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An Innovative Approach for Energy Transition in China? Chinese National Hydrogen Policies from 2001 to 2020

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Abstract: To accelerate clean energy transition, China has explored the potential of hydrogen as an energy carrier since 2001. Until 2020, 49 national hydrogen policies were enacted. This paper explores the relevance of these policies to the development of the hydrogen industry and energy transition in China. We examine the reasons, impacts, and challenges of Chinese national hydrogen policies through the conceptual framework of Thomas Dye's policy analysis method and the European Training Foundation's policy analysis guide. This research provides an ex-post analysis for previous policies and an ex-ante analysis for future options. We argue that the energy supply revolution and energy technology revolution highlight the importance of hydrogen development in China. Particularly, the pressure of the automobile industry transition leads to experimentation concerning the application of hydrogen in the transportation sector. This paper also reveals that hydrogen policy development coincides with an increase in resource input and has positive spill over effects. Furthermore, we note that two challenges have impeded progress: a lack of regulations for the industry threshold and holistic planning. To address these challenges, the Chinese government can design a national hydrogen roadmap and work closely with other countries through the Belt and Road Initiative.

Keywords: Chinese national hydrogen policies; energy transition; hydrogen industry; hydrogen fuel cell vehicles



Citation: Yuan, Y.; Tan-Mullins, M. An Innovative Approach for Energy Transition in China? Chinese National Hydrogen Policies from 2001 to 2020. *Sustainability* **2023**, *15*, 1265. <https://doi.org/10.3390/su15021265>

Academic Editor: Georgios Archimidis Tsalidis

Received: 22 November 2022

Revised: 11 December 2022

Accepted: 15 December 2022

Published: 9 January 2023



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1. Introduction

On 22 September 2020, President Xi Jinping announced a long-term goal at the general debate of the 75th session of the United Nations General Assembly. China pledged to reach peak CO₂ emissions before 2030 and achieve carbon neutrality before 2060 [1]. This ambitious commitment surprised the world, demonstrating China's commitments to mitigating climate change. Following this strategic decision, China put forward several guiding principles, which include prioritising green and low-carbon energy transition. In addition to developing prevalent renewable energy sources such as wind and solar energy, the Chinese government also plans to construct a hydrogen energy chain [2]. Hydrogen has received growing attention worldwide in recent years and many developed economies have chosen hydrogen development as an essential environmental strategy to help decarbonise the energy sector. The Chinese authorities also think of hydrogen development as a breakthrough regarding green energy transition. As a result, they emphasise the importance of boosting research and development of cutting-edge technologies in all sectors including hydrogen production, storage, transmission, and usage [2].

According to the International Renewable Energy Agency [3], hydrogen has three major advantages. First, the only by-product of burning hydrogen is water, which does not contain any pollutants. This could support decarbonisation efforts in some major

emitting sectors, such as the chemical and steel industries. Second, hydrogen is a secondary energy form converted from primary energy sources that exist naturally [4]. In other words, many kinds of energy sources can produce hydrogen, which guarantees a sufficient supply. Third, as an energy carrier, hydrogen can store renewable energy for a long time, which could compensate for shortages of electricity. Therefore, a synergistic use of hydrogen and renewable energy can promote renewable electricity generation and application, which brings about more choices for renewable solutions. Due to the increasing urgency of decarbonisation, especially in the energy sector, national governments, companies, and other stakeholders have endeavoured to develop hydrogen policies and projects all over the world. Over the coming years, more efforts will be undertaken with respect to substantially increasing the share of hydrogen in the energy system [3].

A recent notable example of the application of hydrogen is the Tokyo 2020 Summer Olympics, which was also termed the ‘Hydrogen Olympics’. Japan not only utilised hydrogen fuel cell vehicles (H-FCV) to transport athletes and staff between venues, but also built a hydrogen-powered building in the Olympic Village [5]. Demonstrating advanced technologies through the Olympics was of vital strategic importance to Japan’s transition towards a ‘hydrogen society’ [6]. In addition to Japan, the United States, the European Union, and the United Kingdom have also designed a strategic framework or a roadmap with which to support hydrogen development. In China, the Beijing 2008 Summer Olympics and the Expo Shanghai 2010 also launched the H-FCV demonstration projects, which were two large-scale field trials of the application of hydrogen to public transport [7]. Currently, China is the largest hydrogen producer and the third-largest market for H-FCV worldwide [8]. However, in contrast to other countries, China did not have a holistic action plan before 2022. Instead, between 2001 and 2020, the national government issued approximately fifty sectorally siloed policies, and only some of those are loosely connected between the different sectors.

Research on the development of the hydrogen industry in China can be traced back to the early 2010s. Previous research has studied the prospect of the transition to a hydrogen economy in China [9,10] and the application of hydrogen in the transportation sector [11–13]. Scholars have also recently analysed the significance of developing hydrogen from geopolitical perspectives [14,15]. Although previous studies argued for the importance of formulating more policies [9,13], very little research has been dedicated to the relevance of hydrogen policies to the development of the industry and the transition to a clean energy system. Therefore, this paper addresses this gap by answering the following question: ‘What are the rationales, impacts, and challenges of Chinese national hydrogen policies from 2001 to 2020?’. Through critically analysing primary data such as policy papers, politicians’ speeches, and enacted regulations, we found that the energy supply revolution and energy technology revolution are two driving factors of the issued policies during this period. In addition, current policies focus on the application of hydrogen in the transportation sector, which is stimulated by the urgent need for achieving automotive decarbonisation. We also found that when more hydrogen policies are issued, more resources are invested in the hydrogen industry, resulting in more rapid development with spill-over effects. Finally, we deduced that China faces two major problems, namely, a lack of industrial entry barriers (which has resulted in an unmonitored number of players) and a proactively planned strategic, holistic, and coherent approach.

This paper will proceed as follows. Section 2 will introduce the current debates about the potential of hydrogen in the energy system, particularly in the context of China. Section 3 explains the conceptual framework and methodology utilised in this research. Then, Section 4 will discuss Chinese national hydrogen policies from 2001 to 2020, focusing on the rationales, impacts, and challenges of these policies. Section 5 will provide a conclusion to summarise the main findings and propose two future policy options.

2. Current Debates

As early as 1972, Bockris [16] put forward the idea of building a hydrogen economy. This was the first time hydrogen was perceived to possess the potential to constitute a medium for energy storage and transport. Nowadays, many scholars and institutions are still certain of the prospects for hydrogen in clean energy transition [3,17–19]. However, some scholars have asserted that the role of hydrogen in future renewable energy systems has been overstated. Moliner et al. [20] and Chapman et al. [21] pointed out that the costs of hydrogen production, storage, distribution, use, and maintenance would impede the transition to a hydrogen economy. Parra et al. [22] also stated that at the global scale, as an alternative to traditional energy sources such as electricity and heat, hydrogen acts more as a complement for other renewable sources in the energy system for specific conditions. This is mainly because of technological barriers, which affect its affordability, reliability, and durability. For instance, although CO₂ capture and sequestration can theoretically help reduce the environmental impacts of hydrogen produced by fossil fuels, its feasibility is still highly uncertain [20].

In China, scholars also hold different opinions regarding the future of hydrogen [14,23,24]. On the one hand, the Chinese government, especially the local agencies, have made many efforts to support hydrogen development, implying their certainty of its potential [24,25]. On the other hand, scholars have shown some concerns about future hydrogen development in China. For example, Verheul [23] argued that China's greatest interests in hydrogen were in the automotive sector, and that its growth is hampered by the weak storage and delivery sectors in the hydrogen value chain. This challenge is further compounded by a lack of relevant regulations, codes, and standards. Through SWOT analysis, Tu [24] summarised that China still lagged far behind other countries in terms of key technologies, and that other countries' decoupling of supply chains from China due to the US–China trade war would affect international cooperation with respect to hydrogen. Most importantly, scholars are concerned about the sources of hydrogen production [14,23,26]. This is because in China, using fossil fuels such as coal to produce hydrogen is a prevalent practice, as it is the least costly due to the maturity of the technology. However, coal-based hydrogen production results in CO₂ emissions, which exacerbates environmental issues. Unfortunately, this concern has not stopped some Chinese entities' pursuit of fossil fuel-based hydrogen production. Some Chinese researchers, nevertheless, hold positive views regarding cleaner hydrogen production in the future. The director of the hydrogen fuel cell laboratory at Tsinghua University, Wang Cheng, demonstrated that since green hydrogen production was still stymied by technological bottlenecks, both China and foreign countries have the chance to achieve a breakthrough [27]. The China Hydrogen Alliance [28] also forecasted that hydrogen production from renewable resources would rise from 3% in 2020 to 70% in 2050, and thereby reduce fossil fuel-based production from 67% to 20%.

The ongoing debates imply great research interest in hydrogen development in China. Since national policies are usually the main impetus for the energy sector's development, it is vital to analyse these hydrogen policies in depth, questioning the reasons, impacts, and challenges of these regulations from 2001 until 2020. The year 2001 was selected as the beginning because it was on 14 November 2001 when the policy 'Guide to Key Development Areas of High Technology Industrialisation at Present' first recognised the use of hydrogen as a clean energy carrier, and this research concluded by January 2021. We will now proceed to discussing the conceptual framework and methods applied in this paper.

3. Conceptual Framework and Methodology

This section introduces the conceptual framework and methodology applied in our research. Thomas Dye's policy analysis method and the European Training Foundation's (ETF) policy analysis guide are integrated to help us analyse the hydrogen policies by assessing their rationales, implications, and challenges.

3.1. Conceptual Framework

Policy analysis is conceptualised as ‘a process of multidisciplinary inquiry aiming at the creation, critical assessment, and communication of policy-relevant information’ [29] (p. 3). It is assumed to bring reliable knowledge to scrutinise governmental public policies. As argued by Einbinder [30], there is no agreed standard or guideline for conducting policy analysis. Instead, policy analysts need to find an approach most fitting for the policy issue and generate valid and valuable results. Hence, this paper combines Thomas Dye’s policy analysis method and the European Training Foundation’s policy analysis guide as the most relevant approach to answering our main question. The following few paragraphs will detail why this is the case.

According to Dye [31], policy analysis consists of three parts: description, causes, and consequences. This framework investigates ‘what governments do, why they do it, and what difference, (if any) would it makes’. Based on the factual basis of policies, this method provides two research paradigms: one seeks to explain the purposes, and the other investigates the impacts of policies [32]. This systematic inquiry deduces the reciprocal effect between the political system and society, namely, how society influences the government so as to formulate policies and how these enacted policies influence society. Dye [31] also emphasises that the purpose of policy analysis is not to tell governments what they should change or act. Politicians can make decisions on policy issues, while policy analysts cannot.

However, there has been a debate on the purpose of the policy analysis approach. As early as the 1980s, policy research was criticised for merely producing knowledge to make politicians notice a given policy issue without providing knowledge applicable to problem-solving [33]. As such, the main shortcoming of Dye’s method is a lack of ex-ante policy analysis, resulting in an insufficient degree of knowledge generation. Policy analysis then becomes a one-off tool with which to merely evaluate the existing policies without providing suggestions for future policies.

The ETF [34] addresses this shortcoming by using a process-oriented view to apply ex-post and ex-ante analysis together via a framework built on the idea of policy cycle. The continual cycle includes agenda setting, policy formulation, policy implementation, and policy evaluation. The evaluation outcomes will become inputs of a succeeding policy-making process and then form a cyclical model [35]. Thus, policy analysis should deal with tasks at all stages of the cycle [34]. Although policy analysts cannot directly formulate future policies, it is essential for them to generate helpful suggestions. In line with this thinking, this paper combines these two analytical approaches by commencing with Dye’s method to describe the contents, explain the reasons, and examine the consequences of Chinese national hydrogen policies. Then, this paper will apply the ETF’s approach to analyse the challenges and provide policy recommendations in the conclusions section (see Figure 1).

3.2. Methodology

In this paper, we have adopted qualitative methods, as they help us to understand the underlying development of Chinese national hydrogen policies. We consulted both primary and secondary data. The primary sources include official documents such as formal and written policies, regulations, and politicians’ speeches. In addition to these official primary data, we also conducted two semi-structured interviews with top hydrogen energy experts in China to ascertain the practitioners’ perspectives on the role of policies in the development of the sector. The secondary data include journal articles, news op-eds, and other commentary pieces from various think-tanks and research institutions. The primary and secondary data helped us to triangulate the information to ensure our research outcome is robust and strong.

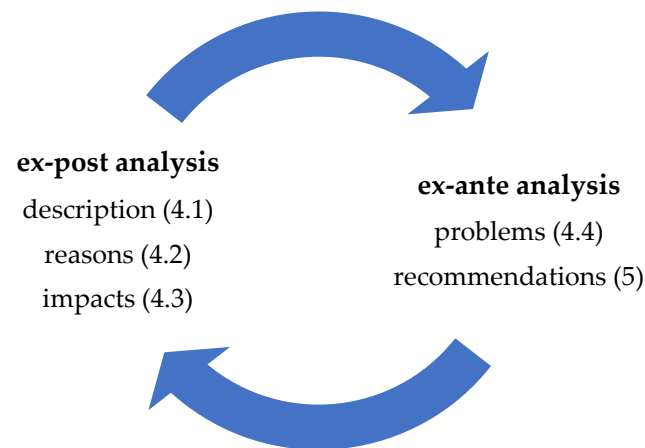


Figure 1. Conceptual framework applied in this article (adapted from Refs. [31,34]).

4. Discussion

This section delves into the discussion of this study's key findings through ex-post and ex-ante analysis. First, we summarise the extent to which the Chinese government has invested in policymaking to develop the hydrogen industry. The reasons, impacts, and challenges of national hydrogen policies are evaluated afterwards.

4.1. Description of Chinese National Hydrogen Policies from 2001 to 2020

Dye's method emphasised the importance of ascertaining the policies the government has enacted, which is indispensable to policy analysis. Utilising the search engine in the Chinese national government's official website, we have collected 49 hydrogen related policies enacted between 2001 and 2020. Before 2001, the only three policies related to hydrogen aimed at developing hydrogen production for industrial and chemical processes. It was in 2001 that the role of hydrogen was transformed; since then, hydrogen has been in the spotlight as an important future energy source with which to help tackle climate change (please see Appendix A for the full list of Chinese national hydrogen policies from 2001 to 2020). Two main characteristics were deduced from these hydrogen policies.

The first characteristic is that the most recent hydrogen policies provided more targeted support in broader fields, especially after 2019. We categorised the policies into three phases representing various stages of development (see Figure 2). The first phase was the early infancy stage, which we identified to span from 2001 to 2012. Fifteen policies were formulated in this period, and most of them provided very general guidelines. For example, the MoST [36–38] mentioned the need for encouraging the R&D of hydrogen technology in three different policies but failed to give specific measures. The second phase, which we termed as the gradual development stage, spanned from 2012 to 2019. In this stage, we observed that policymakers began to design more specific and detailed guidelines for the industry. The SC [39] set a goal for hydrogen development detailing that China planned to realise synchronous development in both fuel-cell-powered vehicles (FCV) and the H-FCV industry with the rest of the world by 2020. Fuel cells utilise the chemical energy of fuels such as hydrogen to produce electricity, which can be applied to automobile propulsion systems. In terms of the H-FCV industry, it embodies the industrial chain of H-FCV components, the construction of fuelling infrastructure, marketing, and after-sales services [39]. Meanwhile, the SC [39] also announced a plan for conducting pilot projects to test the possibility of H-FCV application. Later, twenty-four policies were issued in the second phase to help reach this goal, e.g., providing subsidies for the purchases of H-FCV [40] and constructing more hydrogen fuelling stations [41]. This period also witnessed an expansion in research into the application of hydrogen to more fields. According to the SC [41], China would attempt to apply hydrogen fuel to aerospace. Moreover, in addition to being utilised as fuel, hydrogen was also seen as a possible solution to the intermittent

electricity problem. Hydrogen production via electrolysis can help store surplus renewable electricity generated by water, wind, and sunlight [42].

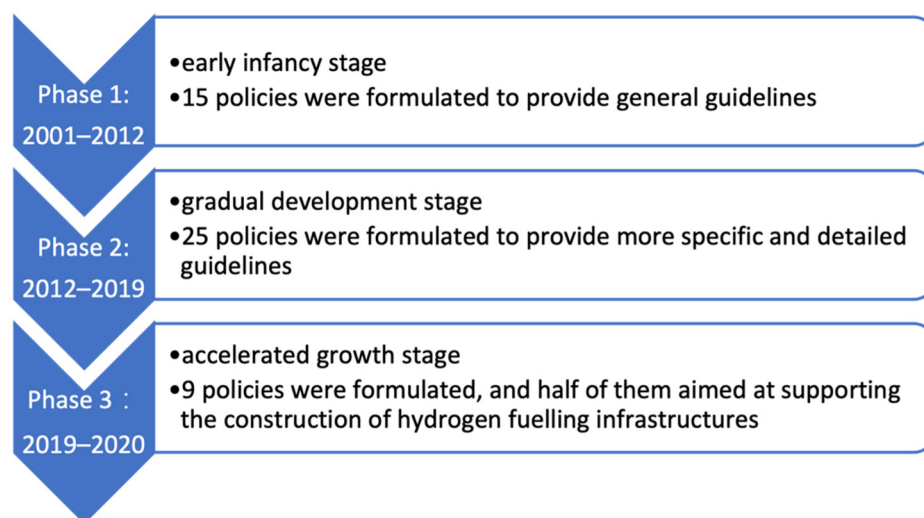


Figure 2. Three phases of Chinese national hydrogen policies from 2001 to 2020.

We termed the third phase ‘an accelerated growth stage’, which spanned from 2019 to 2020. An important turning point in this stage is that the Premier of the State Council, Li Keqiang [43], suggested in the ‘Report on the Work of the Government’ that the Chinese government would formulate more policies to support the construction of hydrogen fuelling infrastructure. Henceforth, nine additional policies were formulated between 2019 and 2020. Half of them were closely related to hydrogen fuelling stations, including promoting construction and operation, encouraging foreign investment, and designing standards [44–47]. Moreover, the application of hydrogen in transportation was expected to expand to the inland waterway transport sector [48]. This indicated the Chinese government’s resolution to expand the use of hydrogen to more sectors.

The second characteristic is that hydrogen development focuses on H-FCV at all stages. Twenty-six of the forty-nine policies explicitly mentioned H-FCV or FCV. Another sixteen policies were highly but indirectly related. They mentioned fuel cell technologies and hydrogen fuelling stations, which are vital for developing H-FCV (see Appendix A). The concept of H-FCV was first put forward in 2004, during the early infancy stage. Transportation was the first sector that the Chinese national government decided to experiment in with respect to the application of hydrogen [49], as fuel cell technologies were expected to create technical advantages in the future [37,50]. At the gradual development stage, around half of the twenty-five policies were related to the H-FCV industry. Some of the policies called for the research and development of H-FCV technologies, while others encouraged foreign investment in key components, and some started pilot projects to explore the usage scenarios of H-FCV. There were also proposals to provide subsidies and support the construction of infrastructure, especially in the third phase [40,45–47,51–53]. In addition, the Chinese government constantly adjusted the type of support for H-FCV. From 2009, subsidies were provided for the promotion of H-FCV. However, in 2020, the MoF decided to stop subsidies due to the lack of rapid developments and significant breakthroughs in the fuel cell industry [54]. Instead, the government shifted to rewarding cities that contributed significantly to the promotion and commercialisation of H-FCV. Cities were encouraged to cooperate beyond the city boundaries so that they could more effectively exploit their advantages and compensate each other [46].

4.2. Reasons for the Chinese National Government’s Efforts towards Formulating Hydrogen Policies

In general, all these policies have two foci: energy transition and automotive decarbonisation. The Chinese government set different strategies at different periods of energy

development. In our context, the strategy of ‘four revolutions’ is most influential in the development of the hydrogen industry. The four revolutions refer to the energy consumption revolution, energy supply revolution, energy technology revolution, and energy market revolution [55]. Current hydrogen development is mostly driven by two revolutions, the energy supply revolution and energy technology revolution, with the prospect of diversifying energy supply and grasping frontier technologies. In addition, the automotive industry transition also helps explain why the Chinese government prioritised the development of H-FCV through policymaking. These three reasons will be analysed in detail below.

Reason 1: The energy supply revolution stimulates hydrogen development endogenously.

Sustainable energy development and carbon emissions reduction are vital to the energy supply revolution. According to President Xi Jinping [55], this revolution aims to diversify energy sources and enhance the cleanliness and efficiency of energy use so as to realise energy system upgrades. At present, coal, a common non-renewable and polluting energy source, accounts for the largest share of China’s energy system. However, according to BP’s report ‘Statistical Review of World Energy’ [56], the domestic production of coal in China is 1.85 million tonnes less than its consumption. The shortage results in energy imports, which increase China’s dependency on foreign countries and affect energy security. Either the fluctuation of coal prices or changes in supply will affect the country’s use of energy and, subsequently, people’s daily lives. Therefore, it is vital to diversify and increase the share of other energy sources that can be produced domestically and promote the more efficient use of energy sources. As such, hydrogen has been expected to account for an increasing share in the energy system. The China Hydrogen Alliance [28] has predicted that hydrogen will account for at least 10% of the energy system by 2050, which will partly substitute for fossil fuels. In terms of efficiency, when compared with other common fuels, hydrogen has the highest calorific value, which is three times that of oil and four and half times that of coal. The efficiency of hydrogen’s conversion to energy through fuel cells, which can be put into use later, will reach 90% in the future [28]. Hydrogen is not only superior in terms of its own efficiency but is also beneficial for the more efficient use of other renewable energy sources. Nowadays, solar and wind power face problems regarding intermittency and abandonment, which result in reliability and efficiency limits, because the supplies are highly dependent on weather conditions. As a result, it is more challenging for the electrical system to balance supply and demand. Hydrogen could help to store these energies, which, subsequently, can be utilised or transported to other areas based on consumption demands [57]. Therefore, policies were enacted to improve the current electricity system and realise a superior strategy for the mixed use of different energy sources [42,52,58].

In addition, the use of the current energy system, which is dominated by fossil fuels, has resulted in a great deal of carbon pollution and negatively impacted the environment, inducing climate fluctuations. Climate change has harmful impacts on both the natural ecosystem and the human living environment. In the context of China, the NDRC [59] has warned that China is more vulnerable to climate change compared with areas of similar latitude such as Western Europe. This is because most areas in China have a continental monsoon climate, in which the temperature changes more drastically with the seasons. Therefore, the Chinese government called upon society to reduce greenhouse gas emissions and optimise the energy system [59]. Hence, hydrogen was introduced as an option to help diversify clean energy sources. When hydrogen is burned, water is the only by-product, and in turn, water can be processed to produce hydrogen [60]. Encouraging the application of hydrogen to transportation, industry, and other fields with high emissions will help reduce the release of carbon dioxide. Moreover, to further reduce carbon emissions when generating hydrogen, some policies were enacted in order to support research into hydrogen production from renewable energy sources [61,62].

Reason 2: The energy technology revolution stimulates hydrogen development exogenously.

The research into and development of frontier and innovative technologies is key to the energy technology revolution. Nowadays, many countries consider technological

innovation to be one of their top strategies for enhancing national power [63]. According to President Xi Jinping [64], in the previous scientific and technological revolution, China failed to keep pace with the leading countries, which has affected China's technological power. A new round of revolution is under way and new energy technology development is one of the key impetuses. At the global scale, the United States of America has announced its 'All-of-the-above Energy Strategy', the European Union has published the 'Energy Roadmap 2050', and many other heavily energy-consuming countries have also decided to take immediate action to accelerate innovation in energy technology [61]. As the largest developing country in the world, China has recognised and seized the opportunity to narrow the gap with developed countries by improving its competitiveness regarding new energy technologies. This is because these new technological breakthroughs are perceived to potentially be capable of allowing China to play a leading role in the global energy transition and in terms of climate change issues.

Hence, the formulation of policies for the development of the hydrogen sector is important for the energy technology revolution. Although the United States, Japan, and some European countries started research into hydrogen after the 1973 oil crisis, only Japan and Germany have achieved apparent advantages through hydrogen development [60]. Both countries have accumulated rich experience in hydrogen production and applications, but the hydrogen industry is still in its infancy stage and faces numerous challenges. For instance, in terms of production, only an exceedingly small portion of hydrogen is produced by renewable sources. Most still rely on fossil-fuel-based raw materials, which produce carbon emissions. Water electrolysis technology still requires further research to ensure better efficiency and lower costs [65]. Moreover, while the United States, Japan, and other countries have chosen to promote the use and development of passenger cars, China's strategy is to prioritise the development of commercial H-FCV. This is because China started hydrogen research later than other countries, which have already achieved technological breakthroughs in passenger cars. Therefore, China wants to seize the opportunity to obtain early market shares of the commercial H-FCV. Additionally, the difficulty in developing passenger H-FCV is much greater than that of the commercial ones, which also brings about the opportunity of quicker hydrogen development in China [57,60]. China sees potential in this field, and by promoting technological innovation, they could lead the global hydrogen industry and achieve competitive advantages in the emerging scientific and technological revolution. There is also another reason for China to formulate policies that support and develop independent technologies. Honda, Toyota, Hyundai, and other leading car companies do not share fuel cell stack technologies with others, which are essential components for H-FCV [66]. Countries and companies choose to keep their key technologies secret to protect confidential information and stop competitors from free riding on innovations. Therefore, to reduce its reliance on other countries and realise large-scale production, China must overcome technological bottlenecks on its own.

Reason 3: The automotive industry transition stimulates the application of hydrogen to the transportation industry.

The automotive industry is a major sector of the state's economy. In China, taxes on the automotive sector and its related industries account for 10% of the country's total national taxes. The automotive sector also provides 10% of domestic jobs [67]. Additionally, people's daily travelling, the transportation of necessity goods, and the environment's sustainability are all tied to the automotive industry [68]. However, the transport industry has faced several challenges in recent years. China has incurred a high dependency on fossil fuel imports in order to cater to the demand of the traditional auto industry. The emissions from vehicles also seriously pollute the air. According to the results of the latest national survey of pollution sources, NO_x emissions from vehicles account for approximately one-third of the total emissions [69].

Therefore, the automotive industry's transition from fossil fuels to renewable energy is necessary, and new energy vehicles are seen as a substitute for traditional cars in the future. Hybrid cars, pure electric vehicles (PEV), and H-FCV are three ideal options [70].

Hybrid cars still require the use of fossil fuels, which constitute the least sustainable option. Even though PEV are now taking a leading role in terms of new energy vehicles in China, H-FCV have their advantages, and it is well worth supporting the R&D sector. PEV are more suitable for short trips while H-FCV can meet the demand of longer trips. An H-FCV's charging time is much shorter while supporting longer ranges. Meanwhile, in a low-temperature environment, the charging capacity of PEV is lower and affords longer charging times. On the contrary, H-FCV are unlikely to be affected by temperature [60]. H-FCV can compensate for the shortcomings of PEV and better satisfy the diverse needs from the automotive industry. Finally, rapid urbanisation has also generated challenges relating to the limited space for PEV-charging infrastructure. It has been argued that one likely reason for Japan's efforts towards hydrogen development is that H-FCV are more convenient in dense urban areas as they need less space [71]. This also signals to China that the use of H-FCV could help solve potential land-use challenges in the future.

4.3. Impacts

A major step in ex-post analysis is to provide a policy evaluation. According to Dye [31], policy evaluation aims to determine the differences brought by the existing policies to society. Our research has demonstrated that the increasing number of more targeted policies is closely correlated with the resources invested in the hydrogen industry and its achieved progress and breakthroughs. The impacts of these policies will be detailed in the following paragraphs.

Impact 1: The increased number of more targeted hydrogen policies translates to more resources being invested in the hydrogen industry.

In recent years, more policies have been enacted to promote the hydrogen industry, which directly translates to more human and financial resources being invested in the sector. In terms of hydrogen research, the government has provided more financial support, leading to more opportunities for researchers. For example, in 2018, MoST [72] announced a plan to increase the number of research projects in 6 fields from 34 to 64, with a budget of CNY 656.5 million. Hydrogen was included, and for the first time, it was listed as a national key research topic [73]. Since then, mirroring the boom in hydrogen policies in 2019, MoST [74,75] has increased national support in 2019 and 2020's budget to further provide research and development funding for renewable energy and hydrogen technologies. The increased research interest in the hydrogen sector is further evidenced by the increasing number of researchers engaged in the hydrogen industry over the past three years, which was disclosed by one of our interviewees. For example, some experts in the catalyst fields have undertaken research into the availability and reliability of catalyst usage in hydrogen production. This demonstrated an expansion of research activities with a more active participation of experts in other fields.

The higher number of enacted hydrogen policies also brought about an increasing number of stakeholders entering the sector. There was a spike in new entrants into the market in 2019, with sixteen new companies established to develop key components of H-FCV. This translated into a 20% increase in the number of competitors in the hydrogen industry [66]. The China Hydrogen Alliance [28] argued that at the infancy stage of hydrogen development, small and medium-sized private enterprises were the main stakeholders, but more large enterprises have been involved over the past few years. Until the end of 2018, large-scale enterprises accounted for approximately 20% of the companies in the hydrogen industry in China. Later, for example, Weichai and Cummins, two leading enterprises that specialised in engines and generators, increased their investments in the research and development of hydrogen fuel cells and established research institutes in China in 2019 [66]. This also coincided with Sinopec Group's (a massive state-owned Chinese oil and gas enterprise) investment into the construction of hydrogen infrastructure. In 2019, Sinopec successfully built the first joint hydrogen and oil station in Foshan, China. This was a milestone for the development of hydrogen retail as the station provided services for both hydrogen fuelling and the retail sales of conventional fuels [76,77]. One of our

interviewees also revealed that there are more representatives from state-owned enterprises in conferences related to hydrogen development.

Impact 2: The increased number of more targeted hydrogen policies translates to spill over effects in the development of the hydrogen industry.

We observed that progress regarding H-FCV technologies has positive spill over effects into its costs and sales. As illustrated above, more than eighty-five per cent of hydrogen policies were closely related to the application of hydrogen in the transportation sector. These policies brought about the rapid development of H-FCV technology. According to the China Society of Automotive Engineers [76], through years of research and development, local Chinese companies have had the ability to independently produce a few key components of fuel cells. The performance of relevant products had been greatly enhanced at the same time. For instance, in 2019, the engine system net output of commercial H-FCV was between 30 and 100 kW [66]. One year later, China made a significant breakthrough: a 130 kW fuel cell engine called VISH-130A passed the certification of the China Automotive Technology and Research Center (CATRC). This set a record for the maximum power output of hydrogen fuel cell engine in China. The company also started mass production of VISH-130A engines, which are expected to be applied to heavy trucks and ships soon [57,78]. These increasingly mature technologies have led to cost reduction. According to Dong [66], the rapid development of fuel cell technologies has resulted in cheaper locally produced products. An example would be the air compressor for hydrogen fuel cells. This is an important device utilised to deliver pressurised air for the hydrogen–oxygen reaction, an indispensable process to the fuel cell system assembly [79]. In 2016, the price of one compressor fluctuated between CNY 100,000 and 200,000. In 2019, the price was reduced to less than CNY 100,000 [66]. Moreover, the reducing costs and government subsidies have helped boost the sales of H-FCV. Between 2013 and 2017, around 2000 H-FCV were sold [80]. Since 2018, the production and total sales of H-FCV were officially reported by the national government. Figure 3 shows that the volume of annual sales increased substantially to 2737 in 2019. However, in 2020, due to the COVID-19 pandemic and the gradual removal of subsidies for the purchasing of H-FCV [51], we observed a decline of 56% in sales of H-FCV in 2020. By contrast, the scale of production was not affected and maintained the status quo.

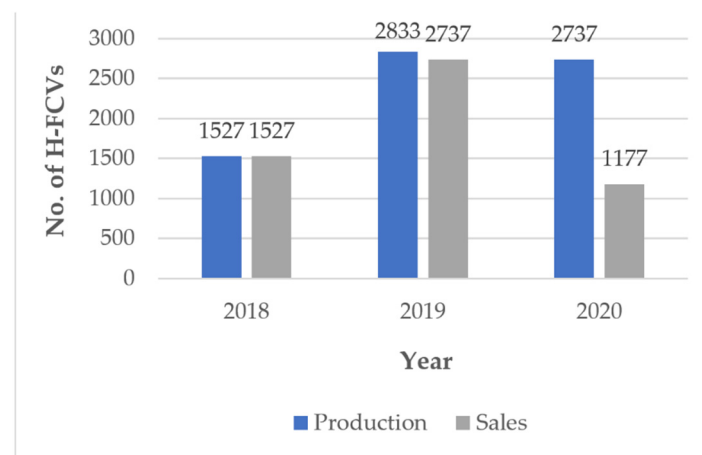


Figure 3. The production and sales results of H-FCV in China from 2018 to 2020. Data collected from China Association of Automobile Manufacturers [81–84].

The rapid development of H-FCV also promoted improvements in other segments in the hydrogen industry. Due to the rising usage of H-FCV, it is vital to meet the demand for fuelling infrastructure as well. In 2019, the facilitation of hydrogen infrastructure was included in the Report on the Work of the Government [43]. Six policies were later issued to provide support for the construction of hydrogen facilities, and this is the same number

as in the previous eighteen years. For instance, MoF et al. [45] announced more subsidies would be provided for this sector, while NDRC and Mofcom [47] called for more foreign investment. This promotion translated to the doubling of newly built hydrogen fuelling stations to a total of sixty-one in 2019, as illustrated in Figure 4. According to the latest data, China constructed forty-three new stations in 2020 and reached an overall number of 104 [85]. This increasing amount of hydrogen fuelling infrastructure also presents the spill-over effect wherein the government formulates and enacts more standards. In recent years, policies mentioned the need to foster standardisation across the sector [46,86,87]. According to the CATRC [73], the currently issued and modified national standards cover many aspects, including the quality of hydrogen, hydrogen fuelling equipment, and the management of hydrogen fuelling stations. Therefore, it can be argued that the increasing formulation of hydrogen policies with more targeted support has not only stimulated the rapid development of the targeted segment in the hydrogen industry, but also later resulted in a spill over effect concerning the progress achieved in other segments.

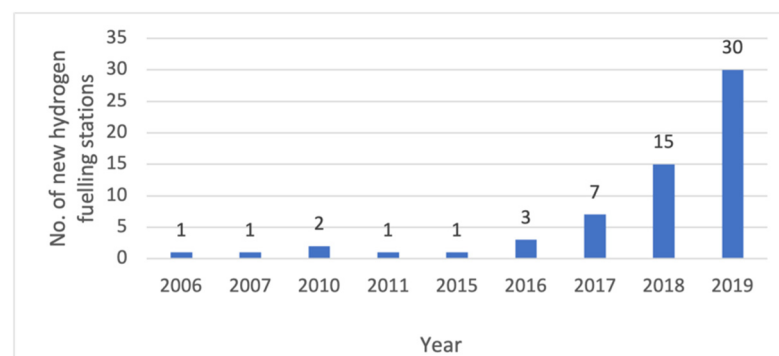


Figure 4. The number of new hydrogen fuelling stations from 2006 to 2019 (adapted from Ref. [57]).

4.4. Problems

The previous discussion presented the existing hydrogen policies in China from 2001 to 2020, with an evaluation of the rationale and impacts of these policies on the hydrogen industry. However, as mentioned in Section 3.1, policy analysis should not be limited to ex-post analysis and only focus on an inquiry concerning existing policies. It should be complemented by an ex-ante analysis, which queries the first stage of the policy cycle, namely, agenda setting. This stage is also called problem identification, which diagnoses the current barriers to policy effectiveness. It lays the foundation for creating appropriate responses in order to mitigate failures and improve the current situation [34]. Hence, this section identifies two problems confronting the Chinese government, which have hindered hydrogen development.

4.4.1. Problem 1: The Lack of Regulations for the Industry Threshold

As shown in Appendix A, the 49 policies released by the Chinese national government attempted to attract public attention and encourage more stakeholders to support hydrogen development. The increasing support from the national government has stimulated many companies, scholars, and individuals to enter this emerging industry. However, none of these policies provided inclusion and exclusion criteria for newcomers to the hydrogen industry. Therefore, new investors into the sector tended to fail to carefully consider their existing technological competence and resource capacity [73]. This resulted in an unprecedented flood of new companies into the hydrogen industry. On the one hand, the entry of more stakeholders can help expand the industry. On the other hand, it can also bring about several risks. During the interview, one interviewee indicated that the increasing number of hydrogen policies has attracted opportunists into the sector, resulting in increased competition for limited resources and undermining development in the sector. Driven by economic interests, those opportunists might be short-sighted, causing an interruption to long-term research. Companies or individuals flooding into the

industry have also led to the problem of excess capacity [73]. Based on the preliminary statistics provided by the Research Team from the China Center for International Economic Exchanges [60], around 100,000 H-FCV will soon be produced in total due to the stimulus provided by the government. However, the increase in the demand for H-FCV is much slower when compared to that of the supply. This imbalance between supply and demand will cause surpluses in the marketplace, which still fails to bring about significant changes with respect to the transition towards green transport. In general, the existing policies with additional resources have attracted more investors and researchers. However, the low barriers to entry and a lack of government-supervisory regulations result in unhealthy competition in the hydrogen industry, which will be harmful to the long-term development of the sector.

4.4.2. Problem 2: The Lack of a Holistic Plan

A bigger challenge is that the Chinese government fails to take a holistic view of hydrogen development. Compared with the United States, Japan, the Republic of Korea, and other leading countries in the hydrogen industry, all the existing hydrogen policies until 2020 in China are fragmentary, siloed in their own segments (see Appendix A). This affects policy consistency because current policies are designed to meet short-term demands and lack long-term goals. A case in point is that the enacted policies focused on the application of hydrogen in the transportation sector and the construction of infrastructure with a lack of specific support for hydrogen storage, delivery, and fuel cells. This will cause an unbalanced growth in the upstream and downstream activities in hydrogen development. However, all these segments in the industry are interrelated, and the underdevelopment of one segment will affect the other segments. Scholars are concerned that this imbalance could result in China experiencing hydrogen technology-related hollowing, which entails a lack of key techniques mastered by local companies and hampers the progress in the hydrogen industry [60,73]. During the Two Sessions in 2020, the general manager of the Sinopec Qilu Petrochemical Company, Han Feng, also raised the issue that despite the rapid development of the hydrogen industry, there are major technical problems in terms of fuel cells that are yet to be resolved [88]. This is evidenced by the fact that at present, China still imports most of the key components of fuel cells from foreign countries. Accordingly, even though car manufacturers are putting H-FCV on the market, their high dependency on other countries for their core technologies results in a great deal of uncertainty, e.g., fluctuations in the prices of those key components. Without a holistic and coherent plan, China may underestimate its reliance on other countries' resources, which would compromise the growth of the industry in the long run.

5. Conclusions and Policy Implications

To cope with the challenges of reducing carbon dioxide emissions and mitigating climate change, hydrogen has been identified as possessing the potential to become a key energy carrier in the future energy system. Since 2001, the year in which the Chinese national government first mentioned the need for developing hydrogen as a clean energy source, forty-eight additional policies were issued in the following 19 years. These policies separately focussed on various aspects of the hydrogen industry, resulting in its rapid development in recent years. Previous research did not specify whether and to what extent hydrogen policies influenced the industry's development and energy transition in China. Hence, this research explored the reasons for, impacts of, and challenges faced by Chinese national hydrogen policies from 2001 to 2020.

This paper has developed a conceptual framework integrating Thomas Dye's policy analysis method and the ETF's policy analysis guide. Evaluating existing policies while simultaneously deriving future options helped us to conduct a complete, in-depth investigation. The ex-post analysis started with a description of previous Chinese national hydrogen policies enacted between 2001 and 2020, which we categorised into three phases. This article finds that more detailed and targeted hydrogen policies appeared in recent

years and that the Chinese government primarily endeavoured to develop hydrogen in the transportation sector. We also ascertained that the main reason for this is the urgent need for the energy supply revolution and energy technology revolution. China's heavy reliance on the import of fossil fuels has warned the country of the necessity of diversifying energy sources on the supply side. Accordingly, hydrogen provides a timely solution, as it possesses the advantages of sufficient production capacity, high efficiency, and the fewest and least harmful environmental impacts. In addition, the technology competition regarding energy revolution at the international stage also encouraged China to promote the research into and development of the emerging hydrogen industry such that China could gain competitive advantages. We also deduced that the necessary renewable energy transition and the inability of PEV to meet all the transportation demands in the automotive industry accounted for numerous efforts with respect to the development of H-FCV. Hence, this paper delved into the policy impacts and found that the existing policies provided a vital impetus for hydrogen development in China. The increased number of more targeted hydrogen policies translated to an increase in resources invested in the hydrogen industry, thereby accelerating its development. Meanwhile, with efforts towards the development of H-FCV prioritised, the initial progress in technology had spill over effects on product costs and sales. The success regarding H-FCV also gave rise to the development of fuelling infrastructure.

Realising the key role of policies in hydrogen development in China, this paper also provides an ex-ante analysis in order to suggest some insights to policymakers. We identified two challenges hampering the industry's development. The first is the lack of regulations for the industry threshold. This has attracted short-sighted and opportunistic investors, which affects healthy competition in the industry. The second is the lack of the strategic and holistic planning of hydrogen development, which has affected the consistency and connection in the enacted policies. We would like to propose two recommendations herein: design a detailed roadmap for the whole hydrogen industry and tap into the potential for BRI collaboration in this sector.

First and most importantly, the Chinese government should enhance the strategic planning of hydrogen development. A holistic plan should set specific and coherent goals concerning the following areas: upstream—hydrogen production; midstream—hydrogen storage and delivery; and downstream—the application of hydrogen. This roadmap will ensure synchronous development in all segments and support those currently less-developed segments. With this holistic approach, the Chinese government can also better allocate scarce resources to those areas most in need. Second, long-term strategic planning would weed out short-term investors, thereby generating better and healthier competition in the market as well as research and development. The consequences of overextension, overcapacity, overinvestment, and other dangers can be avoided or restricted to some extent. Third, a national hydrogen roadmap will also help improve public awareness concerning hydrogen's potential in the energy sector. Building a roadmap symbolises the Chinese government's resolution to develop hydrogen and implies its significant role in the field of new energy [59,70,73]. Therefore, the roadmap will increase public awareness and encourage the public to learn more knowledge about hydrogen. This might translate to acceptance and demand; thus, the public may buy more hydrogen products, which will, in turn, stimulate upstream and midstream development.

Policy advice is not limited to solving problems but can also explore opportunities [34]. Our second suggestion is that the Chinese government could tap into the BRI and promote hydrogen development through cross-national collaboration. The BRI proposes connecting the Asian, European, and African continents more closely to establish a mutually beneficial partnership. One of the cooperation priorities mentions that countries should promote collaboration in terms of clean and renewable energy sources based on the principles of mutual complementarity and mutual benefit [89]. Currently, most cooperation projects focus on hydropower and solar PV. However, the countries along the Belt and Road Routes have abundant hydrogen resources, advanced hydrogen technologies, and rich experience

in hydrogen development. A total of 85% of the countries that have announced hydrogen strategies joined the BRI. These countries also own 79% of the hydrogen refuelling infrastructure and 42% of H-FCV worldwide [60]. Thus, China can utilise this opportunity to cooperate with these countries along the routes, engaging in activities such as exchanging hydrogen resources and initiating joint research projects. In addition, the Chinese government could also encourage domestic companies to establish more partnerships with foreign companies, especially in terms of technological cooperation. This multilevel transnational collaboration will help pool resources, capitalise on individual states' competitive advantages, overcome barriers through collective power, and promote hydrogen development collaboratively.

Author Contributions: Conceptualization, Y.Y. and M.T.-M.; methodology, Y.Y. and M.T.-M.; formal analysis, Y.Y.; investigation, Y.Y.; validation, Y.Y. and M.T.-M.; writing—original draft preparation, Y.Y.; writing—review and editing, Y.Y. and M.T.-M.; visualization, Y.Y.; supervision, M.T.-M.; project administration, Y.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

BRI	Belt and Road Initiative
CATRC	China Automotive Technology and Research Center
CREC	China Railway Group Limited
H-FCV	Hydrogen Fuel Cell Vehicles
MEE	Ministry of Ecology and Environment, PRC
MIIT	Ministry of Industry and Information Technology, PRC
MoF	Ministry of Finance, PRC
Mofcom	Ministry of Commerce, PRC
MoS	Ministry of Supervision, PRC
MoST	Ministry of Science and Technology, PRC
MoT	Ministry of Transport
MPS	Ministry of Public Security, PRC
NDRC	National Development and Reform Commission, PRC
NEA	National Energy Administration
NRA	National Railway Administration
SAMR	State Administration for Market Regulation
SC	State Council, PRC
SPC	State Planning Commission, PRC

Appendix A

Table A1. Chinese Hydrogen Policies from 2001 to 2020.

No.	Issued Date	Issuing Departments	Title of the Policy	Key Points
Phase I: An Early Infancy Stage				
1. ** [90]	14 November 2001	SPC, MoST	Guide to Key Development Areas of High Technology Industrialisation at Present	<ul style="list-style-type: none"> - Encourage R&D and promotion of hydrogen as a clean energy source. - Appeal for increased R&D of hydrogen fuel cell. - Enhance hydrogen recovery from refinery gas streams.
2. [91]	2 August 2002	MoST	Outline of Sustainable Development of Science and Technology (2001–2010)	<ul style="list-style-type: none"> - Encourage R&D of hydrogen production, storage, and application technologies.
3. * [49]	21 May 2004	NDRC	Policy on Development of Automotive Industry	<ul style="list-style-type: none"> - Support R&D of hydrogen fuel. Encourage auto companies to develop and produce H-FCV.
4. * [92]	2 December 2005	NDRC	Directory Catalogue on Readjustment of Industrial Structure (Version 2005)	<ul style="list-style-type: none"> - Encourage R&D and production of H-FCV and their key components.
5. * [93]	25 December 2005	NDRC, Ministry of Construction, PRC, MPS, MoF, MoS, State Environmental Protection Administration	Opinions on Development of Energy-Efficient and Low-Emission Vehicles	<ul style="list-style-type: none"> - Encourage R&D and production of H-FCV.
6. ** [94]	30 December 2005	SC	Outline of the National Medium- and Long-Term Program for Science and Technology Development (2006–2020)	<ul style="list-style-type: none"> - Propose the potential of hydrogen as a clean energy source. - Encourage R&D of hydrogen and fuel cell technologies.
7. ** [36]	14 May 2006	MoST	National 11th Five-Year Plan for Science and Technology Development	<ul style="list-style-type: none"> - Encourage development and application of hydrogen technologies, especially in terms of fuel cell technologies.
8. ** [59]	3 June 2007	NDRC	China's National Climate Change Programme	<ul style="list-style-type: none"> - Request for international cooperation in fuel cell and hydrogen technologies to mitigate climate change.
9. * [95]	31 October 2007	NDRC, Mofcom	Catalogue of Industries for Guiding Foreign Investment (2007 Revision)	<ul style="list-style-type: none"> - Encourage foreign investment in R&D of hydrogen energy, as well as R&D and manufacturing of key components of H-FCV.
No.	Issued Date	Issuing Departments	Title of the Policy	Key Points
10. * [70]	20 March 2009	SC	Plan on Restructuring and Revitalisation of Auto Industry	<ul style="list-style-type: none"> - Encourage R&D of key components of FCV. - Provide subsidies for promotion and application of FCV.
11. * [50]	10 October 2010	SC	Decision on Accelerating the Development of Strategic Emerging Industries	<ul style="list-style-type: none"> - Encourage R&D of FCV innovative technologies.

Table A1. Cont.

12. ** [37]	13 July 2011	MoST	National 12th Five-Year Plan for Science and Technology Development	- Encourage R&D of key hydrogen technologies, equipment, and systems. Emphasise hydrogen and fuel cell innovative technologies.
13. [96]	24 December 2011	NDRC, Mofcom	Catalogue of Industries for Guiding Foreign Investment (2011 Revision)	- Encourage foreign investment into R&D of hydrogen energy.
14. * [97]	30 December 2011	SC	Industrial Transformation and Upgrade Plan (2011–2015)	- Encourage R&D of FCV and their key components.
15. * [38]	27 March 2012	MoST	12th Five-Year Plan for Science and Technology Development of Electric Vehicles	- Propose the potential of hydrogen technologies with respect to reducing carbon emissions. - Encourage R&D of hydrogen production, storage, and fuelling technologies and equipment. - Encourage R&D and production of H-FCV and their key components.
Phase II: A Gradual Development Stage				
16. * [39]	28 June 2012	SC	Plan for the Development of the Energy-Saving and New Energy Automobile Industry (2012–2020)	- Set a goal in which both fuel cell vehicles and H-FCV industry will have been in synchronous development with the rest of the world by 2020. - Encourage the pilot application of FCV and promote the development of hydrogen production, storage, and fuelling technologies.
17. * [53]	9 July 2012	SC	12th Five-Year Plan for National Strategic Emerging Industries	- Advance R&D, promotion, and application of FCV.
18. [98]	23 January 2013	SC	The Circular Economy Development Strategy and Near-Term Action Plan	- Improve the use of hydrogen.
19. ** [99]	7 June 2014	General Office of the State Council, PRC	Action Plan for Energy Development Strategy	- Encourage technological innovation of hydrogen energy and fuel cells.
20. * [40]	14 July 2014	General Office of the State Council, PRC	Guide to Accelerate Promotion and Application of New Energy Vehicles	- Encourage R&D of FCV. - Plan to provide subsidies for purchases of FCV. - Support R&D of fuel cell technologies.
No.	Issued Date	Issuing Departments	Title of the Policy	Key Points
21. ** [100]	18 November 2014	MoF, MoST, MIIT, NDRC	Notice of Reward for New Energy Vehicle Charging Infrastructure	- Plan to provide subsidies for the construction of hydrogen fuelling stations.
22. * [101]	22 April 2015	MoF, MoST, MIIT, NDRC	Notice of Financial Support for Promotion and Application of New Energy Vehicles (2016–2020)	- Provide subsidies for purchases of FCV. - Make requirements of minimum FCV range.
23. * [102]	19 May 2015	Central Committee of the Communist Party of China, SC	Made in China 2025	- Support development of FCV, improve technical skills, and align with international standards.

Table A1. Cont.

24. [103]	10 March 2015	NDRC, Mofcom	Catalogue of Industries for Guiding Foreign Investment (2015 Revision)	- Encourage foreign investment into R&D of hydrogen energy.
25. ** [86]	17 December 2015	General Office of the State Council, PRC	Plan for National Standardisation System Construction	- Foster fuel cell standardisation.
26. [52]	24 February 2016	NDRC, NEA, MIIT	Guiding Opinions on Promoting Internet Plus Smart Energy Development	- Support the construction of infrastructure of flexible transfer, efficient storage, and intelligent cooperation of different energy sources such as electricity, gas, and hydrogen.
27. ** [61]	7 April 2016	NDRC, NEA	Action Plan for the Energy Technology Revolution Innovation (2016–2030)	- Encourage R&D of hydrogen production from renewable energy sources. - Encourage technological innovation of hydrogen energy and fuel cell.
28. ** [63]	19 May 2016	Central Committee of the Communist Party of China, SC	Outline of the National Strategy of Innovation-Driven Development	- Encourage development of hydrogen energy- and fuel cell-innovative technologies.
29. ** [104]	28 July 2016	SC	13th Five-Year Plan for Science, Technology and Innovation	- Encourage R&D of hydrogen energy technologies. - Encourage R&D of hydrogen energy and fuel cell-innovative technologies.
30. ** [41]	29 November 2016	SC	13th Five-Year Plan for Strategic Emerging Industries Development	- Encourage development of onboard hydrogen storage, hydrogen production, storage, and fuelling technologies. - Promote the construction of hydrogen fuelling stations. - Encourage R&D of hydrogen fuel application in the aerospace field.
No.	Issued Date	Issuing Departments	Title of the Policy	Key Points
31. ** [62]	6 December 2016	NDRC, NEA	13th Five-Year Plan for Energy Development	- Encourage R&D of hydrogen and fuel cell technologies. - Encourage technological innovation of hydrogen production.
32. ** [105]	29 December 2016	NDRC, NEA	Energy Supply and Consumption Revolution Strategy (2016–2030)	- Encourage development of hydrogen fuel cell technologies. - Foster technological innovation of hydrogen energy, such as hydrogen production by algae. - Encourage development of hydrogen fuel as an alternative fuel.
33. * [106]	29 December 2016	MoF, MoST, MIIT, NDRC	Notice of Adjusting the Policies on Government Subsidies for Promotion and Application of New Energy Vehicles	- Improve requirements of minimum FCV range and FCV technologies. - Maintain subsidies for promotion and application of FCV.
34. * [68]	6 April 2017	MIIT, NDRC, MoST	Mid- to Long-Term Development Plan for the Automotive Industry	- Plan to develop an H-FCV technology roadmap to support resource pooling and R&D.

Table A1. Cont.

35. * [87]	2 May 2017	MoST, MoT	13th Five-Year Special Plan for Science and Technology Innovation in the Transportation Sector	<ul style="list-style-type: none"> - Encourage R&D of key components of FCV. - Encourage construction of hydrogen fuelling stations and advance standardisation. - Encourage R&D of hydrogen fuel unmanned cargo aircraft.
36. * [107]	28 June 2017	NDRC, Mofcom	Catalogue of Industries for Guiding Foreign Investment (2017 Revision)	<ul style="list-style-type: none"> - Encourage foreign investment into R&D of hydrogen energy, R&D and manufacturing of key components of H-FCV, and construction and operation of hydrogen fuelling stations.
37. [42]	8 November 2017	NDRC, NEA	Implementation of a Solution to Water, Wind and Light Abandonment	<ul style="list-style-type: none"> - Encourage electrolytic hydrogen production in areas rich in renewable energy sources.
38. * [108]	12 February 2018	MoF, MIIT, MoST, NDRC	Notice of Adjusting and Improving the Financial Subsidy Policies for Promotion and Application of New Energy Vehicles	<ul style="list-style-type: none"> - Improve the requirements of FCV technologies. - Maintain subsidies for promotion and application of FCV.
39. [109]	28 February 2018	NDRC, NEA	Guiding Opinions on Improving the Electricity System's Adjustment Capabilities	<ul style="list-style-type: none"> - Encourage promotion and application of interruptible electrolytic hydrogen production.
40. * [110]	30 December 2018	MEE, NDRC, MIIT, MPS, MoF, MoT, Mofcom, SAMR, NEA, NRA, CREC	Action Plan for Diesel Truck Emissions Control	<ul style="list-style-type: none"> - Encourage pilot application of fuel cell vans and construction of hydrogen fuelling stations.
No.	Issued Date	Issuing Departments	Title of the Policy	Key Points
Phase III: An Accelerated Growth Stage				
41. ** [45]	26 March 2019	MoF, MIIT, MoST, NDRC	Notice on Further Improving the Financial Subsidy Policies for the Promotion and Application of New Energy Vehicles	<ul style="list-style-type: none"> - Plan to provide more subsidies for the construction and operation of hydrogen fuelling stations.
42. * [47]	30 June 2019	NDRC, Mofcom	Catalogue of Industries for Guiding Foreign Investment (2019 Revision)	<ul style="list-style-type: none"> - Encourage foreign investment into R&D of hydrogen fuels and hydrogen energy, R&D and manufacturing of key components of H-FCV, and construction and operation of hydrogen fuelling stations.
43. ** [111]	19 September 2019	Central Committee of the Communist Party of China, SC	Outline on Building China's Strength in Transport	<ul style="list-style-type: none"> - Advance hydrogen fuelling infrastructures.
44. * [58]	30 October 2019	NDRC	Catalogue for Guiding Industry Restructuring (2019 Version)	<ul style="list-style-type: none"> - Encourage R&D of the hybrid power system based on hydrogen, wind, and photovoltaic energy. - Encourage R&D of hydrogen energy including hydrogen production, storage, delivery, and application. - Encourage R&D of key components of H-FCV.

Table A1. Cont.

45. * [51]	23 April 2020	MoF, MIIT, MoST, NDRC	Notice of Improving the Financial Subsidy Policies for the Promotion and Application of New Energy Vehicles	<ul style="list-style-type: none"> - Plan to remove subsidies for purchases of H-FCV. - Propose to provide rewards for the cities that contribute to technological innovation and application of hydrogen and H-FCV.
46. * [48]	29 May 2020	MoT	Outline on Developing Inland Waterway Transport	<ul style="list-style-type: none"> - Encourage R&D of hydrogen application in the field of inland waterway transport.
47. * [46]	16 September 2020	MoF, MIIT, MoST, NDRC, NEA	Notice of the Pilot Application of Fuel Cell Vehicles	<ul style="list-style-type: none"> - Establish a four-year program to provide financial support for trial city groups. - Encourage technological innovation, promotion, and application of H-FCV. - Plan to improve the technical standards related to H-FCV and hydrogen. - Support R&D to lower the costs of H-FCV. - Plan to make more policies, e.g., supporting construction and operation of hydrogen fuelling stations.
No.	Issued Date	Issuing Departments	Title of the Policy	Key Points
48. * [44]	20 October 2020	General Office of the State Council, PRC	New Energy Vehicle Industry Development Plan (2021–2035)	<ul style="list-style-type: none"> - Achieve a better balance of supply and demand of hydrogen fuel. - Reduce costs of hydrogen fuel production, storage, and delivery. - Foster technological innovation and application of hydrogen fuel cells in vehicles. - Encourage promotion and application of H-FCV. - Improve hydrogen fuelling infrastructures, e.g., enhancing safety.
49. * [112]	27 December 2020	NDRC, Mofcom	Catalogue of Industries for Encouraging Foreign Investment (2020 Version)	<ul style="list-style-type: none"> - Encourage foreign investment into R&D of hydrogen fuels and hydrogen energy, R&D and manufacturing of key parts and components of H-FCV, and construction and operation of hydrogen fuelling stations.

*: Policies directly mentioning H-FCV/FCV. **: Policies highly but indirectly related to H-FCV.

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