

High-quality Development Path of Hydrogen Energy Enterprises under the Goal of Carbon Neutrality

Jiaxin Hang¹, Cheng Wenhong^{1,*}, Bin Li², Chennan Hua¹

¹*School of Business, Jiaxing University, Jiaxing, Zhejiang, China*

²*School of Biological and Chemical Engineering, Jiaxing University, Jiaixng, Zhejiang, China*

**Corresponding Author.*

Abstract: Under the current strategic goal of "double carbon" in China, hydrogen energy, as one of the energies in the next era, has become a "hot" energy carrier with its high energy storage density, clean efficiency, net zero carbon emissions and sustainability, and has also become the key direction of the development of the new energy industry. Despite the strong support of policies, it is still in the development process. There are problems such as insufficient technological innovation and incomplete business models. Taking the development of the hydrogen energy industry(HEI) in JiaXing as an example, this paper makes an in-depth analysis of the current situation, characteristics, and economy of the HEI, puts forward improvement measures according to its shortcomings, and predicts the future development trend to help achieve "carbon neutrality" and "carbon peak".

Keywords: Carbon Neutral; Carbon Peak; Hydrogen Energy; Clean Energy; Industrial Development

1. Introduction

In September 2020, the country officially put forward the "double carbon" strategy, which requires carbon emissions to peak by 2030 and achieve the strategic goal of carbon neutrality by 2060. The definition of these two keywords is: "carbon peak" refers to the gradual reduction of emissions in a certain period of time after the total annual carbon dioxide emissions reach a historical peak, that is, the turning point of carbon dioxide emissions from high to low is the carbon peak; and "carbon neutrality" refers to a series of high Effective cleaning methods thus offset unnatural and man-made carbon dioxide emissions and achieve the goal of zero net

emissions.

After the signing of the Paris Agreement, in order to achieve rapid and long-term development of energy, economy and society, how to deal with climate change has become a top-level strategy. Low-carbon energy with green and clean properties is regarded as a key target for future energy development. As a potential stock for sustainable development in the new century, hydrogen energy has attracted great attention worldwide, and relevant industries in China have paid extensive attention to this secondary clean energy, which is expected to become one of the key factors for China to achieve the "double carbon" goal and play an important role in future energy transformation [1].

Under the above background, China's hydrogen energy enterprises have formed a market-oriented main body of clean energy innovation technology, which not only maintains the original innovation momentum in development, but also considers high quality. Therefore, how to develop hydrogen energy with high quality has become an important issue under the goal of carbon neutrality.

Due to the outstanding structural problems in the development path of China's traditional HEI, there are a series of problems such as unsound industrial standard system, limitations in technological innovation ability and shortcomings in promoting hydrogen to civilian business models. Therefore, in the context of achieving the goal of carbon neutrality and responding to the high-quality development of energy, the exploration of energy development paths has become more and more prominent. This paper will take the HEI in Jiaxing as the analysis goal and explore the current advantages and remaining problems of the industry through classification and comparison, so that relevant

energy enterprises can better respond to the dual-carbon target and put forward suggestions for improvement.

2. Literature Review

2.1 Current Situation of Foreign Research

Professor Jeffrey Sacks, chairman of the United Nations Sustainable Development Solutions Network and director of the Center for Sustainable Development Research at Columbia University, pointed out that from a global perspective, developed countries attach great importance to the development of hydrogen energy, because hydrogen energy is a high-quality raw material and sustainable development. Clean energy on display [2].

Britain has proposed technical support for hydrogen energy strategy, including "blue" carbon hydrogen capture and "green" electrolysis; France has achieved hydrogen energy decarbonization through four steps, first of which is to form a large-scale electrolysis hydrogen decarbonization technology, secondly phase out carbon-based hydrogen, then strengthens the use of dicarbon hydrogen in large vehicles, and finally supports hydrogen. Technological innovation and development.

At the same time, the United States is also actively carrying out projects to produce clean hydrogen. The Utah Power Project, a construction project in the United States, uses natural gas and clean hydrogen to achieve tens of megawatt-hours of power generation. So far, there are related projects under construction to electrolytic water hydrogen production of more than 620 megawatts in the United States.

2.2 Current Status of Domestic Research

Through previous literature research, it is found that the speed and quality of China's HEI are improving day by day, and there have been profound changes in both policy support and market application.

2.2.1 The development and innovation status and policy environment of China's HEI

In order to achieve the goal of "carbon peak and carbon neutrality", hydrogen energy has become an excellent energy carrier with its characteristics of zero carbon emissions, sustainable utilization, green efficiency, and high energy storage density, thus extending

the large-scale chain industrial system and promoting related fields and industries such as new technologies and new materials. Expansion of the industry [3].

The "double carbon" strategic goal is an important action for all human beings to address the challenges of climate change and energy crisis, and the goal of carbon neutrality is far-reaching and systematic economic change for society. In 2019, China's carbon emissions ranked first in the world, and the emission intensity has been significantly higher than the world average. Compared with developed countries, China faces greater difficulties in achieving the "double carbon" goal in a more urgent and more extensive latitude. Therefore, it is particularly important to study the high-quality development path of the HEI.

2.2.2 Vigorously building a HEI is an important means to achieve carbon neutrality

At present, hydrogen energy plays an important role in China's high attention to carbon neutrality. Liu pointed out that the essence of tapping the domestic market space and giving full play to the potential of the domestic market is to develop the whole HEI in an all-round and efficient manner [4]. In order to achieve the upcoming "double carbon" strategy and carbon neutrality goals, we must plan and form corresponding industrial and technological support.

Once hydrogen energy is well developed with high-quality innovation and development, it will become a relatively complete socio-economic system, and its expected strategic and economic value is immeasurable. Li Chenglin (2021) pointed out that it is also difficult for more developed countries with hegemony in a non-hydrogen society to sanction a less developed country in a hydrogen society [5].

2.3 Research Summary

Based on the current research situation at home and abroad, it is found that from a global perspective, developed countries attach great importance to the development of hydrogen energy. However, when analyzing the development and innovation status of China's HEI, it is found that compared with the HEI in other developed countries, China started relatively late and there is a big gap in construction and development scale. It is

specifically reflected in material manufacturing, product performance, industrial scale, and time cost.

At present, in the investigation and research of the HEI in China, which is still in its infancy, it is found that the industrial chain has not been fully opened, and the development of the business model has not been tested by the market. Among them, production, transportation, and sales are not concentrated together, which hinders the layout and future planning of the HEI. In addition, affected by the infrastructure construction of hydrogenation stations, fuel cell development costs, technology and other factors, the application scenario of hydrogen energy is relatively simple. China is mainly used in the field of transportation, and its

process is relatively backward with the global hydrogen energy industrialization [6].

Many international leading hydrogen energy enterprises have now entered the domestic market. As a result, the competition in the energy market has gradually become fierce. Once the technology is "overhead", it may cause the loss of the company's industry. Therefore, it is urgent for hydrogen energy enterprises to carry out high-quality development.

3. Current Situation of Economic, Social and Energy Development

3.1 Economic and Social Overview

3.1.1 The relationship between energy consumption and economic development

Table 1. The Relationship between Energy Consumption and Economic Development

Index	2022	2021	2020	2019	2018
Gross national income (billion yuan)	1197250.4	1141230.8	1005451.3	983751.2	915243.5
Gross domestic product (billion yuan)	1210207.2	1149237.0	1013567.0	986515.2	919281.1
Total energy consumption (tons of standard coal)	541000	525896	498314	487488	471925

Data source from: National Bureau of Statistics

According to the table 1, with the growth of the economy, the total energy consumption has also increased. At the same time, it is calculated that from 2018 to 2022, the growth rate of GDP is about 24%, while the growth rate of energy consumption is about 12%,

indicating that the growth rate of regional GDP is higher than the growth rate of energy consumption. It is concluded that the growth of China's economy can offset its dependence on energy consumption.

3.1.2 The relationship between energy consumption and industrial structure

Table 2. The Relationship between Energy Consumption and Industrial Structure

Index	2022	2021	2020	2019	2018
Gross national income (billion yuan)	1197250.4	1141230.8	1005451.3	983751.2	915243.5
Gross domestic product (billion yuan)	1210207.2	1149237.0	1013567.0	986515.2	919281.1
The added value of primary industry (billion yuan)	88345.1	83216.5	78030.9	70473.6	64745.2
The added value of secondary industry (billion yuan)	483164.5	451544.1	383562.4	380670.6	364835.2
The added value of tertiary industry (billion yuan)	638697.6	614476.4	551973.7	535371.0	489700.8

Data source from: National Bureau of Statistics

From the above table 2, it can be seen that China's current industrial structure is presented in a "three-two-one" structure, and the gradual expansion of the proportion of tertiary industry can alleviate the problem of

resource dependence in the secondary industry in the past.

3.2 Energy Overview and the Development of the HEI

3.2.1 Energy overview

Table 3. Energy Overview and the Development of the HEI

Index	2022	2021	2020	2019	2018
Total energy consumption (tons of standard coal)	541000	525896	498314	487488	471925
Coal as a share of total energy consumption (%)	56.2	55.9	56.9	57.7	59.0
Oil as a share of total energy consumption (%)	17.9	18.6	18.8	19.0	18.9
Nature gas as a share of total energy consumption (%)	8.4	8.8	8.4	8.0	7.6

Data source from: National Bureau of

Statistics

According to the above table 3, the total energy consumption in China is growing steadily, and coal and petroleum resources have always accounted for a large proportion of the total energy consumption. China relies on traditional energy sources, such as oil and coal, which also leads to the country's need to import a large number of these energy sources from the international market, and factors such as rising international resource prices and supply shortages are likely to affect China's energy supply and economic stability. In addition, although China is rich in coal and oil reserves, there is still a risk of resource depletion over time, which also promotes China's development from traditional energy to new energy.

3.2.2 Development of HEI

After years of development, the development rate of the national HEI has grown rapidly, and the scale of the industry is also expanding. According to the White Paper on China's Hydrogen Energy and Fuel Cell Industry (2020) [7], Chinese annual hydrogen production capacity is about 4.1×10^7 t, and the annual output is about 3.342×10^7 t.

By the beginning of 2022, China had 255 hydrogen refueling stations and 9,315 hydrogen-fueled battery vehicles, which has become the world's largest commercial fuel cell vehicle market and the largest country of hydrogen energy production.

From the analysis of the future planning direction of the HEI, dozens of provinces (cities) and regions such as Beijing, Shanghai, Zhejiang Province, Shandong Province, Henan Province, and Sichuan Province have carried out implementation plans and action plans for the HEI. According to a survey conducted in provinces (cities) and regions that have been announced and implemented, it is estimated that more than 150 thousand fuel cell vehicles will be promoted by 2025, and more than 1,000 hydrogen fueling stations will be built and completed.

The output value of the HEI market is expected to grow rapidly and exceed 960 billion yuan. In addition, in terms of analyzing the future R&D funds invested by China, although the industrial layout of the energy is relatively late, it has gradually become the largest increased country with the largest increase in R&D budget [8].

3.3 The Necessity of Development and

Innovation in the HEI

From the above data, with the continuous development of the economy, the transformation and development of the energy industry is imminent, and hydrogen energy, as the clean energy with the lightest weight, abundant reserves, and high utilization rate, undoubtedly provides a good path for energy transformation and development.

Hydrogen energy is a difficult or indispensable part of building a green energy system, and the excellent properties and future development of hydrogen are indisputable. Analyzing its industrial development, it will be found that the current market can be described as a "influence", but enterprises should first calmly evaluate the investment environment of the energy market after seeing the future promising HEI development market. For example, the industrialization and commercialization of the fuel cell automobile market is still relatively backward compared with other industries, especially the market environment and industrial ecology that have not yet been built, and there are still many problems and difficulties in the market for the promotion and application of hydrogen energy.

At present, global energy is rapidly transforming into clean energy, and domestic hydrogen energy is also facing the following challenges. First, it is necessary to meet the future growth of the economy and the supply demand of energy, especially the unresolved problems in hydrogen production and storage technology. Secondly, the structure of the HEI should be gradually adjusted, and the overall R&D, supporting, operational capabilities and supporting facilities of enterprises cannot keep up with the international pace. Finally, breakthroughs in core technologies are difficult, and there is a big gap between the country's most critical self-owned technologies and developed countries. However, even if there will be difficulties and challenges in the process of building a hydrogen energy society, the above problems are the only way for every country to develop and transform.

4. Analysis of the Strategic Transformation Path of Hydrogen Energy Enterprises

Since the improvement of industry concentration is an inevitable trend, this paper

will take the development of Jiaxing HEI, the representative of HEI in the Yangtze River Delta region, as an example for further analysis.

4.1 Develop HEI Based on Regional Advantages

The first pilot city to develop HEI in Zhejiang Province is in Jiaxing, and it is also a demonstration city leading the development of HEI in the Yangtze River Delta, which gives full play to its role in connecting with Shanghai's "bridgehead" area, and focuses on the construction of Jiaxing Park, a HEI in the Yangtze River Delta in Jiaxing Port Area.

The strategic goal of carbon neutrality has accelerated the arrival of the new energy era [9]. Promoting the high-quality development of the integration of the Yangtze River Delta has now become a national strategy. As can be seen from figure 1, Jiaxing has a superior urban location, and is bordered by Shanghai in the east, Hangzhou Bay in the south, Hangzhou in the west and Suzhou in the north. It's located in the geometric center of the Yangtze River Delta and closely interacts with the society and economy of surrounding cities.

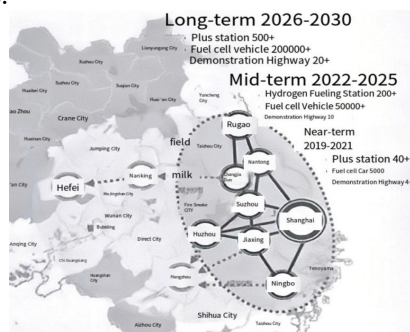


Figure 1. Strategic Spatial Layout of the Yangtze River Delta Hydrogen Corridor

In 2019, Jiaxing City docked with a few HEI projects, and the Provincial Development and Reform Commission clearly listed Jiaxing as a demonstration pilot for the development of

HEI and technological innovation. As shown in Figure 1, the government actively promoted the construction of relevant hydrogen energy projects and strongly supported Jiaxing City to develop the energy industry and give priority to demonstration and application pilots. For example, in 2022, the American Air Products Company built China's first large commercial liquid hydrogen factory in Haiyan County, Jiaxing City, Zhejiang Province and put it into production and use.

In summary, due to regional advantages and the support of policies, Jiaxing City has seized the development opportunities of the HEI and carried out a series of pilot demonstration projects for the HEI, which has made great contributions to the realization of the "double carbon" goal.

4.2 Develop the HEI Based on the Complete Industrial Chain

Compared with other cities in China, Jiaxing has more advantages, feasibility, and operability in terms of energy industry scale development and regional construction. As can be seen from table 4, in order to build a new pattern of the development of the HEI, Jiaxing City has basically realized hydrogen energy production built by hydrogen storage, preparation, filling and core hydrogen energy equipment components and fuel cell power systems through a strong chain investment in a large number of leading enterprises in the industry, such as Fengyuan, Meijin, Guohong, etc. The overall layout of the industry chain.

The HEI in Jiaxing has a large scale and a wide industrial coverage. As shown in figure 2, whether it is downstream systems, components and parts, or upstream hydrogen production, the upstream and downstream industrial chain of energy has developed relatively completely, which greatly improves the industrial green innovation ability.

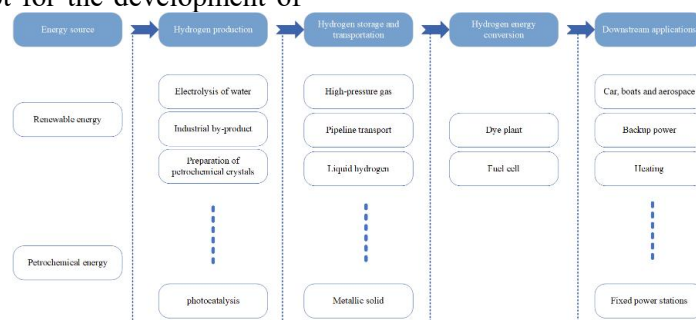


Figure 2. The Whole Industrial Chain of Hydrogen Energy

Table 4. Distribution of Hydrogen Energy Upstream and Downstream Industrial Chain in Jiaxing

Industrial links	Classification	Product	Jiaxing local enterprises
Upstream Industry	Hydrogen production	Industrial by-product hydrogen	STL, Zhejiang Jiahua Energy
		Liquid hydrogen	APD
Midstream Industry	Store up and transport	70MPa hydrogen cylindre, etc	Jiaxing Deyi new material
Downstream Industry	Basic material	Catalyst	Fenergy
		Proton exchange membrane	HYPROOF
	Key components	Membrane electrode	Edelman, Fenergy
		Bipolar board	Edelman, Fenergy
		Air compressor	D.R. Power
		Hydrogen circulation system	D.R. Power
	System reactor	Electric reactor	Edelman, Meijin, Fenergy
Fuel cell system		Edelman, D.R. Power, Meijin	

4.3 Development of HEI Based on Technological Innovation

In 2016, Jiashan County, Jiaxing City, Zhejiang Province, cooperated with Edelman for the first time to carry out a battery project with hydrogen energy as fuel, and in order to inspect the project, it invited experts from

hydrogen energy and other related industries to evaluate the maturity of the project and the advancement of technology. And successfully signed the contract in April 2016, promoting the speed of the project's landing, and the 35-45KV hydrogen-fueled battery stack of Edelman's own technology was produced.

Table 5. Development Indicators of HEI in Jiaxing

number	Core indicator	2025 target	2035 target
1	Total output value (billion yuan)	> 400	> 1000
2	R&D funding as a proportion of GDP (%)	> 5%	> 8%
3	Listed companies in the HEI	3	—
4	Introduce leading enterprises	≥ 10	≥ 20
5	Hydrogen energy-related enterprises above	≥ 50	—
6	Professional innovative enterprise	≥ 15	≥ 30
7	Hydrogen energy supply capacity	≥ 25	≥ 40
	Among them: high purity oxygen	≥ 10	≥ 30
8	Hydrogen fuel cell vehicle promotion	> 2500	> 10000
9	Hydrogen fuel cell bus demonstration line	≥ 10	—

Jiashan County takes technological innovation as the focus, actively promotes the pilot demonstration of fuel cells and hydrogen energy, promotes the introduction of advanced and widely used technologies such as hydrogen storage technology and control systems, and cooperates with relevant well-known universities in China that carry out in-depth research on hydrogen energy after digestion and absorption. At present, successful industrial projects have been implemented. In addition, Jiashan County has also built the Zhejiang Hydrogen Energy Equipment Research Institute, which focuses on core hydrogen energy components, so as to jointly promote the research and development

of hydrogen energy equipment and the research of advanced scientific common technologies.

It can be seen from the data in table 5, as one of the leading cities in the development of the HEI in the Yangtze River Delta region, Jiaxing City has continuously improved the whole chain of hydrogen energy and carried out technological innovation through academic forums, research cooperation and other means to add impetus to the smooth development of the HEI.

5. Implementation Strategy for the Transformation of Hydrogen Energy Enterprises under the Goal of Carbon

Neutrality

Under the goal of carbon neutrality, carbon-based energy will leapfrog to non-carbon-based energy, and the energy system will accelerate the transformation to low-carbon and zero-carbonization. Fossil energy will gradually transition from the main energy to guaranteed energy, and new energy will gradually become the main clean energy [10]. From the above examples, it can be seen from the exploration of the development path of Jiaying's HEI that to actively transform hydrogen energy enterprises under the national carbon neutrality goal, there are the following implementation measures:

5.1 Strengthen the Top-level Design for the Development of HEI

We will accelerate the implementation of the "1+N" policy support system for hydrogen energy development, closely follow the "double carbon" goal, and plan the development path of the HEI, mainly from the three aspects of energy supply, industrial production, and energy consumption.

In terms of energy supply, in order to supply a sufficient amount, large-scale and long-term periodic energy storage is the ideal choice. In industrial production, the hydrogen production process cannot be won by quantity. It is also necessary to guide the hydrogen production process from high carbon to low carbon and encourage the development of renewable energy to produce hydrogen, so as to reduce carbon emissions from the source. In terms of energy consumption, it is urgent to expand the application range of clean and low-carbon hydrogen energy in energy terminals and significantly reduce carbon dioxide emissions.

5.2 Improve Hydrogen Energy Scientific and Technological Innovation to Achieve High-quality Development

We will improve the hydrogen energy research and development system, increase investment in research and development, and guide diversified hydrogen energy technology innovation in an orderly manner. Cooperate with upstream and downstream enterprises in the industrial chain and regional hydrogen energy research platforms to carry out cooperation and development, focus on key core technologies, and concentrate resources

on scientific and technological research and development in the field of hydrogen energy.

5.3 Improve the Whole Industrial Chain of Hydrogen Energy and Increase Pilot Demonstration and Promotion

In the upstream industrial chain, we actively respond to the latest "wind, light, storage and hydrogen" integration project, and strive to realize green hydrogen instead of gray hydrogen to achieve deep coordination of integrated coupling, production, and fusion. In the midstream industrial chain, we actively develop new storage and transportation methods such as solid state, deep cold and high pressure to form a low-input, high-density storage, and transportation system with diversified hydrogen energy. In the downstream industrial chain, starting with the pilot demonstration, we will gradually expand the scale of application, strengthen supervision, strengthen the price mechanism for regulating carbon emission transactions, carbon taxes, etc, and provide a good market environment for the operation of the HEI.

5.4 Update the Traditional Business Model

The HEI should be committed to transforming from a single supplier model, operator model and end-user model under tradition to a diversified integration model in the new economic environment, combining hydrogen energy with other fields, so that it can have flexible cooperation and diversified sales forms and become a new cross-domain industry. Therefore, over time, the global HEI ecosystem can be established, making it gradually become an ecosystem, increasingly reflecting the characteristics of multiple integration models.

6. Conclusions

Hydrogen energy is indispensable in building a green energy system. There is no doubt about its excellent attributes and future development, but its market environment and industrial ecology are not yet fully built, and the industrial market is relatively backward. Through the analysis of the current research situation and policy environment at home and abroad, from a global perspective, developed countries usually pay attention to the development of hydrogen energy.

Compared with developed countries, the

current situation of the development and innovation of China's HEI is relatively late, and there is a big gap in the scale of construction and development. The gap is mainly reflected in the fact that the HEI chain has not been fully opened, and the development of the business model has not been tested, in which the production, transportation and sales links have not been concentrated. Therefore, there are still many unsolved problems and difficulties in the promotion and application market of hydrogen energy.

From the perspective of the macro environment, combining energy consumption, economic development and industrial structure, the development of China's economy can offset its dependence on energy consumption and expand the industrial scale. At present, China has become the country with the largest hydrogen energy production. Therefore, the hydrogen energy research and development funds invested by China in the future will gradually become the country with the largest increase in R&D budget.

According to the above problems, this article is about the strategic transformation path of hydrogen energy enterprises and the specific implementation strategy of the transformation of hydrogen energy enterprises under the goal of "carbon neutrality".

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