Energy Proceedings
Vol 33, 2023
ISSN 2004-2965

Carbon neutral goal and green development of petroleum industry

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ABSTRACT:

Carbon capture, use and storage (CCUS) has been widely developed worldwide as a technology with great potential for large-scale emission reduction. The petroleum industry is a "three high" industry with high energy consumption, high pollution and high carbon emission. Under the social development of carbon peaking and carbon neutrality, in order to achieve the goal of carbon peaking and carbon neutrality, promoting the coordinated and sustainable development of the petroleum industry and ecological environment has become a hot issue facing today. On the basis of the new demands brought by carbon capture, utilization and sequestration in current development and the concrete measures and results taken by our country for achieving carbon peak and carbon neutralization goals, this paper analyzed the current development status of carbon neutralization goals, and investigated and analyzed the development path for the future green development in the petroleum field under carbon peak and carbon neutralization goals. The carbon peaking contribution value of the petroleum industry and the estimated amount of carbon peaking contribution were obtained through the emission prediction. The assisting ways of the petroleum industry in carbon neutralization were analyzed, and the contributions to carbon neutralization through underground storage and enhanced oil recovery by carbon dioxide capture were also analyzed.

Keywords: Peak of carbon； Carbon neutral； Carbon capture, use and storage (CCUS)

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1. INTRODUCTION

In the current domestic and industrial sectors, the existing actions to achieve emission reduction targets have only a short-term effect. For example, the nationwide phase-out of small, long-lived and inefficient power plants has only a short-term effect. Replacing these plants with larger, more efficient plants would indeed greatly increase total energy use, but scaling up fossil-fuel generation would result in slightly lower energy efficiency. According to the actual investigation, most of the coal-fired power plants currently in operation in China are large modern power plants built in the middle and late 1990s, with a designed operating life of more than 30 years [1]. Therefore, China plans to build about 200 coal-fired power plants in the next few years, combined with existing infrastructure, which are projected by statistical models to contribute about 250 Gt CO_2 over their lifetime, accounting for half of total global emissions [2]. Carbon neutrality refers to all net zero carbon dioxide emissions -- a balance between all anthropogenic carbon emissions from fossil fuel burning, industrial processes, land use modification and carbon dioxide removal (such as carbon capture, use and storage) from land, oceans and human society. Since China is currently the world's largest carbon emitter, its path to net zero emissions (including all greenhouse

This is a paper for International CCUS Conference 2023 (ICCUSC2023), April 14-15, 2023, Beijing, China.

gases) is critical to achieving the 2°c temperature limit outlined in the Paris Agreement. However, achieving the target of carbon neutrality by 2060 cannot depend solely on measures taken to achieve the intensity reduction target by 2020. Instead, China must break its lock on fossil fuels.

2. CCUS TECHNOLOGY INNOVATION AND CCUS STANDARD SYSTEM CONSTRUCTION

Carbon dioxide capture, utilization and storage (CCUS), as one of the carbon removal technologies that can be widely applied, is an important frontier technology to achieve carbon peaking and carbon neutrality. According to the Global Carbon Capture and Storage Institute's "Status of Global Carbon Capture and Storage 2020" report, there are currently 65 commercial CCS facilities worldwide, of which 26 are in operation. There are three operational commercial CCS facilities in China, with a maximum annual capture capacity of about 0.82 metric tons of carbon dioxide. About 2% of the world's CCS warehouses. Three other commercial CCS facilities are also under construction or in early development and are expected to add about 1.8 metric tons of CO_2 capture capacity per year [3], as well as 13 pilot and demonstration CCS facilities [4]. However, the inquiry heard that current CCS facilities are capturing CO_2 emissions from fossil fuel burning (such as coal-fired power plants) or fossil or mineral process emissions (such as clinker production and many petrochemical processes), reducing them to low or even near zero levels. Negative emissions are only possible through bioenergy combustion using CCS or through capturing CO_2 emissions from biological sources rather than fossil sources [5]. In China, the deployment of bio-energy combustion with CCS is still some time away [6]. Therefore, to play a more important role in carbon neutrality in China, CCUS technology must be rapidly developed, and both CCS and bio-energy combustion with CCS facilities need to be deployed on a large scale as soon as possible. Otherwise, CCUS 'contribution to China's carbon neutrality by 2060 is likely to be extremely limited.

According to the survey, in terms of CCUS, carbonization of cement is a less common negative emission technology, but it has great potential for carbon intake [7-10]. According to the survey, the cumulative reduction of carbon dioxide in China from 1930 to 2019 by this method is about 6.2Gt[10], and it can be concluded that improving the weathering of cement and other alkaline solid wastes has become one of the main methods to reduce emissions [9]. Recycling building materials in daily life will not only greatly increase the carbonization of cement materials, but also potentially reduce the energy intensity of the building industry by 90%. Therefore, to achieve the net zero emissions target of 2060, China must recycle 100% of its building materials and industrial by-products to achieve the optimal state by 2030 [11]. Other CCUS technologies can also be improved to some extent through the recycling of biomass and cascading use of energy and materials, while the development and enforcement of relevant regulations and laws is a top priority for both central and local governments. What deserves to be emphasized is direct air capture technology, which is also one of the most important negative emission technologies and has the potential to remove CO_2 on a large scale. This method can directly adsorb CO_2 from the air through physical or chemical adsorption [12]. However, the technology to capture CO_2 directly in the air is still under development and expensive, and is not officially listed as valid work by the Chinese government. Low-carbon cities have been a major battleground in the fight against climate change in China [13-16], especially considering that more than 60% of the population currently lives in cities, and this segment of the population produces 85% of the national carbon emissions [17], and this figure is expected to increase further with population and economic growth [18-20]. Looking at the low-carbon landscape, we need to develop long-term city-level emission inventories to further clarify the drivers of urban emission growth. Through surveys, city-level energy and emission inventories can be counted by consumption, but this means that their emissions can be transferred to other cities. For example, 70% of emissions in China's metropolitan areas are related to products and services imported from other regions [21], so we can set reasonable and feasible CO_2 emission reduction targets for specific regions in provinces and cities [22]. For example, in 2010, China launched three batches of pilot low-carbon development projects in 80 cities and 7 provinces [23], which outlined carbon intensity reduction targets and low-carbon development plans [24], including peaking emissions by 2025 [25]. The development of low-carbon cities is mainly promoted by government policies rather than other factors such as public awareness [26-29], including setting emission peak paths, establishing near-zero carbon emission zones or establishing evaluation systems for controlling carbon emissions [30]. According to statistics, these low-carbon pilots have made substantial progress [27, 31], including cities such as Xiamen [32], and carbon intensity of most cities has decreased to a certain extent [33-34]. However, from 2015 to 2019, only three of China's 36 typical large cities (Kunming, Shenzhen and Wuhan) peaked their emissions, while eight of them (Beijing, Foshan, Nanjing, Nantong, Qingdao, Shanghai, Wuxi and Xiamen) peaked and then stagnated [35].

The "green market" concept plays a crucial role in accelerating the green development and deployment of renewable energy, and given the size of China's "green market" and the timing of its transition to a high value-added economic structure, market reforms related to environmental protection could bring about dramatic changes. In 2020, China had 12 trillion yuan ($1.9 trillion) in outstanding green loans and about 1.2 trillion yuan in green bonds issued. Therefore, China has become the world's second largest green bond market [36], and has gradually formed its unique trading system from top to bottom [37-40]. According to statistics, the cumulative investment in the energy sector is expected to be 99-138 trillion yuan from 2020 to 2050. [41] However, inadequate energy statistics, as well as incomplete information on sectors and types of energy, pose a challenge in developing city-level carbon reduction policies.

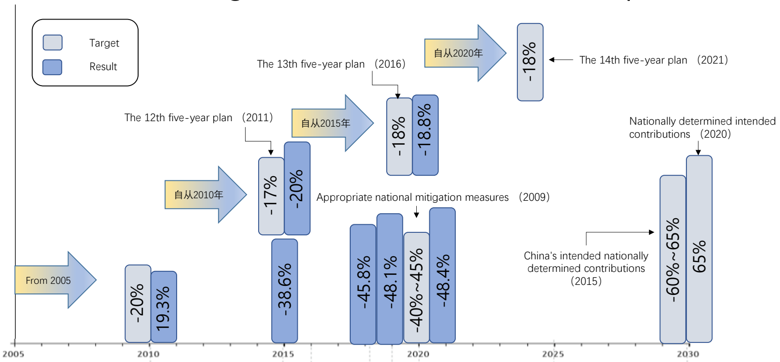

Fig.1 Timeline of China's carbon intensity reduction targets (light blue) and achievements (dark blue)

3. RELATIONSHIP BETWEEN CARBON NEUTRALITY AND GREEN DEVELOPMENT OF PETROLEUM INDUSTRY

Our milestones for achieving the national 2060 carbon neutral goal include: a comprehensive cap-and-trade system covering all sectors, afforestation, recycling and negative emissions from CCUS; 100% recycling of construction materials and industrial by-products; Achieve 70% or 85% non-fossil share of primary energy consumption in 2050 under 1.5 ℃ and 2 ℃ temperature limit scenarios, respectively; And develop full CCU facilities for the remaining fossil fuel based boilers and plants. Concrete progress on these fronts will help meet China's commitment to a carbon-neutral 2060. However, developing this carbon emission trend and trajectory remains challenging, given the uncertainty of world economic and technological breakthroughs. To achieve net zero emissions by 2060, China needs to embrace an era full of opportunities and challenges.

According to the types of CO_2 capture sources, CCUS-related technologies can be divided into three categories, namely fossil energy and carbon capture and storage (FECCS), biomass and carbon capture and storage (BECCS), and direct air carbon capture and storage (DACCS). The latter two types of these technologies exhibit negative emission characteristics.

There are also some national pilot and demonstration projects: the CCUS model covers a wide range of domestic CO_2 capture projects, and its new chapter dates back to 2007. After long-term practice, the industrialization of CCUS-EOR technology was first realized in Caoshe Oilfield of Jilin Oilfield of petrochina, and five types of CO_2 flooding and storage demonstration zones were established, with an annual CO_2 storage capacity of 350,000 tons [42]. In the same year, the pilot project with an annual CO_2 injection capacity of 40,000 tons was completed in the Caoshe Oilfield of SINOPEC East China Branch, and a CO_2 recovery device with an annual CO_2 treatment capacity of 20,000 tons was built in the later stage [43]. In 2010, Sinopec Shengli Oilfield completed the CCUS demonstration project, China's first coal-fired power plant. Using the flue gas of coal-fired power plants as CO_2 source, the captured CO_2 is injected into oil field flooding by post-combustion capture technology, with an annual capture volume of 40,000 tons [44]. In 2011, Shenhua Erdos adopted the methanol absorption method to capture CO_2 from the tail gas of the coal gasification hydrogen production project, and then injected CO_2 into the brine layer. This project is the first geological storage experiment project of saline layer in China, with a construction scale of 100,000 t/a. In 2012, Yanchang Petroleum used the CO_2 produced by coal chemical industry and adopted the low-temperature methanol washing technology to inject CO_2 into the oilfield after purification, pressure and liquefaction, thus reducing the viscosity of crude oil, improving the oil recovery efficiency and realizing the permanent storage of CO_2. The project construction scale is 50,000 t/a. In 2015, the exhaust gas CCUS project of Sinopec Zhongyuan Oilfield Refinery was completed. The project improved storage rates by 15% by flooding an almost abandoned field with CO_2. Currently, millions of tons of carbon dioxide have been injected into the ground. In 2021, the 150,000 t/a CCS demonstration project passed 168 hours of trial operation in China Energy Jinjie Co., LTD., which is the largest demonstration project in the whole process of CO_2 capture, oil displacement and storage after combustion of coal-fired power plants in China. During the trial operation, the continuous production of 99.5% of industrial grade qualified liquid carbon dioxide products. Large-scale CO_2 capture from flue gas of coal-fired power plant has been achieved successfully. [45]

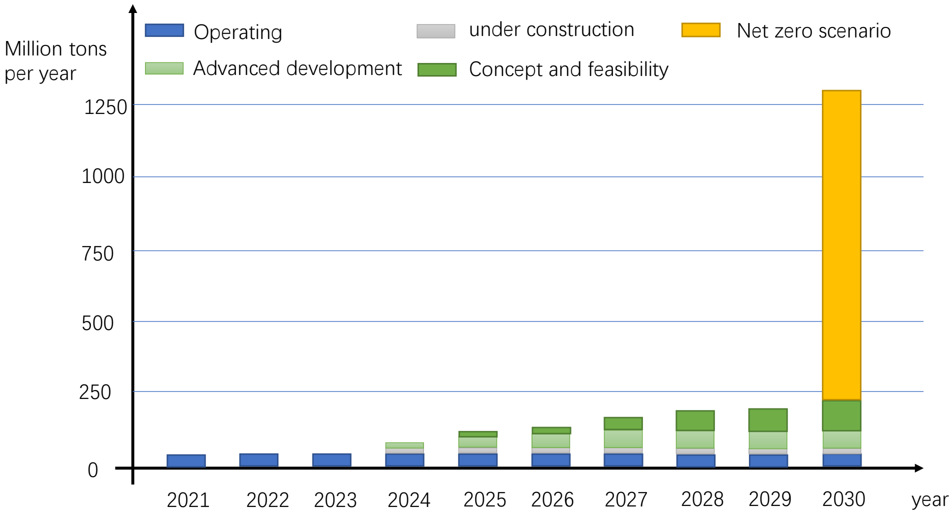

Fig.2 Capture capacity of large carbon dioxide capture projects

4. FORECAST RESULT

According to the Global Clean Energy Transition Roadmap (Net Zero by 2050) published by the International Energy Agency (IEA), achieving global carbon neutrality by 2050 requires a 75 per cent drop in net zero emissions from oil and 55 per cent from natural gas. Specifically, the oil industry can achieve its reduction targets by:

Adoption of low-carbon technologies: The oil and gas industry is expected to reduce carbon dioxide emissions by about 250 million tons by 2030 through adoption of low-carbon technologies, accounting for about 15% of the total reduction.

Increase the share of renewables: The oil and gas industry could reduce carbon dioxide emissions by about 160 million tons by 2030 by increasing the share of renewables, accounting for about 10 percent of the total reduction.

Adoption of carbon capture and storage: The oil and gas industry could reduce carbon dioxide emissions by about 140 million tons by 2030 through the adoption of carbon capture and storage, accounting for about 8% of the total reduction.

Adopting sustainable production practices: The oil and gas industry could reduce carbon dioxide emissions by about 120 million tons by 2030 by adopting sustainable production practices, accounting for about 7% of the total reduction.

However, these data are only forecast through modeling and are for reference only. The potential and percentage of emission reduction are still affected by many factors, so specific circumstances may vary. In general, the oil industry needs to take a number of measures to reduce carbon emissions, in a number of ways to achieve carbon neutrality.

5. DISCUSSION

Carbon capture and storage in the petroleum industry is implemented in the following ways:

Carbon capture: Carbon capture in the oil industry focuses on two areas: carbon dioxide emissions during the refining and burning of oil. Carbon dioxide emissions from petroleum refining come from distillation and hydrogen production, and these emissions can be captured using carbon capture technology. Burning oil also produces large amounts of carbon dioxide emissions, which can be carbon captured in the exhaust after the combustion. Carbon capture technology in petroleum industry includes chemical absorption, physical adsorption and membrane separation. Among them, chemical absorption is the most common method, usually using amine compounds, such as diethanolamine (DEA), methanolamine (MEA), etc., to absorb carbon dioxide.

Carbon transportation: The transportation of carbon in the petroleum industry is mainly through pipelines. The carbon dioxide is compressed into a liquid state and then piped to a storage site. In the transportation process, need to consider the pipeline design, transportation distance, cost and other factors.

Carbon storage: Carbon storage in the petroleum industry is mainly underground. Carbon dioxide is usually stored in underground oil fields, salt caverns or coal mines. During the storage process, factors such as geological conditions, storage capacity and safety should be considered, and appropriate monitoring and management measures should be taken to ensure the safety and stability of the storage process. It should be noted that there are certain risks in carbon storage in the petroleum industry, such as carbon dioxide leakage, earthquake risk and so on, and appropriate measures should be taken to reduce the risks.

Overall, carbon capture and storage in the oil industry is an effective way to reduce carbon dioxide emissions and achieve the goal of carbon neutrality. However, the high cost of the technology requires governments and enterprises to take a series of measures to promote its development, such as providing financial and tax incentives, and establishing regulatory and management systems.

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