}\frac{P_{2:j}}{3}\right) + P_3\left(\sum_{j=1}^{3}\frac{P_{3:j}}{3}\right) + P_4\left(\sum_{j=1}^{3}\frac{P_{4:j}}{3}\right) + P_5\left(\sum_{j=1}^{2}\frac{P_{5:j}}{2}\right) \\ + P_6\left(\sum_{j=1}^{2}\frac{P_{6:j}}{2}\right) + P_7\left(\sum_{j=1}^{3}\frac{P_{7:j}}{3}\right) + P_8\left(\sum_{j=1}^{3}\frac{P_{8:j}}{3}\right) + P_9\left(\sum_{j=1}^{2}\frac{P_{9:j}}{2}\right) + P_{10} \end{array} \right] \qquad \text{(Formula 3)}$$

Regarding the grading of the PMC Index, and with reference to the research of Estrada (2011) the results are categorized into five grades based on the characteristics and evaluation needs of hydrogen energy industry policies: a score of [8-9] corresponds to Grade A (Perfect), indicating comprehensive policy content, logical coherence, and strong alignment with industrial development needs; a score within [6,8) corresponds to Grade B (Excellent), reflecting robust performance in core dimensions while requiring only minor adjustments in specific areas; a score within [4,6) corresponds to Grade C (Good), suggesting the presence of certain shortcomings that necessitate targeted supplementation of key measures; a score within [2,4) corresponds to Grade D (Average), denoting a lower level of policy consistency and a need for systematic optimization of the framework design; and a score within [0,2) corresponds to Grade E (Poor), highlighting significant deficiencies in core dimensions and calling for a thorough reassessment of objectives and pathways. Specific details are provided in Table 5.

Table 5. Policy text grading.

Score Range	**[8-9]**	**[6-8)**	**[4-6)**	**[2-4)**	**[0-2)**
Evaluation	Grade A (Perfect)	Grade B (Excellent)	Grade C (Good)	Grade D (Average)	Grade E (Poor)

Note: This table shows the classification criteria for policy evaluation scores. Policies are divided into five grades from A to E according to different score intervals to reflect the overall quality of policy texts.

To more precisely identify the shortcomings in hydrogen energy industry policies, a Deficiency Index (Z) is introduced for further analysis based on the PMC Index evaluation. Calculated by relying on the PMC Index and Formula 4, it can directly reflect the gap between a policy and the "ideal state," clearly quantifying the extent of the policy's shortcomings in meeting the multi-dimensional variables. This provides more direct guidance for the subsequent targeted optimization of policies.

$$Z = 9 - PMC_{index} \qquad \text{(Formula 4)}$$

Building upon the previous explanation of the calculation logic for the PMC Index and the Deficiency Index, and after organizing the assignments of secondary indicators for each policy in the multi-input-output table, Table 6 is ultimately formulated. This table systematically presents the scores of the eight policy samples across the 10 primary variables. It also includes the Deficiency Index calculated based on Formula 4 (where a lower value indicates higher alignment with the dimensional variables and greater overall completeness of the policy), the grades from "A (Perfect)" to "E (Poor)" derived from the PMC Index grading intervals, and a ranking based on the PMC Index scores. This provides a comprehensive and clear overview of the quantitative evaluation results for the hydrogen energy industry policies.

Table 6. PMC index of hydrogen energy industry policies.

Indicator Text	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	PMC Index	Deficiency Index (Z)	Grade	Ranking
P_1	1.00	1.00	1.00	1.00	1.00	0.50	1.00	1.00	1.00	1.00	8.50	0.50	A	1
P_2	1.00	1.00	1.00	0.67	1.00	0.50	1.00	1.00	1.00	1.00	8.17	0.83	A	2
P_3	0.80	0.67	0.67	0.67	1.00	0.50	0.67	1.00	1.00	1.00	7.08	1.92	B	6
P_4	1.00	0.67	0.67	1.00	1.00	0.50	0.67	1.00	1.00	1.00	7.51	1.49	B	4
P_5	1.00	1.00	0.67	1.00	1.00	0.50	0.67	1.00	0.50	1.00	7.94	1.06	A	3
P_6	0.80	0.67	0.67	1.00	1.00	0.50	0.67	1.00	1.00	1.00	7.31	1.69	B	5
P_7	0.60	0.67	0.67	0.67	1.00	0.50	0.67	1.00	1.00	1.00	6.78	2.22	B	7
P_8	0.60	0.67	0.67	0.67	1.00	0.50	0.67	1.00	0.50	1.00	6.58	2.42	B	8
Mean	0.83	0.83	0.83	0.83	1.00	0.50	0.79	1.00	0.94	1.00	7.44	1.56	-	-

Note: This table presents the calculated PMC index, deficiency index, evaluation grade and ranking of the 8 hydrogen energy policies. Mean refers to the average value of each indicator and overall index.

4.4. Plotting the PMC Surface Map

Plotting the PMC Surface Map provides an intuitive visualization of the performance differences and structural characteristics of hydrogen energy industry policies across multiple variables. The map is constructed based on Formula 5 to form the PMC matrix. To ensure both balance and clarity of the matrix, one variable (X_{10}) was excluded, retaining the remaining nine primary variables to build a 3×3 matrix. The scores of these nine primary variables serve as the dimensional axes, and a three-dimensional irregular surface is generated using Excel. The surface is color-coded according to numerical ranges (e.g., green corresponds to the score interval of 0.6–0.8). Values closer to 1 indicate higher scores, better consistency, and more comprehensive coverage for the corresponding policy indicators; values closer to 0 indicate lower scores and weaker consistency. This visualization clearly reveals the distribution of multi-dimensional alignment across different policies and their spatial deviation from the "ideal state," offering a graphical foundation for analyzing policy strengths and weaknesses.

$$S_{PMC} = \begin{bmatrix} X_1 \cdot X_2 \cdot X_3 \\ X_4 \cdot X_5 \cdot X_6 \\ X_7 \cdot X_8 \cdot X_9 \end{bmatrix} \quad \text{(Formula 5)}$$

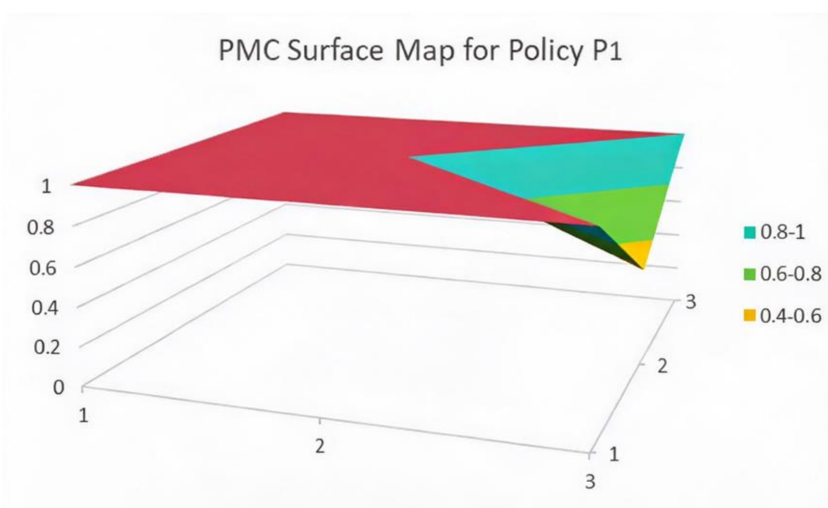

Figure 2. P_1 (National-level).

Note: Red represents the highest consistency zone, with variable scores extremely close to 1, reflecting that the policy performs nearly perfectly in those dimensions.

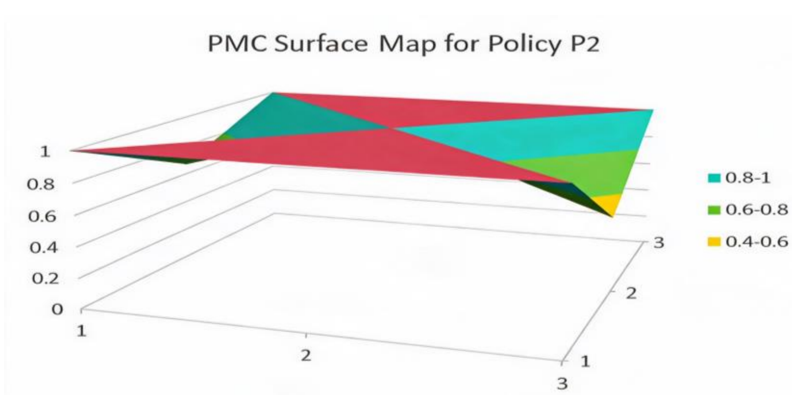

Figure 3. P_2 (National-level).

Note: This and the following PMC surface maps (Figure 2 to 9) visualize the PMC index scores of each evaluation dimension for the respective policies using three-dimensional surface maps. The color gradient in all figures follows the same scale, representing score levels from 0 to 1: the higher the score, the redder the surface, indicating more comprehensive and effective policy design in the corresponding dimension. Red represents the highest consistency zone, with variable scores extremely close to 1, reflecting that the policy performs nearly perfectly in those dimensions.

The PMC Surface Maps for both Policy P_1 and Policy P_2 are predominantly characterized by red, high-alignment areas, with the core primary variables (Policy Nature, Timeliness, and Content) performing close to the "ideal state." Only the non-core dimensions exhibit limited green areas (0.6–0.8). Their PMC Index scores of 8.50 and 8.17, respectively, fully reflect the high-quality characteristics of Grade A policies. Among them, P_1, as a guiding document in the hydrogen energy field, provides comprehensive coverage of the industrial chain and demonstrates rigorous interconnections across all dimensions, serving as a benchmark document that balances guidance with practicality. P_2 focuses on the overall energy system and excels in the coordinated development design between hydrogen and other clean energy sources, with only minor room for optimization in specific variables such as "Policy Binding Force," making it highly aligned with the systematic planning orientation of the "14th Five-Year Plan."

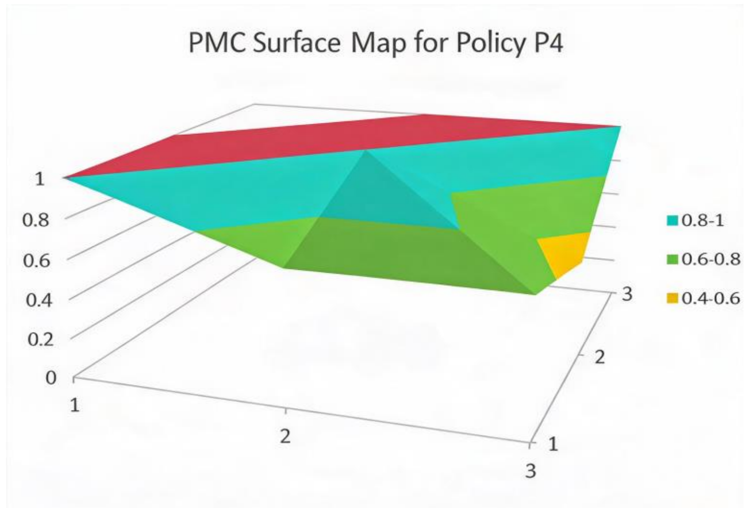

Figure 4. P4 (Provincial-level, Sichuan).

Note: Red represents the highest consistency zone, with variable scores extremely close to 1, reflecting that the policy performs nearly perfectly in those dimensions.

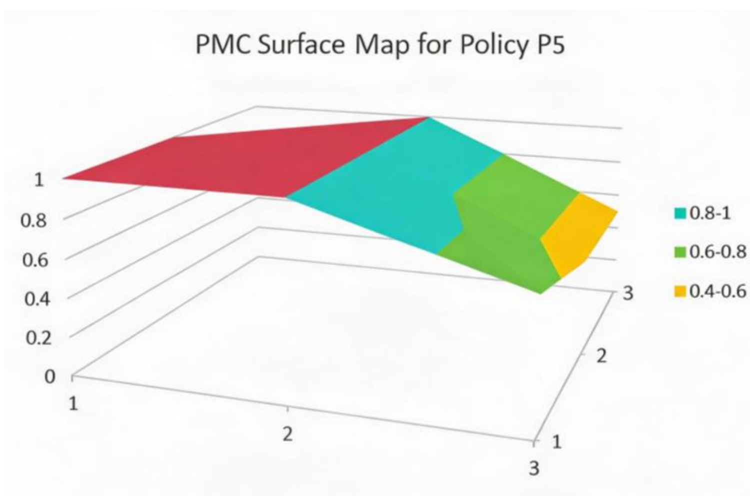

Figure 5. P5 (Provincial-level, Shandong).

Note: Red represents the highest consistency zone, with variable scores extremely close to 1, reflecting that the policy performs nearly perfectly in those dimensions.

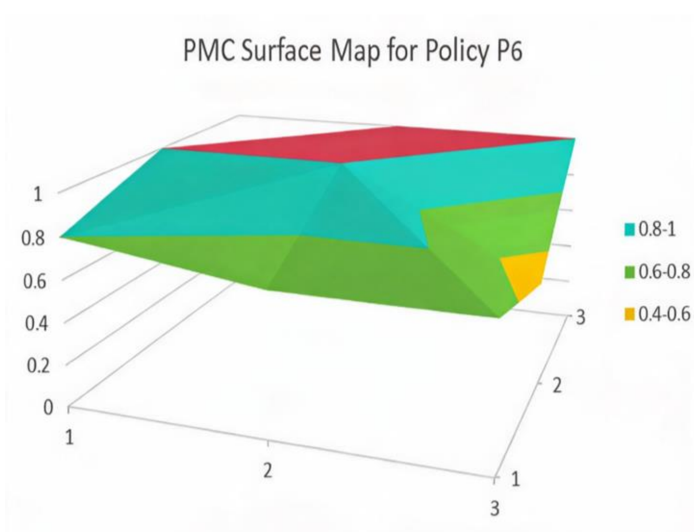

Figure 6. P6 (Provincial-level, Qinghai).

Note: Red represents the highest consistency zone, with variable scores extremely close to 1, reflecting that the policy performs nearly perfectly in those dimensions.

The surface map for Policy P_5 is predominantly red, with a PMC Index of 7.94 placing it in Grade A. Its strategic positioning aligns well with its implementation timeline, closely matching Shandong's energy transition needs, showing only a minor weakness in the granularity of dedicated hydrogen energy provisions. Both Policy P_4 and P_6 are graded B (with indices of 7.51 and 7.31, respectively), and their surface maps are mainly composed of cyan (0.8-1) and green (0.6-0.8) areas. Each leverages its regional resource endowment (Sichuan's natural gas and hydropower, Qinghai's green electricity) to demonstrate strengths in either policy systematicity or regional adaptability. However, P_4 exhibits issues with insufficient refinement in policy binding force and penalty mechanisms, while P_6 faces shortcomings in downstream application scenario development and a lack of cross-regional coordination clauses, resulting in a gap compared to Grade A policies.

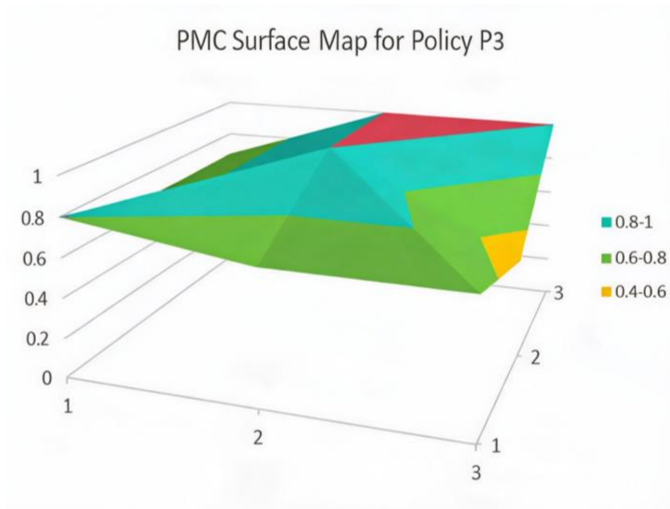

Figure 7. P3 (Municipal-level, Shanghai).

Note: Red represents the highest consistency zone, with variable scores extremely close to 1, reflecting that the policy performs nearly perfectly in those dimensions.

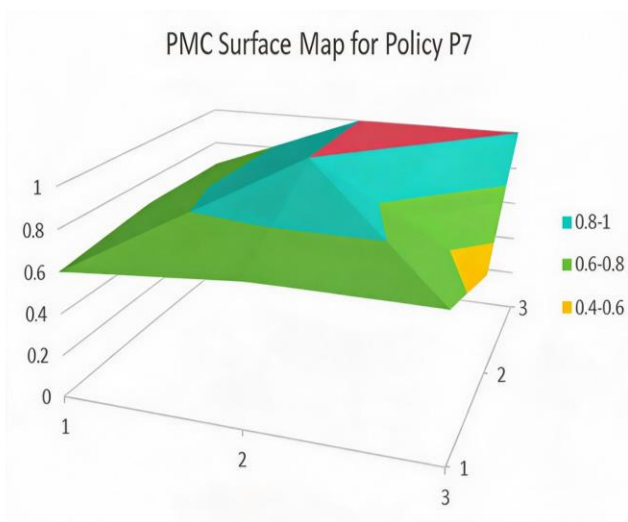

Figure 8. P7 (Municipal-level, Wuhan).

Note: Red represents the highest consistency zone, with variable scores extremely close to 1, reflecting that the policy performs nearly perfectly in those dimensions.

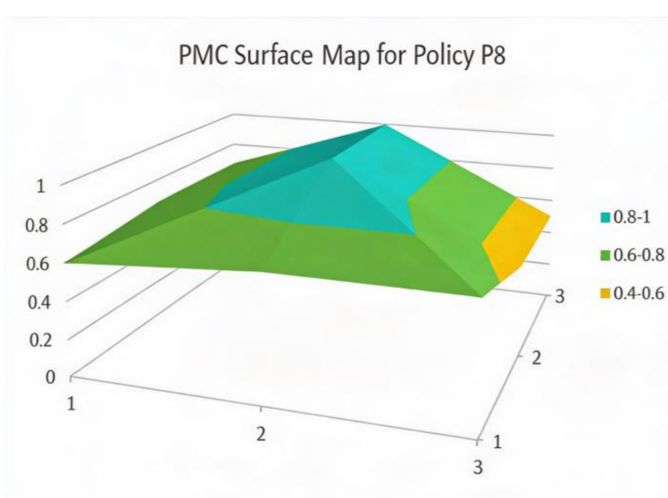

Figure 9. P8 (Municipal-level, Guangzhou).

The surface maps for P3, P7, and P8 are primarily composed of cyan and green areas, with some presence of yellow areas (0.4-0.6) and no distinct red high-alignment regions. Their PMC Indices range between 6.58 and 7.08, indicating an overall alignment lower than that of the previous two policy groups. Among these, P3 focuses on transportation scenarios, demonstrating strong policy targeting and regional adaptability, but shows deficiencies in cross-departmental coordination and the refinement of technical standards. As municipal-level policies, P7 and P8, while aligned with local industrial foundations (such as Wuhan's automotive industry), generally exhibit notable shortcomings, including incomplete industrial chain coverage, weak policy binding force, and a lack of implementation safeguard mechanisms. Consequently, the fullness of their surface morphology ranks among the lowest across the eight samples.

Overall, the surface maps of Grade A policies (P1, P2, P5) are dominated by red high-alignment areas, reflecting concentrated core strengths, clear strategic positioning, comprehensive full-chain coverage, and strong implementation adaptability. Although Grade B policies (P3, P4, P6, P7, P8) show strengths in regional resource alignment or industrial focus, the proportion of high-alignment areas in their surface maps is limited. They commonly face issues such as incomplete policy content coverage and weak binding clauses, resulting in a significant gap in morphological fullness compared to Grade A policies.

These results reveal the hierarchical characteristics of the hydrogen energy industry policy system: national-level top-level planning possesses the strongest systematic nature and guidance; provincial comprehensive policies can enhance the effectiveness of hydrogen deployment through synergy with related fields; while local specialized policies need to strengthen efforts in "full-chain coverage" and "rigorous constraint design" to narrow the structural gap with high-quality policies and promote the high-quality development of the hydrogen energy industry. Based on this, spider-web comparison charts for two representative policy types, P5 and P3, are plotted. The charts show that the perfect-type P5 and the excellent-type P3 perform similarly across five dimensions, including policy nature and timeliness, but differ significantly in another five dimensions, such as policy content and binding force. When mapped across all eight samples, this characteristic reveals a common pattern of "hierarchical differentiation": Grade A policies like P1, P2, and P5 achieve systematic top-level design through high alignment across all dimensions. In contrast, Grade B policies like P3, P4, P6, P7, and P8, constrained by shortcomings such as incomplete policy content coverage and weak binding clauses, can only function effectively within regional or specialized domains. This clearly illustrates the structural features and optimization directions of China's hydrogen energy policy system, characterized by "top-level guidance complemented by local implementation."

Figure 10 illustrates the comparative radar chart between Policy P_5 (Shandong, Grade A) and Policy P_3 (Shanghai, Grade B). It shows that these two policies perform similarly across five dimensions (e.g., Policy Nature and Policy Timeliness) but differ significantly in the other five dimensions, particularly in Policy Content and Policy Binding Force. This contrast between the two representative policies reflects a broader pattern of "hierarchical differentiation" within China's hydrogen energy policy system: top-level plans exhibit systematic coherence and high consistency across all dimensions, while local specialized policies tend to suffer from incomplete industrial chain coverage and weaker enforceability.

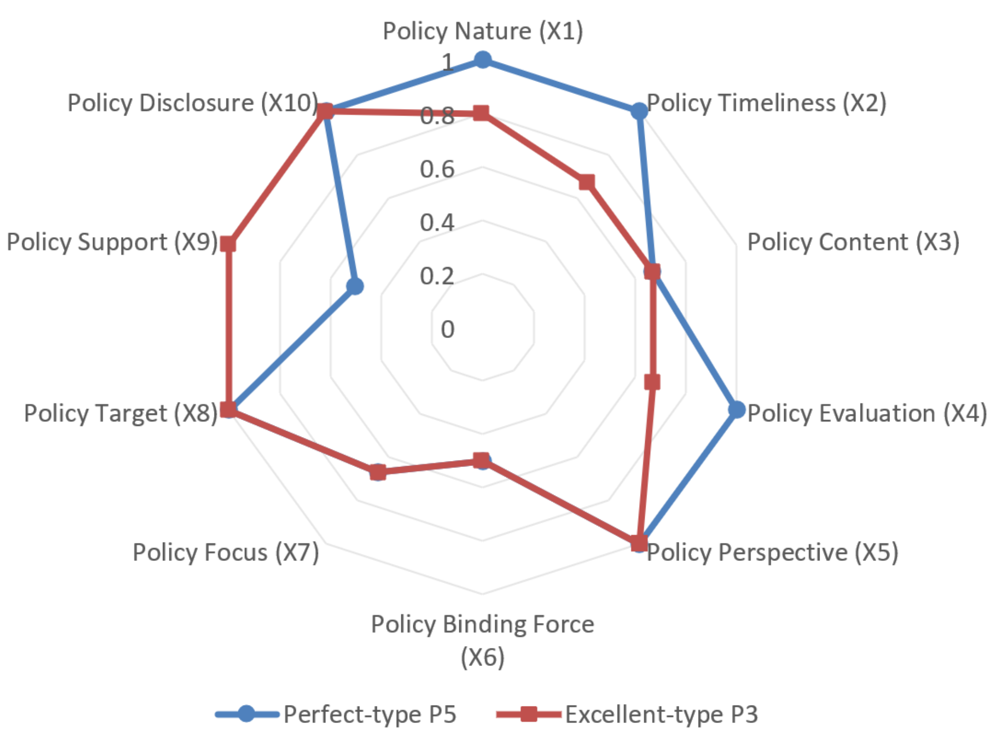

Figure 10. Policy Comparison Radar Chart.

Note: This radar chart compares the PMC index scores of two representative policies (Perfect-type P5 and Excellent-type P3) across 10 evaluation dimensions. Each axis corresponds to a primary variable of the PMC index model, and the radial scale ranges from 0 to 1. The blue line represents the high-performing policy P5, while the orange line represents policy P3, highlighting their structural differences in policy quality.

4.5. Comparative Evaluation

Through the quantitative analysis of the eight hydrogen energy policy texts (P_1-P_8), P_1 (the "Medium and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035)" (National Development and Reform Commission & National Energy Administration of the People's Republic of China, 2022b)) stands out due to its high-alignment PMC surface map performance, with its core dimension values approaching 1, emerging as the top-performing policy text in China's quantitative evaluation. Accordingly, this piece selects it for an in-depth comparative analysis with policies from South Korea (the "Hydrogen Economy Promotion and Hydrogen Safety Management Act" (National Assembly of the Republic of Korea, 2022)), Australia (the "Australia's National Hydrogen Strategy"), and South Africa (the "Department of Science and Innovation. Hydrogen Society Roadmap for South Africa 2021") (see Table 7). The comparison dissects differences and strengths across four key dimensions: legislative framework, strategic positioning, implementation pathways, and safeguard mechanisms. This aims to distill insights with both an international perspective and local adaptability for optimizing China's policies.

China's Medium and Long-Term Plan for the Development of the Hydrogen Energy Industry positions hydrogen energy as a key component of the national energy system, emphasizing the principle of "safety first, market leadership, and government guidance" (Ling, Li, & Zhang, 2022). South Korea's Hydrogen Economy Promotion and Hydrogen Safety Management Act establishes a dedicated Hydrogen Economy Committee through legislation, specifying provisions such as "hydrogen-exclusive industrial complexes" and "tax incentives," thereby forming a complete closed loop from legal authorization to fiscal incentives. Australia's National Hydrogen Strategy adopts a three-tiered "vision-goals-actions" structure, supported by an AUD 8 billion incentive fund to promote industrial scale-up. South Africa's National Hydrogen Society Roadmap integrates hydrogen energy into the national framework of a "just energy transition," emphasizing social inclusion and job creation.

In terms of the legislative framework, China still mainly relies on planning documents and lacks dedicated hydrogen energy laws and regulations. South Korea has established mandatory standards and regulatory authority through special legislation. Australia has formed a quasi-legal effect via regulatory guidelines supporting its Strategy. South Africa has developed a multi-level regulatory system by means of policy coordination between the "Green Hydrogen Commercialization Strategy for South Africa (Department of Trade Industry and Competition South Africa, 2022) and the Roadmap (Wan, Xiong, & Wang, 2022). In terms of strategic positioning, China emphasizes hydrogen energy's supporting role in achieving the "dual carbon" goals and focuses on the integrity of the industrial chain. South Korea leverages the hydrogen economy to drive industrial competitiveness and energy security. Australia prioritizes the export-oriented development of hydrogen energy. South Africa focuses on the "zero-carbon economy" and "green jobs" (Chen & Chen, 2022). Regarding the implementation pathway, China follows a government-guided model structured around a four-phase sequence of "demonstration first, followed by industrial chain improvement, technological breakthroughs, and market cultivation." South Korea has established a collaborative innovation chain involving "government, enterprises, and research institutions." Australia implements a trinity mechanism of "goals, actions, and funding." South Africa advances its scale-up through a model of "phased milestones, multi-departmental coordination, and international cooperation." Concerning safeguard mechanisms, China focuses more on the policy environment and standards development, with relatively weaker provisions for fiscal incentives and risk sharing. In contrast, South Korea, Australia, and South Africa all specify concrete measures for capital investment, tax incentives, and risk-sharing clauses. Notably, South Korea has established a dedicated safety regulatory agency; Australia leverages its carbon pricing policy to provide strong backing for project financing; and South Africa integrates hydrogen energy into the national "Just Energy Transition" investment plan to mitigate technological and market risks.

Table 7. Comparative analysis of core dimensions in hydrogen energy policies: China, South Korea, Australia, and South Africa.

Comparative Dimensions	**China: Medium and Long-Term Plan for the Development of the Hydrogen Energy Industry (2021-2035)**	**South Korea: Hydrogen Economy Promotion and Hydrogen Safety Management Act**	**Australia: Australia's National Hydrogen Strategy**	**South Africa: Hydrogen Society Roadmap for South Africa 2021**
Legislative Framework	Primarily relies on non-statutory planning documents, with no dedicated hydrogen energy legislation at present, and coordinates under the framework of the Energy Law.	Specialized legislation establishes a Hydrogen Economy Committee; specifies regulatory and penalty provisions.	No dedicated legislation; achieves quasi-legal effect through regulatory guidance supporting the Strategy.	Multi-policy alignment, embedded within the "Just Energy Transition" framework.
Strategic Positioning	Supports the "Dual Carbon" goals with a focus on achieving a complete industrial chain.	Driving industrial competitiveness and energy security through the hydrogen economy.	With an export-oriented approach to hydrogen energy.	Promoting a "zero-carbon economy" and "green jobs".
Implementation Pathways	Four-phase pathway: demonstration first → industrial chain improvement → technological breakthroughs → market cultivation	Government-Enterprise-Research Collaboration	Trinity mechanism of goals, actions, and funding	Model structured in three phases: milestone-driven planning, cross-departmental collaboration, and international partnership
Safeguard Mechanisms	Policy environment and standard building, supported by demonstration guidance; fiscal incentives and risk-sharing mechanisms remain relatively underdeveloped.	Tax incentives and a dedicated safety regulatory agency.	AUD 8 billion incentive fund and a risk-sharing mechanism.	Included in the national transition investment plan to mitigate technological and market risks.

Note: This table compares the core dimensions of representative hydrogen energy policies from four countries, including legislative framework, strategic positioning, implementation pathways and supporting mechanisms, so as to identify the differences and characteristics of relevant policies across nations.

5. Conclusions and Recommendations

5.1. Research Conclusions

5.1.1. China's Hydrogen Energy Policies Are of High Overall Quality with Marked Differentiation Across Hierarchies and Types

Based on the evaluation of eight hydrogen energy policies from 2021 to 2025 using the PMC Index model, the overall mean score reached 7.44, placing them within the "Excellent to Perfect" tier. However, significant differentiation is evident: national-level comprehensive plans (P_1, P_2) and the provincial-level cross-sectoral policy (P_5) achieved Grade A "Perfect" status (with indices exceeding 7.9). Their PMC surface maps are predominantly characterized by red, high-alignment areas, indicating comprehensive coverage of core dimensions, logical coherence, and strong implementation adaptability. In contrast, local specialized policies (P_3, P_4, P_6, P_7, P_8) all fall into Grade B

"Excellent" (with indices ranging from 6.58 to 7.51). Their surface maps are mainly composed of cyan and green areas. While these policies demonstrate alignment with regional resource endowments and industrial contexts, they commonly exhibit shortcomings such as incomplete industrial chain coverage and weak policy binding force.

5.1.2. Chinese and International Hydrogen Energy Policies Exhibit Significant Differences in Legislative, Strategic, and Safeguard Dimensions

A comparison of China's P_1 (the Plan) with South Korea's Act, Australia's Strategy, and South Africa's Roadmap reveals that the core differences in policy are concentrated across three key dimensions: In terms of the legislative framework, China primarily relies on planning documents, while the other countries have established legal safeguard systems through dedicated legislation, supporting regulatory guidance, or multi-policy alignment. Regarding strategic positioning, China focuses on the role of hydrogen energy in supporting the "Dual Carbon" goals, whereas South Korea, Australia, and South Africa center their strategies on industrial competitiveness, energy security, export orientation, or green employment. Concerning safeguard mechanisms, China emphasizes standard development and demonstration guidance, while the other three parties all specify concrete measures for capital investment, tax incentives, and risk-sharing clauses.

5.1.3. The Hydrogen Energy Policy System Exhibits a Hierarchical Division of Labor with Systemic Shortcomings

China's hydrogen energy policy system has formed a hierarchical structure characterized by "top-level guidance, mid-level coordination, and local-level supplementation." National-level top-tier plans (P_1, P_2) play a guiding role across the entire industrial chain. Provincial comprehensive policies (P_5) achieve cross-sectoral synergy by integrating with carbon peaking goals. Local specialized policies (P_3, P_4, P_6, P_7, P_8) leverage regional characteristics to advance scenario-based implementation. However, the system exhibits distinct shortcomings: top-level plans lack dedicated legislative backing, resulting in insufficient enforcement rigidity; provincial and municipal policies suffer from weak coordination and linkage, leading to duplicated industrial layouts in some regions; local policies predominantly focus on the application end of hydrogen energy, with support provisions for upstream segments like hydrogen production, storage, and transportation being overly brief, failing to establish comprehensive, full-chain policy support.

5.2. Policy Recommendations

5.2.1. Establish a Hydrogen Energy Legal Governance System to Overcome Institutional Bottlenecks

Currently, China has included hydrogen energy as a statutory energy type in the "Energy Law of the People's Republic of China" (Standing Committee of the National People's Congress of the People's Republic of China, 2024). The legal text explicitly places hydrogen energy under the same regulatory framework as coal, petroleum, natural gas, nuclear energy, wind energy, solar energy, and others, and sets forth requirements to actively and systematically advance its development and utilization. However, beyond the Energy Law, there has been no enactment of specialized legislation dedicated to the hydrogen energy industry, nor are there specific laws covering the entire "production-storage-transportation-refueling-application" chain. Existing hydrogen energy policies mainly consist of planning documents, industry guidelines, and standards. The regulatory system remains fragmented, particularly lacking unified and binding legal constraints for specific aspects such as safety distances for hydrogen refueling stations and emergency response protocols for hydrogen storage and transportation leaks.

Therefore, it is recommended to establish a three-tier legal governance system comprising "top-level laws - specialized legislation - implementation rules": refine the hydrogen energy chapter under the framework of the Energy Law to clarify its strategic positioning, thereby providing a higher-level legal foundation for subsequent specialized legislation. Drawing on South Korea's model of a "Hydrogen Economy Promotion Committee" for integrated legislation and implementation, as well as Germany's experience with the cross-departmental coordination mechanism of NOW GmbH, a national-level hydrogen energy coordination and management body should be established to formulate dedicated laws. These laws should specify enterprise qualification standards, safe operation norms, and penalties for violations. Furthermore, the core requirements of the United Nations Sustainable Development Goals (SDGs) should be deeply embedded incorporating quantifiable carbon reduction targets from SDG 13 (Climate Action), innovation incentive clauses from SDG 9 (Industry, Innovation and Infrastructure), and safeguarding content from SDG 7 (Affordable and Clean Energy) into legally binding provisions. Additionally, relevant departments such as energy, transportation, and market regulation should be promoted to issue supporting implementation rules, focusing on pain points in key areas like hydrogen production, storage, transportation, and application, thereby forming a complete legal governance loop. This would provide a reference for other countries to address the common challenge of "low-carbon energy development lacking legal safeguards," highlighting the institutional value of hydrogen energy policy research for global sustainable development.

5.2.2. Deepen International Cooperation and Joint Rule-Making to Enhance Discourse Power in Global Hydrogen Governance

Currently, the development of global hydrogen standards and rule-making is dominated by developed countries such as the United States, Japan, and Germany, while developing countries exhibit low participation. The rule design fails to adequately consider the resource endowments and technological levels of developing nations and does not sufficiently incorporate the inclusive objectives outlined in the SDGs, resulting in an imbalance in development.

Therefore, based on existing practices, it is recommended to advance a "Two-Way Mutual Recognition" strategy. This involves collaborating with countries along the Belt and Road to propose a China-led initiative integrating "Tiered Certification" with "Technology Inclusivity," setting flexible standard clauses tailored to differences in resource endowments and technological levels, thereby forming a regional standard system. In key areas such as fuel cell core components and hydrogen storage or transportation interfaces, China should leverage its industrial scale and technological expertise to deepen its involvement in ISO's international standard-setting processes, thereby avoiding future "Regulatory Traps." Regarding cross-border hydrogen trade and technical cooperation, partnerships with countries rich in green hydrogen resources, such as Australia, should be deepened to explore tripartite synergy in "Resources-Market-Technology" and develop cross-border trade mechanisms combining "Green Hydrogen," "Carbon Sinks," and "Technology Transfer." For international industrial chain collaboration, joint R&D with entities like the EU and Japan should be conducted to tackle global technological challenges, such as hydrogen storage or transportation efficiency and fuel cell durability. In response to transnational challenges like hydrogen storage/transportation safety and cross-border technology transfer, it is recommended that China take the lead in initiating a "Global Hydrogen Sustainable Development Cooperation Organization." This organization would collaborate with international institutions to establish a global platform and create a "Hydrogen Technology Inclusivity Fund," providing low-interest loans for hydrogen infrastructure construction, technical training, and talent support to developing countries. This aims to facilitate a transition in global hydrogen rule-making from "minority dominance" to "pluralistic co-governance and inclusive sharing." By doing so, a fair, reasonable, inclusive, and equitable global hydrogen governance system can be constructed, injecting collaborative momentum into the global energy transition and sustainable development, and demonstrating the governance responsibility of China as a major power.

5.2.3. Innovate Policy Instruments and Governance Models to Unblock Bottlenecks in Technology-Market-Capital Transformation

China's hydrogen energy industry has achieved a scale advantage, with hydrogen production and consumption exceeding 36.5 million tonnes in 2024, ranking first globally. However, it still faces challenges in core technological competitiveness, cost control, and business models. There is an urgent need to draw on internationally proven policy instruments to facilitate the industry's transition from "policy-driven" to "market-driven" growth.

It is recommended to draw on international experience to innovate governance models: Drawing on the collaborative multi-agency approach of the U.S. (e.g., the Fuel Cell Technologies Office-FCTO (United States Department of Energy, 2020)) and the integrated planning of Japan's "Hydrogen and Fuel Cell Strategy Office," (Energy Observer Network, 2019) establish a dedicated functional department for "National Hydrogen Economy Development" to coordinate national hydrogen industry planning, cross-regional infrastructure development, and R&D fund allocation. Drawing on mechanisms like the UK's Hydrogen Contracts for Difference (CfD) (Poudineh, 2024) and the EU's "European Hydrogen Bank" (Hydrogen Europe, 2023), implement a CfD-like policy instrument with Chinese characteristics, and establish a "National Hydrogen Bank" to integrate fiscal funds, green bonds, and development financing tools to support green hydrogen commercialization. In hydrogen-intensive regions like the Beijing-Tianjin-Hebei area and the Guangdong-Hong Kong-Macao Greater Bay Area, promote the "Hydrogen Hub + Application Cluster" model, developing intensive industrial parks that focus on deploying essential applications such as industrial decarbonization, heavy-duty transportation, and long-duration energy storage. This approach leverages economies of scale to reduce costs and facilitates the industry's transition from "policy-driven" to "market-driven" growth. The innovation of these policy instruments and governance models can not only address bottlenecks in China's hydrogen industry development but also provide actionable implementation blueprints for other countries, especially developing nations, thereby demonstrating the practical value of this research.

References

Aba, M. M., Sauer, I. L., & Amado, N. B. (2024). Comparative review of hydrogen and electricity as energy carriers for the energy transition. *International Journal of Hydrogen Energy, 57*, 660-678. https://doi.org/10.1016/j.ijhydene.2024.01.034

Adebisi, B. (2025). *Comparative analysis of global hydrogen policies and strategies with recommendations for Nigeria: Focusing on green hydrogen regulation, value chain development, and power-to-X*. Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Arup. (2024). *The potential for exporting hydrogen from the UK to continental Europe*. London: Arup.

Australian Government. (2019). *Australia's national hydrogen strategy*. Canberra, ACT, Australia: Australian Government.

Australian Hydrogen Council. (2020). *Getting to H2 under $2: Key milestones for achieving a hydrogen export industry at scale in Australia*. Canberra, ACT, Australia: Australian Hydrogen Council.

Ba, Y., & Luo, Z. (2025). Evaluation of China's medical and older adult care integration policy based on the PMC model. *Frontiers in Public Health, 13*, 1660238. https://doi.org/10.3389/fpubh.2025.1660238

Bu, L. T., & Zhang, J. W. (2023). Quantitative evaluation of digital economy policies based on the PMC index model. *Statistical Decision, 7*, 22–27.

Cai, D., Chai, Y., & Tian, Z. (2021). Quantitative evaluation of digital economy policy text in Jilin Province based on PMC index model. *Information Science, 12*, 139-145.

Chen, Q. Y., & Chen, Y. W. (2022). Comparative analysis of international hydrogen energy development strategies. *Science Observation, 17*(2), 1–12.

Department of Science and Innovation. (2021). *Hydrogen society roadmap for South Africa 2021*. Pretoria, South Africa: Government of the Republic of South Africa.

Department of Trade Industry and Competition South Africa. (2022). *Green hydrogen commercialisation strategy for South Africa*. Pretoria, South Africa: Government of South Africa.

Energy Observer Network. (2019). *It is not necessary to follow the path taken or being taken by developed countries in setting up hydrogen energy management institutions*: Energy Observer Network.

Estrada, M. A. R. (2011). Policy modeling: Definition, classification and evaluation. *Journal of Policy Modeling, 33*(4), 523-536. https://doi.org/10.1016/j.jpolmod.2011.02.003

General Office of the People's Government of Guangzhou Municipality. (2024). *Several measures for accelerating the high-quality development of hydrogen energy industry*. Guangzhou, China: Guangzhou Municipal Government.

General Office of the People's Government of Sichuan Province. (2024). *Action plan of Sichuan Province for further promoting the integrated development and application of the whole hydrogen energy industry chain (2024–2027)*. Sichuan, China: Sichuan Provincial Government.

Han, X., Zhang, X., Yan, H., Kang, J., Li, J., & Zhang, H. (2021). Current situation and prospect of global hydrogen energy industry policy. *Electric Power Information and Communication Technology, 19*(12), 27-34.

Hren, R., Vujanović, A., Van Fan, Y., Klemeš, J. J., Krajnc, D., & Čuček, L. (2023). Hydrogen production, storage and transport for renewable energy and chemicals: An environmental footprint assessment. *Renewable and Sustainable Energy Reviews, 173*, 113113. https://doi.org/10.1016/j.rser.2022.113113

Huang, X. L., Hu, X. S., & Huang, H. (2021). Quantitative analysis of China's hydrogen energy industry policies and research on regional layout. *Journal of Science and Technology Information Research, 3*(2), 83–95.

Hydrogen Europe. (2023). *The European Hydrogen Bank: Kickstarting the European hydrogen market*. Brussels, Belgium: Hydrogen Europe.

Jia, Y., Yuan, X., & Li, M. (2022). Supporting policies for the whole industrial chain of hydrogen energy: The practice and enlightenment of EU. *Fiscal Science, 1*, 141-151.

Li, H. Y., Tan, Q., & Chen, J. A. (2024). Research history of hydrogen energy in China based on bibliometric method. *Acta Energiae Solaris Sinica*, *45*(5), 276–288.

Ling, W., Li, Q. S., & Zhang, K. (2022). Research on the development strategy of China's hydrogen energy industry. *Engineering Science in China*, *24*(3), 80–88.

Ma, H., Sun, Z., Xue, Z., Zhang, C., & Chen, Z. (2023). A systemic review of hydrogen supply chain in energy transition. *Frontiers in Energy*, *17*, 102-122. https://doi.org/10.1007/s11708-023-0861-0

Ministry of Science and Technology of the People's Republic of China National Development and Reform Commission & Ministry of Foreign Affairs of the Peoples Republic of China. (2007). *China's science and technology special action for addressing climate change*. Beijing, China: State Council of the People's Republic of China.

Ministry of Trade Industry and Energy. (2019). *Hydrogen economy roadmap of Korea*. Sejong, South Korea: Government of the Republic of Korea.

Ministry of Transport of the People's Republic of China. (2025). *Guiding opinions on promoting the integrated development of transportation and energy*. Beijing, China: Ministry of Transport of the People's Republic of China.

Ministry of Transport of the People's Republic of China, & Ministry of Science and Technology of the People's Republic of China. (2022). *Medium and long-term development plan for science and technology innovation in the transport sector (2021–2035)*. Beijing, China: State Council of the People's Republic of China.

National Assembly of the Republic of Korea. (2022). *Hydrogen economy promotion and hydrogen safety management act*. Seoul, South Korea: Government of the Republic of Korea.

National Development and Reform Commission, & National Energy Administration of the People's Republic of China. (2022a). *14th Five-Year Plan for a modern energy system*. Beijing, China: State Council of the People's Republic of China.

National Development and Reform Commission & National Energy Administration of the People's Republic of China. (2022b). *Medium and long-term plan for the development of the hydrogen energy industry (2021–2035)*. Beijing, China: State Council of the People's Republic of China.

Norwegian Ministry of Petroleum and Energy, & Norwegian Ministry of Climate and Environment. (2020). *The Norwegian Government's hydrogen strategy: Towards a low emission society*. Oslo, Norway: Government of Norway.

People's Government of Shandong Province. (2022). *Carbon peaking implementation plan of Shandong Province*. Shandong, China: Shandong Provincial Government.

People's Government of Wuhan Municipality. (2022). *Opinions of the Municipal People's Government on supporting the development of hydrogen energy industry*. Wuhan, China: Wuhan Municipal Government.

Poudineh, R. (2024). *Can UK green hydrogen contract for difference (CfD) match the cost-saving success of renewable electricity?* Oxford, United Kingdom: Oxford Institute for Energy Studies.

Qinghai Provincial Development and Reform Commission & Qinghai Provincial Energy Administration. (2023). *Three-year action plan for the development of hydrogen energy industry in Qinghai Province (2022–2025)*. Qinghai, China: Qinghai Provincial Government.

Scholvin, S., Black, A., & Robbins, G. (2024). *Green hydrogen as a driver of development? De-risking and production linkages with new value chains in South Africa and Chile*. PRISM Working Paper 2024-3, Policy Research in International Services and Manufacturing (PRISM), University of Cape Town, Cape Town, South Africa.

Shanghai Municipal Transportation Commission Shanghai Municipal Development and Reform Commission & Shanghai Municipal Commission of Economy and Informatization. (2023). *Plan for the promotion and application of hydrogen energy in Shanghai's transportation sector (2023–2025)*. Shanghai, China: Shanghai Municipal Government.

Standing Committee of the National People's Congress of the People's Republic of China. (2024). *Energy law of the People's Republic of China*. Beijing, China: Standing Committee of the National People's Congress of the People's Republic of China.

Stetson, N., & Wieliczko, M. (2020). Hydrogen technologies for energy storage: A perspective. *MRS Energy & Sustainability*, *7*(1), 41. https://doi.org/10.1557/mre.2020.43

Sun, X., Zhao, Y., Li, S., Wang, Q., Li, X., & Zhang, B. (2023). Textual quantitative analysis on China's local hydrogen energy development policies. *Chemical Industry and Engineering Progress*, *42*(7), 3478–3488.

United States Department of Energy. (2020). *Hydrogen and fuel cell activities, progress and plans: September 2016 to August 2019*. Washington, D.C., United States: U.S. Department of Energy.

Wan, Y. M., Xiong, Y. L., & Wang, X. Y. (2022). Analysis of hydrogen energy development strategies of major countries worldwide. *Energy Storage Science and Technology*, *11*(10), 3401–3410.

Yang, L. (2025). Study on the characteristics and evolutionary trends of China's hydrogen energy industry policy hierarchy. *Theory and Practice Think Tank*, *10*(1), 94–104.

Yong'an, Z., & Haituo, Q. (2017). Quantitative evaluation innovation policies of the state council. *Science & Technology Progress and Policy*, *34*(17), 127-136. https://doi.org/10.6049/kjjbydc.2016110731

Zhang, C., Zhang, M. Z., & Shen, S. (2022). Path suggestions and policy discussion for the high-quality development of hydrogen energy in China. *Southern Energy Construction*, *9*(4), 11–23.

Zhang, Q. S., & Huang, X. S. (2023). Analysis of policies and technical economy of hydrogen energy industry at home and abroad. *Low-Carbon Chemical and Chemical Engineering*, *48*(2), 133–139.

Zhang, Y., & Geng, Z. (2015). The quantitative evaluation of regional science and technology innovation policy: Based on the index of PMC model. *Science and Technology Management Research*, *14*, 26-31.

Zhang, Y. F. (2019). Main contents and enlightenments of South Korea's hydrogen economy roadmap. *Global Science, Technology and Economy Outlook*, *34*(Z1), 4–6.