

# Research of Patents for Automotive Hydrogen Energy in China

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**Abstract:** Hydrogen fuel cell vehicle (FCV) technology is of great significance to energy security and environmental protection. With the rapid development of automotive hydrogen patents in the world, the development and application of automotive hydrogen energy will promote carbon emission reduction and energy transformation in the transportation sector. Based on the comparative analysis of the patent application of automotive hydrogen energy in the world and the application of automotive hydrogen energy in China, it is concluded that China has a large development space of technology and market.

**Keywords:** Automotive Hydrogen Energy; Hydrogen Fuel Cell Vehicle (FCV) Technology; Development and Application of Automotive Hydrogen Energy; Carbon Emission Reduction and Energy Transformation.

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## 1. Introduction

Hydrogen energy can not only achieve zero carbon emission from end-use energy but also benefit carbon storage and utilization at the source. It can also be interconnected with the power grid through efficient hydrogen-electricity interaction technologies such as hydrogen production by electrolysis and fuel cells, thus accelerating the sustainable transition from fossil to renewable energy and the transition to carbon neutrality. Transportation is one of the critical areas leading to increased carbon emissions. The development and application of automotive hydrogen energy will promote carbon emissions reduction and energy transition in the transportation sector. According to the International Hydrogen Energy Council, the global investment in the hydrogen energy sector will total \$500 billion by 2030, while the value of the global hydrogen energy industry chain in 2050 will exceed \$2.5 trillion. The purpose of this research is to identify the status quo and the trend of the development of hydrogen energy, the patent of automotive hydrogen energy, and put forward suggestions on specific issues. The development of hydrogen vehicles has put forward new demands for related technical standards. ISO, IEC, and other international standards bodies are committed to the development of standards for the automotive hydrogen industry, and the standards covered in this research are collected based on publicly available information.

With the emphasis of the global society on environmental protection and sustainable development, an increasing number of scholars have become devoted to research on hydrogen patents. Yu et al.[1] proposed that promising technologies that will be the core of the hydrogen fuel supply chain in the future were identified using the published patents and research paper database (DB) in Korea, the United States, Europe, China, and Japan. Baumann et al.[2] found that the patenting activity of Germany is considered lower in comparison to countries such as Japan, China, and the US. Whereas the position of Germany for batteries and hydrogen is comparable, bioenergy shows different results regarding the identified countries and the number of patents found. Patent portfolios of car manufacturers are used as indicators of the variation and selection dynamics of different options[3]. The current investigation has revealed that the hydrogen

patent activities in the field are growing steadily at an annual growth rate of 4.21%, with the most recorded growth occurring in the first decade of the study period[4]. Choi and Woo[5] used a semiautomated, unsupervised learning approach for patent data analysis to identify specific technology topics in various fields of hydrogen technology. They found that the primary technological focus was on fuel cell technologies for South Korea and Japan whereas hydrogen production technologies for France and the United States. Meng et al.[6] explored the current development strategy, technology, and industrialization of China's hydrogen energy industry in the transportation field. China's hydrogen energy industry is still facing problems such as high cost of comprehensive utilization, and imperfect standards and regulations for hydrogen energy utilization. Cader et al.[7] applied Spearman's correlation and a linear regression model to estimate the influence of gross domestic product, population, final energy consumption, renewable energy, and CO<sub>2</sub> emission on chosen hydrogen indicators—production, patents, energy technology research, development, and demonstration budgets.

## 2. Analysis of National Hydrogen Energy Strategies

### 2.1. U.S. National Hydrogen Strategy

The United States was the earliest country to develop hydrogen energy, and over the years has always taken hydrogen energy as an important energy strategic reserve technology, continued to support the hydrogen energy industry chain technology research and development, and accelerated the demonstration of the creation and strategic deployment, to realize the scale of development of the hydrogen energy industry. In July 2021, the U.S. Department of Energy (hereinafter referred to as "DOE") announced that it would invest \$52.5 million in green hydrogen technology research and development. In July 2021, the U.S. Department of Energy ("DOE") announced an investment of \$52.5 million in green hydrogen technology research and development, which will benefit several hydrogen research and development projects, to reduce the cost of hydrogen by 80% within ten years to \$1 per kg.<sup>2</sup> In November 2022, the DOE also released the "Carbon Neutral Hydrogen Technology

Basic Science" research and development guidelines, which clearly define the four priority research and development directions of high-efficiency and new electrolysis of water to produce hydrogen and the mechanism of hydrogen.<sup>3</sup> In February 2022, the Office of Fossil Energy and Carbon Management of DOE announced \$28 million of federal funding to accelerate demonstrations and strategies to realize the scale development of the hydrogen industry. Office announced \$28 million in federal funding to promote the use of green hydrogen as a carbon-free fuel for transportation, industry, and electricity production. In November 2022, DOE released the National Clean Hydrogen Strategy and Roadmap (Draft), which establishes a timeline of near-, mid-, and long-term clean hydrogen development actions for the years 2022-2035, as shown in Table 1, and specifies a clear focus in the various stages of development goals for hydrogen production, storage, transportation and end-use applications. In addition, the U.S. released its first national energy strategic planning roadmap in June 2023.<sup>3</sup> the U.S. has also developed its national energy strategy and roadmap.

## 2.2. EU Hydrogen Energy Strategy

The EU hydrogen energy industry is one of the regions that is currently most actively promoting the development of hydrogen energy. The EU is committed to exploring the supply of hydrogen energy on a large scale and building a comprehensive application system of hydrogen energy in order to realize low-carbon development. In 2020, the EU launched the European Hydrogen Energy Strategy, which plans to install 40GW of renewable energy hydrogen production devices in each of the EU and non-EU countries by 2030, and at the same time, formulate a roadmap for the application of hydrogen energy terminals in multiple fields including transportation, construction, industrial energy and raw materials, and power generation, as shown in Figure 2. As shown in Figure 2, a comprehensive hydrogen energy application system will be gradually constructed. In order to continue to expand the supply of hydrogen energy, in 2022, the European Commission and the European Hydrogen Trade Association (EHTA) will form the "Clean Hydrogen Partnership", which will provide 300 million euros to support the production, storage, and distribution of clean hydrogen, and to promote the application of hydrogen energy in the typical hard-to-reduce industries such as aviation and heavy transportation; at the same time, the EU will launch the "Joint Action on Clean Hydrogen Energy", which is a joint action of the European Union and the European Union. At the same time, the EU launched the "Joint Action Plan for Clean Hydrogen", investing 1 billion euros in research and development of hydrogen production, storage, cross-cutting areas, etc., and supporting hydrogen demonstration projects to increase the supply of local hydrogen; in addition, most EU countries are seeking hydrogen supply partners around the world to accelerate the construction of hydrogen infrastructure in ports and ensure hydrogen imports.

## 2.3. Japanese Hydrogen Energy Strategy

In order to realize the goal of a hydrogen energy society, Japan has laid out an all-encompassing and multi-level strategy for the development of hydrogen energy. At the national level, Japan has continuously improved its hydrogen energy policy system. Since Japan first formulated the Hydrogen Energy Basic Strategy in 2017, the Japanese government has issued a number of policies to support the

development of hydrogen energy. In 2020, Japan issued the Carbon Neutrality Declaration 2050, pointing out the prominent role of hydrogen energy in the goal of carbon neutrality; the Sixth Energy Basic Plan issued in February 2022 emphasized that green hydrogen and ammonia energy play an important role in the energy system; and in addition, in June 2023 Japan revised its hydrogen energy basic strategy. At the city level, in 2016, the Tokyo Metropolitan Government launched the "Hydrogen Society" program for the 2020 Tokyo Olympics and Paralympics, aiming to demonstrate the results of the development of the "Hydrogen Society" through the Tokyo Olympics, and in February 2022, the city of Fukuoka, Japan, announced its Hydrogen Society Plan, focusing on the role of green hydrogen and ammonia energy in the energy system. In February 2022, the City of Fukuoka, Japan, announced its Hydrogen Society Plan, which focuses on fuel cell vehicles and the use of hydrogen energy in the lives of residents, as well as revisions to the Hydrogen Society Law. At the corporate level, hydrogen energy industry synergy is being actively pursued. Recognizing the importance of national energy strategies to corporate development strategies, Japanese energy companies are actively involved in research activities in related fields. For example, in October 2020, nine Japanese private companies, including Toyota, Toshiba, ENEOS, Iwatani, and Kawasaki Heavy Industries, formed the "Japan Hydrogen Energy Association" to promote the supply chain of the hydrogen industry and the formation of a global partnership; and in May 2023, four Japanese OEMs, namely Kawasaki, Suzuki, Honda, and Yamaha, established the "Engine Technology Research Group". Establishment of HySE, an engine technology research group, to promote the popularization of hydrogen fuel engines.

## 2.4. Korea Hydrogen Energy Strategy

South Korea has made the hydrogen energy industry one of the three strategic investment areas for South Korea's future development. South Korean government The South Korean government has provided a construction subsidy of KRW 3 billion for newly-built hydrogen refueling stations since 2019, and an operating subsidy of 66% of the previous year's operating expenses for the already existing hydrogen refueling stations; it has reduced or waived 50% of the lease fees for state-owned land for hydrogen refueling stations and provided long-term low-interest loans for private hydrogen refueling stations; it has also launched the Hydrogen City Program, which provides a financial subsidy of KRW 130.4 billion for hydrogen fuel-cell vehicles.<sup>2020</sup> , Korea's Ministry of Industry and Energy released the 2020 New and Renewable Energy Technology Development and Utilization and Action Plan, providing 29.9 billion won in financial support for hydrogen production base projects. In order to accelerate the application of hydrogen energy and promote the development of hydrogen fuel cell vehicles, South Korea announced that it will provide subsidies for 16,920 hydrogen fuel cell vehicles in 2023, including 16,000 passenger cars, 700 buses, 100 trucks, and 120 clean vehicles, and that the local government of the place of residence of the individuals/businesses that purchase hydrogen fuel cell vehicles will provide subsidies of up to 22.5 million KRW for hydrogen fuel cell passenger cars. The local government where the individual/company purchases the hydrogen fuel cell vehicle will provide a subsidy of up to 22.5 million won for the hydrogen fuel cell passenger car, and up to 30 million won for some of the

passenger cars, taking into account the differences in different regions. Through the development of the hydrogen economy, the Korean government expects that by 2040, 420,000 jobs will be created and 43 trillion won of economic value added will be generated.

### 3. Patents of Automotive Hydrogen Energy

The patent literature data of this report are all from the

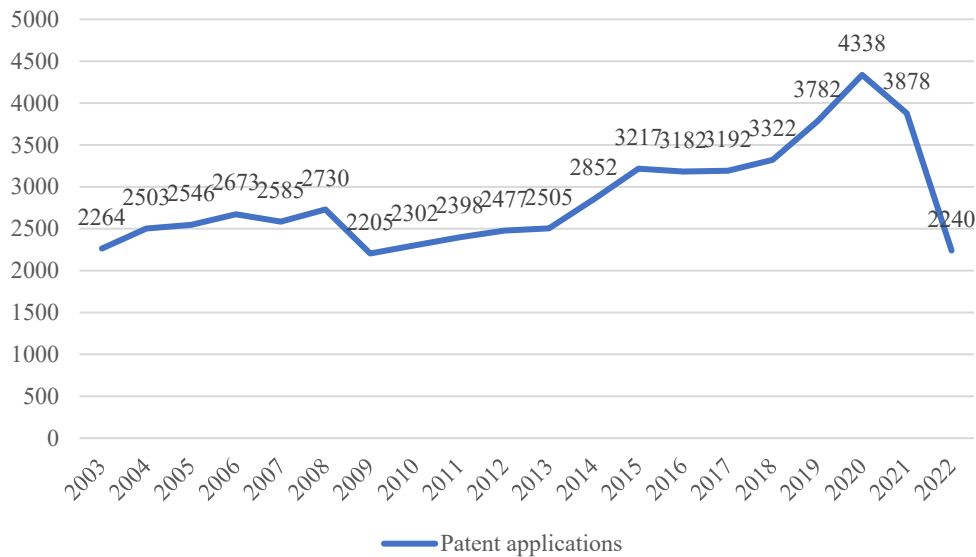


Fig 1. Global trends in patent applications for automotive hydrogen

In 1980, Japan started to study the technology of hydrogen energy for vehicles. With the global greenhouse effect increasing, more and more countries joined the exploration in this field, with many years of technological development. From 2003 to 2013, research results continued to emerge, and the trend of patent applications slowed growth. Since 2014, major countries around the world have attached great importance to the development of hydrogen energy technology for vehicles, with many countries raising hydrogen energy to the height of national energy strategies and continuously increasing support for research and industrialization of hydrogen energy technology for vehicles, it has effectively promoted the technical progress of hydrogen energy for vehicles in the world. The patent application curve has increased sharply, with the highest annual application

INCOPAT Global Patent Database. The data collection period of this section is from January 1st, 2003, to December 31st, 2022. It covers patent technologies related to vehicle integration, Proton exchange membrane fuel cell systems, and hydrogen internal combustion engines, and patent trends are shown in Fig. A total of 57,191 patents, of which a total of 41,338 were processed by simple consanguineous merger.

volume reaching more than 4,000 pieces, entering a period of rapid development.

From the perspective of global hydrogen technology flow, the United States, Japan, Germany, and South Korea as the main technology exporters, with strong technology innovation, strong R&D strength, and market, and technology control. China, the United States, Japan, and Europe are the main target countries of technology import, especially China, which has a large market space and is the focus of market competition.

### 4. Patents of Automotive Hydrogen Energy in China

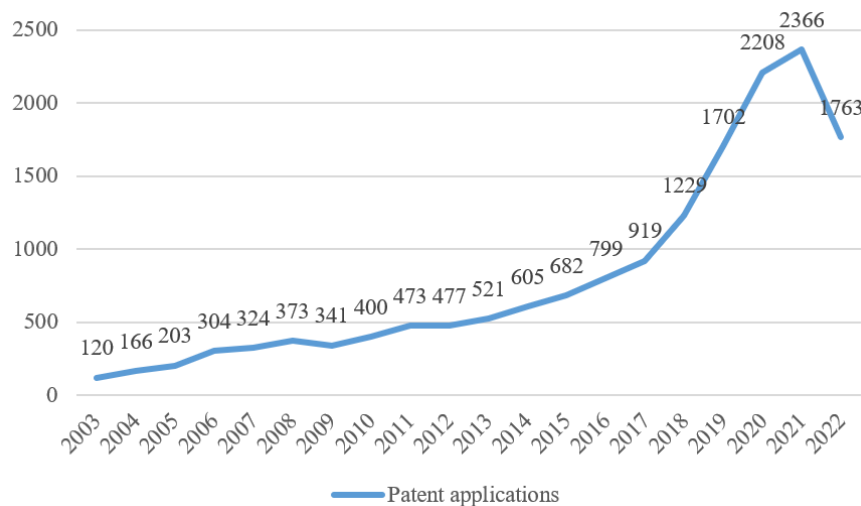


Fig 2. Trend of patent applications for automotive hydrogen energy in China

The data of patent applications for automotive hydrogen energy in China collection period of this section is from January 1st, 2003, to December 31st, 2022, covering the vehicle integration, proton exchange membrane fuel cell system, and hydrogen internal combustion engine-related patent technology, a total of 15,975 patents, with a total of 15,890 patents after processing by simple homologation and consolidation of the trend of the patent applications as shown in Fig.

In terms of regional distribution, the core areas of the first batch of fuel cell vehicle demonstration city clusters: Beijing, Shanghai, and Guangdong ranked first, second, and fourth in the country in the number of patent applications for automotive hydrogen energy technology, which fully illustrates the significant leading role of policy orientation on industrial development and the important supporting role of technological innovation on the popularization and application. Jiangsu Province is adjacent to Shanghai, the leading city in the Yangtze River Delta, and effectively receives the technology spillover demand from Shanghai. In addition, Jiangsu has five advantages abundant local hydrogen supply, obvious enterprise agglomeration effect, well-built innovation platform, rich demonstration application scenarios, and supporting policy focus. The number of vehicle hydrogen energy technology patent applications in the region ranks third in the country. The first batch of demonstration city clusters highly overlap with the Beijing-Tianjin-Hebei cluster centered on Beijing, the Yangtze River Delta cluster centered on Jiangsu-Shanghai, and the Pearl River Delta cluster centered on Guangzhou, and the strong combination of innovation and development factors and the strong foundation of the automotive industry will continue to lead the development of the automotive hydrogen energy industry.

## 5. Comparative Analysis

Hydrogen production can be categorized according to the type of raw material: hydrogen production from fossil fuels, hydrogen production from cracking of fossil raw materials, industrial by-production of hydrogen, hydrogen production from water electrolysis, etc. The respective numbers of these patent types in the world are 3,360, 4,859, 8,756, and 14,291. The number of patents for hydrogen production from water electrolysis dominated the patent market, with a share of 46%.

Analyzed from the perspective of annual patent applications, the growth of technology patents in the field of water electrolysis hydrogen production exceeds the patent growth of the overall technology. In recent years, China's electrolytic water patent applications have been significantly ahead of other countries, China's electrolytic water to hydrogen patent applications since 2008, growth rate has accelerated significantly, especially after 2020. The number of patent applications per year almost doubled, and electrolytic water to hydrogen patent applications in 2022 to reach about 2,500 pieces. It can be seen that electrolytic water hydrogen production technology has received more and more attention, and electrolytic water hydrogen production technology will be one of the main hydrogen production methods in the future.

At the same time, Sinopec reflects that domestic applicants in the field of hydrogen production technology are stuck in

the research of water electrolysis application, and there is still a certain gap with the commercialization of the French side, which is led by professional gas enterprises. In recent years, Air Liquide has been laying out patents on hydrogen purification and catalyst technology in China to occupy the hydrogen production market in China, which also shows that the company's development strategy is also to patent/technology first, and then to occupy the market.

## 6. Conclusion

Currently, China's companies have less business and lower market expectations overseas, as well as fewer revolutionary technological innovations, so they have a lower necessity and less willingness to be competent in filing international patents, which results in a situation in which the domestic hydrogen energy patent field is vibrant but is just getting started in the IEA report.

There are large technological space and market space in China and has become a hot spot for technology and market competition in various countries. The other countries have a large number of patent distributions in China. Taking the United States, Japan, and South Korea as examples, they mainly export technology on a global scale, paying attention to the technology and market distribution on a global scale, especially in China, while China mainly applies and imports technology domestically, less technology output, to a large extent occupied the domestic technology and market, for the development of China's automotive hydrogen technology provides a favorable basis.

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