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The Main Obstacles and Overcoming Paths for the Technical Development of CCS

Yicheng Zhang

School of Architecture and Planning, Hunan University, Changsha, China
ZhangYC123@hnu.edu.cn

Abstract. Since the beginning of the 21st century, in response to the increasingly frequent climate crisis, more and more countries have incorporated goals such as carbon reduction and carbon neutrality into their national strategies. With the acceleration of global carbon neutrality, carbon capture and storage (CCS) technology gained widespread attention as an important means of achieving carbon neutrality in the industrial sector. After a period of development, the current development of CCS technology faces challenges in four aspects: technological maturity, economic feasibility, policy synergy, and social acceptance. To further understand and propose possible solutions, this article systematically reviews the current development status of global CCS technology through a literature review, focusing on key bottlenecks in capture, storage, cost and other technical processes. Combining materials, policies and business, and social acceptance, a solution for the coordinated promotion of technology economy policy is finally proposed, providing suggestions for promoting the large-scale application of CCS technology and providing decision-making references for the promotion of global climate governance and carbon neutrality processes.

Keywords: CCS technology, Carbon neutral, Development dilemma, Solution

1. Introduction

Since the beginning of the steam age, the conflict between humans and nature has been intensifying, especially in terms of climate, as climate problems caused by carbon dioxide emissions, such as global warming, rising sea levels, and extreme weather, continue to occur. With the passage of time, the impact of the Industrial Revolution continues to deepen. Since entering the 21st century, driven by both population growth and technological progress, the scale of industrial production has continued to expand, and the global climate crisis has intensified at an unexpected pace. According to the latest assessment by the Intergovernmental Panel on Climate Change (IPCC), global temperature rise triggered "widespread and irreversible" ecological disasters: extreme heatwaves, floods, rising sea levels, and other disasters have doubled in frequency and intensity, and the rate of biodiversity loss has reached a historical peak. If the temperature rises above the 1.5 °C threshold, the world will face a chain risk of food crisis, water scarcity, and ecosystem collapse [1]. Realizing carbon neutrality shifted from a long-term goal to a survival proposition of "immediate action". With each year of delay in achieving carbon neutrality, the feasible path for humanity to respond to climate disasters will narrow, and systemic risks may grow exponentially. At present, global climate

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governance has entered a new stage. According to data from the United Nations Environment Programme, global carbon dioxide emissions will reach 41 billion tons by 2025, with the industrial sector accounting for over 40%. Therefore, how to effectively reduce carbon emissions in industrial production has become the key to achieving carbon reduction and carbon neutrality goals. Carbon capture and storage (CCS) technology is currently recognized as a key technology that can achieve carbon neutrality.

The importance of CCS technology lies in three aspects: deep emission reduction capability, direct capture of carbon dioxide in industrial production and energy utilization, especially suitable for high emission industries such as steel and cement, and filling the emission reduction gap that renewable energy cannot cover. Coping with the climate crisis, as recommended by the IPCC as a large-scale emission reduction plan, can significantly reduce atmospheric greenhouse gas concentrations, which is crucial for achieving the temperature control goals of the Paris Agreement. The strategic support role of providing a low-carbon transformation path for fossil fuels through storage or resource utilization, ensuring energy security while promoting industrial upgrading, is the pillar technology of the net-zero emission system after 2050. These three aspects are interrelated and complementary, highlighting the importance of CCS technology in achieving carbon neutrality goals. After years of research and practical application, there are still some obstacles in the large-scale application and promotion of this technology, such as the contradiction between high energy consumption and low economy proposed by Wang Siyao [2], and Wang Ruxin's discussion on carbon emission rights prices and investment return cycles [3].

This article aims to review the current research status and achievements of CCS technology, summarize the difficulties encountered in the industrialization and large-scale application of CCS technology, and refer to the existing experience or practical attempts of some countries to propose feasible solutions. This article mainly focuses on the obstacles and breakthrough paths in the development of CCS technology, based on the practice and cutting-edge research of 22 large-scale CCS projects worldwide. After analyzing multiple papers, it summarizes and systematically analyzes the bottlenecks encountered in the promotion of CCS technology, and proposes three possible solutions: technological innovation, policy innovation, and business model reconstruction.

2. Development status of CCS technology

2.1. Technology maturity bottleneck

CCS has many types of technologies and complex applications, and the development degree of each link is uneven. Its technology integration includes chain integration and system integration with chemical, cement, steel, and other industries. According to the advanced level, capture technology can be divided into the first, second and third generation technologies: the first generation technology is based on fossil fuel capture technology, mainly including physical absorption technology before combustion and chemical absorption technology after combustion; The second generation technology adopts more advanced absorbent and system design, such as new chemical absorption/adsorption technology, pressurized oxygen enriched combustion technology, etc; The third generation technology is also called revolutionary technology, such as chemical chain combustion technology. The first-generation technology at home and abroad is the most mature, while the second and third generation technologies are relatively lagging behind [4].

In addition to the inadequate development of capture technology, there are also safety risks in the technologies related to carbon dioxide storage. There is a risk of carbon dioxide leakage in geological storage. The monitoring of the Sleipner project in Norway shows that the pressure of the

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storage layer increases by 0.5 MPa every year, which may lead to rock fracture [5]. At the same time, the storage site needs to avoid the seismic zone and groundwater, and only 15% of the global sedimentary basins have commercial storage conditions [6].

2.2. Economic feasibility dilemma

At present, the promotion of CCS technology has the problem of an unbalanced cost structure. Taking the construction industry as an example, in order to build a carbon-neutral society, the large-scale application of CCS technology is very helpful. However, the current application of CCS technology will bring a considerable cost increase. For instance, the integration of CCS technology within a cement manufacturing facility has the potential to reduce carbon dioxide emissions by as much as 90%. However, this implementation is associated with an increase in production costs ranging from 65% to 95%, contingent upon the specific CO_2 capture technology employed. Given that industries such as cement, steel, and other chemical sectors generally operate with narrow profit margins, the escalation in production expenses may pose significant economic challenges. These challenges include diminished product competitiveness and a reluctance among producers to adopt CCS technologies in their industrial operations [7]. Even with government financial subsidies and policy support, the extra costs will be borne by users, which greatly reduces the desire to buy.

2.3. Insufficient policy synergy

The relevant international conventions of CCS can be divided into two parts. The first is to define CCS as a reduction option. The second is the provisions on the capture of carbon dioxide for marine storage. These international conventions promote the research and development of CCS through relevant regulations. However, due to the uncertainty of the technology itself, CCS has not been approved to be included in the emission reduction mechanism.

Injecting a large amount of carbon dioxide into underground storage is a key focus of this technology. The storage site selection requirements are very safe and reliable, and extensive geological investigations must be conducted in the early stage. The current lack of monitoring and management of carbon dioxide storage risks is due to the absence of relevant measurement systems. The responsibility of enterprises and the role of the government need to be clarified, as the storage time of carbon dioxide is likely to be longer than the operation and management time [8].

2.4. Low social acceptance

Taking Europe as an example, as the first region to carry out CCS technology research and promotion, ordinary people in Europe have insufficient cognition of the technology and limited social acceptance. In contrast to CO_2 storage, CO_2 utilization seems to be more acceptable to most people. This may happen as CO_2 is considered waste recycling. Jones et al. have studied public perception in the UK. Many participants have been found to have limited awareness and require a deeper understanding of this technology. Researchers also found that there is insufficient public awareness of the sustainability and lifespan of products, resulting in limited social recognition [9].

The public may have a negative perception of CCS technology due to its relative novelty. New technologies often lack practical experience and high usage risks, making it difficult to gain public trust. Meanwhile, investors often oppose the implementation of CCS technology due to their insufficient understanding of the technology. Therefore, project activities are likely to be delayed or postponed, and even cancelled in some cases [10]. Because with the current technical conditions, the

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introduction of CCS technology into the industrial production process will inevitably lead to rising costs, which will reduce the competitiveness of products in the market, and then reduce the confidence of investors and the enthusiasm of producers.

The public will oppose the use of new technology in reality due to a lack of understanding and concerns about its security. Government agencies should formulate relevant policies aimed at the general public and goals, in order to gain the favor of investors for related technologies and activities.

3. Breakthrough path and solution

3.1. Technology innovation drive

Now, more CCS related innovative technologies are emerging. Take the oase&gas processing technology in 2023 as an example. Open Access to Scholarly Ecosystems (OASE) is the leading carbon-capture technology installed and minimize emissions in the treated gas. Furthermore, in references with a combined capacity of over 100 million, a unique degradation-component management system is Nm^3/h. Today, 7.6 million tons per year of CO2 extracted ensures minimisation of these components and minimizes emissions with OASE are sequestered, while tens of millions of emissions. Tons per year of CO2 separated with OASE are used in the OASE deliverables include a process design for downstream applications [11].

At the same time, carbon capture through new materials can also effectively reduce the cost of the CCS technology chain. Take Ion Clean Energy's lean solvent carbon capture as an example. Ion Clean Energy's initial feasibility study at the Nebraska Public Power District's Gerald Gentleman Station Unit 2, a coal-fired generator, estimated capture costs of US$39 – 44 per tonne of CO_2. This is a 25 - 33% cost reduction in comparison to the cost of current industry-standard amine solvents used for coal-fired power plants [12].

3.2. Innovation of policy tools

As the first region to attach importance to CCS technology to achieve carbon neutrality, as early as 2008, the European Commission issued a directive to establish a legal framework for the development of CCS, and issued the carbon dioxide geological storage directive as the legal framework for the geological storage of carbon dioxide. The EU subsequently issued various incentive measures to promote the development of CCS. The means can be divided into: reducing the operating cost of CCS; Provide added value (environmental tax relief, project investment grants) to CCS participants. In addition, the European Commission is assessing whether CCS subsidies will offset investment in energy efficiency and renewable energy [13]. The introduction of such policies can stimulate people's interest in participating in and using CCS technology, and can promote the development and promotion of this technology in the long run.

China has also formulated policies on carbon emissions, carbon trading and carbon pricing in recent years. China's national carbon market included CCS in the CCER transaction, and the pilot project received a subsidy of up to 120 yuan/tco α. The government hopes to regulate the operation of the CCS market and promote it in this way.

3.3. Business model reconstruction

The reconstruction of the business model can bring some advantages by adjusting the process of value creation, delivery and acquisition, such as improving operational efficiency, innovating the

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value proposition, expanding the market, etc. When applied to CCS technology, in addition to the energy conservation and efficiency increase of the product itself, in recent years, countries are also actively explored a new development mode of combining the technology with other industries, aiming to improve the economic value and promote the technology while carrying out industrial integration. For example, the "capture displacement storage" integration project of Shengli Oilfield in China has increased crude oil production by 500000 tons annually, with an internal rate of return of 12%. The green hydrogen coupling model of the H2H project in Australia uses carbon dioxide capture for methanol synthesis, with a product premium of 20%.

4. Conclusion

The large-scale application of CCS technology still faces some obstacles, such as technological bottlenecks, high costs, incomplete policies, and low social acceptance. In order to further develop and promote CCS technology, it is necessary to establish a technology economy policy triangle support system and achieve predetermined goals within different time periods. In the short term, through material innovation and process optimization, reduce the additional costs incurred by additional processes during the use of CCS technology, thereby reducing total costs, enhancing the market competitiveness of goods, and achieving profit increase. In the medium term, relying on carbon emission pricing, carbon trading, and other means, improving the policy framework, and introducing trading policies, the value of CCS technology and its derivatives will be determined by market competitiveness, injecting a continuous stream of power into the development and application of technology. Long-term exploration of new business models combining hydrogen energy and bioenergy, while expanding the market, attempts to apply CCS technology under different conditions, accumulate richer practical experience, and continuously improve public acceptance through practical application, laying a solid foundation for future large-scale promotion. Under this influence, the application scale of CCS technology may gradually increase and contribute more to the global carbon neutrality goal. Further research in the future should continue to delve into the value aspects related to carbon neutrality and environmental issues, and promote the transformation of CCS technology from a cost center to a value center.

References

[1] Zheng, S. M., & He, Y. J. (2022). Science, politics and policy: Explaining the multiple logic of global climate crisis governance. Journal of China University of Geosciences (Social Science Edition), 22, 41–53.

[2] Wang, S. Y. (2022). Research on the response mechanism and path of coal production to CO_2 emission reduction under the dual carbon target [Master's thesis]. China University of Mining and Technology, 12, 66-78.

[3] Wang, R. X. (2022). Research on the correlation between carbon emission trading price and fossil energy price in China [Master's thesis]. Nankai University, 22, 88-108.

[4] Liu, G. Z., Fang, R. R., & Dou, L. R. (2024). China's CCS/CCUS development bottlenecks and countermeasures. Natural Gas and Oil, 42, 8–14.

[5] Osman, A. I., Hefny, M., Abdel Maksoud, M. I. A., et al. (2021). Recent advances in carbon capture storage and utilisation technologies: A review. Environmental Chemistry Letters, 19(2), 797–849.

[6] Wang, S. J. (2025). From paper mountain to cloud: CCS new guidelines activate full life cycle data assets. China Ship Inspection, 8, 57–61.

[7] Subraveti, S. G., Rodríguez Angel, E., Ramírez, A., et al. (2023). Is carbon capture and storage (CCS) really so expensive? An analysis of cascading costs and CO_2 emissions reduction of industrial CCS implementation on the construction of a bridge. Environmental Science & Technology, 57, 2595–2601.

[8] Fan, Y., Zhu, L., & Zhang, X. B. (2011). Analysis of global CCS technology, regulations and its potential for emission reduction with focus on China. Advances in Climate Change Research, 2, 57–66.

DOI: 10.54254/2753-7048/2026.ZJU31211

[9] Koukouzas, N., Christopoulou, M., Giannakopoulou, P. P., et al. (2022). Current CO_2 capture and storage trends in Europe in a view of social knowledge and acceptance. A short review. Energies, 15, 57-76.

[10] Cherepovitsyn, A., Chvileva, T., & Fedoseev, S. (2020). Popularization of carbon capture and storage technology in society: Principles and methods. International Journal of Environmental Research and Public Health, 17, 83-88.

[11] Barlow, H., Shahi, S. S. M., & Loughrey, M. (2023). State of the art: CCS technologies 2023. Global CCS Institute, 32, 26-36.

[12] Kearns, D., Liu, H., & Consoli, C. (2021). Technology readiness and costs of CCS. Global CCS Institute, 10, 12-22.

[13] IEA. (2016). 20 years of carbon capture and storage.