



Study of the upstream and downstream industries of traditional coal energy and new hydrogen energy to envisage the further sustainable energy development pathways in China

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Abstract. The energy structure of China is in urgent need of transformation and reform. New energy is a necessary path for sustainable development. Hydrogen as a new energy, clean energy and renewable energy in recent years has received more attention. However, traditional coal energy still occupies the main energy market in China, and it is difficult to completely transform to new energy in a short time. Hence, to achieve sustainable development of the combination of traditional coal energy and new hydrogen energy, this study provides new insights into the sustainable development of China energy resources by examining the development of upstream and downstream industries of traditional coal energy and hydrogen energy in recent years. Moreover, the development of hydrogen energy in other developed countries, such as the United States and Japan are also reported. Finally, the paper concludes the suggestions and directions for sustainable energy development in China.

Keywords: Sustainable development, green energy economics, economic transition of energy field.

1 Introduction

Nowadays, the rapid technological and economic development within more industries and products require higher energy consumption. The development of energy sources has become one of the problems to be solved. Moreover, the consumption can also cause air pollution, environmental pollution and greenhouse gases. Therefore, the extremely high growth of traditional fossil energy consumption has become one of the energy issues that will continue to be addressed in the future. Coal as one of the traditional fossil energy sources, coal occupies a pivotal position in Chinese energy industry structure. In 2016, coal was the main energy supply for the power generation and smelting industries, accounting for 66% of total national power generation and providing about 70% of industrial energy supply [1, 2]. As a result, the upstream mining industry of coal is important. However, coal releases large amounts of greenhouse gases and other by-products during the combustion process of the downstream indus-

try, causing harm to the environment and the air. According to statistics, in 2017, the amount of carbon dioxide emitted from burning coal accounted for 44% of the global carbon dioxide emissions from total fuel combustion [3]. Therefore, the future direction of coal energy will focus on more efficient and cleaner usage. This study will discuss the upstream and downstream of coal energy in recent years and the future route of development. The emergence and development of new energy sources is also an aspect of Chinese energy reform. Clean energy and renewable plays an important role in gradually realize the replacement of traditional fossil energy. This will reduce the emission of greenhouse gases and air pollutants, enrich the country's energy structure and reduce dependence on a single energy source. At the same time, the utilization of new energy sources also contributes to the achievement of sustainable national and social development. There are also many new forms of clean and renewable energy, such as wind, solar, seawater power generation and hydrogen energy. Hydrogen energy has become one of the popular clean energy sources due to its combustion final products, which is only water, and it can release higher energy by the high temperature combustion process. Hence, this study will discuss the development and related upstream and downstream industrial structures of hydrogen energy in China, and through comparing the upstream and downstream structures of hydrogen energy in other countries to discuss the future development directions of hydrogen energy in China. Figure 1 shows the analysis pathway of this study.

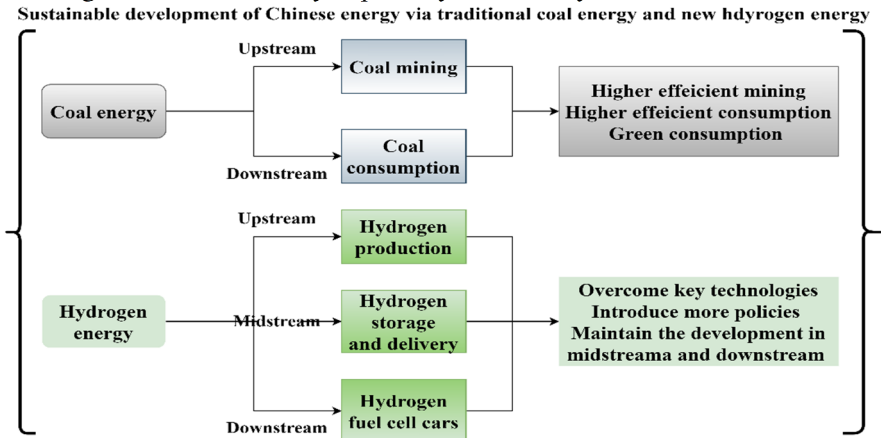


Fig. 1. summary of the structure of this study.

2 Discussion and results

China is rich in coal resources, with large coal reserves in Shanxi, Inner Mongolia and other provinces. In contrast, China is relatively poor in petroleum and natural gas. Coal energy is still working as the main source of energy in China. Therefore, the reform and sustainable development of China's coal energy industry is significant to the structure of Chinese energy supply and energy security. There are several factors can affect coal development such as coal mining, coal consumption and relative com-

bustion technologies. The two most important factors are the mining and consumption as upstream and downstream industry. Coal mining in China is in two main ways, underground mining and open pit mining. Underground mining is due to coal is deposited in sedimentary rock formations in the earth's crust by the geological action of plant remains over a long period of time. Therefore, underground mining involves the construction of underground tunnels to transport workers and mining equipment to the sedimentary rock formations to carry out the mining operations. Open pit mining is the process whereby some of the coal is transferred from the earth's floor to the surface layer during crustal movement, thus it is not required for construction of underground pits and allowing direct operations at the surface of the earth's crust. Hence, the advantages and disadvantages through two main coal mining in China can be concluded [4]. Underground mining normally does not account a significant amount of surface area, and the dust and pollutants generated during the mining process will be finely controlled and not affect on the surface air. In addition, underground mining can avoid subsidence and contribute to protect geological stability. However, underground mining carries a risk of collapse. Therefore, maintaining a stable and safe operating environment in the pits is necessary, and the associated costs are high. Open pit mining can save cost on construction and easier to operate but occupying more areas on the ground and damaging on the air environment. Table 1 concluded the output efficiency, the cost of investment, maintenance, other costs and lifetime of several different underground mining and open pit mining. The investment cost of underground mining is nearly 10 times than open pit mining, as well as maintenance and other costs. Moreover, the lifetime of open pit mining is nearly same and even longer than underground mining. Therefore, it is suggested that the open pit mining should be further developed in China to create more cost-effective mining solutions with less air pollution.

Table 1. Comparison of several underground mining and open pit mining via costs and lifetime [5].

	Output efficiency (%)	Investment (CNY/)	Maintenance (CNY/t)	Other-costs (CNY/t)	Lifetime (Years)
Underground mining	35	1285	88	86	60
	30	611	50	49	50
	30	1421	145	142	40
	30	1803	123	120	60
	35	2451	167	163	60
	35	2325	190	186	50
	30	2319	237	232	40
	Open pit mining	35	272	24	23

The downstream of coal energy is the coal consumption. Coal energy is widely used in various industries in China. Figure 2 shows the coal consumption applications from 1995 to 2016. The consumption of coal energy increased from 1.5 Bt to around 4 Bt from 1995 to 2014 with the increasing coal consumption in the power and heat generation. However, the coal consumption of manufacturing of non-metallic mineral

products and chemical products are decreasing from 2014 to 2016. And total amount of coal consumption is decreased from 2014 to 2016. This is due to the aiming of carbon neutral in China.

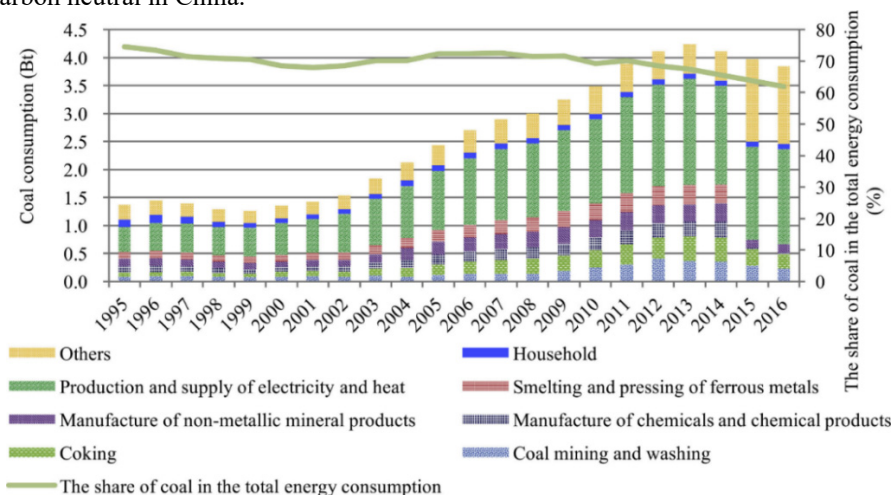


Fig. 2. Varied applications of coal consumption from 1995 to 2016 with amount of coal consumption (Bt) and percentage of each fields (%) [5].

The highly efficient power generation technologies also contribute to the lower consumption of coal energy. China has developed efficient and cleaner power generation technologies and retrofitted old generating units in recent years, resulting in higher efficiency of power generation, reducing carbon dioxide and pollutant emissions. The future development of coal energy should consider the coal mining and consumption. Most coal mining of China is still underground, the more efficient, safer, and lower-cost underground mining models should be developed to increase the rate of coal extraction and reduce the waste of coal in the mining process. The application and consumption of coal energy should follow a sustainable direction, continue to reduce the pollutants and greenhouse gases via the consumption process, and further improve the efficiency of coal utilisation. In order to reduce the single dependence on coal energy, hydrogen energy has become one of the important new and clean energy sources in China. To promote the development of hydrogen energy, address energy security and protect the atmospheric environment, China has introduced a set of policies related to hydrogen energy.

Table 2. Hydrogen energy policies of China [6].

Year	Main policy	Brief contents
2001	Hydrogen energy of 973 project	Study of hydrogen production, storage, delivery and fuel cells
2006	Outline of the National Medium- and Long-term Planning for Development of Science and Technology	Proposed research of hydrogen energy and fuel cells

2012	Plan for Development of the Energy Efficient and New Energy Automobile Industry	New energy technology and development of fuel cells
2014	Energy Development Strategy Action Plan	Research on new energy and renewable energy
2016	13th National Five-Year Plan for the Development of Strategic Emerging Industries	Investigating hydrogen production, storage, delivery and refuelling strategy
2019	Guiding Catalogue for the Green Industry	Manufacturing of new energy vehicles and green ship

Table 2 states the development and progress of hydrogen energy policy in China. The policy emphasises upstream and downstream industries for hydrogen energy development. The upstream industry is hydrogen production, the midstream is hydrogen storage and transport, and the downstream is hydrogen applications. China has advantages in the midstream industry and downstream applications of hydrogen energy. Influencing and promoting through national policies, the number of hydrogen fuel cell vehicles in China has reached 7,497, accounting for 22.5% of the global number. Meanwhile, the first hydrogen fuel cell hybrid locomotive in China starts working in November 2021, which will help China reduce its carbon emissions by 96,000 tonnes per year [7]. China currently has 101 hydrogen refuelling stations and aims to build 1,000 by 2030. China has mature technology reserves in the field of hydrogen storage, especially high-pressure gaseous storage technology. Current hydrogen transportation in China is still dominated by vehicle transport, but vehicle transport cannot meet the requirements of long-distance transportation. Therefore, pipeline transport and cargo ship transport are the future development direction in China. Japan and the United States have a greater advantage in upstream hydrogen production. The United States is focusing more on development and innovation in key technologies, and has invested more than \$150 million in related researches [8]. The downstream hydrogen industry in the United States is hydrogen fuel cell vehicles and residential cogeneration. In contrast, Chinese downstream industry is almost close to the United States, but it shows better in the midstream industry of hydrogen storages. In the upstream hydrogen production industry, China still needs to increase investment through policy guidance to overcome and control the key technologies. Japan has about 4,000 volumes of hydrogen fuel cell vehicles in downstream [3]. But Japan has the largest number of hydrogen refuelling stations in the world, which is about 142.

3 Conclusion

By analysing the upstream and downstream industrial development and changes in Chinese coal and hydrogen energy, it is found that China is shifting from a crude energy utilization route to a sustainable development route. In the upstream industry of coal energy, it improves the efficiency of coal mining and reduces the waste of coal in the mining process. It also reduces the investment costs required for mining and protects the safety of mining workers and the air environment. In the downstream coal industry, China has invented and applied green and efficient coal combustion technologies that provide higher energy efficiency, reduce the total coal consumption of

China, also reduce pollutants and greenhouse gases during the operation process. For the sustainable development of China energy, China also guided the development route of upstream, midstream and downstream industries of hydrogen energy through relative policies, providing a new pathway for the sustainable development of China energy. China contains advantages in the midstream and downstream industries of hydrogen energy with its unique high-pressure gaseous storage technology and a large number of hydrogen fuel cell vehicles. However, compared to the United States and Japan, they have more key technologies in hydrogen production in the upstream industry. Therefore, the future direction of sustainable development of China energy field should increase the investment in continuing to improve the efficiency of extraction and utilization of traditional coal energy upstream and downstream and develop green coal technologies through related policy. For hydrogen energy, China should continue to introduce policies to guide the research and development of key technologies in the upstream industry and maintain the leading position in the midstream and downstream of hydrogen energy industries in the world.

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