The analysis of government policies for hydrogen fuel cell

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Abstract. Coming into an era when the world is becoming more and more concerning about environmental issues and energy dilemma, hydrogen fuel cell is a very ideal clean energy resource profited from its low carbon emission, low noise production, high energy efficiency and its renewable property. In the last few decades, many efforts had been made in policies and technology, trying to make hydrogen stable, convenient and popular enough to be a substitution of fossil fuel. This article paid close attention to the relationship between hydrogen technology of different developing stages and hydrogen industry policies set up by government around the globe. By using the statistical method to compare and contrast hydrogen fuel development analyzed from the number of patents and the government's policy of three representative countries, funds and other types of proposals in history, it can be concluded that there is a close relationship between the condition of receiving government support and the enthusiasm in research and innovation in hydrogen fuel cell. This evidence reveals that during the long-term focus in the political and environmental topic of carbon neutral, the industrial policy can make a significant influence in lowering carbon emission.

Keywords: Hydrogen fuel cell; government policies; renewable energy.

1. Introduction

Hydrogen fuel cell is the most commonly mentioned fuel cell. It produces energy by releasing the Gibbs free energy in hydrogen gas through catalyst. Inside the cell, hydrogen gas is split into electrons and protons through the catalyst (usually platinum) in the positive electrode. Protons travel through a proton exchange membrane to the negative electrode and react with oxygen to form water and heat, while the corresponding electrons flow from the positive electrode to the negative electrode. Hydrogen fuel cells are varied by different types of porous membranes.

The terminal goal of 'carbon peak' and 'carbon neutral' is to transform carbon consuming fossil fuel into clean renewable fuel, as well as transforming high carbon fuel into low carbon fuel. As a result, it is actually a process of adding hydrogen and reducing carbon in the fuels. This conclusion reveals that green hydrogen discarding carbon shall be the final target of new energy in the future.

As a source of energy, hydrogen has non-negligible potential value, benefited from its high efficiency and high energy abundance. H is the most commonly existing element in the natural world. It is estimated that about 75% of the universe is made up of it, and it is mainly stored in the form of water. Water is also the compound most commonly seen on Earth. Hydrogen has the highest caloric value among all the fossil fuel, industrial fuel and bio fuel, for 142.351 kJ/kg. This is about 2 times larger than gasoline, 3.9 times of alcohol and 4.5 times of coal [1].

Hydrogen is the lightest element. Under the standard condition(298K,100KPa), the density of hydrogen is 0.0899g/L. Hydrogen can occur in the form of gas, liquid, solid and metal hydrides, facilitating various types of transport and environmental requirements. Hydrogen is nontoxic, and it is cleaner than other fuels--it only produces water and little amount of hydrogen nitride. Simply small amount of hydrogen nitride will not affect the environment, and water can be reused to prepare hydrogen gas.

There are a wide range of applications for hydrogen. It can provide thermal energy through burning, produce mechanical energy in heat engine, be applied in fuel cells, as well as solidified into construction materials. Substitute coal and oil into hydrogen avoids big revolution in contemporary technical equipment as the internal combustion engines can suit it very well within a few reconstructions.

Therefore, many countries chose to develop strategies and policies to promote hydrogen fuel. Under the background of the first oil crisis caused by war in Middle East in 1970s, the U.S. government first proposed the idea of 'hydrogen economy'. By the same time, China and Japan also began their exploration in hydrogen. Until 2023, there were 43 thousand patent applications from China, taking up 31.4%; Japan had applied for 41 thousand patents, sharing 30.2% of the total; US had 21 thousand patents applied, making up the proportion of 15.2%. This article will study the relationship between government leadership and the development in hydrogen related technology. By comparing and contrasting the data from the three main power of the hydrogen market, the author aims at finding the relationships between hydrogen fuel development and these factors, to give an expectation on the future of hydrogen power.

2. Mechanisms for hydrogen fuel cell

All fuel cells have similar mechanisms, their structure contains electrolyte, a porous separator and two electrodes. Hydrogen molecule enters the fuel cell, and when it tries to move across the proton exchange membrane, electrons are split out and move through negative electrode to positive electrode. Oxygen is pumped around the positive electrode; the oxygen molecule gains electrons and combine with proton to form water. The reaction does not evolve combustion so it will not explode.

Hydrogen is a typical secondary energy, which means that it does not naturally exist in the Earth's environment. There are three types of hydrogen fuels, categorized by the way they are prepared. Gray hydrogen and blue hydrogen are both made from burning crude oil, whereas gray hydrogen produces plenty of carbon emission and blue hydrogen can seal the carbon emissions during the production. Blue hydrogen can also come from decomposition of methanol and ammonia gas. Green hydrogen is completely clean in the manufacture stage. It stands for hydrogen coming out from nuclear power or water electrolysis. Nowadays, about 96%-97% of hydrogen energy came from fossil fuel,which is gray hydrogen. are trying to transform more gray hydrogen into blue and green hydrogen.

Hydrogen has an explosion limit of 4.0% to 75.6%, which means that transporting hydrogen improperly may lead to an explosion easily [2]. Also, it is hard to store enough amount of hydrogen gas in a vehicle due to its low density.

3. Oil crisis and government policies

Because of the special properties of hydrogen, many countries around the world are paying attention to it as a significant strategic energy. As early as the 1970s, the US had successfully applied fuel cell on the Apollo spaceship. Nevertheless, until the late 20th century to early 21st century, the high cost was problematic that research and development in this area was obstructed. When it came to 2014, a huge breakthrough in Japan's fuel cell technology as well as the deficiency of coal and oil arouse the attention of hydrogen again [3].

3.1. United States

Influenced by the first and the second oil crisis both happened in the 1970s, United States of America started to propose the concept of 'hydrogen economy'. the first International Conference on Hydrogen Energy was held in Miami. After that, International Hydrogen Energy Association was set up there. It is the international hydrogen organization with the longest history [3].

In 2002, the government published the Development Strategy of National Hydrogen Energy, being the first time for America to put the theory of hydrogen industry into practice. Since 2003, America started the project of Presidential Hydrogen Initiative,120 million dollars were spent into investing hydrogen energy on commercialization. In 2012, president Obama handed in 3.8 trillion dollars to the congress, and 6.3 billion were funded to energy department for hydrogen, fuel cell and other clean energy [3]. Comprehensive Energy Strategy was published two years later during a serious global climate issue was giving pressure, and investment continued to support work done in hydrogen

industrialization and developing fuel cells. The US has the second largest number of patent applications around the world, taking up 15% in hydrogen storage techniques.

3.2. Japan

The oil crisis in the 1970s also effected Japan for its high international-oil-relying economy. From 1992 to 2002, the hydrogen energy association successively came on 'the sunshine project' 'the moonlight project' 'the new sunshine project' and the 'WE-NET project', covering both hydrogen production and transportation [4].

Toyota Motor participated the research and application in hydrogen fuel cell vehicle since 1992.[4] However, in order to achieve energy independence and a goal of cleaner energy, during this period, the mainstream of Japan's energy transition was nuclear and liquefied natural gas. Fukushima nuclear disaster in 2011 was a huge crackdown of nuclear energy. The restarting of coal electricity induced heavier environmental pressure. The conceive of 'hydrogen society' was proposed under this condition. In 2014, hydrogen fuel was put into practice. in 2017, 'the basic strategy of hydrogen' aimed at minoring cost in hydrogens and electricity's generations [4].

In the past 30 years, Japan government spent hundreds of billions of Japanese yen, kept funding for research and public promotion of hydrogen fuel. Several strategies and blue maps were declared after that. In 2019, it was already the third time for Japanese government to modify the Strategic Development Road map of Hydrogen Energy and Fuel Cell.

Generally speaking, the improvements in hydrogen exploration of Japan was already boosting within the 2000s partially due to the third oil crisis in 1990, and the patents in porous membrane shows the most significant influence. Nevertheless, this trend is no longer seen in the later ten years, not only caused by the gradually mature hydrogen energy application, but also the industrial impact of electric cars. In other words, hydrogen battery was not as popular as new energy vehicles, and there was a reasonable decline in the enthusiasm in hydrogen field.

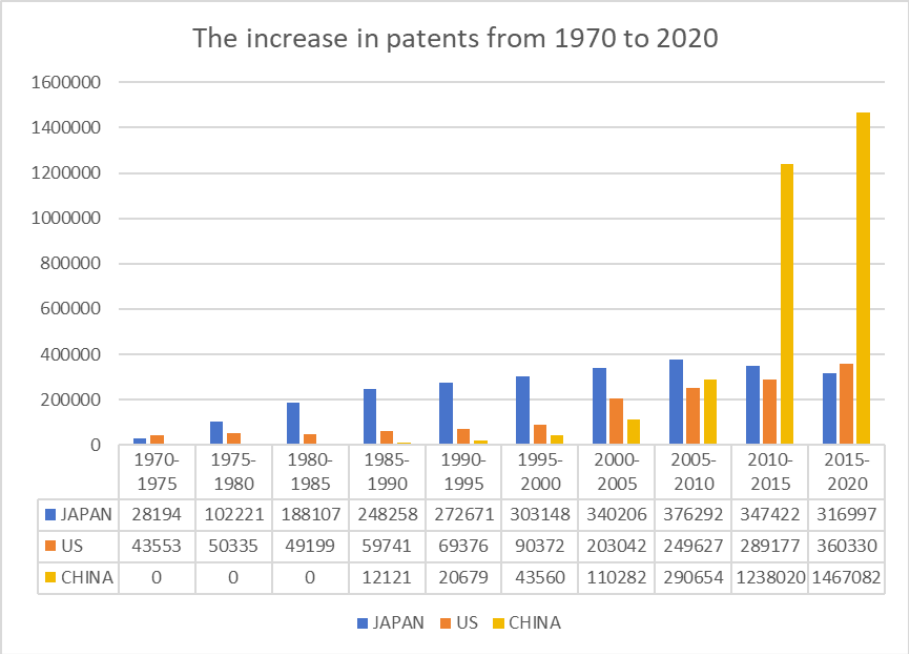
3.3. China

Although the exploration also began at around the 1970s, it was already 2000 for China to attach the importance to the potential of hydrogen. In the 1990s, fuel cell was in the list of the National Science and Technology Project. Most of the plans were made by long-term goals for about 5 years. Taking the statement from 2014 to 2020 published by state council as an example, developing low-carbon emission energies shall be the main target. This is also the time when China began to publish detailed plans and subsidy policies [5].

The patents could show that hydrogen fuel was a flourishing topic in China after 2000. Benefited from the fundamental exploration of US and Japan, research breakthroughs in hydrogen transporting and fabricating continued to thrive.

4. Analysis for the effects of government policies by patent number

This article uses Incopat as the data source of patents, take the hydrogen industrial chain as analysis object, uses key words to construct the formula. Fig.1 reveals the trend and when number of patents both applied for and authorized flourished in half a century after 1970. It is obvious that for the first 15 years, Japan and America are leading this trend as the pioneers of hydrogen preparation and transportation. The ascending process steadily went up while the trend in Japan was more significant. This corresponded to the continuous support in Sunshine and Moonlight projects. The new coming of patents in the USA was quite stable before 1995-2000. after that, the bar showed a gap between 90372 and 203042. this can be understood as it was the development strategy that guided a clear blue map of hydrogen fuel industry. The evolution of China was initially slow. The prosperity of hydrogen didn't begin until 2000. the phenomenon can also be explained by the Project in the 90s.



	1970-1975	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020
JAPAN	28194	102221	188107	248258	272671	303148	340206	376292	347422	316997
US	43553	50335	49199	59741	69376	90372	203042	249627	289177	360330
CHINA	0	0	0	12121	20679	43560	110282	290654	1238020	1467082

Fig 1. The increase in patents from 1970 to 2020.

When the era of 21st century began, the topic of hydrogen energy became popular again due to the energy dilemma and environmental issues. Electrolysis of water turned out to be the most famous one for its high fit with solar and wind energy. This partially caused a decline in Japan's hydrogen industry. This is because there were no longer markets for hydrogen vehicles seen in China and America. Financial support is no longer persuasive.

5. Conclusion

Giving the information above, we can see that the progress in hydrogen area is relevant to government's proper guidelines. To face the new theme of carbon neutral in this decade and after, the hierarchy of countries responsible should take actions prudently and decisively to face challenges and opportunities.

References

[1] Wang Lina, Shi Zhe, Wang Yuhui. Development Status and Prospect of Hydrogen Energy Industry,20220130,20230831

[2] Xiao Luomeg,The breaking Logic of Hydrogen Development,20230515,20230831

[3] Liu Yun,After Half a Century of Development, Why Hasn't Japan's 'Hydrogen Economy' Come, 20220830,20230831,https://www.kunlunce.com/ssjj/ssjjhuanqiu/2022-08-30/163610.html

[4] Liu Tao,Ten Facts You Don't Know About Hydrogen Industry,20191018,20230831,https://news.bjx.com.cn/html/20191018/1014245.shtml.

[5] Sun Yuling,Hu Zhihui,Qin Aning, Teng Fei, Lin Hancheng, Analysis of Global Hydrogen Industry Development Strategy and Technology Layout, 20230831.