

Research on the Application of AI Technology in the Hydrogen Energy Industry



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Abstract

This report provides a systematic analysis of the current landscape, challenges, and future trajectories facing the integration of Artificial Intelligence (AI) technology with hydrogen energy – two fields at the forefront of technological innovation.

Chapter 1 highlights the role of hydrogen energy as a critical vector for deepening decarbonisation and enhancing energy security, emphasising the urgent need to overcome key bottlenecks in industry development. Concurrently, it identifies rapidly advancing AI as an emerging key enabler for driving cost reductions and efficiency gains across the hydrogen energy value chain.

Chapter 2 details how AI is driving transformation across the hydrogen energy value chain as it is widely applied across diverse scenarios in the hydrogen energy industry. This chapter analyses the current implementation and future potential of AI in the hydrogen energy industry along two dimensions: scenario maturity and potential value. In hydrogen production AI is revolutionising catalyst R&D paradigms. Machine Learning and A-Labs accelerate novel material discovery and synthesis. AI helps optimise electrolyser parameters by forecasting renewable energy inputs. Digital twins and predictive maintenance enhance equipment longevity. Among these applications, catalyst R&D exhibits low maturity but high value potential, while predictive maintenance is a highly mature and a key application focus. In storage and transportation AI aids in screening high-performance hydrogen storage materials and planning transportation routes. However, applications in this field remain nascent, requiring a careful balance between efficiency and safety. In hydrogen refuelling stations, AI-enabled management systems hold promise for dynamic supply-demand matching and safety risk prediction, but the current scarcity of refuelling stations limits broader AI deployment in this field. In end-use applications such as fuel cell vehicles, AI empowers energy management, range optimisation, and fault diagnosis, among other functions, with relatively high scenario maturity, accelerating the commercialisation process.

Chapter 3 examines global “AI + hydrogen energy” industry practices, highlighting the distinct development pathways of different countries. In Europe, countries such as Germany, France, and the UK have leveraged policy frameworks and financial support to advance AI applications in the examination and approval of hydrogen energy projects, natural hydrogen exploration, and production optimisation. In Asia, China has legally recognised hydrogen energy’s strategic status while promoting full-industry-chain digitalisation; Japan and South Korea are deeply integrating AI into specialised domains like fuel cell systems and hydrogen power plant operations. In North America, US companies are using AI for molecular screening and electrolyser optimisation with significant results, though policy uncertainty persists. In India, the National Green Hydrogen Mission is attracting multinational investment in AI-enabled green hydrogen projects.





Chapter 4 is an in-depth analysis of the challenges impeding the deep integration of AI and hydrogen energy. The primary obstacle lies in data limitations, including a shortage of data, data silos, and inconsistent formats. A second challenge is the stability and reliability gap between laboratory outcomes and industrial deployment at scale. Third, regulatory frameworks and industry standards lag behind technological advancements, lacking unified data standards, models, and testing protocols, while accountability mechanisms and admission requirements also remain unclear. Additionally, a shortage of interdisciplinary expertise, as well as the current overconcentration of application scenarios in transportation while neglecting higher-decarbonisation-potential sectors such as industrial processes and building construction, further constrain the realisation of AI's potential.

Chapter 5 proposes recommendations to advance the high-quality development of "AI + Hydrogen Energy":

1. Improve data quality and establish internationally recognised data governance and sharing frameworks.
2. Accelerate commercialisation by establishing engineering verification platforms and implementing a phased certification process, facilitating the conversion of laboratory results to real industrial applications.
3. Strengthen standards and regulations by promoting internationally unified technical standards and establishing clear legal liability frameworks.
4. Address the talent shortage by cultivating interdisciplinary talent through integrated educational programmes, industry training initiatives, and international exchange opportunities.
5. Expand application scopes by extending AI empowerment beyond transportation into more diverse sectors such as industrial processes, building construction, and energy management systems.

In summary, the synergistic integration of AI and hydrogen energy has emerged as a critical trend driving global energy transformation. By addressing key challenges in data, technology, standards, and talent, while proactively broadening application boundaries, "AI + hydrogen energy" integration holds significant potential to unlock multiplier effects, providing critical support for establishing a clean, safe, and efficient modern energy system.

Introduction

Against the backdrop of profound transformation in the global energy landscape and a growing consensus on carbon neutrality, hydrogen energy is gaining significant strategic prominence as a green, low-carbon, abundant, and versatile secondary energy source. Hydrogen energy's advantages, such as having zero emissions, a high energy density, and its energy storage characteristics, position it as a key decarbonisation vector globally and a vital strategic choice for enhancing national energy security. In 2024, the Energy Law of the People's Republic of China formally established hydrogen energy's legal status for the first time. Furthermore, the 15th Five-Year Plan explicitly identifies hydrogen energy as a new driver for economic growth, signalling how the hydrogen energy industry in China is transitioning from early exploration to a new age of breakthroughs.

Concurrently, artificial intelligence (AI) is being integrated across many industries at an unprecedented pace. As a versatile and targeted technological system, AI demonstrates revolutionary potential for accelerating industrial intelligence upgrades. A KPMG International survey indicates that, while the energy sector currently lags in AI adoption maturity, 79% of surveyed companies report efficiency gains through AI, and 76% plan to increase their AI investments, highlighting the positivity in AI's application outlook. In this context, the deep integration of AI and hydrogen energy not only promises to optimise the hydrogen value chain through intelligent algorithms that enhance green hydrogen production efficiency and reduce costs, but it will also provide key technical support for the digital transformation of the energy systems as a critical pathway for advancing the energy revolution and achieving the dual carbon goals.

In light of this, KPMG China has partnered with the International Hydrogen Fuel Cell Association to jointly launch research exploring the application of AI in the hydrogen energy industry. This research covers an in-depth exploration of how AI may empower the hydrogen value chain – spanning hydrogen production, storage and transportation, refuelling stations, and utilisation, an analysis of global “AI + hydrogen energy” industry practices, identification of the challenges hindering the “AI + hydrogen energy” integration, and targeted recommendations. For the preparation of the report, KPMG and the Association conducted extensive interviews with over a dozen senior executives from hydrogen energy companies and specialists from universities and research institutions, gaining profound insights into the latest advancements of AI applications in the hydrogen energy industry. These valuable insights and perspectives gathered from both industry and academia have significantly enriched the report's scope, enhancing its foresight, practical relevance, and overall depth.

For industry participants, this report aims to foster information sharing and technological exchange between enterprises and academic institutions, building a collaborative innovation ecosystem to drive the high-quality development of the hydrogen energy industry. For investors, this report provides insights into cutting-edge developments in hydrogen energy, helping them identify the key segments within the value chain with high potential and make better investment decisions. For policymakers, the report calls for strengthened collaboration among governments, industry associations, and relevant departments to promote standardisation, policy coordination, and joint efforts for the sustainable development of the global hydrogen energy industry.



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The Significance of Integrating AI into the Hydrogen Energy Industry



1.1

Hydrogen energy is an important means to achieving global decarbonisation

1. A core means for decarbonisation

Hydrogen energy is a green, low-carbon, widely available and used secondary energy source. In recent years, as more and more countries have proposed a carbon neutrality vision, hydrogen energy has become a core means for decarbonisation due to its zero emissions, high energy density, and energy storage characteristics.

According to production methods and carbon emissions volume, hydrogen energy can be classified into three types: grey hydrogen, blue hydrogen, and green hydrogen. Green hydrogen is known as "zero carbon hydrogen" as it is produced by the electrolysis of water using renewable energy sources such as solar power and wind power. Therefore, green hydrogen holds an important position in energy transformation planning across the globe. According to the International Energy Agency (IEA), confirmed electrolytic bath projects have reached 20 gigawatts worldwide. By 2030, the production of green hydrogen is expected to grow fivefold compared with that in 2024.¹ The increase in production and technological progress will expand the use of green hydrogen from the chemical industry to transportation, electricity and other fields, helping the world achieve its carbon neutrality goal.

2. Strategic choice for energy security

From a global perspective, tensions between superpowers are becoming increasingly fierce and, with regional conflicts intensifying, energy security has become an imperative. As sources of hydrogen energy are widely available, helping countries overcome the limitations of natural resource endowment and improve their energy autonomy and security, many countries and regions have formulated hydrogen energy development strategies to enhance national energy security. For example, the United States released a new version of its hydrogen project plan in 2024, with a focus on developing electrolytic hydrogen production technology²; Germany, the Netherlands and other countries have secured green hydrogen production capacity in North Africa, Australia and other countries through their "hydrogen energy import strategy"³.

From the perspective of China's hydrogen energy development, China's hydrogen energy industry is shifting from an exploration stage to a new era where breakthroughs continue to emerge. The Energy Law of the People's Republic of China promulgated by the central government in 2024 clearly includes hydrogen energy within the energy management system, identifying hydrogen energy as one of the major energy sources from a legal perspective for the first time. This "policy design + market-driven" strategy lays a solid foundation for the development of national energy security.



¹ Global Green Transformation Promotes International Cooperation on Hydrogen Energy, Beijing Energy and Environmental Society, 23 October 2024, https://mp.weixin.qq.com/s?__biz=MzUyMTE3OTkwMQ==&mid=2247553838&idx=1&sn=88d397db0cc9102c4b2af0ce71712a2b&chksm=f8a2a2e54b8554df1657a4b1b8c4ab01e2fa05b4a88fd6102f3c21daf7da02ced7d39d70f960&scene=27

² The US Department of Energy updates its multi-year plan on hydrogen energy and fuel cells, Institute of Science and Development of Chinese Academy of Sciences, 28 October 2024, https://www.casid.cn/zkcg/ydkb/kjqyb/2024/kjqyb2407/202410/t20241028_7409469.html

³ Hydrogen Energy, the Game Changer: A Key Variable in the International New Energy Revolution, China Economic Times, 26 March 2025, <https://www.cet.com.cn/yepd/xbt/10185972.shtml>

1.2 The disruptive potential of Artificial Intelligence

1. Definition of Artificial Intelligence

The connotation and denotation of Artificial Intelligence (AI) have been iterated with the development of the times and technological progress, with its definition varying depending on the research purpose and perspective. This report refers to the definitions of international organisations and national standards, and approaches AI from a "systematic" perspective, that is, viewing it as an integrated and targeted system rather than a standalone technology. This perspective helps to unify macro perceptions and provides a clear framework for industrial applications.



Internationally, the Organisation for Economic Cooperation and Development (OECD) defines AI systems as machine-based systems that can infer from inputs how to generate outputs that can affect physical or virtual environments, such as predictions, content, recommendations, or decisions, targeting clear or implicit goals. Additionally, there are differences in the level of autonomy and adaptability of different AI systems deployed.



The **Chinese national** standard (GB/T 41867-2022) defines AI systems as engineering systems with different levels of automation which can develop models that represent data, knowledge, processes, etc. based on human-set goals, using various AI related technologies and methods, and generate outputs such as content, predictions, recommendations, or decisions.



This report refers to the definitions of international organisations and national standards, and approaches AI from a "systematic" perspective, that is, viewing it as an integrated and targeted system rather than a standalone technology. This perspective helps to unify macro perceptions and provides a clear framework for industrial applications.

In terms of a broader range of technologies and applications, AI covers sub-fields such as machine learning, deep learning, natural language processing, and reinforcement learning. Its applications include computer vision, natural language processing, speech recognition, intelligent decision support, and smart robots.

The integration of AI and the hydrogen energy industry is reflected in "intelligence", which not only follows the evolutionary path that has gone from automation and informatisation to digitisation, but also manifests fundamental differences.



Automation: With the core purpose of replacing repetitive human operations, automated execution is achieved through preset rules, emphasising efficiency and precision.



Informatisation: With information technology (IT) and communication technology (CT) at its core, utilising computers to manage resources and processes in the physical world, emphasising processes and management.



Digitisation: With data processing and quantification at its core, the physical world is mapped into a virtual form, a prerequisite for achieving higher-level analysis and decision-making.



Intelligence: With the core of endowing machines with human-like intelligence and abilities (such as perception, cognition, analysis, and decision-making), this process is built upon the foundations of the first three, but is different in that systems now have the ability to learn and adapt, that is, achieving autonomy such as self-learning, self-adapting, and self-evolution, and are capable of dealing with complex and uncertain environments.

2. AI is empowering intelligent upgrades across many different industries

As the integration of AI technologies with technology, retail, energy and many other industries accelerates, KPMG International conducted a survey on the application of AI in over 1,000 companies worldwide, covering eight industries that included technology, healthcare, life sciences, industrial manufacturing, energy, retail, insurance, and banking. The AI applications in these industries were summarised around five key pillars: intelligence maturity, technology applications, investment returns, future expenditure, and risk management (Figure 1).

Figure 1 “AI + Industry Insights” from a global perspective

	Intelligence maturity	Technology applications	Investment returns	Future expenditure	Risk management
 Technology	51% Systematically integrating AI technologies into products and services	81% Viewing embedded AI as the core business value driver	70% Cost reductions achieved	85% Increasing the proportion of AI investment in the global budget	36% Viewing security and data privacy as major challenges
 Healthcare	85% Developing AI solutions internally ; 59% AI systematically integrated into products and services development	84% Using AI capable data platforms; 59% agentic AIs are being extensively used	72% Efficiency improvement achieved; 39% financial conditions improved	36% AI accounting for over 10% of the IT budget	84% Facing with challenges such as data issues, skill shortage, and legal issues
 Life sciences	65% AI systems have been integrated into their products and services	85% Autonomous agentic systems are being widely used or increasingly used	73% Efficiency improved by using AI	69% A clear strategic vision has been developed for the role that AI will play in the next five years	68% Facing with issues such as data silos, quality differences, and privacy concerns
 Industrial manufacturing	84% Developing AI solutions internally; 62% AI has been used for over three years	74% Machine learning has been introduced; 72% predictive analysis is being used; 67% AI agents have been deployed	96% Operational and efficiency improvements achieved; 62% investment returns exceed 10%	77% Planning to increase AI investment within the next 12 months; 71% expected growth rate to exceed 10%	65% Adopted a structured AI-enabled risk management approaches; 57% data privacy and regulatory compliance 44% are the main areas of concern

Figure 1 “AI + Industry Insights” from a global perspective (cont)



	Intelligence maturity	Technology applications	Investment returns	Future expenditure	Risk management
Energy	56% AI is already on trial; 13% Establishing an AI Centre of Excellence	64% Cloud IT infrastructure deployed; 59% AI has been integrated into the core of operations	79% Efficiency improvements achieved; 60% returns on investment exceed 10%	76% Planning to increase AI expenditure; 63% Growth rates to exceed 10%	58% Challenges in scaling up AI applications: data quality, 38% regulatory complexity, 37% limited budget
Retail	56% AI has been used for over three years; 47% AI has become the core of business	64% Using Gen AI; 58% adopting predictive analysis; 51% adopting robotic process automation	55% Returns on investment exceed 10%; 47% investment returns exceed 30%	55% Planning to increase the proportion of AI investment in the budget; 33% indicating that AI investment will grow by over 20%	68% Managing data privacy is the biggest risk area
Insurance	59% Still relying on locally deployed AI solutions; 59% internally developing and customising AI tools	58% Data and analytic platforms with AI functionalities have been established; 57% AI has been integrated with robotic process automation	66% AI investment is expected to achieve a moderate to extremely high investment returns	67% Planning to increase the proportion of AI investment in the budget 66% by 20%; 34% by over 20%	72% Data is the main challenge
Banking	25% An integrated or hybrid cloud platform that can provide strategic support for data-driven services has been established	83% Adopting locally deployed solutions; 66% utilising cloud-based AI platforms; 46% using open-source tools	66% Cost savings achieved; 25% revenue growth achieved; 13% utilising AI to generate higher revenues	70% Planning to increase the proportion of AI investment in the budget 62% by 20%; 34% by over 20%	72% Concerns about data quality; 71% indicating a need for establishing a sound regulatory compliance framework

Source: KPMG International, KPMG Analysis



In terms of intelligence maturity, over half of the eight surveyed industries have varying degrees of AI applications. Among the surveyed companies, 85% of healthcare companies and 84% of industrial manufacturing companies are actively developing internal AI solutions, demonstrating their disruptive capabilities. But it should also be noted that only 56% of the surveyed energy companies are trying out AI applications, reflecting how the energy industry still needs to work harder to improve and catch up with the industry-leading practices.



In terms of technology applications, most of the industries surveyed have an advanced degree of technology application. 85% of the surveyed life sciences companies have extensively used or are gradually increasing the use of autonomous agentic systems; 84% of the surveyed healthcare companies are using data platforms with AI capabilities; 83% of the surveyed banking institutions adopt locally deployed solutions; and 81% of the surveyed technology companies consider embedded AI as a core business value driver. However, only 64% of the surveyed energy companies have deployed a cloud IT infrastructure, indicating significant room for improvement at the AI application level compared to other industries.



In terms of investment returns, the use of AI technologies has brought considerable returns and efficiency optimisation to various industries. According to our survey, 79% of surveyed energy companies indicated that they have achieved efficiency improvements, and 60% of surveyed energy companies stated that they have achieved over 10% investment returns through AI technologies. In comparison, due to a low technology conversion rate, only 56% of the surveyed retail companies reported investment returns exceeding 10%, reflecting how some retail companies have not yet achieved quantifiable returns on their AI investments.



In terms of future expenditure, all the surveyed industries plan to increase their AI investment as returns increase. The survey shows that 85% of surveyed technology companies, 77% of surveyed industrial manufacturing companies, and 76% of surveyed energy companies plan to increase their AI investments, ranking as the top three in this category. Although the intelligence maturity and technology application level of the energy industry are relatively low, the energy industry is paying more attention to potential applications of AI in the energy industry. Most energy companies plan to increase their spending on AI technologies to improve the industry's intelligence level.



In terms of risk management, as a disruptive technology with a wide range of impacts, the development of AI technologies is accompanied by risks in the areas of data privacy, regulatory compliance, data silos, and quality differences. The surveyed energy companies stated that they are facing risks arising from data quality (58%), regulatory complexity (38%), and limited budgets (37%). In addition, 71% of the surveyed banking institutions indicated that a sound regulatory compliance framework should be established, reflecting the privacy risks and data security pressures faced by various industries during the development of AI technologies.

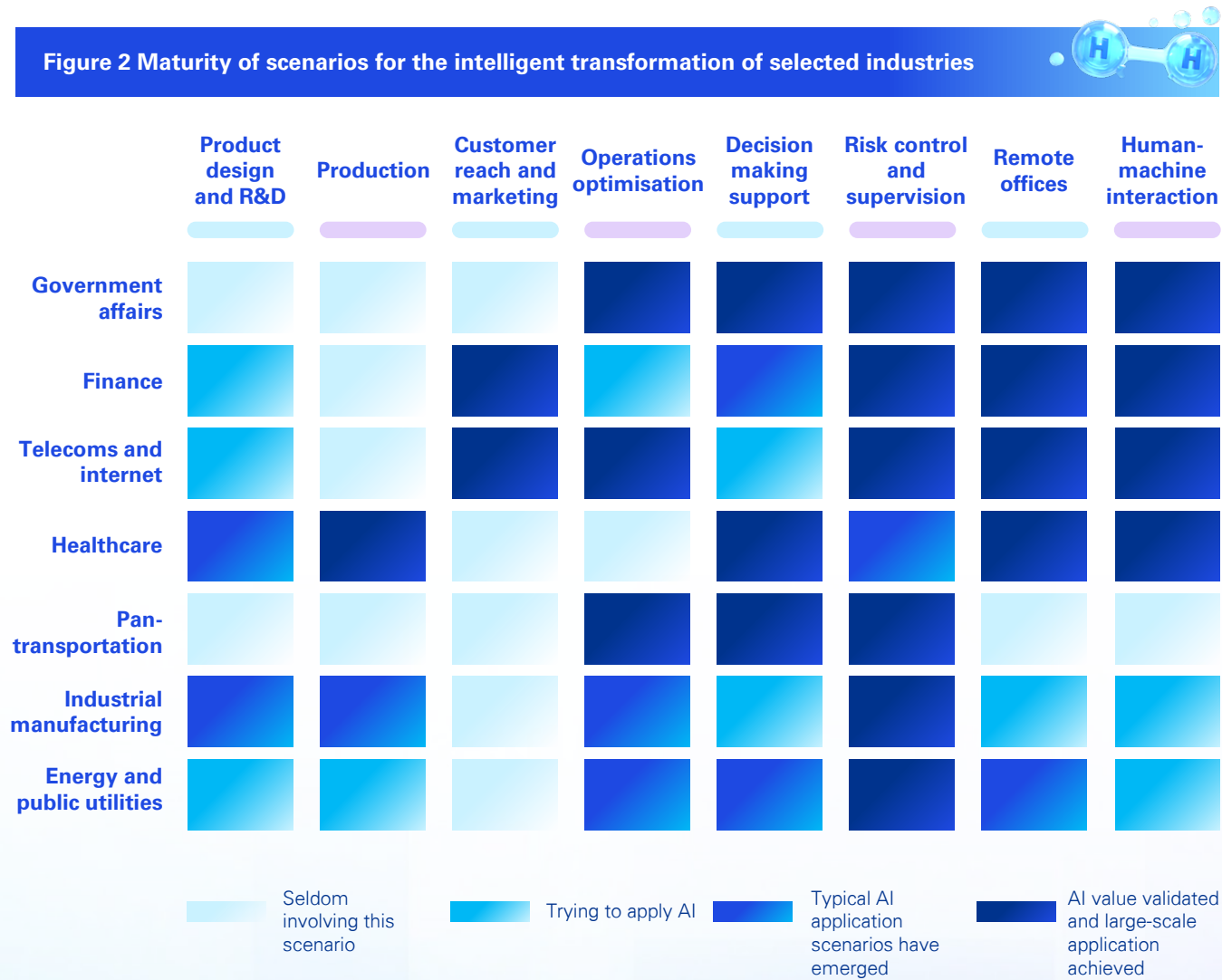


AI technologies have been widely applied in scenarios such as risk control and supervision and human-machine interaction

AI technologies are being integrated into various industries at an unprecedented speed, with application scenarios constantly expanding and deepening. In respect of the range of applications, due to differences in the intelligence maturity across different industries, the application of AI technologies shows a progressive trend. Currently, AI technologies have been adopted in the fields of telecommunications, the internet, government affairs, and finance, and are gradually being extended to various other industries such as healthcare, pan-transportation, industrial manufacturing, and energy.

In terms of the depth of application, while currently focused on achieving cost reductions and efficiency improvements in practical operations, AI performs particularly well in scenarios with frequent human-machine interaction and repetitive tasks, such as smart customer services and risk compliance. (Figure 2).

Figure 2 Maturity of scenarios for the intelligent transformation of selected industries



Source: White Paper on Artificial Intelligence Readiness, KPMG China

3. Multiplier effect of “AI + hydrogen energy”

For achieving the “dual carbon” goal, “AI + hydrogen energy” is indispensable. The development focus of the hydrogen energy industry lies in efficiency improvements and cost reductions, with technological innovation as the fundamental driving force. With sensors, data collection, and intelligent algorithms, AI can achieve the visualisation of water electrolyser status, operational safety, and regulation optimisation, building an intelligent control system that covers the entire “hydrogen production — hydrogen storage — hydrogen consumption” chain. This system can achieve millisecond-level alignment between renewable energy power fluctuations and flexible loads of electrolysis devices, improving the efficiency of hydrogen production at scale and refuelling station safety. For cost reductions, AI can reduce power consumption by simulating and optimising parameters such as current densities and temperatures in the water electrolysis process. AI can also quickly screen hydrogen storage materials with high hydrogen storage capacity, high safety, and low costs through machine learning algorithms, reducing hydrogen energy research and production costs.

The development of the hydrogen energy industry and the innovation of AI technology are mutually reinforcing. The development of the hydrogen energy industry requires the support of multiple AI technologies, including machine learning and natural language processing. Such cross-domain integration promotes the comprehensive upgrading of technology. In return, AI technology innovation provides solid technological support for the cost reductions, efficiency improvements, and the sustainable development of the hydrogen energy industry. With continuous breakthroughs in hydrogen energy technology and the expansion of application scenarios, the hydrogen energy industry will continue to drive the transformation of the global energy system and contribute to the achievement of carbon neutrality goals.

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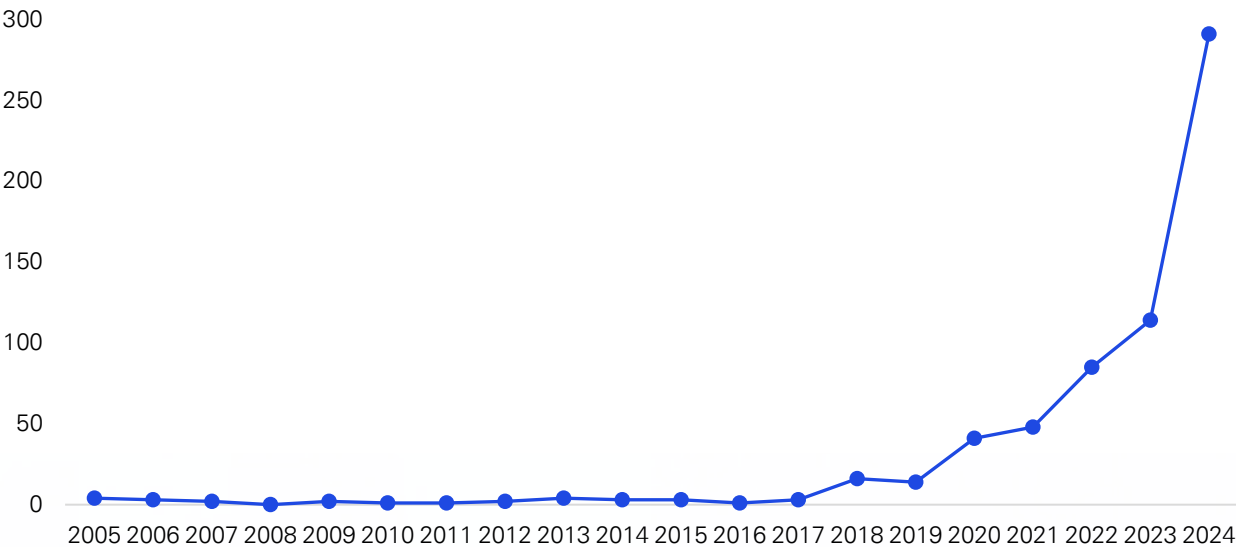
AI Technology Drives Transformation in the Hydrogen Energy Industry Chain



2.1 Overview of AI applications in the hydrogen energy industry

The exponential growth of AI technology has catalysed a surge in academic research exploring AI applications in the hydrogen energy industry. According to data from Scopus and IEEE Xplore, the number of publications focusing on AI and robotics in hydrogen energy has risen dramatically—from only 41 in 2020 to 291 in 2024 (Figure 3). This remarkable growth reflects both the academic community’s heightened interest in this area and the growing recognition of AI-driven solutions as critical enablers in advancing the hydrogen energy industry.

Figure 3: Number of articles on the application of AI and robotics in hydrogen energy from Scopus and IEEE Xplore (2005-2024)



Source: AI and robotics in the hydrogen lifecycle, KPMG Analysis

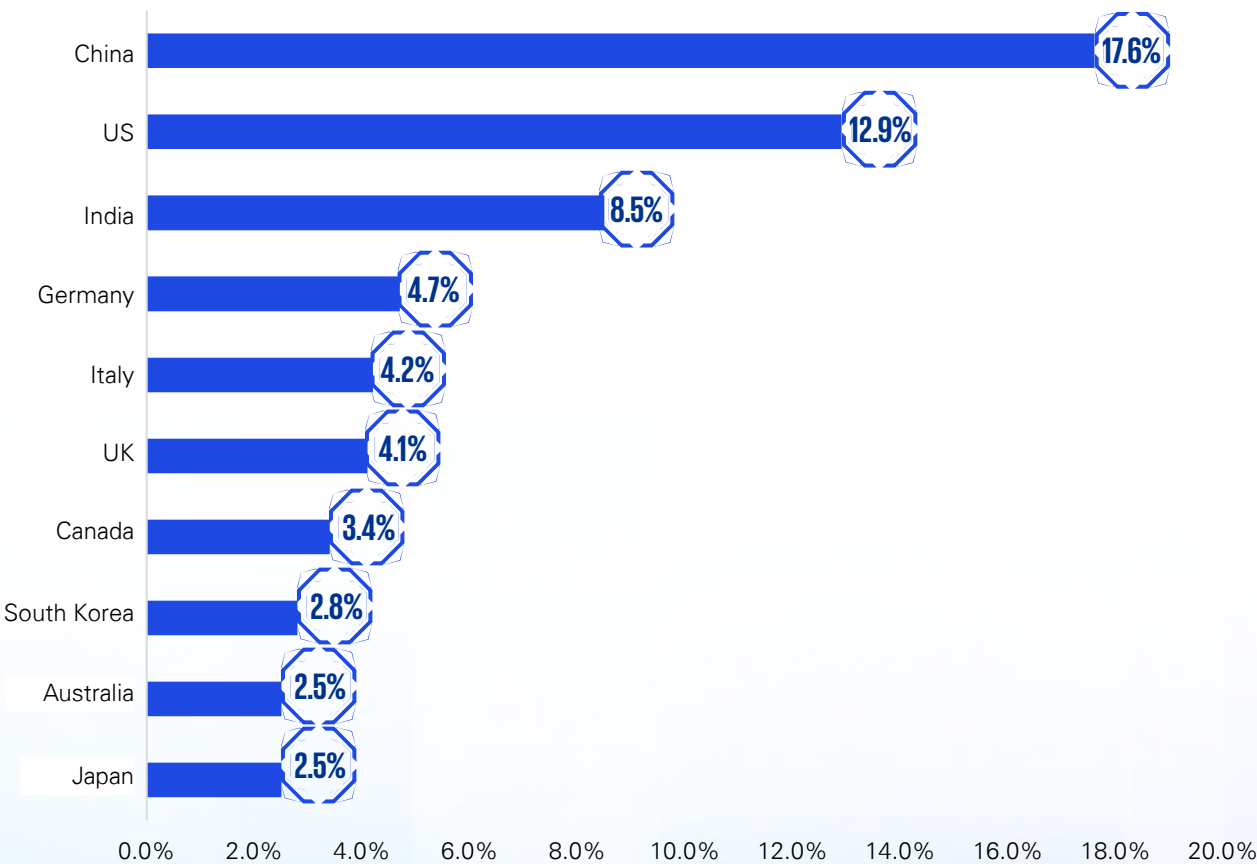
In terms of the geographical distribution of AI and robotics research in hydrogen energy, the Asian region has emerged as a prominent player. China leads the way, contributing 17.6% of global publications in this domain and ranking first worldwide. India closely follows, holding second position in Asia and third globally with an 8.5% share, reflecting India’s strong promotion of its national green hydrogen mission in recent years. South Korea (2.8%) and Japan (2.5%) have also been actively advancing hydrogen energy development.

In Europe, countries such as Germany, Italy, and the United Kingdom play a crucial role in integrating hydrogen energy with AI and robotics technology. As staunch advocates and practitioners of clean energy, European nations have implemented a series of strong policies to promote the development of the hydrogen energy industry. Among these, Germany is demonstrating significant strength with a 4.7% share, followed by Italy with 4.2%, and the United Kingdom with 4.1%. These countries have made substantial contributions to the innovation and application of hydrogen energy technology.

In North America, the United States follows closely behind China with a share of 12.9%, ranking second globally, reflecting its continued investment in hydrogen energy technology. Canada also performed notably, accounting for 3.4%.

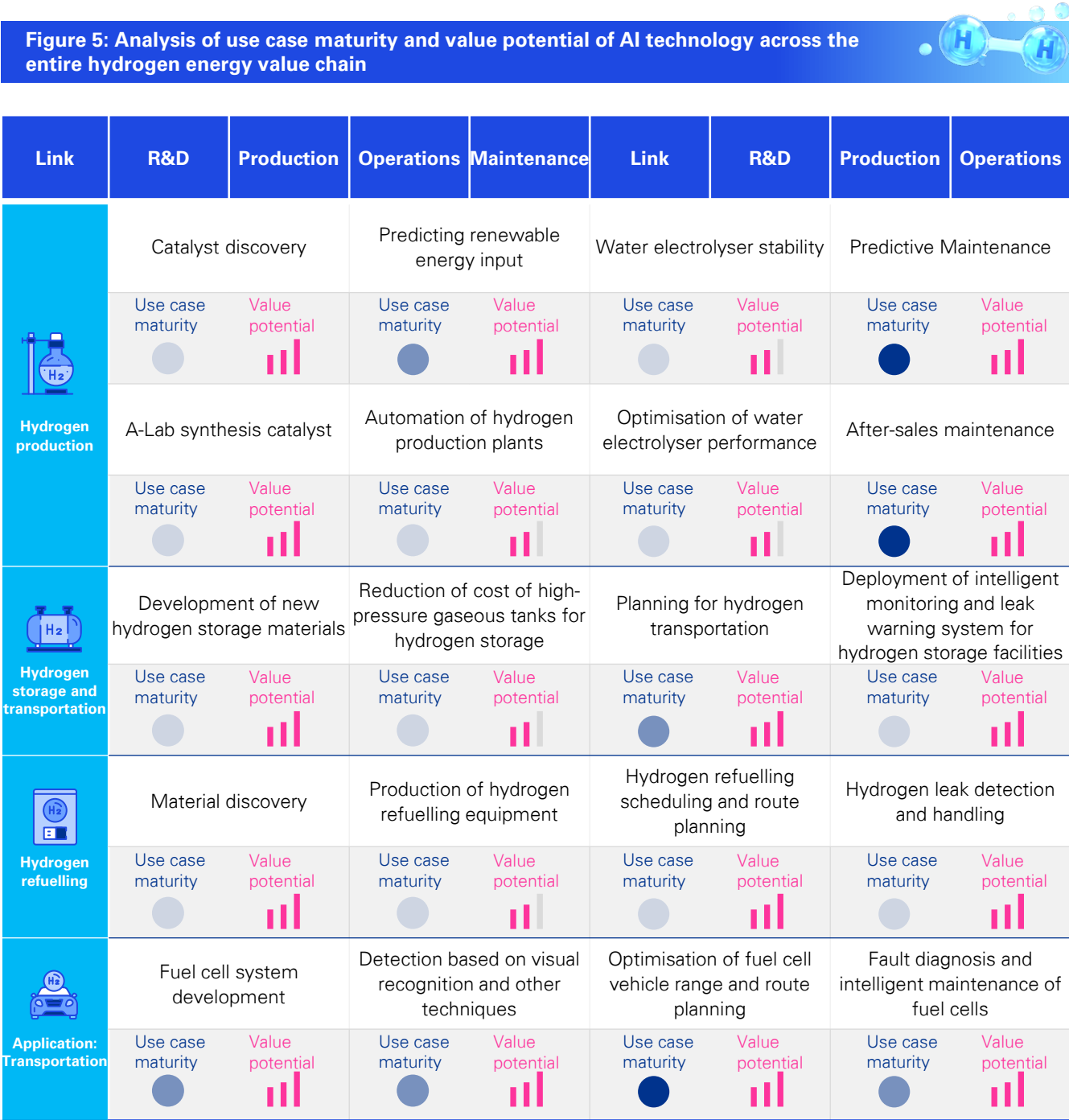
Additionally, Middle Eastern countries such as Saudi Arabia (1.3%) and Iran (1.1%), as well as Southeast Asian countries like Malaysia (1.5%) and Indonesia (0.74%), are making contributions to the application of AI and robotics in hydrogen energy, particularly in hydrogen storage and industrial automation. This demonstrates significant potential and indicates growing global interest in the application of AI and robotics in hydrogen technology (Figure 4).

Figure 4: Geographical distribution of scientific literature on the application of AI and robotics in hydrogen energy from Scopus/IEEE Xplore, 2005-2024



Source: AI and robotics in the hydrogen lifecycle, KPMG Analysis

AI technology is widely applied across the hydrogen energy value chain, covering areas such as hydrogen production, storage and transportation, hydrogen refuelling stations, and hydrogen fuel cell vehicles. This article analyses these applications from two dimensions: use case maturity and value potential, aiming to reveal the current status and future potential of AI technology in the hydrogen energy industry (Figure 5).



Note: Use cases are classified into three categories depending on their maturity and

Use case maturity: low medium high value potential: low medium high

Source: KPMG Analysis

Hydrogen production: high value potential in catalyst R&D, high scenario maturity in maintenance

In hydrogen production, AI technology demonstrates diverse levels of use case maturity and value potential across various applications. In the catalyst discovery phase, while data-driven and AI-powered research accelerates the catalyst development process and AI-assisted A-Lab synthesis techniques offer significant innovation potential, the long cycles and high uncertainties associated with new materials research keep use case maturity relatively low. However, the value potential in this area is substantial, as innovation in catalysts can significantly reduce hydrogen production costs and improve efficiency, thereby having a profound impact on the long-term development of the hydrogen industry.

Likewise, AI technology in hydrogen plant automation and predictive maintenance has achieved higher levels of maturity. The use of AI makes production processes more intelligent, particularly in predictive maintenance, where data analysis enables early identification of equipment failures, enhancing equipment stability and reducing labour costs and directly translating into economic benefits. The combination of high use case maturity and significant value potential in this area makes it a hot spot for AI applications in the hydrogen sector.

Hydrogen storage and transportation: Nascent but with significant potential, requiring balance between safety and efficiency

In hydrogen storage and transportation, the application of AI technology is still in its early stages, with generally low levels of use case maturity. The development of new hydrogen storage materials and reduced costs for high-pressure gas storage tanks both face technical bottlenecks and cost challenges. However, the value potential of these areas should not be overlooked. Once new hydrogen storage materials are successfully developed or the costs of high-pressure gas storage tanks are reduced, the efficiency of hydrogen storage and transportation will be significantly improved.

At the same time, AI technology is beginning to demonstrate its value in terms of hydrogen transportation planning and in the intelligent monitoring of hydrogen storage facilities. By optimising transportation routes and providing real-time monitoring of facility conditions, AI technology offers strong support for the safety and efficiency of the storage and transportation process. Although the maturity of these applications still needs time, their value potential is becoming increasingly evident with the scaling of the hydrogen industry, especially in the deployment of intelligent monitoring and leak detection systems, which are crucial for storage and transportation safety and in reducing accidental losses.

Hydrogen refuelling and application: higher scenario maturity in transportation, accelerating commercialisation

In the hydrogen refuelling segment, material development and hydrogen refuelling equipment production are constrained by technological accumulation and market demand, resulting in relatively low use case maturity. However, as technology continues to advance and market demand grows, the use case maturity of hydrogen vehicle refuelling dispatch management, route planning, and hydrogen leak safety detection will gradually improve.

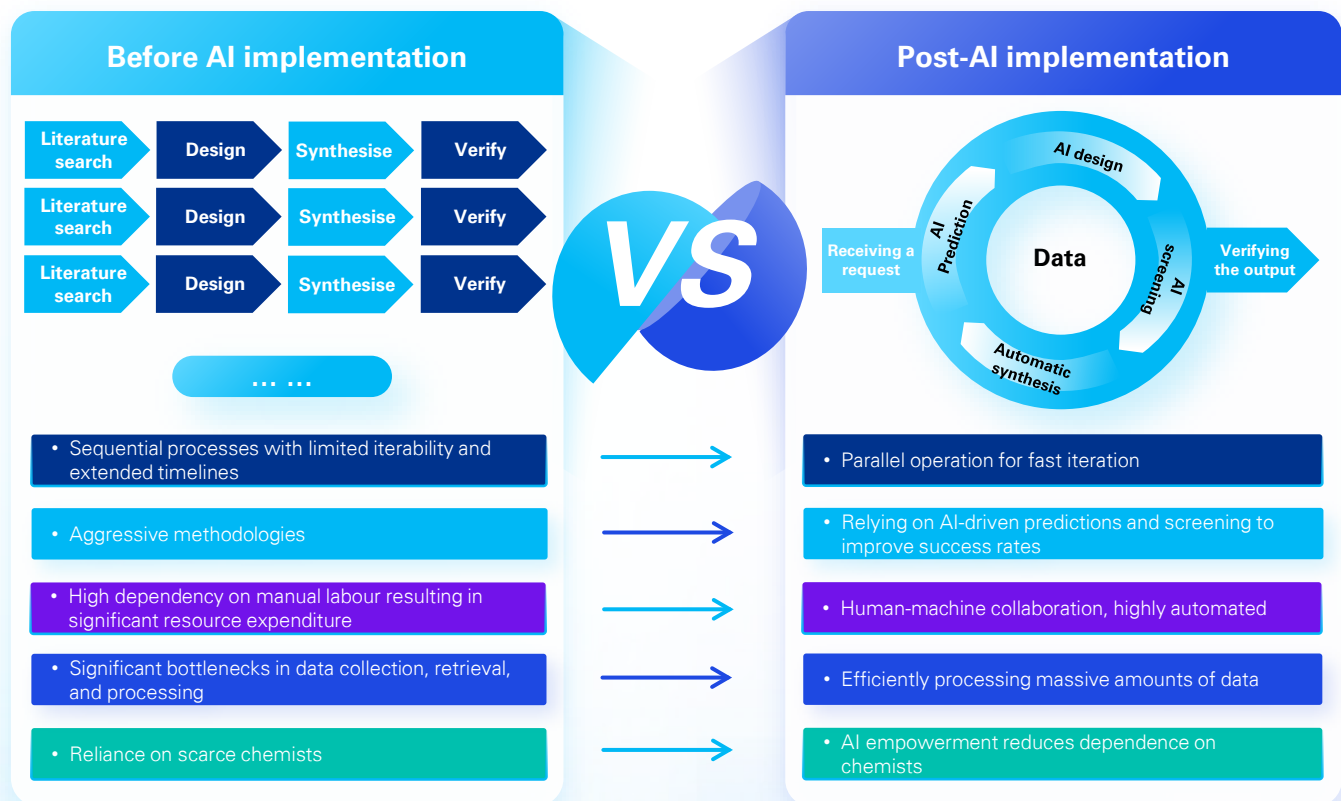
In terms of transportation, AI technology has already demonstrated a higher level of use case maturity. Currently, AI is being applied in the development of fuel cell systems, visual recognition-based detection, range optimisation and route planning, as well as fuel cell fault diagnosis and intelligent maintenance. These applications not only optimise the performance of fuel cell vehicles but also promote the use of hydrogen as a clean energy source in the transportation sector.

2.2 Hydrogen production

1. R&D phase: a data and AI technology driven transformation in catalyst R&D

The high cost of catalysts currently poses a significant barrier to the economic viability of green hydrogen production. To address this challenge, there is an urgent need to develop innovative materials, such as low-iridium and non-precious metal catalysts, to reduce costs and enhance efficiency. However, traditional approaches to material research and development face several limitations, including lengthy iteration cycles driven by trial and error, labour-intensive manual processes, and reliance on the experience and intuition of chemists. The deep integration of AI technology is revolutionising catalyst research and development, shifting the process from a traditional trial-and-error paradigm to a data- and AI-driven framework. As a result, the design of catalytic materials has entered the “autonomous driving” era (Figure 6).

Figure 6 AI technology ushers in a new era for catalyst R&D



Source: Publicly available information, KPMG Analysis

● At the theoretical level, AI technology is accelerating the discovery and prediction of new catalysts.

Discovering novel catalysts is a slow and resource-heavy endeavour. Traditional catalyst development relies on high-cost and time-consuming trial-and-error methodologies, which have shown limitations in addressing the curse of dimensionality and combinatorial explosion in high-dimensional variable optimisation. Therefore, leveraging the AI for Science (AI4S) data-driven paradigm is crucial for identifying high-quality catalytic materials effectively.

1 Accelerating the discovery of catalysts through high-throughput screening.

In the development of catalysts, machine learning has emerged as a powerful tool for both discovering and optimising catalysts. By analysing existing datasets, machine learning builds predictive models to evaluate unknown samples and uncover the correlation between a material's structure and its properties. Once trained, these models can efficiently predict thousands—or even millions—of new materials, drastically reducing experimental and computational costs. Importantly, the predictive accuracy of machine learning models often rivals or surpasses that of traditional theoretical methods⁴. In 2020, Meta launched the Open Catalyst Project, with the goal of developing machine learning models capable of simulating chemical reactions and accelerating the creation of low-cost catalysts. In 2022, Meta released the largest open dataset in the catalyst field at the time, focussed on modelling and simulating oxygen evolution reaction (OER) catalysts for green hydrogen fuel production⁵. Building on this progress, in 2024, Meta and its collaborators unveiled the OCx24 open-source experiment database. Through this initiative, researchers conducted 685 million AI simulations to analyse 20,000 materials and synthesised 525 nanoporous catalysts using high-throughput technology, with applications spanning proton exchange membrane (PEM) electrolysis. This breakthrough reduced the traditional decades-long research and development cycle to just a few months⁶. In 2023, Google introduced the GNoME (Graph Networks for Materials Exploration) model, which predicted over 2.2 million new inorganic materials, significantly expanding the range of stable materials available and offering a wide array of potential catalysts for hydrogen production⁷. Concurrently, Microsoft developed MatterGen, a generative AI tool designed to create new materials based on specific design requirements, marking a new era in reverse material design⁸. GNoME exemplifies AI's capability to efficiently discover new materials within vast chemical spaces, while MatterGen showcases how generative AI can tailor materials to meet particular performance needs. Together, these innovations highlight different approaches AI is taking in material chemistry and signal a move from broad exploration to customised, on-demand design. Simultaneously, catalyst research in China is advancing rapidly. A research team at Nanjing University has established a machine learning model for hydrogen-to-electricity conversion reactions, exploring the application of machine learning in the design of electrocatalysts. The team is focusing on analysing key hydrogen-to-electricity conversion reactions, such as the hydrogen evolution reaction (HER), the oxygen evolution reaction (OER), the hydrogen oxidation reaction (HOR), and the oxygen reduction reaction (ORR), driven by machine learning. This analysis reveals the structure-activity relationships between key variables and the performance of electrocatalysts, thereby accelerating the exploration and optimisation of catalysts⁹. A research team from the University of Science and Technology of China has detailed how AI can revolutionise the design of catalysts for hydrogen production used in electrochemical processes. By employing a variety of advanced techniques, including literature analysis, high-throughput data processing, machine learning algorithms, and automated experimentation, the team has developed a holistic research framework for use cases from atomic-level simulations to large-scale performance predictions¹⁰.

Meanwhile, large language models (LLMs) are accelerating the structured extraction of scientific research texts, supporting machine learning modelling and experimental design. Dagdelen et al. have utilised large language models such as GPT-3 and Llama-2 to perform Joint Named Entity Recognition and Relation Extraction tasks in the field of materials science, fine-tuning these models on annotated text paragraphs. This study demonstrates how LLMs can extract complex structured information about materials from technical texts, such as dopants, host materials, and metal-organic frameworks, thereby simplifying the creation of large-scale, structured professional scientific knowledge databases while promoting progress in materials discovery and design¹¹.

⁴ Ding, Y., Tong, L., Liu, X., Liu, Y. and Zhao, Y. (2025), Artificial Intelligence-Driven Innovations in Hydrogen Storage Technology. *Energy Environ. Mater.*, 8: e70041. <https://doi.org/10.1002/eem2.70041>

⁵ Richard Tran, Janice Lan, et al. The Open Catalyst 2022 (OC22) Dataset and Challenges for Oxide Electrocatalysts, arxiv.org/abs/2206.08917

⁶ Jehad Abed, Jiheon Kim, et al. Open Catalyst Experiments 2024 (OCx24): Bridging Experiments and Computational Models, arxiv.org/abs/2411.11783

⁷ Merchant, A., Batzner, S., Schoenholz, S.S. et al. Scaling deep learning for materials discovery. *Nature* 624, 80–85 (2023). <https://doi.org/10.1038/s41586-023-06735-9>

⁸ Zeni, C., Pinsler, R., Zügner, D. et al. A generative model for inorganic materials design. *Nature* 639, 624–632 (2025). <https://doi.org/10.1038/s41586-025-08628-5>

⁹ Rui Ding, Junhong Chen, Xuebin Wang, et al, Unlocking the potential: machine learning applications in electrocatalyst design for electrochemical hydrogen energy transformation, *Chemical Society Reviews*, 2024,53, 11390

¹⁰ Zhaoyong Jin, Dongxu Gu, Panpan Li, et, al. Artificial intelligence-driven catalyst design for electrocatalytic hydrogen production: Paradigm innovation and challenges in material discovery, *Sustainable Chemistry for Energy Materials*, Volume 2, 2025, <https://doi.org/10.1016/j.scenem.2025.100010>.

¹¹ Dagdelen J, Dunn A, Lee S, Walker N, Rosen AS, Ceder G, Persson KA, Jain A. Structured information extraction from scientific text with large language models. *Nat Commun.* 15 Feb 2024; 15(1):1418. doi: 10.1038/s41467-024-45563-x. PMID: 38360817; PMCID: PMC10869356.



2

Optimising the performance and structure of catalysts.

AI technology can maintain or enhance the activity, corrosion resistance, and thermal stability of catalysts prior to synthesis, while also reducing costs. Researchers at the University of Toronto have developed an ML-assisted computational process to screen the electrochemical stability of 2,070 novel metal oxides under acidic conditions. They ultimately identified an alloy (Ru_{0.6}Cr_{0.2}Ti_{0.2}O_x) composed of ruthenium, chromium, and titanium in specific proportions, which is 20 times more stable and durable than benchmark metals¹¹. Additionally, researchers from the University of Science and Technology of China have innovatively introduced frontier molecular orbital theory into the design of single-atom catalysts. They treated the entire carrier as a “ligand” for metal atoms. By adjusting the type and size of the carrier, they optimised the metal-carrier orbital coupling, leading to the development of a single-atom hydrogen refuelling catalyst with high activity and stability¹². Fudan University researchers have designed an embedded catalyst that incorporates metallic Ir particles into the surface of CeO₂ carriers. By embedding iridium oxide nanoparticles within the cerium oxide carrier, they have created a stable and efficient supported catalyst. This approach reduces the amount of iridium needed by 85% and significantly improves catalytic efficiency, resulting in a 65% increase in overall device energy efficiency¹³. Researchers from Tsinghua University have innovatively combined high-throughput density functional theory (DFT) calculations with Bayesian optimisation to screen Ir-doped TiO₂ as a highly promising OER candidate catalyst. This approach opens up a new routeway to significantly reducing the use of precious metals in proton exchange membrane water electrolyzers¹⁴. Researchers at Jilin University have innovatively developed low-iridium catalysts with high activity and conductivity through the combination of carrier and loading technology. Using this new catalyst, the iridium loading in PEM membrane electrodes has been reduced to 0.15 mg/cm², nearly 90% lower than that of traditional membrane electrodes. At the same time, the membrane electrode shows excellent catalytic performance, with the PEM water electrolyser performance surpassing the 2023 technical benchmarks set by the U.S. Department of Energy¹⁵.

Although these theoretical studies have limitations in direct industrial applications, the establishment of a material gene database has laid a solid data foundation for automated experimental systems. This promotes the transformation of materials research and development from traditional trial-and-error methods to data-driven AI approaches.

¹¹ Dagdelen J, Dunn A, Lee S, Walker N, Rosen AS, Ceder G, Persson KA, Jain A. Structured information extraction from scientific text with large language models. *Nat Commun.* 2024 Feb 15;15(1):1418. doi: 10.1038/s41467-024-45563-x. PMID: 38360817; PMCID: PMC10869356.

¹² Jihad AbedJavier Heras-DomingoRohan Yuri Sanspeur, Pourbaix Machine Learning Framework Identifies Acidic Water Oxidation Catalysts Exhibiting Suppressed Ruthenium Dissolution, *Am. Chem. Soc.* 2024, 146, 23, 15740–15750

¹³ A new theoretical model proposed for the design of single-atom catalysts, Chinese Academy of Sciences website, 3 April 2025, https://www.cas.cn/syky/202504/t20250402_5061072.

¹⁴ Wenjuan Shi, Tonghao Shen, Chengkun Xing, et al. Ultrastable supported oxygen evolution electrocatalyst formed by ripening-induced embedding, *Science*.13 Feb 2025, Vol 387, Issue 6735

¹⁵ Xiangfu Niu, Yanjun Chen, Mingze SunNiu, et al. *Sci. Adv.* 11, eadw0894 (2025)

¹⁶ Wang, Y., Zhang, M., Kang, Z. et al. Nano-metal diborides-supported anode catalyst with strongly coupled TaOx/IrO₂ catalytic layer for low-iridium-loading proton exchange membrane electrolyzer. *Nat Commun* 14, 5119 (2023). <https://doi.org/10.1038/s41467-023-40912-8>

● At the experimental level, A-Lab accelerates material synthesis

After discovering new materials, it is equally important to synthesise and demonstrate their potential applications. Tools like GNoME have predicted millions of new materials that could drive technological innovation, but verifying the synthesisability of these materials remains a slow process. A-Lab aims to bridge the gap between the discovery and experimental synthesis of new materials. The “A” in A-Lab represents multiple core features: AI, Automated, Accelerated, and Abstracted¹⁷. The A-Lab platform leverages computing, historical data from literature, machine learning, and active learning, combined with robotics technology, to optimise the design and synthesis of new materials using catalyst datasets, all without the need for human intervention.

Based on a trained machine learning model, A-Lab processes 50 to 100 times more samples per day than if done manually and uses AI to quickly identify promising materials¹⁸. A-Lab can independently decide how to synthesise target materials and create initial raw material combinations. After each experiment, A-Lab adjusts the raw material combinations based on the experimental results, making even failed syntheses meaningful. The information provides direct and feasible suggestions for improving existing material screening and synthesis design techniques. A-Lab has built a fully automated system from material discovery to performance verification. By integrating automated characterisation technologies (such as high-throughput experimental platforms) and machine learning-driven performance testing systems, A-Lab achieves closed-loop management of material development. AI models can autonomously design experimental plans, control characterisation equipment to collect data, and provide real-time feedback to performance prediction modules for iterative optimisation.

Currently, foreign A-Labs have achieved a fully autonomous decision-making closed loop, requiring no manual intervention from hypothesis generation to experimental verification. Google DeepMind collaborated with Lawrence Berkeley National Laboratory to develop an autonomous new material discovery and synthesis system called A-Lab, which integrates robotics technology with AI. During 17 days of continuous operation, A-Lab conducted 355 experiments and successfully synthesised 41 out of 58 proposed compounds, a success rate of 71%. This verified the synthesisability of materials predicted by GNoME¹⁹.

China is focused on hydrogen energy application research and leads in the implementation of industrial use cases. However, it has not yet established a fully automated A-Lab in the field of materials. China’s intelligent laboratories adopt a task-driven model: after researchers submit experimental objectives, AI automatically decomposes them into executable solutions and then schedules experimental resources. Although this model requires the manual initiation of task instructions and reviews of experimental plans, subsequent experimental deployment, data collection, and preliminary analysis are automated, bringing the technical route closer to full-process intelligence.

The current application of AI technology in catalyst research and development is still focused on the academic exploration and laboratory stages. Scaling up from laboratory outcomes to industrial applications requires rigorous validation processes, including assessments of process adaptability, long-term stability, and cost-benefit analysis. As algorithm models continue to be optimised and validation systems improve, these cutting-edge research achievements are expected to accelerate their transition into actual industrial productivity, providing innovative solutions for the clean energy storage and green chemical industries.



¹⁷ Meet the Autonomous Lab of the Future, April 17, 2023, <https://newscenter.lbl.gov/2023/04/17/meet-the-autonomous-lab-of-the-future/>

¹⁸ Id.

¹⁹ Szymanski, N.J., Rendy, B., Fei, Y. et al. An autonomous laboratory for the accelerated synthesis of novel materials. *Nature* 624, 86–91 (2023). <https://doi.org/10.1038/s41586-023-06734-w>

2. Production process: Optimising hydrogen production plants and enhancing the automation of hydrogen production plants



Predicting renewable energy inputs and improving the stability of hydrogen production

One of the key values of AI technology in integrating renewable energy to drive green hydrogen production lies in addressing the contradiction between intermittent energy supplies and continuous production, thereby ensuring stable hydrogen energy output.

Multi-source data fusion enhances the accuracy of renewable energy predictions. Given the spatiotemporal fluctuations of wind and solar resources, AI technology constructs a power generation prediction model by integrating meteorological satellite data, surface sensors, historical power curves, and other sources. This model not only analyses micro-meteorological changes such as cloud movements and wind speed turbulence but also learns how factors like terrain, vegetation, and seasonal changes affect energy capture efficiency. By predicting the output curve of renewable energy in advance, it provides forward-looking decision-making support for hydrogen production load scheduling.

Based on renewable energy input predictions, AI technology constructs a “predict-optimisation-response” control chain in the hydrogen production process. The system uses deep learning to analyse the multi-parameter coupling relationships between temperature, pressure, and catalyst activity in the water electrolyser, and establishes a real-time optimal energy efficiency control model. When a sharp drop in photovoltaic output is predicted, the system adjusts the current density of the water electrolyser in advance to reduce damage to the membrane electrode. During periods of wind power overproduction, the system dynamically increases the hydrogen production load to absorb excess green electricity. More importantly, the algorithm simultaneously optimises the charging and discharging strategies of the hydrogen storage system, maximising the filling rate of the hydrogen storage tanks during periods of abundant green power, and releasing stored hydrogen as needed during energy trough periods.

For example, at the European Marine Energy Centre (EMEC), a company used AI to model and optimise the hydrogen production process and conducted a 12-month experiment to improve efficiency. In the first phase of the project, data was collected, and AI software was used for modelling and optimisation. In the second phase, the AI system was integrated into the hydrogen production plant to control hydrogen production in real time by combining historical data on weather, tides, wind energy, hydrogen storage capacity, and electricity prices²⁰.



AI technology is accelerating automation in hydrogen production plants

In the process of the large-scale development of the green hydrogen industry, AI technology is transforming the design of hydrogen production plants and shortening the engineering cycle. Traditional hydrogen production plant designs rely on manual drawings and equipment selection, which often results in long cycles and high iteration costs. Generative AI leverages semantic parsing and model generation technologies to enhance the design process: an interactive system based on natural language input can directly analyse process requirements, automatically generate standardised equipment specifications, process flow diagrams and 3D layout models, and correct design conflicts in real-time. This technology significantly reduces manual drawings and repetitive modification time, thereby improving design efficiency. Furthermore, AI integrates data from multiple fields such as mechanical, electrical, and control systems, enabling automatic conversion of design models to simulation software. This cross-domain integration advances critical processes like thermodynamic analysis and structural verification, effectively reducing later engineering changes and shortening the overall design cycle of the plant.

In 2024, a company launched a software tool based on generative AI to accelerate the large-scale production of hydrogen energy. The tool consists of three main components: 1. A Hydrogen Plant Configurator: This significantly shortens the design cycle by generating hydrogen plant design drawings through natural language interaction; 2. A Comos AI Engineering Assistant: This creates equipment specifications and engineering drawings based on text descriptions, improving engineering design efficiency; 3. An SFC Generation Module: Integrated into the Simatic PCS neo control system, this module uses AI to generate sequential functional charts, simplifying the automation process of hydrogen plants²¹.

²⁰ Press release: H2GO Power to trial AI hydrogen optimisation system at EMEC, March 7, 2022, <https://www.emec.org.uk/h2go-power-to-trial-ai-at-emec/>

²¹ Siemens accelerates hydrogen ramp-up with generative artificial intelligence, Siemens, Jun 04, 2024
<https://press.siemens.com/global/en/pressrelease/siemens-accelerates-hydrogen-ramp-generative-artificial-intelligence>



Improving the efficiency of proton exchange membrane quality detection

In the manufacturing of proton exchange membrane water electrolyzers, the bipolar plate serves as a key functional component for integrated current conduction, fluid distribution, and structural support. Its manufacturing precision directly impacts the performance and reliability of the water electrolyser. Traditional detection methods face significant challenges due to the complexity of the detection elements, intricate geometric shapes, and high material sensitivity. To address these challenges, an intelligent detection system incorporating AI technology has been developed to achieve efficient and precise integrated dimension and defect detection. Customised software, developed by a leading company, integrates advanced technologies including Metus' image processing techniques and features extraction algorithms, GD&T evaluation algorithms, and Hex.AI. This innovative solution has successfully reduced the single-unit detection cycle from 900 seconds to just 138.5 seconds, while improving the overall equipment effectiveness (OEE) to 98%²².

3. Operation: improving the performance and efficiency of water electrolyser systems

The operation of a water electrolyser is influenced by parameters such as voltage, temperature, pressure, and current density, with its optimisation level directly impacting system efficiency. Early research focused on traditional control models and empirical optimisation methods. While basic control functions were achieved in the initial stages, inherent limitations became increasingly apparent as large-scale production advanced and system complexity grew. Recent studies have demonstrated the effectiveness of AI technology in enhancing the operational stability, current density regulation, and temperature control of proton exchange membrane water electrolyzers. By leveraging heuristic algorithms and machine learning models to enable dynamic parameter adjustment and adaptive optimisation, AI has shown potential in improving operational stability, achieving precise current density control, and optimising temperature management. These advancements provide effective solutions for enhancing the performance of water electrolyser systems.

AI technology establishes a dynamic response model of electrochemical-thermodynamic coupling characteristics through deep learning. It captures the microstates of membrane water content changes and catalyst activity decay in proton exchange membrane water electrolyzers in real time. By independently adjusting the input power and cooling, AI maintains the best energy efficiency point. In response to fluctuations in renewable energy input, reinforcement learning algorithms predict power fluctuation trends in advance. By pre-adjusting the electrolyte concentration and flow rate of alkaline electrolyzers (AEL), AI avoids the decrease in gas evolution efficiency caused by electrode overload. In the high-temperature scenario of solid oxide electrolysis cells (SOEC), AI technology optimises the thermal cycling route through multi-physics field simulation, reducing the risk of ceramic electrolyte cracking caused by thermal stress. This shift from passive response to active adaptation enhances the average energy efficiency of water electrolyzers under wide power fluctuations. Wang Jiarong et al. modelled the startup and shutdown process of alkaline water electrolyzers and determined the number of operating units of the system's water electrolyzers through short-term wind power prediction. The water electrolyzers were optimised through a multi-objective fitness function to balance their key operating parameters. The optimisation results show that the number of switch start-stop times has decreased by 28.11% and 36.52% respectively compared to simple start-stop and array rotation values, thereby improving the service life of the water electrolyzers²³.

In addition, digital twin technology leverages AI to enable interaction between the physical and virtual models of water electrolyzers, overcoming the limitations of traditional operations and maintenance. At the device level, digital twins integrate real-time sensor data with material degradation models to predict the chemical corrosion rates of proton exchange membrane electrodes and changes in the gas permeability of alkaline electrolysis cell membranes. This allows for the dynamic adjustment of protective voltage thresholds, extending the lifespan of critical components. At the system level, digital twins simulate energy flow routes under various renewable energy input use cases, autonomously optimising start-stop sequences and power distribution ratios of water electrolyser clusters. For instance, during sudden drops in wind power, priority is given to maintaining the insulation energy consumption of high-temperature solid oxide water electrolyzers to prevent thermal inertia losses. More importantly, the digital twin system enhances the adaptability of the water electrolyser system under complex operating conditions by continuously integrating historical operational data and dynamically iterating control strategies. A specific company has developed SimuNPS, a multi-physics simulation tool that accurately simulates the thermal management and electrochemical reactions of water electrolyzers. By combining SimuNPS with AI algorithms, the simulation data can be used to train deep learning models, achieving more precise optimisation and control of the water electrolyser system²⁴.

²² An integrated solution equipped with AI technology for bipolar plate size defect detection is now available for hydrogen applications, 12 August 2024, Hexagon's website, <https://hexagonmi.com.cn/ycnr/38675>

²³ Yang Bo, Zhang Zijian, AI-driven renewable energy electrolytic water hydrogen production technology, *Power Generation Technology*, June 2025, Volume 46, Issue 3

²⁴ A new SimuNPS power system modelling and simulation software, Shanghai Keliang's website, <https://www.keliangtek.com/product/index/130.html>

4. Maintenance: Utilising AI technology to perform predictive maintenance on equipment and improve efficiency



AI technology transforms the maintenance of water electrolysis systems from reactive to predictive approaches.

In the context of green hydrogen production, AI has demonstrated significant application potential in enhancing maintenance operations. By leveraging its capabilities in operational data analysis and fault mechanism modelling through advanced big data analytics, AI enables the identification of potential faults in advance, thereby minimising unplanned downtime. This facilitates intelligent fault diagnosis and maintenance management, ultimately improving operational reliability. Machine learning technology plays a pivotal role in this transformation by effectively identifying trends in component performance degradation and detecting early fault characteristics through continuous monitoring of device sensor time-series data. This proactive approach allows operations personnel to implement preventive maintenance measures before potential issues escalate into unplanned shutdowns, consequently reducing maintenance costs. According to the U.S. Energy Information Administration (EIA), anomaly detection algorithms and neural network models can establish benchmarks for normal equipment operations and predict potential faults by analysing deviations in real-time sensor data. Furthermore, reinforcement learning enables dynamic optimisation of maintenance strategies, achieving a balance between resource allocation and equipment health²⁵. The evolution from reactive to predictive maintenance underscores the transformative impact of AI technology. It not only enhances the reliability of hydrogen production equipment but also contributes to cost savings, with some specific applications achieving up to a 25% reduction in operational expenses²⁶.



Building a professional knowledge base to enhance after-sales maintenance efficiency

The maintenance of hydrogen production equipment through electrolysis water faces several challenges: 1. Scattered Operational and Maintenance Knowledge: Operational and maintenance knowledge is spread across hundreds of historical projects. Traditional document management systems struggle to efficiently extract critical information. Additionally, customers often refuse to transmit real-time equipment parameters due to confidentiality concerns, leading to reliance on delayed experience-based troubleshooting; 2. Unstructured Historical Data: A significant amount of historical fault data, including records of abnormal operating conditions and resolution routes for water electrolyzers, remains unstructured. This makes it difficult to systematically link fault characteristics with their corresponding solutions. Overseas customers face additional challenges, as on-site maintenance requires cross-border support from engineers, increasing both labour and time costs; 3. Limitations in Cross-Border Maintenance: Cross-border maintenance is constrained by offline guidance methods, resulting in collaboration inefficiencies due to factors such as time zone differences, language barriers, and data isolation.

To address these challenges, AI technology enables the construction of a professional knowledge base to effectively resolve the pain points associated with after-sales maintenance. Firstly, leveraging advanced AI technologies such as natural language processing (NLP), diverse datasets including historical documents, maintenance manuals, and fault handling procedures are converted into structured knowledge graphs. This forms a comprehensive professional knowledge base encompassing all fault cases. Crucially, this knowledge base serves as a valuable resource for internal employee training. Maintenance personnel, particularly new employees, can enhance their understanding and problem-solving skills by studying the historical records of water electrolyser fault cases. Secondly, the fault data is utilised to train lightweight AI models. Through transfer learning techniques, these models are adapted to accommodate different device characteristics. This enables symptom-based cause analysis and the generation of actionable disposal suggestions. Finally, a remote collaboration system is established. Upon receiving customer feedback regarding a fault, the system automatically matches the case against the knowledge base and generates step-by-step maintenance instructions. The system also supports video collaboration guidance, thereby eliminating the need for on-site interventions. Additionally, engineers with specialised training can conduct remote diagnostics more efficiently. By building a professional knowledge base for post-sales operations, AI technology transforms historical data into reusable intelligent assets. This approach ensures the efficient application of global operational and maintenance expertise while respecting data sovereignty. As a result, it provides seamless and scalable support for water electrolyser maintenance.

²⁵ Ashish K Saxena, AI-driven optimization for green hydrogen production efficiency, *Journal of Scientific and Engineering Research*, 2024, 11(6):145-155

²⁶ Sharif Md Yousuf Bhuiyan, Adar Chowdhury, Md Shahadat Hossain, Saleh Mohammad Mobin, & Imtiaz Parvez. (2025). AI-driven optimization in renewable hydrogen production: a review. *American Journal of Interdisciplinary Studies*, 6(1), 76-94. <https://doi.org/10.63125/06z40b13>



Overall, AI technology is poised to revolutionise the hydrogen production industry by optimising processes across research, development, production, operations, and maintenance. This integration of AI is expected to enhance both economic viability and operational efficiency, thereby accelerating the commercialisation of hydrogen energy. According to a comprehensive report by the Hydrogen Energy Committee (2024), the application of AI-driven optimisation techniques in water electrolyser operations can achieve significant improvements in green hydrogen production efficiency, ranging from 10% to 15%. By implementing real-time adjustments to critical parameters such as power input and temperature, AI enables systems to operate closer to their theoretical efficiency limits. Furthermore, a recent study conducted by the European Hydrogen Association (2023) highlights that the adoption of AI for predictive maintenance can drastically reduce the likelihood of unplanned downtime by 30-40%, leading to substantial cost savings in maintenance labour and spare parts. Additionally, the Hydrogen Energy Commission’s report (2024) underscores the transformative potential of integrating intelligent control and automation solutions with renewable energy sources and electrolytic systems. Such integrated approaches have been shown to increase system capacity utilisation by 25-30% while improving the output rate of capital-intensive processes (see Table 1).

Table 1 AI-Driven Green Hydrogen Production for Cost Reduction and Efficiency Enhancement



Evaluation indicator	Current value (2023)	AI optimisation and improvement effectiveness	Data source
Energy consumption reduction	Benchmark value	Up to 10%	Hydrogen Council (2024)
Operational cost reduction	Benchmark value	About 15%	Hydrogen Council (2024)
Increased hydrogen production	Benchmark value	20%	European Hydrogen Association (2023)
Extended service life of water electrolyzers	Standard service life	Extended by 20%	Market Analysis Group (2024)
Predictive maintenance effectiveness	Benchmark value	Equipment failure rate reduced by 30%	European Hydrogen Association (2023)

Source: AI Driven Optimisation for Green Hydrogen Production Efficiency, KPMG Analysis

2.3 Storage and transportation

1. Accelerate the screening of hydrogen storage materials and improve their performance

Hydrogen storage technology primarily takes three forms: gaseous, liquid, and solid. Gaseous hydrogen storage relies on high-pressure compression, offering advantages such as being a mature technology and rapid charging and discharging. However, it also presents challenges, including low volumetric energy density and safety risks. Liquid hydrogen storage enhances hydrogen density through deep-freezing liquefaction, making it suitable for long-distance transportation. Nonetheless, the liquefaction process requires significant energy consumption and results in continuous evaporation losses. Solid hydrogen storage, on the other hand, is achieved through physical or chemical adsorption mechanisms. Among these, solid-state hydrogen storage stands out as cutting-edge due to its high hydrogen storage capacity, excellent safety, and reversibility, offering vast potential for commercial applications.

One of the most critical challenges in hydrogen storage is identifying materials with high storage capacity and long-term stability. Traditional material discovery relies on trial-and-error experiments, which are time-consuming and resource intensive. The latest research shows that AI technology accelerates the discovery of high-capacity, low-energy-consumption and long-lifespan materials by predicting the characteristics of hydrogen storage materials and dynamically optimising storage and transportation parameters. Multi-scale modelling based on machine learning breaks through the limitations of traditional trial and error and achieves targeted screening of high-performance materials by analysing the complex mapping relationship between material microstructure and hydrogen storage performance. Artificial neural network models can predict the performance of hydrogen storage materials and optimise the design of hydrogen storage containers. Through multidimensional data analysis, AI has enhanced its understanding of hydrogen adsorption, diffusion, and interactions with material microstructures, improving storage performance. Athul et al. utilised the US Department of Energy Hydrogen Storage Materials Database and Open Quantum Materials Database to identify stable intermetallic compounds for hydrogen storage using an ML algorithm. The study generated 349,772 hypothetical intermetallic compounds, of which 8,568 were identified as stable materials²⁷. The ML model is used in solid-state hydrogen storage systems to predict hydrogen adsorption performance in magnesium-and titanium-based materials, reducing the need for extensive experimental testing²⁸.

AI technology plays a pivotal role in enhancing solid-state hydrogen storage using Metal-Organic Frameworks (MOFs). These frameworks, characterised by their ultra-high specific surface area and adjustable pore structure, are ideal for storing hydrogen through both physical and chemical methods. Optimisation techniques, such as metal doping and ligand modification, significantly improve hydrogen storage density and cycling stability. Moreover, MOFs enable safe hydrogen adsorption and release at room temperature and low pressure, addressing the safety and cost concerns associated with traditional hydrogen storage methods. However, selecting the most suitable MOFs presents challenges due to the vast number of theoretical combinations of metal nodes and organic ligands. Traditional screening methods are inefficient, making AI technology indispensable in this process. By developing targeted large models, AI can efficiently select materials with specialised structures, accelerating advancements in MOF hydrogen storage. For instance, a company utilised AI to screen 12,478 MOF structures, identifying those with the highest membrane selectivity and maximum hydrogen storage capacity (MPS).

²⁷ Yusong Ding, Lele Tong, Xiaolin Liu et al. Artificial intelligence-driven innovations in hydrogen storage technology, *Energy & Environmental Materials*, Volume8, Issue5 September 2025.

²⁸ Paulina Quintanilla, Ayman Elhalwagy, Lijia Duan, et al. Artificial intelligence and robotics in the hydrogen lifecycle: A systematic review, *International Journal of Hydrogen Energy*, Volume 113, 2025, Pages 801-817, ISSN 0360-3199, <https://doi.org/10.1016/j.ijhydene.2025.03.016>.



2. Planning hydrogen transportation to improve safety

Hydrogen transportation primarily relies on three methods: road/rail, shipping, and pipelines. 1. Road/rail: This serves as the fundamental distribution approach and involves the use of high-pressure gas cylinders or containers to deliver hydrogen to end-users such as laboratories and hydrogen refuelling stations. 2. Shipping: Utilising large liquid hydrogen storage tanks and specialised ships, shipping enables the cross-ocean transportation of hydrogen. This method allows for significantly larger quantities of hydrogen to be transported compared to land-based vehicles, with route planning typically avoiding densely populated areas to ensure high safety standards. 3. Pipelines: Leveraging existing natural gas or dedicated hydrogen pipeline networks, this method facilitates the long-distance transportation of hydrogen. It offers advantages such as large transport volumes, strong adaptability over distance, low energy consumption, and lower unit costs. However, the construction of hydrogen pipelines faces practical challenges, including high investment, lengthy construction cycles, and complex maintenance requirements, resulting in limited pipeline network coverage.

Hydrogen transportation requires the consideration of factors like traffic, weather, and time. AI systems analyse historical route data and integrate real-time traffic, road conditions, and speed limits to plan the most efficient routes. For example, a company's AI scheduling system integrates with hydrogen refuelling network data. By incorporating details like vehicle hydrogen consumption, load capacity, and driving routes, the system optimises refuelling timing and locations. This solution improves energy replenishment efficiency and reduces costs for hydrogen logistics vehicles, enhancing overall operational efficiency²⁹.

AI technology can predict hydrogen leaks and enhance the safety of hydrogen transportation. An AI hydrogen storage management system monitors critical parameters such as pressure, temperature, and leaks in real-time, providing timely alerts for potential risks and ensuring facility safety. Additionally, AI algorithms leverage historical data to predict the charging and discharging needs of hydrogen storage tanks, reducing energy losses. Despite these capabilities, the application of AI technology in this field remains limited due to challenges like inconsistent datasets and susceptibility to cyberattacks.

²⁹ Hydrogen + AI! Yuntao Hydrogen Energy and IZHKA Technology jointly promoted the commercialisation of 18-ton hydrogen-fuelled heavy trucks, 16 September 2025, <https://h2.in-en.com/html/h2-2443754.shtml>

2.4 Hydrogen refuelling stations

The hydrogen energy industry is still in its early stages of industrialisation, with infrastructure development lagging, especially in the deployment of hydrogen refuelling stations. As of the end of 2024, 1,369 hydrogen refuelling stations had been deployed across 44 countries and regions, with an additional 416 stations in various stages of planning or construction³⁰. Given the limited infrastructure development, AI technology plays a crucial role in optimising operations and enhancing safety monitoring at hydrogen refuelling stations.

The AI management system at hydrogen refuelling stations efficiently collects real-time data on hydrogen reserves, equipment statuses, and vehicle refuelling demand. Utilising a deep reinforcement learning algorithm, the system predicts short-term refuelling peaks and dynamically adjusts compressor operations to match supply with demand fluctuations. Moreover, the system analyses historical operating data to schedule preventive maintenance, thereby reducing unplanned downtime and improving facility utilisation. For instance, a global company has implemented this intelligent management system in 75% of its 200 hydrogen refuelling stations worldwide. This deployment has led to a significant 40% increase in operational efficiency³¹.

Innovation in hydrogen refuelling station safety monitoring systems lies in their AI-driven risk warning mechanism. This advanced system constantly gathers data from various sensors, including pressure sensors, temperature sensors, and pipeline flow meters, within the hydrogen storage tanks. Upon detecting any anomalies in critical parameters, the system initiates a multi-tiered response within seconds. It promptly closes the hydrogen supply valve, activates the pressure relief device, and dispatches precise location alerts to the monitoring centre. This proactive defence mechanism, powered by deep learning algorithms, represents a significant shift from traditional reactive measures to anticipatory interventions. As a result, it drastically reduces the likelihood of hydrogen leaks or equipment overloads. For instance, a leading company's "AI-Assisted Hydrogen Energy Filling Control Method and System" employs intelligent sensing technology to collect real-time data from temperature and pressure sensors in high-pressure gas cylinders. This data is transmitted to the central controller via an onboard controller and communication module. Through in-depth analysis by AI algorithms, the system identifies an abnormal state if the pressure monitoring data deviates by more than 5% from the normal range or if the temperature change rate exceeds 5°C per minute. In such cases, the system automatically adjusts the gas dispensing parameters or halts the operation entirely. By integrating AI-based safety monitoring, the occurrence of potential safety incidents at hydrogen refuelling stations has been reduced by about 70%. This remarkable improvement significantly enhances the overall safety and operational efficiency of these facilities³².



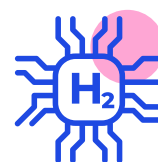
³⁰ 80% of global hydrogen refueling stations are located in just five countries, February 2025, <https://interactanalysis.com/insight/80-of-global-hydrogen-refueling-stations-are-located-in-just-five-countries>

³¹ In-depth analysis of Linde Group's hydrogen energy strategy: shaping the energy future through technological leadership and global expansion, GCNR, 3 April 2025, <http://www.mifce.org/newsinfo/8185223.html>

³² Houpu Group is advancing the integration of ai technology in hydrogen refuelling to enhance the intelligence of its equipment, Sina, 26 April 2025 <https://finance.sina.com.cn/jjxw/2025-04-26/doc-ineunexf8895357.shtml>

2.5 Hydrogen use end

The core applications of hydrogen energy cover industrial manufacturing, transportation, and power generation, among others. The current applications of AI in the field of hydrogen energy are concentrated in the transportation sector, with typical scenarios including energy efficiency optimisation of fuel cell vehicles and intelligent control systems for hydrogen powered drones.



1. Fuel cell vehicles

Research and development: AI technology accelerates the research and development of fuel cell systems

In recent years, the rapid advancement of AI, especially machine learning and deep learning, has accelerated the research and development process of fuel cell materials. The innovation in material research and development brought about by AI has been elaborated in the hydrogen production section. AI also plays an important role in the research and development of fuel cell systems.

The core decision-making unit of fuel cell systems is the controller. The optimisation and management enabled by software technology can help enrich the functions of the controller, conducive to improving the economy, durability, power, and reliability of fuel cells. AI technologies such as the Large Language Model (LLM) are empowering controllers in software testing and other aspects. The current fuel cell system software testing faces challenges such as insufficient testing coverage due to the unstructured requirement documents and low efficiency in manually written use cases. An LLM-based testing agent can automatically generate and evaluate test cases through deep semantic analysis of unstructured requirement documents for fuel cell systems, significantly reducing manual labour, avoiding the risk of human errors, and improving the efficiency of use case generation while ensuring the accuracy of outputs. For example, after a company applied the LLM-based testing agent, the software testing efficiency for the fuel cell system increased by more than 40%, and over 2,600 test cases were added, improving the software testing capability for the fuel cell system in different scenarios³³.

Production: AI visual learning helps solve the detection conundrum

In the production of membrane electrodes, due to the complex background interference of multi-layer soft materials, the recognition accuracy of conventional image algorithms for defects such as bubbles and wrinkles is low, resulting in a heavy reliance on manual visual inspection in the detection process. The pass-fail criteria for such detection method is difficult to unify, and when there are thousands of pieces of samples to be tested daily, the manpower requirement is high. Based on the artificial neural network architecture, the AI system is trained to recognise the form characteristics of bubbles at different positions on the surface of membrane electrodes and learn their correlation with product qualification rate, by which an intelligent quality judgement model is established. The AI system will become the first line of quality inspection with its millisecond-level automatic screening capability. The membrane electrodes that have undergone initial screening only require manual random testing of dozens of pieces for verification, greatly reducing manual labour and improving detection efficiency and consistency. For example, a company innovatively combines AI deep learning technology with traditional algorithms in the key processes of visual defect detection. This not only improves the accuracy of bubble defect detection, but also transforms defect detection from defect recognition only to covering defect classification as well, optimising the product screening and defect root cause analysis. Customer feedback indicates that this solution is expected to reduce the omission rate by 0.5%, reduce the workload of quality inspectors by 20%, and reduce labour costs by 5%³⁴.

³³ The "Strongest Brain" Upgrade 2.0: A New Experience of How Artificial Intelligence Drives Fuel Cell Systems, Sina Finance, 29 November 2024, <https://finance.sina.com.cn/roll/2024-11-29/doc-incxsxxv2085064.shtml>

³⁴ XDC+ Helps Upgrade Visual Inspection Technology for a Hydrogen Fuel Cell Company, htech360.com, 20 October 2025, <https://www.htech360.com/a/31719>

Operation: Dynamic optimisation of fuel cell vehicle range and route planning

Built on multi-layer technology architecture, the fuel cell vehicle AI management system enables dynamic optimisation of fuel cell vehicle range through data collection, analysis, and execution. Firstly, the AI management system collects data such as the working status of fuel cells, operating parameters of driving motors, and real-time vehicle dynamics through a sensor network covering the entire vehicle body. Secondly, the system cleans and filters the collected raw data to eliminate abnormal interference signals and ensure data authenticity and reliability, and then use intelligent algorithms to perform data mining and analysis. Finally, based on the data analysis results, the AI system optimises and controls the fuel cell. For example, for vehicle start-up or low-speed driving when the power demand is weak, the AI system can adjust the operating parameters of the fuel cells to reduce energy consumption.

By utilising data-driven dynamic energy management for fuel cell vehicles, combining real-time traffic flow and hydrogen refuelling station location data, AI can dynamically generate the optimal driving route to minimise hydrogen energy consumption, effectively reducing driving distance and the needs for hydrogen refuelling. For example, a company launched the FCEV intelligent route planning system for hydrogen fuel cell vehicles in 2025, which can automatically plan the optimal driving route for drivers when fuel shortage is detected, and recommend available hydrogen refuelling stations along the way. The system not only displays the fuel supply status of each station in real-time, but also dynamically adjusts the estimated remaining range based on the air conditioning usage status³⁵.

Maintenance: Building an AI-driven fault warning platform to enable timely fault detection

In the commercial operation of fuel cell vehicles, timely identification of potential operational risks and early warning of and response to faults are crucial for improving the reliability and lifespan of fuel cell systems. The traditional troubleshooting approach highly relies on human experience and intervention, which not only consumes a large amount of human resources, but also lacks response speed and accuracy, failing to meet the needs for efficient operation and maintenance. Therefore, a fault identification and early warning platform based on AI and big data has become a crucial solution. The fault warning platform can accurately identify faults and issue warnings when any indication of fault is detected through the analysis of massive operational data; even when it is a minor fault, the system can quickly identify the potential cause and propose optimisation measures to assist operation and maintenance personnel in quick troubleshooting, preventing the fault from deteriorating and affecting the normal operation of the system. The warning mechanism for early intervention enabled by the AI big data platform can reduce the fault occurrence rate and after-sales maintenance costs. More importantly, the data accumulated and minor issues captured by the fault warning platform during operation can be continuously fed back to the product R&D end, forming a "problem identification-solution-iteration" optimisation process to continuously improving fuel cell system's reliability and technological maturity.



³⁵ Design Innovation and Technological Breakthrough: Hyundai Officially Launches the New NEXO for the Second-Generation Hydrogen Fuel Cell Vehicle, NetEase, 3 April 2025, <https://www.163.com/dy/article/JS839PMN0567F0Z.html>

Case

A company builds an AI platform to empower the operation and maintenance management of fuel cell vehicles

To address the challenges brought by the large-scale operation of fuel cell vehicles, a company has built an intelligent collaborative platform covering the full operation chain from R&D to after-sales, forming a value chain of "data collection-intelligent analysis-strategy optimisation-knowledge accumulation".

In terms of intelligent operation and management of fuel cell vehicles, the AI platform has achieved efficient data processing and proactive decision-making optimisation. The AI platform can complete a weekly operational analysis of a 2,000-vehicle fleet within three hours, covering multidimensional assessments covering the economy, reliability, and durability of vehicles. With the help of the AI platform, users can directly trigger the analysis process through natural language interaction (such as "querying the operation status of Shanghai Minhang public transportation"). The system automatically parses semantic requirements, converts them into structured instructions, and calls the underlying algorithm API to obtain deep insights into key indicators. The AI platform can monitor the decay rate of a single battery cell in real-time and compare it with preset aging thresholds. It can also horizontally compare the energy efficiency of vehicles operating in the same region to identify anomalies, and verify the matching degree between the software control strategy version and vehicle operating conditions. The analysis results are presented through a visualisation module, driving fast strategy iteration. For example, for vehicles with abnormal energy efficiency, the root cause of the problem can be quickly identified with optimisation measures pushed based on backend software strategy data to improve customer response efficiency.

In the after-sales operation and maintenance of fuel cell vehicles, the AI platform has a knowledge hub that integrates IoT data and expert experience. To break through the bottleneck in traditional cross functional collaboration, such as the delayed response in the "R&D to after-sales" email flow, the platform has deployed a digital operation and maintenance work flow: R&D personnel submit fault description and initial judgement through the data platform, and the system automatically generates electronic work orders with timestamps and responsible persons indicated; after receiving precise positioning instructions, the after-sales personnel need to complete on-site diagnosis and provide root cause analysis feedback within 24 hours. More importantly, the platform has a structured knowledge base and an AI assisted diagnostic engine. Each vehicle has its own "medical record book" that covers all processes from R&D to after-sales service. All historical maintenance cases are transformed into standardised knowledge points under the "symptom-diagnosis-measures" model, forming a fault feature knowledge base. When a fault occurs, the system automatically associates real-time vehicle condition data with the knowledge base for pattern matching, providing maintenance personnel with suggestions for repairing.

The platform deeply integrates vehicle operation data into after-sales operation and maintenance processes, forming a closed-loop management system covering the entire life cycle of fuel cell vehicles, achieving an overall energy consumption reduction of 8.4% for operating vehicles, improved after-sales response time, and a decrease in the occurrence rate of secondary faults.

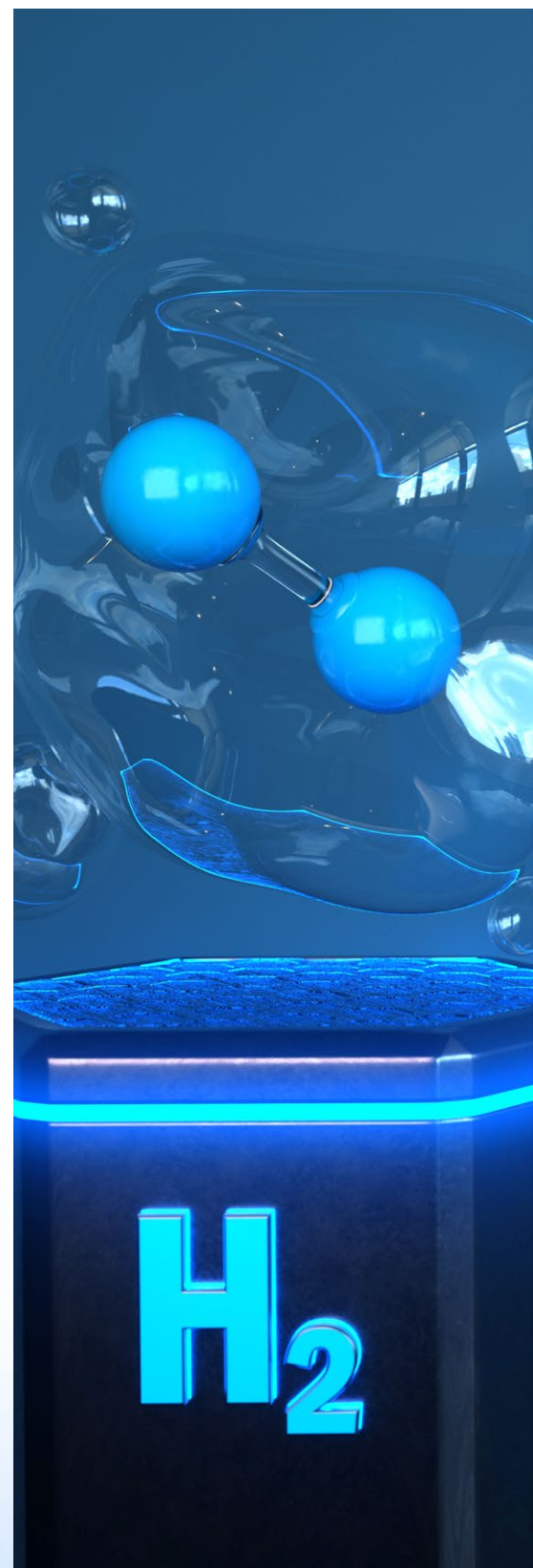
2. Hydrogen powered drones

Drones are another important application scenario for hydrogen energy in the transportation field. The hydrogen powered drone adopts a solid-state hydrogen storage solution at ambient temperature and pressure, with a high mass energy density that prolongs flight time. The minute level hydrogen exchange operation improves energy supply efficiency. The fuel cell and buffer cell ensure continuous and stable power supply through an electrical isolation architecture, while the dynamic response module enhances the agility of the system to respond to sudden load surges through intelligent collaboration with power units. On this basis, the heterogeneous edge computing platform builds a core computing hub that utilises a parallel computing architecture to release local computing power, and forms a data closed-loop through logging, in-service annotation, and continuous optimisation, achieving an optimal match between computing resources and energy consumption control.

The hydrogen powered drones embedded with advanced algorithms break through the limitations resulting from reliance on satellite signals and pre-programmed operations of conventional drones. With the LiDAR, millimetre wave radar, and the communication and navigation integrated technology, combined with edge computing architecture, the system can achieve highly autonomous obstacle avoidance and route planning even without satellite signals or in environments with strong electromagnetic interference. For example, the L4 level autonomous flight system developed by a company embeds the decision logic onboard, establishing a millisecond level "perception-decision-action" loop, which can reduce the accident rate by 90% and improve operational efficiency by 40% without the need for drone flyer's intervention³⁶. This marks the evolution of drones from "vehicles" to "intelligent agents", injecting new momentum into the low-altitude economy.

The autonomous obstacle avoidance and intelligent route planning capabilities of hydrogen powered AI drones have expanded their application scenarios: for intelligent inspection of substations, the anti-interference navigation technology effectively minimises the risks arising from strong electromagnetic environments and satellite signal failure; in the military field, they maintain centimetre level positioning accuracy in communication denial environments through the multi-source fusion SLAM module; the customised railway inspection system overcomes train wind disturbance and power grid interference, meeting strict safety standards; for urban environmental monitoring, the drones integrate the IoT and AI image recognition technology to achieve large-area unmanned monitoring of air pollutants and synchronously support emergency response tasks.

It is worth noting that hydrogen powered AI drones have demonstrated the value of technological integration in chess games. Taking a hydrogen powered AI drone produced by a Beijing company as an example, the hydrogen fuel cells provide stable and long-lasting energy to support complex operations, while the AI decision-making system achieves centimetre level chess game perception and real-time game strategy optimisation. The onboard L4 level autonomous flight architecture integrates multi-sensor data, drives the robotic arm to accurately locate the chess coordinates and achieve adaptive grasping of chess with the support of real-time force feedback. The AI deep learning system not only "perceives" but also deeply "understands" the game and update game strategies in real-time, fully demonstrating its intelligent decision-making capabilities.



³⁶ MOF Robot launched the world's first L4 level "Winged Intelligence" AI drone, ushering in a new era of autonomous flight. MOF Robot's official website, 11 August 2025, <https://www.mof-robot.com/nd.jsp?id=76>

2.6 Safety

Hydrogen safety issues concern leak detection, explosion risk mitigation, material compatibility assessment, storage system optimisation, infrastructure development and planning, diffusion behaviour prediction, combustion characteristic analysis, public awareness management, emergency response planning, and environmental impact assessment³⁷. Like other gaseous fuels, hydrogen leakage and subsequent hazards are the main risks along the hydrogen energy industry chain covering production, storage, transportation to use of hydrogen.

Artificial Neural Network, Machine Learning (ML), Computer Vision (CV), Data Fusion Technology and other AI solutions can achieve stronger detection capability, faster response, predictive modelling, and active risk mitigation, paving the way for a safer, more resilient and sustainable hydrogen economy.



1. Artificial Neural Network (ANN) helps detect hydrogen leakage and evaluates potential hazards

The core principle of ANN is to learn and recognise non-linear patterns in complex data by imitating the way neurons in the human brain process information. The data in hydrogen safety scenarios, such as sensor readings, environmental parameters, and image features, are often highly complex and interrelated, and traditional rule-based or linear model-based solutions are difficult to accurately capture their inherent patterns. This shortfall of conventional solutions can be made up for by ANN.

ANN is mainly used for rapid and effective detection of hydrogen leakage and concentration prediction under hydrogen safety scenarios. Traditional hydrogen sensors may have cross sensitivity or response drift issues. By combining sensors with ANN, an intelligent sensor system can be constructed. ANN can learn and filter out changes in ambient temperature and humidity, interference from other gases and other noises, in order to accurately identify the presence of hydrogen from weak and complex signals and predict its concentration accurately. For example, combining ANN with sensors such as long-period fibre Bragg grating (LPFBG) can accurately predict transmission power based on hydrogen concentration, demonstrating superior performance and computational efficiency compared to the experimental data from using LPFBG alone³⁸.

ANN also has unlimited potential in evaluating potential hazards and providing real-time risk warnings subsequent to detecting leaks. By integrating fluid dynamics equations and real-time data, advanced ANN models such as Physical Information Neural Network (PINN) can quickly predict the diffusion range, concentration distribution, and time to reach the explosion limit of hydrogen clouds, at a speed much higher than the traditional CFD (Computational Fluid Dynamics) simulations, providing real time and visual risk area maps for on-site personnel as guidance for safe evacuation and effective disposal, and avoiding blind entry into hazardous areas.

³⁷ Artificial Intelligence-Driven Innovations in Hydrogen Safety, <https://www.mdpi.com/2673-4141/5/2/18>

³⁸ Id.



2. Machine Learning (ML) algorithms reduce hydrogen leakage risk and optimises storage systems

ML is a broader branch of AI that includes not only ANN, but also more diverse algorithms such as support vector machines (SVM), decision trees, and random forests. Therefore, the application of ML in the field of hydrogen safety is in line with that of ANN in terms of principles, albeit with more diverse approaches, and is seen as a transformative tool for prediction, detection, and risk mitigation.

The core principle of ML algorithms is to enable computers to automatically learn rules and patterns from data, and use these rules to complete prediction, classification, clustering, or decision-making tasks. Compared to ANN, many ML algorithms (such as decision trees) have better interpretability, which is particularly important in the safety field where accountability and understanding of decision logic are required.

The core application scenarios of ML algorithms in the hydrogen safety field are hydrogen leakage detection and risk classification. An effective leak detection model can be built through training by utilising supervised learning algorithms such as random forest or SVM. This model can comprehensively analyse data from multiple sensors and dimensions, to not only determine whether a leak has occurred, but also classify risks based on the severity of the leak, helping operation and maintenance personnel prioritise events with the highest risk. Compared to traditional alerts based on a single threshold, the ML model can significantly reduce the false alarm rate and omission rate, and provide richer risk scenario information. Unsupervised learning can be used to distinguish between leaking and non-leaking states of pipelines, which helps sensor optimisation.

In addition, regression models such as least squares support vector machine (LSSVM) can be used in predicting the effectiveness of porous carbon media in hydrogen absorption. Hydrogen storage systems can be optimised by searching for new solid-state hydrogen storage materials with optimal performance.

3. Computer Vision (CV) and Pattern Recognition help detect hydrogen leakage in industrial environments

Computer vision (CV) and pattern recognition technologies provide a new non-contact, large-area, intuitive and visualised detection paradigm, where a security system can not only "smell" leaks, but also "see" them and the subtle environmental changes they cause.

The core principle is to use image analysis and processing algorithms, such as Convolutional Neural Network (CNN) and regional CNN (R-CNN), to interpret visual cues and patterns, in order to capture physical or chemical phenomena caused by hydrogen leaks that are invisible to the human eye. Then, AI algorithms are used to analyse and recognise the image/video flow, thereby achieving leak detection, positioning, and evaluation.

2.7 Hydrogen energy industry empowers the development of AI technology

1. Electricity is computing power: AI drives data centres to become the major electricity consumer

With the development of AI technology, especially the explosive growth of generative AI, data centres, as digital infrastructure, are rapidly evolving into the most disruptive growth force in global electricity consumption with an unprecedented intensity. In the past, the growth in electricity consumption was mainly driven by industrialisation and residential use, whereas in the future, it is expected to be dominated by the exponential expansion of AI computing power.

Unlike traditional cloud computing, which mainly engages in storage and general computing, AI computing is a high-density, parallel tensor operation with far higher power consumption and cooling requirements than ordinary servers. According to Schneider Electric's calculations, a traditional IT cabinet typically has a power density of 5-10 kilowatts, while the power density of a cabinet carrying AI servers can soar up to 50-100 kilowatts, an increase of nearly 10 times. This means that within the same physical space, the power consumption of AI data centres is several times or even tens of times that of traditional data centres³⁹.

According to data from the International Energy Agency (IEA), it is expected that the power consumption of global data centres will double to 945 terawatt hours by 2030, basically equivalent to the current annual electricity consumption in Japan. The United States and China will become the main regions for the growth of data centre power consumption, accounting for 80% of global data centre power consumption by 2030⁴⁰. The IEA also pointed out that the main driver behind this unprecedented growth is the AI boom.

This AI-driven electricity demand is not only reflected in the total volume of power consumption, but also in its structural impact on the power grid. AI data centres require uninterrupted high-quality power supply around the clock, placing an extremely high bar for the reliability of the power grid. At the same time, in order to meet the ESG requirements, tech giants such as Google, Amazon, and Microsoft have pledged to use 100% renewable energy by 2030, making them the main buyers in the green electricity market⁴¹. It can be seen that AI not only consumes more electricity, but also profoundly changes the way electricity is produced and traded, forcing the global energy system to transform towards a cleaner and smarter model.



³⁹ Addressing the changes and challenges of AI computing centres: Sustainable development remains an important proposition, China Daily, <https://caijing.chinadaily.com.cn/a/202311/21/WS655c4c91a310d5acd876fbef.html>

⁴⁰ Energy demand from AI, IEA, 2025, <https://www.iea.org/reports/energy-and-ai/energy-demand-from-ai>

⁴¹ Google, Microsoft, and Amazon have gone on a shopping spree for around-the-clock carbon free energy, Sina Finance, <https://finance.sina.com.cn/cj/2024-06-26/doc-incaatqw9758613.shtml>



2. Advantages of hydrogen energy as clean energy/stored energy in empowering AI

Hydrogen energy, as a unique clean energy source, is empowering the future development of AI from three aspects: decarbonisation, reliability, and decentralisation.

Firstly, hydrogen energy provides a decarbonisation solution for the greening of computing power required by AI. Although renewable energy sources such as wind and solar energy are clean, their inherent intermittency and instability make them difficult to meet the demand of AI data centres for uninterrupted and high-quality electricity around the clock. Green hydrogen, on the other hand, can convert unstable-state wind and solar power into zero carbon fuel that can be stored for a long time and dispatched for use at any time. By deploying a hydrogen fuel cell power generation system next to a data centre, green hydrogen can be efficiently and stably converted into electricity, providing green electricity, in its true sense, for the operation of AI. For example, Lambda Super Intelligent Cloud recently deployed the industry's first hydrogen powered, production level Nvidia GB300 NVL72 system. The data centre hosting the system is an off grid modular data centre with zero water usage and zero emissions, relying entirely on hydrogen fuel cells to provide energy for AI's inference and basic model training. The GB300 NVL72 system built by Supermicro can provide 142 kW of computing power per unit, which is cooled by liquid cooling systems directly connected to the chips. These liquid cooling systems are supplied with water by central cooling distribution units (CDUs), and water is recycled as a by-product of power generation⁴².

Secondly, stored hydrogen energy provides a reliable foundation for around-the-clock AI services. The instantaneous interruption of AI services such as those for autonomous driving platforms and financial transactions may cause catastrophic consequences. Traditionally, data centres use diesel generators as backup power sources, which is not environmentally friendly and also faces challenges in fuel storage and maintenance. Hydrogen energy storage systems, with their advantages of long-lasting energy storage, quick start, and zero emissions, are becoming an ideal substitute for diesel generators. In the event of power grid failure or extreme weather conditions, hydrogen fuel cells deployed in data centres can respond in milliseconds, providing stable backup power for days or even weeks, ensuring that AI services never go offline. This provides unprecedented security and resilience for the infrastructure of the digital society. For example, Plug Power has reached an agreement with Amazon to provide hydrogen fuel cells for Amazon's data centres as backup power, marking an important step in the application of hydrogen energy in the data centres⁴³.

Finally, hydrogen energy is driving AI's decentralisation to achieve true inclusiveness. The future of AI lies not only in data centres or cloud, but also in edge computing nodes in remote factories, mines, and fields, which often lack reliable grid access. Hydrogen energy, as a transportable and modular energy source, makes it possible to deploy independent AI computing power anywhere. One hydrogen fuel cell power module alone can provide continuous power for a 5G base station in a remote area, an edge server for smart agriculture, or a mobile command centre for post-disaster reconstruction.

⁴² Lambda and ECL Bring the First Hydrogen-Powered NVIDIA GB300 NVL72 Systems Online, <https://www.businesswire.com/news/home/20250923779565/en/Lambda-and-ECL-Bring-the-First-Hydrogen-Powered-NVIDIA-GB300-NVL72-Systems-Online>

⁴³ Amazon Becomes Major Green Hydrogen Purchaser, <https://www.aboutamazon.com/news/sustainability/amazon-adopts-green-hydrogen-to-help-decarbonize-its-operations>

03

Global “AI + Hydrogen Energy Industry Practices”



3.1 Rapid growth in global investment in hydrogen AI

Against the backdrop of the global energy green transformation, the hydrogen industry is undergoing intelligent upgrades and structural changes. In recent years, an increasing number of countries and regions have adopted hydrogen development strategies. According to data from the International Energy Agency (IEA), China, the United States, and the European Union have announced their respective hydrogen development roadmaps. As of 2024, 65 countries worldwide had developed hydrogen strategies, with 29 of them being emerging economies⁴⁴. Driven by both policy support and technological advancements, numerous AI-integrated hydrogen projects are being implemented or planned globally, covering multiple areas such as hydrogen production, storage, transportation, fuel cells, and integrated applications. The Global Hydrogen Review 2023 highlights how over 50 specific projects worldwide have already incorporated AI into green hydrogen production⁴⁵. Notably, several landmark initiatives in 2023 successfully deployed AI technologies, significantly enhancing both the efficiency and economic viability of green hydrogen production (Table 2).

Table 2 Current and Projected Green Hydrogen Production Capacity and Efficiency

Metric	2023 Value	Projected 2030 Value	Source
Global Installed Electrolyses Capacity	25 gigawatts (GW)	Over 80 gigawatts (GW)	International Energy Agency (2023)
Electrolysis System Efficiency	60-80%	Over 90% (with AI optimisations)	Renewable Energy Association (2024)
Number Of AI Optimisation Projects	150 projects	Expected to double	Global Hydrogen Review (2023)
AI-Driven Energy Consumption Reduction	Baseline	Up to 10% reduction	Hydrogen Council (2024)
AI-Driven Cost Reduction	Baseline	Approximately 15% reduction	Hydrogen Council (2024)

Sources: AI-Driven Optimisation for Green Hydrogen Production Efficiency; KPMG Analysis

Looking ahead, the AI solutions market in the green hydrogen sector is poised for substantial global growth. Green hydrogen is projected to grow at a 12% compound annual growth rate (CAGR) from 2024 to 2030⁴⁶, driven by three key factors. First, the increasing adoption of clean energy across industries is fuelling rising demand for hydrogen as a sustainable energy carrier. Second, manufacturers are accelerating investments in AI and automation technologies to optimise hydrogen production and enhance equipment maintenance, aiming to reduce costs and improve operational efficiency. Finally, the declining costs of AI software, sensor systems, and IoT infrastructure are making these solutions more economically viable, thereby accelerating their integration into green hydrogen production systems.

⁴⁴ Global Hydrogen Review 2025, IEA, 2025, <https://www.iea.org/reports/global-energy-review-2025>

⁴⁵ Global Hydrogen Review 2023, IEA, 2023, <https://www.iea.org/reports/global-hydrogen-review-2023>

⁴⁶ Ashish K Saxena, AI-driven optimization for green hydrogen production efficiency, Journal of Scientific and Engineering Research, 2024, 11(6):145-155

3.2 Hydrogen strategies & policies and cases of AI-powered hydrogen projects across Europe

The European Union is a global leader in the development of hydrogen energy. Its strategic goals and policy priorities in this domain focus primarily on increasing the scale of hydrogen production and achieving sustainable clean energy. In 2020, the EU released its hydrogen strategy (the “EU Hydrogen Strategy”), setting an ambitious target of installing at least 40 gigawatts of renewable energy electrolyzers by 2030, aiming to produce 10 million tonnes of renewable hydrogen annually. This ambitious plan aims to integrate hydrogen as a critical component of the integrated energy system⁴⁷. In 2024, the European Commission announced two significant funding initiatives: the Important Project of Common European Interest (IPCEI) and the Cross-Border Energy Infrastructure Project. These initiatives will invest a total of EUR 7.5 billion (approximately RMB 58.4 billion) to support the development of hydrogen energy and transboundary energy infrastructure⁴⁸.

Furthermore, in 2025, the European Commission launched a public consultation on an upcoming digitalisation and AI roadmap for the energy sector. This roadmap aims to promote digital solutions, including AI, in key areas of decarbonisation⁴⁹. These efforts underscore the EU’s commitment to leveraging policy support and AI innovation to make hydrogen energy a crucial pillar in achieving carbon neutrality.



1. Germany: Advancing hydrogen infrastructure to grow the hydrogen industry

To accelerate decarbonisation across various sectors, Germany has introduced a series of measures to promote hydrogen energy development, encompassing the hydrogen value chain and the construction of hydrogen infrastructure. In July 2023, the German federal cabinet approved an updated version of the “National Hydrogen Strategy”, aimed at accelerating the growth of the hydrogen energy market to meet higher climate goals and address new challenges in the energy sector. The measures outlined in the strategy cover the entire hydrogen value chain, and many initiatives were already underway during the strategic update preparation phase⁵⁰.

In terms of infrastructure development, in June 2024, the German government approved the “Hydrogen Acceleration Act,” with the core objective of accelerating the construction of hydrogen infrastructure, import facilities, and production facilities. The goal is to become a global leader in hydrogen technology by 2030. Additionally, Germany has joined the European Hydrogen Backbone initiative, planning to build five major “hydrogen corridors.” Furthermore, Germany aims to upgrade and construct over 1,800 kilometres of hydrogen pipelines between 2027 and 2028, with partial support from the IPCEI programme⁵¹.

⁴⁷ EU Commission Releases the EU Hydrogen Strategy, Chinese Academy of Sciences Institutes of Science and Development, 15 October 2020, https://casisd.cas.cn/zkcg/ydkb/kjzczyxkb/2020/zczxkb202009/202010/t20201015_5717030.html

⁴⁸ EU to Invest € 7.5B in Hydrogen and Cross-Border Energy Infrastructure, Chinese Academy of Sciences Institutes of Science and Development, 6 June 2024, https://casisd.cas.cn/zkcg/ydkb/kjzykb/2024/kjzykb2404/202406/t20240606_7185505.html

⁴⁹ EU Commission Launched a Public Consultation on a Digitalisation and AI Roadmap for the Energy Sector, Newenergy IN-EN.com, 20 August 2025, <https://newenergy.in-en.com/html/newenergy-2444138.shtml>

⁵⁰ Germany Advances Hydrogen Sector at All Fronts Including Infrastructure, Policy Incentives, and International Cooperation, H2. IN-EN.com, 7 August 2023, <https://h2.in-en.com/html/h2-2427356.shtml>

⁵¹ Germany Accelerates Hydrogen Energy Development (International Perspectives), People’s Daily Online, 12 August 2024, <https://world.people.com.cn/n1/2024/0812/c1002-40296775.html>

In addition to policy initiatives, AI technologies also play a crucial role in the hydrogen sector. Below is a selection of cases that demonstrate how Germany develops and integrates AI technologies with the hydrogen industry.

Case 1

Germany is Using AI to Advance Hydrogen Infrastructure

The German Ministry of Urban Development and Housing is working on an AI-supported platform to speed up planning and approval processes and set up a nationwide hydrogen network. Funded by the German government's Climate and Transformation Fund, the platform was launched in April 2025. The "Hamburg Hydrogen Industry Network" (HH-WIN) will be integrated into this hydrogen network. The AI platform will map all the approval procedures relating to the core hydrogen network and simplify procedures. The introduction of AI not only enhances the efficiency of hydrogen infrastructure construction but also provides critical digital infrastructure for the overall hydrogen supply chain⁵².

Case 2

Germany has Allocated EUR 154M to Support Hydrogen Technology Development

Germany's Federal Ministry for Digital Affairs and Transport has invested EUR 154 million to foster the growth of hydrogen technology centres. The investment primarily benefits two major areas: the city of Chemnitz and a northern German cluster that includes Bremen, Bremerhaven, Hamburg, and Stade. These hubs are designed to support small and medium-sized enterprises and the supply industry by enhancing their capabilities in developing climate-friendly technologies. Through the latest developments, inspections, and testing of infrastructure, these hubs provide prerequisites for launching new applications and achieving market readiness⁵³.

2. France: Providing financial subsidies and research support for development of the hydrogen industry

In recent years, the French government has actively promoted the development of the hydrogen industry through policies including financial subsidies and new energy research. In terms of financial subsidies, in April 2025, the French government updated its "National Hydrogen Strategy," establishing a support system worth EUR 4 billion to ensure the competitiveness of low-carbon hydrogen compared to fossil fuel-based hydrogen over the next 15 years⁵⁴. This will gradually establish a long-term support system. In terms of new energy research, the French government approved a "research project" in 2023 to explore natural hydrogen in the Pyrénées-Atlantiques region. Additionally, the government will allocate funds for the production of green hydrogen and nuclear hydrogen, aiming to create a unique hydrogen value chain in France.

Beyond government policy support, French hydrogen companies are also driving the integration of AI with hydrogen, as AI has been increasingly used in the development, production, and application of hydrogen. The following examples illustrate specific AI use cases across the hydrogen sector.

⁵² AI platform accelerating approval procedures for hydrogen projects, Hamburg Business, Dec 12, 2024, <https://hamburg-business.com/en/news/ai-platform-accelerating-approval-procedures-for-hydrogen-projects>

⁵³ Germany Allocates EUR 154 Million to Support Hydrogen Technology Development Across Key Hubs, fuelcellworks, March 7, 2025 <https://fuelcellworks.com/2025/03/07/green-investment/germany-allocates-eur-154-million-to-support-hydrogen-technology-development-across-key-hubs>

⁵⁴ France Revises National Hydrogen Strategy and Plans to Invest €4B in Low-Carbon Hydrogen Projects, Xinhua News Agency, 18 April 2025, <http://www.xinhuanet.com/world/20250418/caa15c51162b4677aa5c948fb903d989/c.html>

Case1

A French Company is Bringing Advanced AI for Green Hydrogen Production

The introduction of AI not only brings intelligence to hydrogen production, but also provides critical technical support for generating hydrogen on an industrial scale. A French company is taking part in the European HYIELD project to build a demonstration plant that generates green hydrogen from waste. The company is to design an AI-based digital twin for the project, with the purpose of providing estimates of operating costs, making production forecasts, and optimising hydrogen production. The digital twin enables precise management and optimisation of hydrogen production, thereby enhancing the economic viability and sustainability of green hydrogen production⁵⁵.

Case2

A French Company is Using AI to Identify Natural Hydrogen Reservoirs

A French company exploring natural hydrogen is leveraging AI to identify underground reservoirs of natural hydrogen in the Pyrenees, particularly in its Comminges exploration zone. The company has developed the HOREX® technology, which integrates AI, geology, geophysics, and geochemistry to comprehensively map the hydrogen system from source rocks to reservoirs. The company validated this technology using extensive soil gas data in April 2025 and plans to conduct further low-environmental-impact imaging work in the Hautes-Pyrénées region⁵⁶.

Case3

A Project that Leverages Digital Tools and AI to Optimise Hydrogen Production

Two major French energy groups, Total and Engie, signed a cooperation agreement to design and develop the Masshylia project, France's largest renewable hydrogen production site, by 2024. Masshylia is one of the largest renewable hydrogen production sites in France. The project uses advanced digital tools and AI technologies to optimise hydrogen production and ensure industrial safety. Furthermore, Total and Engie also expanded their partnership with the industrial AI company Ognite, leveraging data and AI to enhance the operational performance of their assets⁵⁷.



⁵⁵ Eurecat to design an AI-based digital twin to produce green hydrogen from waste, Eurecat, Aug 29, 2024

<https://eurecat.org/en/eurecat-to-design-an-ai-based-digital-twin-to-produce-green-hydrogen-from-waste/>

⁵⁶ Global Hydrogen Review 2025, IEA, 12 September 2025, <https://www.iea.org/reports/global-hydrogen-review-2025>

⁵⁷ MassHylia: the largest hydrogen green site in France, surfeo

<https://surfeo.eu/masshylia-the-largest-hydrogen-green-site-in-france/#:~:text=MassHylia:%20the%20largest%20hydrogen%20green,of%20green%20hydrogen%20per%20day.>

3. United Kingdom: Announcing a list of hydrogen projects and infrastructure strategies to support hydrogen industry development

In recent years, the UK government has been continuously strengthening its policy framework for the hydrogen industry. In 2025, the UK released a new list of hydrogen projects and the “Hydrogen Infrastructure Strategy” to advance hydrogen development and achieve the goals of energy security and becoming a global leader in clean energy. Specifically, in April 2025, the UK government shortlisted 27 hydrogen projects under the Second Hydrogen Allocation Round (HAR2) issuance. The goal is to attract over GBP1 billion of private sector investment by 2029, supporting the strategic objective of making the UK a superpower in clean energy⁵⁸. In June 2025, the UK government announced investment of more than GBP 500 million for building hydrogen infrastructure, including the construction of the UK’s first regional hydrogen transportation and storage network. This initiative aims to connect hydrogen production companies with power plants and other key end-users for the first time⁵⁹, with the ultimate goal of transforming the UK into a clean energy powerhouse.

The introduction of these policies provides a guarantee for the long-term stable development of the UK’s hydrogen enterprises. At the same time, UK energy companies are exploring the synergies of AI technologies and hydrogen. Many of them have already announced hydrogen projects integrating AI technologies. Below are some typical cases.

Case1

A UK Company is Using AI Software to Reduce Hydrogen Production Costs

In July 2024, a UK company launched AI-driven software that uses the same algorithms as those employed in electricity microgrids powered by renewable energy, reducing the levelised cost of hydrogen production by at least 20%⁶⁰.

Case2

A UK Company is Employing AI for Vessels to Enhance Green Hydrogen Production and Storage

A UK-based startup plans to build a fleet of hi-tech sailing vessels which can enhance green hydrogen production and storage by relying on AI routing algorithms, through which, the vessels can dynamically plan the optimal route based on hull design, weather conditions, and critical parameters required for hydrogen production. When the vessel accelerates, it generates energy from underwater turbines. The energy is then used to produce green hydrogen. According to actual sailing tests, an AI-enabled vessel can produce 6 litres of green hydrogen in just 2 hours, far beyond predictions⁶¹.

⁵⁸ UK Government Pushes Hydrogen Projects to Drive Clean Energy Transition and Job Growth, China General Machinery Industry Association (CGMIA), 9 April 2025, <https://www.cgmia.org.cn/Web/News/Detail/22426>

⁵⁹ UK Government to Invest £500M to Support Hydrogen Development, Ministry of Commerce, 10 July 2025, https://www.mofcom.gov.cn/zwjg/jmxw/oz/art/2025/art_7be89291f01647be969a52444222cfb9.html

⁶⁰ Industry News | ZeroAvia Utilises AI Software to Reduce Hydrogen Production Costs, CAST Alliance for Aero-Engine Industry and Academy, 18 July 2024, https://mp.weixin.qq.com/s/SxjF7E4ZVzt6yzJ4a1cr_w

⁶¹ UK startup's yachts to use underwater turbines for green hydrogen production, interestingengineering, Aug 19, 2024, <https://interestingengineering.com/energy/uk-drift-energy-sailing-vessels-green-hydrogen>

3.3 Hydrogen strategies & policies and cases of AI-powered hydrogen projects across Asia

1. China: Making new strategic breakthroughs, moving beyond pilot exploration of hydrogen energy

Under its new energy security strategy of “Four Revolutions and One Cooperation,” China is accelerating its entire hydrogen supply chain. In January 2025, the “Law of the People’s Republic of China on Energy” was officially implemented, explicitly incorporating hydrogen into the national energy management system and legally establishing hydrogen’s status as a source of energy for the first time⁶². In September 2025, the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) jointly issued the “Implementation Opinions on Advancing the High-Quality Development of the Domestic Energy Sector with Artificial Intelligence (AI),” aiming to make China a world-leading country in AI technologies and applications in the energy sector by 2030. Specifically, in the green hydrogen sector, an integrated system is being constructed by combining multidimensional data including wind/solar power fluctuation forecasts, hydrogen storage tank capacity, electrolyser temperatures, and catalyst conditions. Leveraging AI algorithms, this system dynamically optimises electrolyser current density to enable intelligent control of the entire hydrogen production-storage-utilisation chain. The solution achieves millisecond-level synchronisation between renewable energy power fluctuations and the flexible load of electrolyser units⁶³. Looking ahead, the Chinese government will enhance strategic planning and guidance to accelerate hydrogen development, while maximising policy-driven impetus for the hydrogen industry’s strategic advancement.

China has set a national target to achieve carbon neutrality by 2060, with the integration of AI technologies and hydrogen poised to play a pivotal role in this transition. Hydrogen industry players are actively leveraging AI solutions to drive further growth of the industry.

Case1

A Chinese Company is Leveraging AI to Establish a Green Hydrogen-Ammonia Plant

A company has established a green hydrogen-ammonia production plant powered entirely by an off-grid renewable energy system. This system incorporates proprietary AI technologies and features advanced wind turbines, battery storage systems with grid-forming capabilities, and predictive weather models. By dynamically balancing the input of wind and solar energy with the energy demands of electrolysis and ammonia synthesis processes, the system ensures the continuous and cost-effective production of green fuel without grid dependency⁶⁴.

Case2

A Chinese Company has Launched a Digitally Intelligent Alkaline Electrolyser

In 2024, a company launched a digitally intelligent alkaline electrolyser with a capacity of over 2,000 Nm³/h. The electrolyser features an advanced digital management system that enables comprehensive monitoring, proactive safety control, and predictive health management. By integrating sensor networks, real-time data acquisition systems, and AI-driven algorithms, the platform achieves state visualisation, safety assurance, and optimised regulation⁶⁵.

⁶² Energy Law of the People’s Republic of China, State Council, 9 November 2024, https://www.gov.cn/yaowen/liebiao/202411/content_6985761.htm

⁶³ NDRC and NEA Issued “Implementation Opinions on Advancing the High-Quality Development of the Domestic Energy Sector with Artificial Intelligence (AI)”, 4 September 2025, Gov.cn, https://www.gov.cn/zhengce/zhengceku/202509/content_7040253.htm

⁶⁴ ENVISION Successfully Builds World’s Largest Green Hydrogen-Ammonia Plant with Off-Grid Renewable Energy System, PR Newswire, 11 July 2025, <https://www.prnasia.com/story/496250-1.shtml>

⁶⁵ Digital Technologies Drive Innovation: Decoding Sunshine Hydrogen’s Ecosystem, CNEnergyNews, 9 July 2025, https://www.cnenenergynews.cn/guangfu/2025/07/09/detail_20250709220984.html

Case 3

A Chinese Hydrogen Company is Collaborating with a Logistics Firm to Advance Smart Hydrogen-powered Logistics

In September 2025, a hydrogen technology firm and a logistics provider established a strategic collaboration. Through the seamless integration of AI dispatch systems with hydrogen refuelling network data, the partnership leverages critical parameters including vehicle hydrogen efficiency, cargo capacity, and route optimisation algorithms. This enables intelligent scheduling of optimal refuelling windows and station selection, effectively addressing the longstanding challenges of low refuelling efficiency and high operational costs in hydrogen-powered logistics fleets. The innovative solution significantly enhances fleet operational efficiency through data-driven decision-making⁶⁶.

2. Japan: Strategic subsidy mechanisms and hydrogen supply expansion

Japan identified hydrogen energy as a visionary solution for future energy needs as early as the 1970s, and has since pursued it through strategic national initiatives. In June 2023, the government updated its 2017 “Basic Hydrogen Strategy,”⁶⁷ setting a landmark target to increase hydrogen consumption sixfold to 12 million tonnes by 2040. This ambitious plan is being supported by a historic JPY 15 trillion public-private investment commitment over 15 years to accelerate hydrogen infrastructure development. The strategic momentum continued in May 2024 with the enactment of the “Hydrogen Society Promotion Act,”⁶⁸ a groundbreaking legislation providing 15-year subsidy guarantees for both domestically produced and imported low-carbon hydrogen. This innovative subsidy model features project-specific funding determinations, with producers qualifying for extended financial support if their projects begin supplies by 2030. Through this comprehensive policy framework and sustained technological innovation, Japan is well-positioned to achieve breakthroughs in hydrogen energy development, offering a strategic model for the global energy transition.

Supported by government policies, Japanese energy firms are integrating AI with hydrogen technology to develop solutions targeting the global market. For instance, one company is advancing practical applications of hydrogen energy through robotic systems, while another is constructing AI-driven hydrogen-powered power plants to accelerate innovation in the hydrogen energy sector.

Case 1

A Company's AI-driven Robotic System is Revolutionising Hydrogen-Powered Equipment Through Advanced Capabilities

A Japanese firm has developed a hydrogen-powered quadruped robot that is achieving technological breakthroughs through the integration of AI and hydrogen energy. AI technology is primarily used to optimise the riding experience and enhance operational performance. The robot's AI-driven system continuously analyses real-time biometric data such as rider weight to dynamically optimise motion parameters, ensuring both high energy efficiency and enhanced safety. This innovative application not only expands the application boundaries of hydrogen technology in smart mobility devices but also redefines user experience standards for clean energy equipment through optimised human-machine interaction⁶⁹.

⁶⁶ Hydrogen Meets AI: Yuntao Hydrogen Partners with Guangzhou Zhika to Commercialise 18-Tonne Hydrogen Fuel-Cell Trucks, H2. IN-EN.com, 16 September 2025, <https://h2.in-en.com/html/h2-2443754.shtml>

⁶⁷ Japan Revises Hydrogen Strategy, But Still Faces Challenges Ahead, People's Daily Online, 12 June 2023, https://paper.people.com.cn/zgnyb/html/2023-06/12/content_25999054.htm

⁶⁸ Japan Passes “Hydrogen Society Promotion Act”, Paving Way for 15-Year Subsidies for Domestic and Imported Hydrogen, Hydrogen Energy Industry Promotion Association, 20 May 2024, <https://cn-heipa.com/newsinfo/7191689.html>

⁶⁹ Japan introduces hydrogen-powered, AI-equipped four-legged robot designed for riding like a horse, Supercarblondie, Apr 07, 2025

Case2

A Japanese Firm is Leveraging AI to Optimise Hydrogen Production

A Japanese firm has established an AI-operated hydrogen fuel power plant, leveraging AI to enhance the adaptability of the power system. This system enables predictive maintenance and dynamic optimisation of grid scheduling. The plant combines wind and solar energy to produce hydrogen, which is then combusted to generate electricity during peak demand periods. Through an integrated network of sensors and advanced data analytics, the facility achieves autonomous operations. Notably, the plant has successfully tested a 30% hydrogen-blended fuel gas turbine, resulting in a 10% reduction in CO₂ emissions compared to conventional natural gas turbines. At the heart of this innovation lies the AI platform MHPS-Tomoni, which diagnoses equipment faults in real-time and dynamically adjusts power generation to respond to demand fluctuations⁷⁰.

Case3

Fukushima Renewable Energy Institute is Pioneering AI-Driven Energy Storage Innovation

The Fukushima Renewable Energy Institute has developed an AI-powered hydrogen energy storage system that leverages deep learning models to forecast demand and optimise energy allocation. Through the analysis of supply-demand dynamics, the system enables efficient hydrogen resource scheduling, facilitating the integration of large-scale renewable energy systems. This breakthrough technology provides a scalable solution for long-term hydrogen storage, effectively mitigating the intermittency challenges inherent in renewable energy sources⁷¹.

3. South Korea: Introducing two major initiatives to accelerate clean hydrogen development

As a major energy consumer, South Korea is under dual pressures to ensure energy security and reduce carbon emissions. Since 2018, the South Korean government has prioritised hydrogen energy as a national core strategy. In 2022, the 5th Hydrogen Energy Economic Committee released new policy directions for the hydrogen economy⁷², formally promoting the development of the domestic hydrogen energy industry. These policies focus on three key strategies: expanding scale and scope, strengthening infrastructure and systems, and upgrading industries and technologies. These strategies aim to promote the development of the hydrogen energy industry from various angles. With the improvement of energy infrastructure, hydrogen energy has seen significant development in South Korea. 2024 is a pivotal year for the country's clean hydrogen economy. The South Korean government has introduced the "Clean Hydrogen Certification System Operation Plan"⁷³ and the "Clean Hydrogen Portfolio Standard (CHPS)."⁷⁴ These initiatives have two main objectives: first, to grant clean hydrogen certification and provide financial support to businesses; and second, to implement a mandatory renewable energy supply system. By fostering long-term collaborations with businesses, these initiatives aim to incentivise power producers to use clean hydrogen, thereby driving further growth in the hydrogen industry.

To ensure stable future hydrogen energy supplies, Korean energy companies and research teams are leveraging AI technologies as a critical production tool. By optimising hydrogen fuel-cell design, enhancing driving assistance systems, and collaborating on hydrogen projects, they aim to boost the efficiency and safety of the entire hydrogen supply chain.

⁷⁰ World's First AI-Operated Hydrogen Power Plant: Mitsubishi-Hitachi Hydrogen Power Plant, Beijixing.com, 13 April 2018, <https://news.bjx.com.cn/html/20180413/891574.shtml>

⁷¹ AI-Optimised Energy Storage: Solving the Renewable Intermittency Challenge, Venturous, Apr 01, 2025, <https://www.venturousgroup.com/resources/ai-optimised-energy-storage-solving-the-renewable-intermittency-challenge/>

⁷² South Korea Announces New Hydrogen Economy Policy Directions, Chinese Academy of Sciences Institutes of Science and Development, 3 April 2023, https://www.casisd.cn/zkcg/ydkb/kjczyxkb/2023/zczxkb202301/202304/t20230403_6726408.html

⁷³ Clean Hydrogen Certification System Operation Plan Republic of Korea (2024), climate policy database, 2024, <https://climatepolicydatabase.org/policies/clean-hydrogen-certification-system-operation-plan>

⁷⁴ Clean Hydrogen Portfolio Standard (CHPS) Republic of Korea (2024), climatepolicydatabase, 2024, <https://climatepolicydatabase.org/policies/clean-hydrogen-portfolio-standard-chps>

Case1

A Research Team is Using AI to Optimise Hydrogen Fuel-Cell Design

A research team from the Hydrogen Research & Demonstration Centre, Korea Institute of Energy Research (KIER) has achieved a breakthrough in carbon fibre paper microstructure analysis for hydrogen fuel cells. Their revolutionary approach enables 100x faster structural analysis of carbon fibre paper - a critical component in fuel-cell stacks - through digital twin technology and advanced machine learning algorithms. The research team analysed over 200 carbon-fibre paper samples to extract 5,000 images, which were then used to train machine learning algorithms. The resulting model can predict the three-dimensional spatial distribution and orientation of key components in carbon-fibre composites—including carbon fibres, binding agents, and surface coatings—with an accuracy exceeding 98%⁷⁵.

Case2

A Company has Integrated AI into the Driving Assistance System for Hydrogen Fuel Electric Trucks

A company has launched an XCIENT hydrogen fuel-cell truck, which features enhanced power through upgraded hydrogen fuel-cell systems and incorporates advanced driver assistance technologies previously unavailable in commercial vehicles. These include forward collision warnings, lane departure alerts, side collision alerts, and intelligent adaptive cruise control systems, all leveraging AI to significantly enhance road safety⁷⁶.

Case3

Two Companies are Collaborating to Build a Hydrogen Fuel-Cell Power Plant to Support Data Centres

In 2025, two South Korean energy companies announced the “Dangjin Green Energy Hub” project - an integrated hydrogen fuel-cell power plant and data centre infrastructure slated for November 2025. Upon completion, this pioneering initiative will establish South Korea’s first commercial-scale hydrogen fuel-cell power plant, equipped with 900 MW of hydrogen generation capacity and 300 MW of battery energy storage systems to reliably power large-scale data centre operations⁷⁷.



⁷⁵ AI Replaces Humans in Identifying Fuel Cell Fault Causes, Nengyuanjie.net, 4 January 2025, <https://www.nengyuanjie.net/article/108100.html>

⁷⁶ Hyundai Plans to Launch New XCIENT Fuel Cell Trucks in North America, Ministry of Commerce, 6 May 2025, https://kr.mofcom.gov.cn/jmxw/art/2025/art_114b04616a0e4a6fa49aab89c0031e4c.html

⁷⁷ South Korean gov't to explore development of AI powered power grid, datacenterdynamics, August 11, 2025, <https://www.datacenterdynamics.com/en/news/south-korean-govt-to-explore-development-of-ai-powered-power-grid/>

4. India: Approving the National Green Hydrogen Mission to boost green hydrogen production capacity

With the global energy landscape transitioning toward a clean and sustainable future, India is aggressively advancing hydrogen energy technology to reduce fossil fuel dependence, mitigate greenhouse gas emissions, and diversify its energy mix. In January 2023, the Indian Cabinet approved the “National Green Hydrogen Mission” with a planned expenditure of INR 1,974.4 billion (RMB 171 billion). This strategic initiative aims to position India as a global hub for the production, utilisation, and export of green hydrogen and its derivatives, targeting annual output of 5 million metric tonnes of green hydrogen by 2030⁷⁸.

However, India’s hydrogen production technology and infrastructure still face significant bottlenecks that require continued government support. Against this backdrop, the country approved 19 green hydrogen production projects in 2025⁷⁹, which will collectively achieve an annual production capacity of 862,000 tonnes. Additionally, India has selected 15 companies to develop 3 gigawatts of electrolyser manufacturing capacity, demonstrating robust growth in domestic supply chain capabilities.

With India’s government policy support and energy enterprises’ technological advancements, the Indian industry is confident about its hydrogen economy’s future. AI is opening new possibilities for hydrogen development in India, as multinational corporations deploy pilot projects there to provide technical expertise for future hydrogen applications.

Case1

A Multinational Company is Building a Green Hydrogen Plant Equipped with AI-Driven Remote Monitoring and Analytics

An Indian multinational corporation is developing a state-of-the-art green hydrogen production facility in Hazira. The facility is powered by an integrated solar power generation system and advanced battery energy storage solutions. In terms of smart operations, the plant features a next-generation intelligent control system that integrates a remote monitoring and data analytics platform. This enables real-time performance optimisation insights, demonstrating the company’s strategic commitment to leveraging cutting-edge technology in the green energy sector⁸⁰.

Case2

Two Enterprises are Collaborating to Provide Hydrogen Energy Solutions for a Data Centre

A hydrogen energy company and an internet company have partnered to supply hydrogen storage power generation systems for a new data centre in Bangalore, India. Specifically, the hydrogen energy storage system provided by the hydrogen company employs self-developed technologies such as efficient filtration and intelligent flow control, dual-nozzle full-power-range hydrogen injection, and others. These innovations achieve a 20% reduction in hydrogen consumption while maintaining a combined heat and power (CHP) efficiency of up to 80%, significantly outperforming conventional diesel generators⁸¹.

⁷⁸ India’s National Green Hydrogen Mission (NGHM) Details Revealed, Hydrogen Energy Industry Promotion Association, 31 July 2024, <https://www.cn-heipa.com/newsinfo/7438021.html>

⁷⁹ India Approves 19 Green Hydrogen Projects with Combined Annual Capacity of 862,000 Metric Tonnes, H2. IN-EN.com, 21 August 2025, <https://h2.in-en.com/html/h2-2443526.shtml>

⁸⁰ L&T Commissions Green Hydrogen Plant at its Industrial Site in India, knowesg, August 21, 2022, <https://knowesg.com/tech/l-and-t-commissions-green-hydrogen-plant-at-its-industrial-site-in-india-21082022>

⁸¹ China’s HydraV Collaborates with Amazon to Build a Zero-Carbon Data Centre in India, ikanchai.com, 3 October 2025, <https://news.ikanchai.com/2025/1003/639667.shtml>



3.4 Hydrogen Strategies & Policies and Cases of AI-powered Hydrogen Projects across North America

1. United States: New tax reform bill substantially cuts hydrogen energy subsidies

In recent years, the US hydrogen strategy has undergone strategic shifts. In December 2024, the US Department of Energy released its “Hydrogen Programme Plan,” revealing that the nation already operates over 2,575 kilometres of hydrogen transmission pipelines. However, the high capital expenditure associated with hydrogen pipeline infrastructure has prompted the department to prioritise alternative hydrogen storage solutions in future development. These include cost-effective underground rock cavern storage systems⁸².

However, in May 2025, the US House Ways and Means Committee proposed a tax reform bill that would significantly revise the clean energy subsidy provisions under the Inflation Reduction Act (IRA). Specifically, the Section 45V Clean Hydrogen Production Tax Credit (up to USD 3 per kilogram) was originally set to expire in 2033, but the US government now intends to terminate it ahead of schedule, moving the deadline to the end of 2026 — seven years earlier than previously planned. Given this development, hydrogen industry stakeholders and investors must carefully reassess their strategies, prioritise preparedness, and proactively adapt to potential policy shifts.

Against the backdrop of the evolving policy landscape, the development trajectory of American energy enterprises is fraught with challenges yet simultaneously presents new opportunities. Advancements in AI technology have significantly facilitated the hydrogen industry’s technological innovation and digital transformation. These developments will be explored through specific case studies.

⁸² Clean Hydrogen Demand to Reach ~50MMT by 2050! U.S. Department of Energy Releases New Hydrogen Programme Plan, H2. IN-EN.com, 25 December 2024, <https://mh2.in-en.com/html/h2-2440083.shtml>

Case1

The US Department of Energy is Using AI to Screen Liquid Hydrogen Carriers

Scientists at the Argonne National Laboratory of the U.S. Department of Energy (DOE) have developed a novel approach by integrating AI with advanced theoretical calculations to evaluate 160 billion molecules, aiming to identify those suitable as liquid carriers for hydrogen. By using efficient AI algorithms, the laboratory identifies potential candidate molecules from a vast molecular library, thereby advancing the development of hydrogen energy storage and transportation technologies⁸³.

Case2

US Energy Information Administration Predicts AI Algorithms Will Enhance Hydrogen

The U.S. Energy Information Administration (EIA) forecasts that integrating AI with electrolyser optimisation and predictive maintenance could reduce green hydrogen costs by over 20% over the next decade. A startup's pilot project has demonstrated that optimising operational parameters through metaheuristic algorithms can enhance hydrogen production efficiency by 15-30%⁸⁴.

Case3

A Company is Using AI to Support Efficient, Cost-Effective Green Hydrogen Production

A leading technology firm has launched a comprehensive product suite powered by AI and driven by machine learning. This product suite consists of three innovative solutions: the Conceptual Design Optimiser – a tool designed to optimise factory layouts, reduce the Levelised Cost of Hydrogen (LCOH), and accelerate capital investment decisions; the Hydrogen Electrolyser Control System – a performance analytics platform that enhances electrolyser efficiency and longevity; and the Hydrogen Unified Control & Optimiser – a digital twin-enabled solution that streamlines energy management and operational workflows across entire facilities through AI/ML optimisation and predictive analytics, ultimately reducing operational expenditure. The technology suite addresses critical industry challenges, including intermittent power supplies, high carbon intensity, and elevated production costs. By integrating advanced predictive control algorithms, the new solution advances the scalability and efficiency of hydrogen production⁸⁵.

⁸³ American Scientists Aid in Screening Liquid Hydrogen Carriers Using AI, H2. IN-EN.com, 12 January 2024, <https://h2.in-en.com/html/h2-2432879.shtml>

⁸⁴ AI-driven Optimisation for Green Hydrogen Production Efficiency, Journal of Scientific and Engineering Research, 16 July 2024, <https://jsaer.com/download/vol-11-iss-6-2024/JSAER2024-11-6-145-155.pdf>

⁸⁵ Honeywell Uses AI to Optimise Hydrogen Production, H2. IN-EN.com, 11 April 2025, <https://h2.in-en.com/html/h2-2441890.shtml>

04

Challenges for the Deep Integration of "AI + Hydrogen Energy"



4.1 Poor data quality

The deep integration of artificial intelligence (AI) technology and hydrogen energy is an important trend in the development of energy technology, but the integration process faces significant data challenges. Problems such as insufficient data and data silos seriously hinder the application of AI in the hydrogen energy field, not only impeding technological innovation and cost reduction, but also delaying the commercialisation process for the hydrogen energy industry.



1. Data shortage and data silos in the hydrogen energy industry

As a strategic emerging industry, the hydrogen energy industry is still in an early stage of development, and it has not yet fully achieved large-scale and commercialised operations, with a weak data foundation. Although China's hydrogen production capacity exceeded 50 million tonnes per year at the end of 2024, the main source of hydrogen production is still fossil fuels, with a limited scale of green hydrogen production⁸⁶. According to the China Green Hydrogen Market Summary and Outlook (2025H1), as of the end of June 2025, the total number of domestic green hydrogen projects reached 866, with a potential production capacity of 11.06 million tonnes per year. However, the operating rate was less than 30%, and stable operational cases were lacking⁸⁷. Limitations in the scale of commercialisation directly constrain the breadth and depth of data collection.

The technical complexities of the industry exacerbate the data shortage. The hydrogen energy industry has a long industry chain and high technical threshold, involving multiple processes such as hydrogen production, storage and transportation, refuelling, and application. Each process involves different types of data and has different standards. For example, the complex reaction process inside the water electrolyser and the performance changes of hydrogen storage materials at different temperatures and pressures require long-term monitoring enabled by precision instruments in order to obtain reliable data. These technical complexities not only increase the cost of data collection, but also render data standardisation more difficult. Especially in the field of renewable energy hydrogen production, the intermittency and volatility of wind and solar power generation pose great challenges to data collection, making it difficult to obtain high-quality and continuous datasets.

At the same time, data silos have become another major obstacle to the digital transformation of the hydrogen energy industry, and competitive barriers are the primary cause of data silos. The early stage of the commercialisation of the hydrogen energy industry has attracted a large number of enterprises. However, due to the high commercial value of hydrogen energy technology, many enterprises consider operational data, technical parameters, etc. to be their core assets and are unwilling to share them with other enterprises or research institutions, fearing that data sharing may lead to a loss of competitive advantage. This "data privatisation" phenomenon poses difficulties for the effort to establish effective data circulation and sharing mechanisms within the industry.

Another main factor that leads to the data silo problem is the lack of industry standards. Industry standards in key areas such as data formats, interface protocols, and transmission security have not yet been established, which restricts data sharing across departments, regions, hierarchies, systems, and enterprises in the hydrogen energy industry. The lack of industry standards poses significant technical barriers and conversion costs to data integration and sharing within the industry.

⁸⁶ China's hydrogen energy production and consumption scale ranked first globally in 2024, Science and Technology Daily, 30 May 2025, <https://www.nea.gov.cn/20250530/a2ec7c8861f14df993ad4b1857bf82b9/c.html>

⁸⁷ Trend Bank: China Green Hydrogen Market Summary and Outlook (2025H1), Sohu.com, 23 September 2025, https://www.sohu.com/a/937674756_121654159

2. Inconsistent data formats result in difficulties in integrating heterogeneous data

The hydrogen energy industry chain covers multiple processes such as hydrogen production, storage and transportation, refuelling, and application, each of which involves complex multi-physics coupling and multi-scale processes. The data generated from these processes is inherently heterogeneous, posing the main obstacle to data integration.

From the perspective of data sources, the multi-physics coupling characteristics of hydrogen energy systems lead to inherently heterogeneous data. In respect of renewable energy hydrogen production, the digitisation of data related to internal flow field distribution, equipment layout logic, and the operational status of the water electrolyser is the foundation for achieving intelligent management. However, this data originates from multiple physical processes such as electrochemical reactions, thermodynamic transfer, and fluid dynamics, each of which generates data of different structures and formats. For example, the electrolysis of water for hydrogen production is a process that involves key parameters such as current, voltage, temperature, and pressure. These parameters are independently controlled, with limited interaction achieved only through results feedback and early warnings, resulting in inconsistent data storage formats and a lack of unified standards within the systems, significantly increasing difficulties in data integration and analysis. In addition, the hydrogen energy industry has a long industry chain and involves multiple processes, further exacerbating the complexities in external data integration. Enterprises need to align multiple sources of data from government organs, industry associations, supply chain partners, and market platforms, which are inconsistent in terms of format, communication protocols, and semantics, further increasing difficulties in data synchronisation and system integration.

Data in the hydrogen energy industry has diversified data formats, further exacerbating difficulties in data integration. Industry data includes not only structured database information such as equipment parameters and production statistics, but also a large amount of unstructured research and development literature, technical reports, and patent documents. This heterogeneous data lacks unified standards and is described in different ways. For example, there may be significant differences in data format, units, and technical terminology between the performance test reports for hydrogen fuel cells and the operational logs for water electrolyzers. Even if the data is generated from sensors, the data protocol, sampling frequency, and precision of devices from different manufacturers may vary greatly, resulting in uneven data quality, errors, omissions, inconsistencies, and other problems. A significant amount of data cleaning and preprocessing work is required, greatly increasing technical complexities in data integration.



The multi-physics coupling characteristics of hydrogen energy systems lead to inherently heterogeneous data.



Data in the hydrogen energy industry has diversified data formats, further exacerbating difficulties in data integration.

3. AI hallucinations

In the deep integration of AI technology and the hydrogen energy industry, the AI hallucination problem is becoming a technical bottleneck that cannot be ignored. “AI hallucinations” refer to the generation of false, misleading, or even completely fictional content by AI, resulting from the underlying architecture of AI models, which is based on probability statistics rather than logical reasoning. But in fields that require high levels of safety and precision like hydrogen energy, this problem may trigger risks along the entire industry chain from research and development to operations.

In the rapidly developing frontier of hydrogen energy, the lack of high-quality data is one of the main causes of AI hallucinations. Hydrogen energy technology involves complex chemical reaction mechanisms, precise engineering parameters, and strict safety standards. However, the current mainstream large language models mainly generate text based on probability statistics, and they lack true logical reasoning capabilities, making it technically difficult to avoid hallucinations. Especially when training data is insufficient, AI often uses algorithmic predictions to make up for the lack of information. However, in the field of hydrogen energy, consensus has not yet been established among a large amount of research, and professional knowledge updates rapidly, which further exacerbates the risk of hallucinations. Research shows that when there is only 0.01 % false text in the training data, harmful content generated by the model will increase by 11.2%.

In addition to the challenges at the data level, AI models have inherent limitations in understanding the complex physical and chemical mechanisms behind hydrogen energy systems. The hydrogen energy production process involves the deep integration of multiple disciplines such as electro-chemistry, thermodynamics, and fluid dynamics, while existing large language models essentially lack the inferential capability for causality. Therefore, when applied in professional scenarios such as flow field distribution in water electrolyzers, the evaluation of pressure resistance of hydrogen storage tank materials, and the formulation of transportation safety regulations, although the AI models can generate smooth text, they may not be able to accurately grasp the intrinsic connection between parameters, leading to hallucinations in terms of fact or faithfulness, such as fabricating non-existing technical parameters or distorting experimental data; and incorrect extension of and logical deviation from existing information.

The risks brought by such hallucinations will be further amplified in the high-risk scenarios of hydrogen energy. Systems often operate in high-temperature, high-pressure, flammable and explosive environments, such as in the electrolysis of water process and liquid hydrogen storage and transportation. If AI produces unreliable content in equipment status prediction, control strategy generation, or safety regulation design, it may cause process failure, equipment malfunctioning, and even safety accidents. As AI has been gradually embedded into various aspects of hydrogen energy research, including literature analysis, experimental design, system simulation, and operational prediction, hallucination risks also run through the entire scientific research and application chain, posing a potential threat to the reliability and safety of technological development.



4.2 Multiple obstacles need to be overcome, from laboratory experiments to factory applications

At present, the application of AI has been explored many times in catalyst research and development, material design, and process optimisation in the field of hydrogen energy, but most of these applications are still at the theoretical calculation or laboratory stage. How to leap from theoretical calculation to laboratory, and then from laboratory to factory, is one of the core and more arduous challenges facing "AI + hydrogen energy" applications.



1. The first gap: from theoretical calculation to lab experimentation

In AI-driven hydrogen energy development, selecting the most promising materials from massive theoretical calculation data is the first step in accelerating the research and development process. However, pure theoretical parameters cannot be directly applied in a laboratory environment due to significant differences between the idealised assumptions used by theoretical models and the real laboratory environment.

For example, the Open Catalyst Project led by Meta AI generated a massive database containing millions of catalyst-adsorbent interactions through large-scale Density Functional Theory calculations, and trained AI models on this basis to predict the catalytic activity of new materials at an unprecedented speed. In just a few months, 20,000 materials were analysed through 685 million AI-accelerated simulations, with 525 potential catalyst materials identified⁸⁸. This AI project greatly accelerated the screening process for new catalysts and achieved great success at the theoretical level. However, AI predictions are usually based on ideal conditions, while real-world experiments involve numerous uncontrollable factors such as impurities, surface defects, and fluctuations in reaction conditions, which are difficult to fully simulate in computational models.



⁸⁸ 20,000 materials analysed through 685 million AI-accelerated simulations, Meta released catalyst dataset OCx24, https://www.sohu.com/a/830536551_121156425

2. The second gap: from laboratory experiments to factory applications

If we consider AI as building a preliminary bridge between theoretical calculation and laboratory synthesis of new materials, then how to transform laboratory results into standard products on factory assembly lines is a more challenging test.

For example, Google AI Lab's automated material synthesis platform (A-Lab) successfully runs a closed-loop system covering prediction, synthesis and characterisation in the laboratory environment by integrating AI prediction, robotic automated experiments, and active learning, achieving the "0 to 1" automation of new material research and development. However, to mass produce and apply the synthetic materials created by AI in dust-free, constant temperature, and precision laboratories in factories, multiple challenges will emerge, including stability and scalability issues.

For example, in respect of stability, in a laboratory environment, the properties of synthetic materials are characterised in an anti-interference and constant temperature and humidity environment, in order to achieve peak performance under ideal conditions. However, when these laboratory synthetics are applied in a factory environment, for example, as anode catalysts in a hydrogen energy water electrolyser or as membrane electrodes for fuel cells, the following issues may need to be addressed:



The challenge of dynamic changes

Unlike steady-state testing in a laboratory, factory equipment undergoes frequent start-ups and shut-downs, load fluctuations, and power cycles. This dynamic and non-steady-state working condition will impose stricter requirements on the structural stability of materials, causing irreversible performance degradation.



Long-term reliability

Commercial hydrogen energy equipment requires a stable operating life of thousands or even tens of thousands of hours. AI typically only performs accelerated aging testing in the laboratory spanning several hours or tens of hours, which is different from its entire service life in the real world, presenting significant uncertainty.



4.3 Standard specifications and regulations lag behind

First, there is a lack of unified standards on data formats, model development, testing and verification for AI applications in hydrogen energy scenarios. Second, accountability and admission requirements for AI applications in areas such as hydrogen energy safety control have not yet been clarified in existing regulations.



1. Lack of unified standards on data formats, model development, testing and validation, etc. for AI applications in hydrogen energy scenarios

On the path to "AI + hydrogen energy" integration, in addition to the core constraint of data scarcity, the lack of unified standards that cover data, model, and verification processes fundamentally hinders collaborative innovation around technology, the recognition and exchange of achievements, and industry development at scale. Currently, the hydrogen energy industry is being fragmented by countless "standard silos" defined by different enterprises, technical routes, and application scenarios. This lack of standardisation greatly increases the cost of collaboration and buries serious safety risks.

First, the lack of unified data format and semantic standards at the data level results in data exchange failures. The output data format, communication protocol, sampling frequency, and data units of water electrolyzers, fuel cells, and sensors from different manufacturers vary. To integrate and analyse these pieces of data, a huge amount of effort must be spent on data cleaning and format alignment, greatly reducing research and development efficiency.

Second, in respect of model development, the lack of standardised development frameworks and benchmarks leads to resource waste and model incomparability. Due to the lack of open-source and validated AI development frameworks or basic models specific to the hydrogen energy field, enterprises need to start from scratch, performing foundational work such as data cleaning, feature engineering, model selection, and training. This not only leads to a huge waste of resources, but also subjects the technological progress of the entire industry to the research and development capabilities of an individual enterprise, disabling rapid iteration and collaborative innovation that would otherwise be made possible through the power of an open-source community. Moreover, due to the lack of standards, different models that are developed cannot be compared horizontally.

Finally, at the testing and validation level, the lack of unified testing standards and certification systems makes it difficult for AI applications to gain trust. As hydrogen energy is an industry with extremely high safety requirements, AI tools should not be allowed to be deployed in real production environments if they cannot pass rigorous, unified, and industry-recognised testing and validation standards. Currently, the testing of AI applications is mostly done by developers who define their own testing scenarios and use cases, which can easily lead to the AI model being unprepared for unknown and extreme edge scenarios. For future development, the industry requires standardised test case libraries covering all operating conditions—from normal operations to extreme failure—to fully stress test the robustness and safety of AI models. In addition, just as electrical appliances require 3C certification, AI applications used in key processes of the hydrogen energy industry chain also require independent and authoritative third-party certification systems. These systems should have clear certification standards, covering multiple dimensions of AI models such as accuracy, reliability, interpretability, and network security. Otherwise, the commercialisation of AI will always remain in the pilot stage.

2. Accountability and admission requirements for AI applications in areas such as hydrogen energy safety control have not yet been clarified in existing regulations

The rapid development of AI has provided important support for the intelligent upgrading of the hydrogen energy industry. However, in the process of deep integration between AI and the hydrogen energy industry, the existing regulatory system has failed to keep up with the pace of technological advancement, especially in terms of the accountability and admission requirements for AI in areas such as hydrogen energy safety control. This not only hinders the popularisation of AI technology, but also poses a serious challenge to the regulated development of the industry.

In terms of accountability, existing regulations lack clear requirements for AI in the area of hydrogen energy safety control. Safety is crucial to the high-quality development of the hydrogen energy industry. Although AI technology can improve the safety of hydrogen energy systems through real-time monitoring and data analysis; in terms of practical application, once an accident occurs, accountability often becomes a major problem. For example, if an AI system's algorithm errors lead to hydrogen leakage or explosion, the party that should be held responsible is difficult to define in legal terms. Even more complex is that the decision-making process of AI systems with autonomous learning capabilities often constitutes a "black box," making it difficult to trace the root of their decisions in subsequent investigations. The ambiguity in accountability raises concerns for enterprises in applying AI technology, especially in high-risk scenarios such as electric pile control and safety monitoring for hydrogen refuelling stations.

In terms of admission requirements, existing regulations do not have clear requirements for AI. Although relevant government departments have issued policy documents such as the Medium- and Long-term Plan for the Development of the Hydrogen Energy Industry (2021-2035), encouraging the use of new generation information technologies such as AI to improve hydrogen energy safety, specific admission criteria, technical specifications, certification procedures, and regulatory requirements for the application of AI systems in the hydrogen energy field are still absent. In addition, regulatory requirements for the approval and management of hydrogen energy facilities vary across the country. This fragmented regulatory environment further exacerbates the entry barriers for AI applications. The lack of clear guidance for investments in research and development, and the absence of a basis for regulatory enforcement have seriously constrained technological innovation and industrial upgrading.



The lack of clear guidance for investments in research and development, and the absence of a basis for regulatory enforcement have seriously constrained technological innovation and industrial upgrading.



4.4 Lack of interdisciplinary talent

Talented professionals provide important strategic support for the intelligent development of the hydrogen energy industry. Currently, the hydrogen energy industry across the globe thirsts for composite talents with both professional knowledge in hydrogen energy and AI skills. Underdeveloped mechanisms for talent cultivation and collaboration also pose major challenges.



1. Lack of composite talents who possess both hydrogen energy expertise and AI skills

The scarcity of composite talents partly results from knowledge barriers across disciplines. The hydrogen energy industry involves multiple complex processes such as production, storage, transportation, and utilisation, requiring traditional engineering expertise in fields such as electrochemistry, materials science, fluid mechanics, and safety engineering. The sector has high technical barriers and a strong dependence on experience. AI technology, on the other hand, is based on data science, algorithmic models, and computing power platforms, with thinking patterns and skill requirements that are different from those in traditional engineering fields. It is extremely difficult for an AI algorithm engineer to gain a deep understanding of the micro mechanism of catalyst decay in water electrolyzers, or for a hydrogen energy expert to independently build predictive maintenance models. Moreover, most “AI + hydrogen energy” applications are still at the laboratory stage; but within enterprises and research institutions, hydrogen energy teams and AI teams are often subordinate to different departments, between which organisational barriers exist, hindering effective cross-functional collaboration and knowledge sharing and further amplifying the negative impact of talent fragmentation.

The talent problem can also be attributed to uneven talent development across different regions. For example, the European Union (EU) has vigorously increased its efforts on green hydrogen projects in recent years and has actively developed digital hydrogen energy detection systems and digital twin technologies. However, a large number of high-level scientific and technological professionals in the EU region are immigrating to other countries, resulting in a shrinkage of the labour force and a significant gap in terms of the scale and quality of AI talents compared to the United States and China⁸⁹, slowing down the intelligent transformation of the hydrogen energy industry.

2. Existing education and vocational training systems need to be improved

Under-developed talent cultivation and collaboration mechanisms are also major challenges. For example, China's domestic university education system is predominantly single-discipline-based, with interdisciplinary curriculum design, project practice, and degree training programmes still in the experimentation stage, which means the education system struggles to deliver composite talents who understand both “molecules” and “algorithms” at scale. As of August 2024, there were only seven universities in China offering hydrogen energy technology application majors, and they are located in Guangdong, Jilin and other places⁹⁰, making it difficult to meet the need for talents for the rapid development of the hydrogen energy industry. From the perspective of training content, major weakness is seen in the incubation environment of current training institutions. Current curricula and trainings mainly focus on hydrogen energy overview, hydrogen production technology, hydrogen storage technology, and other related aspects, and there is still significant room for improvement regarding talent cultivation in advanced technology fields such as big data engineering and AI.

In addition, in respect of practical teaching, due to the high value of hydrogen energy experimental equipment and the high safety risk of hydrogen-related operations, students lack opportunities to engage in practical operations, and for this reason it is difficult for them to combine theoretical knowledge with practical applications. Therefore, in the future, universities need to develop scientific plans for the development of hydrogen energy and AI technology courses, comprehensively optimise training content and faculty, and enrich digital training resources to effectively cultivate high-quality talent.

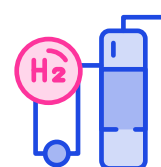
⁸⁹ [Science and Technology Reference] Fostering “Deep Tech Talents”: The EU’s Deep Tech Talent Initiative and what we can learn from it, National Academy of Innovation Strategy, 22 July 2025

https://mp.weixin.qq.com/s?__biz=MzAxMjY2OTkxOA==&mid=2652072748&idx=3&sn=b49d42dc5fa978beea3cfe2fdd0d7d4&chksm=8162cbd5eb6f7d4e8999313e989bbd64cef75e5b2cf08c2b1997ac2bc674dc1354e4691db966&scene=27

⁹⁰ Inner Mongolia Actively Tackles the Talent Shortage Problem in Emerging Industries, Inner Mongolia Economic Web, 10 August 2024
<https://www.nmgsb.com.cn/system/yaowen/2024/0Q015Q62024.html>

4.5 Limited scenarios for "AI + hydrogen energy" applications

The hydrogen energy industry chain covers multiple processes such as production, storage, transportation, and application, and the infrastructure in each process directly affects the application effectiveness of AI technology. In addition, current policy support is overly focused on the transportation field, which limits the potential of AI to empower cross-scenario applications along the entire hydrogen energy industry chain.



1. Weak hydrogen energy infrastructure hinders the realisation of AI's value

From a global perspective, weak and fragmented infrastructure, with inconsistent standards, is a problem common to the hydrogen energy industry, limiting the realisation of AI's application value.

For example, with regard to the hydrogen storage and transportation process, the fragmentation of the hydrogen transportation network makes it difficult for AI to realise its path optimisation function. In theory, AI can integrate multi-dimensional data such as real-time traffic conditions, hydrogen demand, transportation costs, and safety risks to plan an optimal transportation route for tube trailers or liquid hydrogen tank trucks, achieving optimal cost-effectiveness. This is a very mature application of AI in the logistics field. However, in reality, current hydrogen transportation mainly consists of costly and inefficient tube trailer transportation; and true long-distance, cross-regional hydrogen pipeline networks are almost absent. In addition, the digitalisation and intelligence level of the transportation process is generally low, and key data such as vehicle location, hydrogen pressure, and temperature often cannot be accurately uploaded to the cloud in real-time. These infrastructure weaknesses greatly limit AI's optimisation potential.

In respect of the hydrogen refuelling process, the insufficient coverage of hydrogen refuelling stations also renders AI unable to realise intelligent network collaboration. In an ideal state, AI can provide users with intelligent navigation and reservations based on real-time vehicle location, remaining range, queuing status at hydrogen refuelling stations, real-time hydrogen prices, and other information. Through collaborative scheduling, AI can smooth out load peaks and valleys among different stations, maximising efficiency across the entire hydrogen refuelling network. However, the reality is that hydrogen refuelling stations are still scarce, and they have serious data silo problems. As of the end of December 2024, 497 hydrogen refuelling stations had been built in China, ranking first in the world⁹¹. However, compared to the number of gas stations and electric vehicle charging stations, hydrogen refuelling stations are still very rare, making it difficult to create a network effect. More importantly, hydrogen refuelling stations of different operators have varying data standards and lack unified and open data interfaces. As AI cannot access real-time dynamic data for all hydrogen refuelling stations in a region, it is unable to perform collaborative scheduling at the network level.

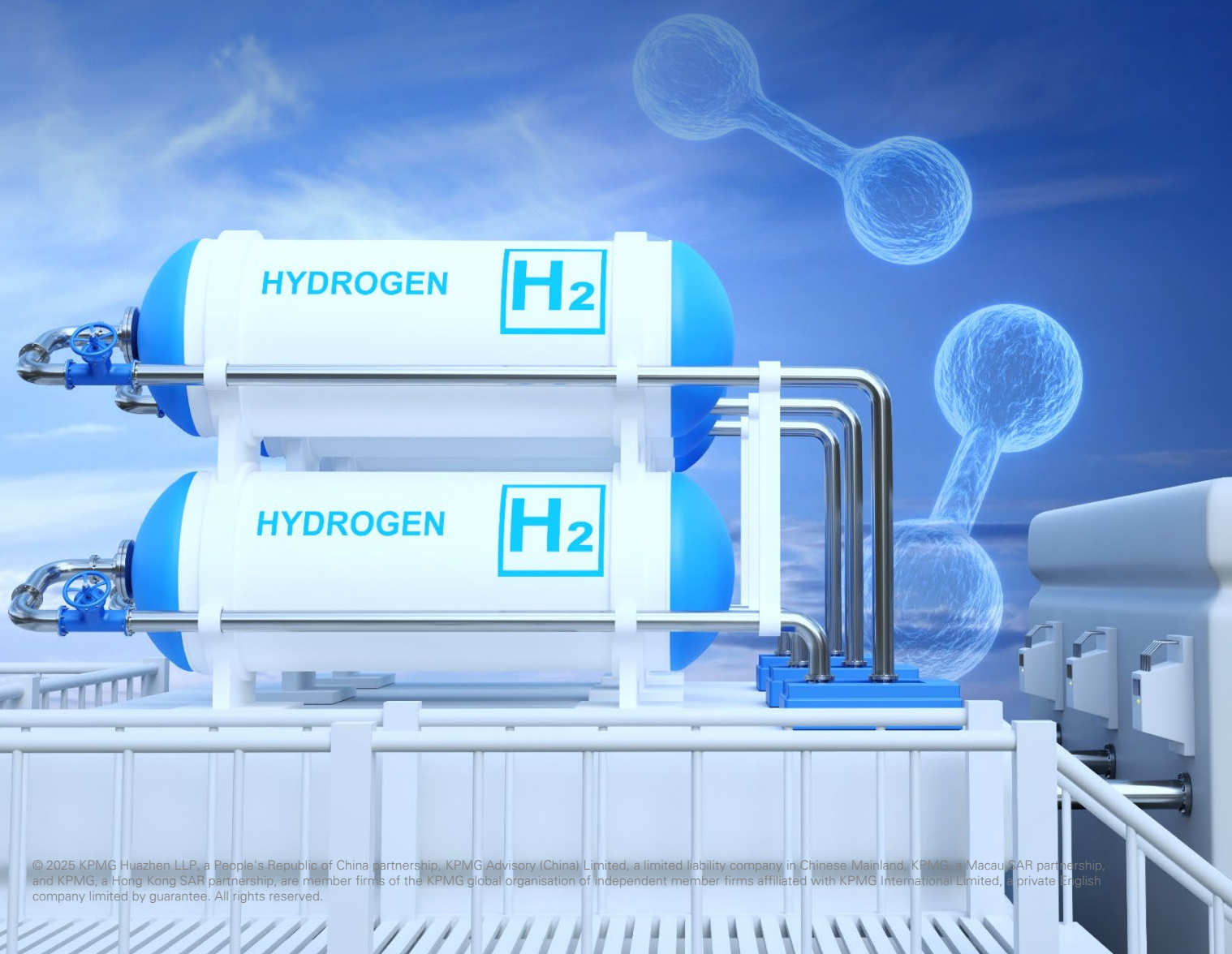
⁹¹ Development of hydrogen refuelling stations in China: New status quo, new trends, and new future, https://www.sohu.com/a/858566226_120717004

2. Existing policies focus on the transportation field, neglecting other application scenarios such as industrial and construction applications, which suppresses the potential of AI in cross-scenario empowerment

Current hydrogen energy policy is clearly tilted towards the transportation sector. For example, the demonstrative subsidy policies for highway travel of hydrogen energy vehicles launched by various provinces and cities in China mostly target fuel cell vehicles. Although this policy orientation has achieved certain demonstrative effects in specific fields, it has also led to applications of hydrogen energy in industrial, construction and other scenarios being neglected. In addition, due to policy guidance, funding, talents, and research and development investment have all been directed towards hydrogen fuel cell vehicles and support for hydrogen refuelling stations, which has also led to data accumulation and model development for AI applications in the hydrogen energy field being focused on these scenarios.

As a zero-carbon secondary energy, hydrogen energy should be widely applied in various fields such as industry, transportation, construction, and electric power to maximise its zero-carbon effect. For example, in the industrial field, AI can optimise the production process for hydrogen energy and achieve intelligent optimisation in hydrogen production through renewable energy; in the construction field, AI can assist in managing the application of hydrogen energy in multi-energy source complementary systems, improving the comprehensive energy efficiency of the combined supply of electricity, heat, cooling, and gas. However, due to the lack of demonstration projects and policy support for these scenarios, AI lacks necessary carriers and data feedback for its applications.

In the future, more demonstrative policies are needed to encourage the application of hydrogen energy in multiple scenarios such as industrial decarbonisation, green power consumption and storage, long-term energy storage, and building energy supply. Such policies will create broader access to data and application scenarios for AI's interdisciplinary learning and global optimisation.



05

Suggestions for Promoting the High-quality Development of "AI + Hydrogen Energy"



5.1 Improving data quality: Building an internationally recognised data governance and sharing system



Establish regional and international hydrogen energy data funds and hubs: It is recommended that governments, international organisations, and leading enterprises in the hydrogen energy industry contribute funds to support the collection, cleaning, labelling, and hosting of demonstration project data (such as water electrolyzers, storage and transportation, refuelling, operational logs, etc.) to form a "trusted hydrogen energy industry dataset". The dataset can be made accessible to collaborators according to hierarchical access rules, which facilitates scientific research collaboration while protecting commercially sensitive information. In addition, funding should be allocated for the research and development of efficient and cost-effective data acquisition devices to improve both the precision and scope of data collection.



Develop data quality and semantic standards: Promote the development of unified standards for data formats, timestamps, units, metadata, semantic lexicons, communication protocols, and semantic annotations. The initiative can facilitate collaboration among governments, representative enterprises, and research institutions to conduct pilot projects in hydrogen energy industry demonstration zones. These efforts can then be gradually scaled up internationally to eliminate data silos and enhance data interoperability.



Establish a data credibility assessment and certification mechanism: Conduct evaluations of data sources for traceability, completeness, accuracy, and credibility, and issue graded "credibility labels" for AI model training. These labels can serve as critical compliance criteria for investment and financing, procurement, and other related activities.

5.2 Accelerating the transformation of laboratory achievements into industrial applications: Building an "engineering verification chain" and demonstration accelerator



Establish an AI + hydrogen engineering test field (industrial digital twin and on-site pilot): Establish a collaborative testing platform within a demonstration park equipped with large-scale hydrogen production, storage and transportation capabilities. The platform will encompass a closed-loop process from laboratory validation, pilot-scale testing, to industrial trial operations. It will integrate resources for AI-driven predictive analytics, laboratory verification, and full-scale industrial production, with a primary focus on validating long-term stability, performance under varying load conditions, and robustness in extreme operational scenarios. For example, by simulating the prolonged continuous operation of an electrolyser, AI can provide early warnings about the expected failure time of catalysts, thereby enabling accurate prediction of the electrolyser's lifespan. Furthermore, digital twin technology can be employed to simulate the factory environment, optimise production processes, and mitigate the uncertainties associated with scaling laboratory results to industrial applications.



Implement a "step-by-step scaling" certification process: It is recommended that national governments, international organisations, and leading enterprises take the lead in establishing an independent and authoritative multi-stage certification system and systematic admission process covering model simulation, equipment soft launches, quality control, and commercial launches. Each stage should include quantifiable metrics such as accuracy, stability, reliability, explainability, security thresholds, and cybersecurity across multiple dimensions.



Encourage industrial automation and modular design: Support the development and deployment of replicable modular equipment and processes, conducive to the parallel scaling of laboratory results in a modular fashion, and further reducing uncertainties associated with industrialisation.

5.3 Promoting international standardisation, certification, and regulatory coordination: Establishing traceable and verifiable legal accountability and accreditation systems



Promote the process of international standardisation: Collaborate with international standardisation organisations such as ISO TC/197 (Hydrogen Technology) and ISO/IEC JTC 1 (Information Technology), as well as relevant industry associations (such as the International Electrotechnical Commission, the United Nations Industrial Development Organisation, and the International Energy Agency), and work with major national research institutes, key laboratories, and leading enterprises to draft and promote the establishment of technical access clauses covering data formats, model development, testing and validation, etc., so as to facilitate international alignment, establish globally unified standards, and promote technological synergy and the mutual recognition of achievements.



It is recommended to approach this from the following aspects:

- Data and interface criteria
- Model development and testing benchmarks
- Security, reliability, and trustworthiness requirements for data and models
- Real-time monitoring, logging and model version management



Clarify legal responsibilities and admission requirements: Hydrogen poses significant safety risks due to its high pressure, tendency to leak, and narrow flammability range. The consequences of an accident can be severe. Therefore, it is imperative to swiftly establish national-level regulations for the attribution of liability, real-time monitoring, and redundancy requirements for AI applications in critical safety controls across various scenarios in the hydrogen industry, to ensure that accident responsibilities are fully traceable. Furthermore, it is essential to clearly delineate the liability boundaries between technology suppliers and operators, and to facilitate the implementation of insurance and third-party assurance mechanisms.



Establish cross-border compliance recognition mechanisms: Promote bilateral and multilateral agreements to achieve mutual recognition of testing and certification and reduce standards and regulatory friction in cross-regional and cross-border demonstrations and industrial collaborations.

5.4 Fostering interdisciplinary composite talent: Establishing international talent cultivation and mobility mechanisms



Support interdisciplinary training programmes: Firstly, encourage universities to establish interdisciplinary majors such as "Artificial Intelligence +" and develop scientific curriculum systems, covering hydrogen energy, fuel cells, electrochemistry, materials science, data science, and algorithm engineering. Secondly, establish government-university-enterprise training programmes to offer joint courses such as "AI + hydrogen energy", continuing education for engineers, industry training camps, and other initiatives. In addition, provide funds to support universities and educational institutions with industrial training facilities to establish practical training bases. Meanwhile, it is recommended to simultaneously develop virtual laboratories and online courses to reduce the initial costs of practical instruction and enhance students' interdisciplinary thinking and application capabilities.



Establish a talent mobility and short-term training mechanism: Attract high-end technological talent globally through various international cooperation initiatives and talent exchange programmes, including joint laboratories, corporate internships, and joint mentorship systems. These efforts will not only equip engineers with data and algorithmic skills but also enhance their understanding of hydrogen energy, electrochemistry, materials science, safety engineering, and other disciplines, thereby addressing regional talent shortages.



Establish certification and career pathways: Develop professional standards and competency certification for "AI engineers in the field of hydrogen energy" at both the national and local levels, and encourage enterprises to adopt these certification standards in their recruitment processes and project tenders.

5.5 Expanding applications of "AI + hydrogen energy": Extending the application scenarios from transportation to industrial, building, and energy systems



Encourage the design of "multi scenario + multi stakeholder" cross-scenario demonstration projects and incentive policies:

Build "AI-driven hydrogen decarbonisation demonstration factories" in high energy consuming industries such as steel, chemicals, and cement. These factories can utilise reinforcement learning algorithms to dynamically adjust the ratio of hydrogen to natural gas, thereby improving overall energy efficiency. In the development of intelligent and clean city systems, it is recommended to promote the demonstration of an "AI technology + hydrogen community." This involves leveraging AI technology to predict building energy loads and control the operation of hydrogen storage systems, thereby constructing distributed hydrogen microgrids in cities and enhancing energy utilisation efficiency. In terms of the integration of energy storage and renewable energy, it is recommended to continue promoting the deep application of AI technology in photovoltaic (PV) and wind power hydrogen production systems. This involves using high-precision weather forecasting models and real-time electricity price curve analysis to dynamically optimise hydrogen production and storage strategies. Based on multi-objective optimisation algorithms, the optimal timing for hydrogen production or hydrogen release can be intelligently determined to achieve peak load shaving and valley filling, thereby enhancing the stability of the power grid.



Promote the digital transformation of infrastructure and create an AI-ready intelligent base: It is recommended that digitalisation and intelligence be integrated into the planning of hydrogen infrastructure. This includes equipping pipelines and hydrogen refuelling stations with smart sensors and data collection systems, funding upgrades to sensors, communication, and edge computing in hydrogen refuelling stations, hydrogen transport fleets, and storage and transportation facilities, and forming a digital foundation that supports real-time decision-making by AI. This will enable AI to analyse pressure fluctuations, temperature anomalies, and leakage risks in real time, facilitating predictive maintenance. It is also recommended to promote the development of hydrogen energy data standards (covering the entire chain from production, storage, transportation, and processing, to end-use) to support the cross-scenario application of AI algorithms. Furthermore, governments at all levels can establish data-sharing incentive mechanisms to encourage enterprises to open up certain operational data, thereby nurturing an AI model ecosystem for the hydrogen energy sector.

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About IHFCA

Headquartered in Beijing, China, the International Hydrogen Fuel Cell Association (IHFCA) is an international, academic, and non-profit organization formed by enterprises, research institutions, and industry organizations from various countries and regions engaged in the fields of hydrogen energy, fuel cells, and fuel cell vehicles.

IHFCA is dedicated to promoting global exchange and cooperation in the hydrogen and fuel cell sectors. It strives to build an international platform for communication and collaboration that covers the entire industrial chain, enhance the development of international technical standards and norms, facilitate information sharing and open science, and advance the technological progress and commercial deployment of hydrogen and fuel cell technologies worldwide.

IHFCA's key members include the China Society of Automotive Engineers (China SAE), FORVIA Group, Sinopec Group, SAIC Motor, Toyota Motor Corporation, Hyundai Motor Company, Valterra Platinum, Saudi Aramco, Honda Motor Co., Ltd., the China Energy Investment Corporation, and Tsinghua University, among other renowned domestic and international enterprises, research institutions, and universities.

As of the second half of 2025, IHFCA has 110 member organizations across 23 countries and regions, covering the entire hydrogen energy value chain. The IHFCA focuses on four major areas of work: industrial and policy research, standards and regulatory studies, international exchange and cooperation, and public education and outreach. Its main scope of activities includes academic exchange, industry research, development of IHFCA standards, collaborative innovation, and high-quality member services.

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