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Challenges and Strategies for Carbon Capture and Storage Commercialization in China

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Abstract. Global warming remains one of the most pressing challenges confronting human society, carbon capture and storage (CCS) is widely regarded as a key technological pathway for deep emission reductions. Although China has established the "dual carbon" goal and has also written carbon capture, utilization and storage (CCUS) into the "14th Five-Year Plan", the implementation of the project is not ideal. As of July 2024, there are only 30 CCS projects in China, while there are 293 in the United States, with a clear gap. Across the four dimensions of technology, economy, policy, and risk, the constraints on CCS commercialization entangle and amplify one another. The capture cost accounts for 70%-80% of the whole process, and carbon prices have long stayed below the incentive threshold of $25-30 per ton. The carbon market has not yet formed realization channels for CCUS emission reductions, and legislative gaps leave sequestration rights and long-term responsibility attribution unclear, which gives rise to policy and regulatory risks. In response to the above problems, this article puts forward five countermeasures: first, to lay out cluster projects in the west, second, to promote the construction of pipelines into networks, third, to connect CCUS to the carbon market and China Certified Emission Reduction (CCER) system, fourth, to introduce special management standards, fifth, to establish a full-process monitoring and early-warning mechanism. Generally, CCS needs to move from demonstration to commercialization, and China needs joint efforts in technology, market, regulations and risk control.

Keywords: Carbon Capture and Storage, Commercialization, Policies and Regulations, Carbon Market

1. Introduction

Global warming is still a major problem that human society needs to deal with. According to statistics from the Intergovernmental Panel on Climate Change (IPCC), there are 7,887 large-scale fixed emission sources with annual carbon dioxide emissions of more than 100,000 tons worldwide, with a total annual emission of about 13.466 billion tons of carbon dioxide, and power plants account for 4,942 [1]. Carbon capture and storage (CCS) is to separate the carbon dioxide generated by the emission sources of the industrial and energy industries and seal it in the underground geological structure after transportation. Carbon capture, utilization and storage (CCUS) is

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developed on the basis of CCS. In addition to the sequestration of carbon dioxide, the collected carbon dioxide is also used as a resource. It is generally believed internationally that these two technologies are important means to achieve deep emission reduction. At present, the separation efficiency of capture technology for carbon dioxide can reach 85%-95%. If it can be applied on a large scale, the overall cost of global climate emission reduction can be reduced by more than 30% [1].

In 2020, China put forward the "dual carbon" development goal of carbon peaking and carbon neutrality, CCUS was included in the "14th Five-Year Plan" and became a technical direction that needs to be focused on demonstrating. China's major sedimentary basins possess a theoretical total carbon dioxide (CO_2) storage capacity of approximately 4.12 trillion tonnes, and the country has already developed engineering capacity for million-tonne-scale CCS projects. However, the actual project implementation speed is far from reaching the previously expected level. As of July 2024, there are a total of 680 CCS projects in different stages of construction worldwide. The United States accounts for 293, while China has only 30 projects invested in the layout [2]. The fluctuation of carbon prices in the national carbon emission rights trading market is very obvious, and there is still a significant gap between the current price and the $25-30 per ton of carbon dioxide threshold required to promote the large-scale landing of CCS [1]. Most of the storage resources are concentrated in western basins, while high-carbon emission sources are concentrated along the eastern coastal zone. This reality of "source-sink spatial mismatch" adds a lot of practical obstacles to the commercial application of the whole set of technology [3].

Most existing studies focus on individual CCS technologies or source-sink matching in isolation, leaving a gap in systematic analysis of the full CCS industrial chain in China. This paper sorts out the main constraints facing the commercialization of CCS in China from the four levels of technology, economy, policy and risk. Based on this analysis, comprehensive solutions are put forward.

2. Current status of CCS development in China

2.1. Technical route maturity assessment

The complete process of CCS consists of three stages: capture, transportation, and storage, and the technical maturity of each link varies greatly.

The cost of capture is the highest in the whole process, accounting for 70%-80% of the total cost [4]. There are three main types of existing capture technologies. First, it is collected after combustion, and the technology is the most mature, which is suitable for the transformation of existing power plants. The second is pre-combustion capture, suitable for the integrated gasification combined cycle (IGCC) power plant, which has a high concentration of carbon dioxide and is easy to separate. Third, oxygen-enriched combustion is assisted by pure oxygen. The concentration of flue gas carbon dioxide is very high, but the energy consumption of the oxygen production link is high [4]. The IPCC has noted that power plants equipped with CCS consume 10–40% more energy than comparable plants without CCS [1].

The cost of transportation accounts for about 10%-20% of the total cost of the project [4]. To carry out large-scale carbon dioxide transportation on land, pipeline is the main way to realize it at this stage. North America has established over 8,000 kilometers of CO_2 pipeline infrastructure, whereas China has yet to develop a large-scale pipeline transport system and continues to rely primarily on tanker trucks [5].

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In terms of storage, this stage accounts for approximately 5–10% of total costs [4]. Deep saline formations offer the greatest potential and represent the primary direction for future large-scale storage. Depleted oil and gas reservoirs, due to well-established geological understanding and reusable infrastructure, already have mature operational experience, whereas unmineable coal seams are still in the research and demonstration phase.

The development of CCS technologies in China is uneven across different stages. Pre-combustion capture has reached commercial application levels; post-combustion chemical absorption, however, remains at the industrial demonstration stage and lags behind the international commercial application level. In terms of transportation, China has not yet established a large-scale pipeline network and currently relies primarily on tanker trucks. Yao et al. pointed out that China has achieved industrial demonstration and technological innovation in CO_2 chemical utilization and biological utilization, with CO_2 enhanced oil recovery already entering the commercial application phase [6].

2.2. Representative demonstration projects

China has established a "four large, six small" CCUS industry landscape: comprising four large-scale demonstration zones (Changqing, Daqing, Xinjiang, and Jilin) and six small-scale pilot test areas (including Jidong and Dagang) [7]. By the end of 2022, the cumulative CO_2 injection volume nationwide had reached approximately 7.8 million tonnes, of which China National Petroleum Corporation (CNPC) accounted for 5.63 million tonnes, representing over 70% of the national total. CO_2-enhanced oil recovery (CO_2-EOR) in oil reservoirs can enhance oil recovery by 10 to 25 percentage points [5].

The Qilu Petrochemical-Shengli Oilfield project is China's first full-industry-chain demonstration project for a million-ton-scale CCUS initiative, launched in 2022 with a supporting 109-kilometer CO_2 pipeline [2]. This project purifies the CO_2 tail gas from the coal-to-syngas facility at Qilu Petrochemical and injects it into the ultra-low-permeability reservoir of the Shengli Oilfield for enhanced oil recovery. By the end of 2024, the cumulative CO_2 injection and storage volume had exceeded 1.5 million tonnes [2]. The project has achieved breakthroughs in million-tonne-scale, low-energy, low-cost capture technologies, increased crude oil recovery by more than 15 percentage points, improved the primary storage rate by 20 percentage points, reduced unit energy consumption by 19%, and lowered costs by over 30%. The key technological equipment has received the Special Commendation Gold Award, the highest honor at the International Exhibition of Inventions in Geneva [8].

The Jilin Oilfield CCUS project is China's first national science and technology demonstration program for CCUS-EOR. Since 2008, a pilot test has been conducted at the Daqingzijing oilfield, operating steadily for over a decade. Among its components, the Hei 79 North small well-spacing full-lifecycle test has cumulatively injected 432,000 tonnes of CO_2 and is projected to ultimately enhance oil recovery by more than 27 percentage points [5]. The project has developed an integrated technology system for the full CCUS-EOR industrial chain in continental sedimentary reservoirs, laying the foundation for the transition of China's CCUS technology from pilot testing to industrial application.

The Enping 15-1 oilfield group project is China's first offshore CO_2 storage demonstration project, launched in 2021 in the Pearl River Mouth Basin of the South China Sea. The project carries out capture operations for carbon dioxide generated during the development of offshore oil fields. The collected gas will be re-injected into the seabed salt water layer, and the project can achieve a sequestration scale of about 300,000 tons every year. By October 2025, cumulative CO_2 storage

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volume had exceeded 100 million cubic meters [7]. The gap in the field of carbon dioxide sequestration technology in China's offshore has been filled by this demonstration project. At the same time, it also provides a reference technical model for coastal enterprises to carry out large-scale emission reduction.

The above three projects represent the engineering progress of three technical pathways: onshore full industrial chain, onshore EOR-based storage, and offshore storage. Beyond these representative cases, numerous other CCUS demonstration projects are in operation or under construction across the country. Existing literature has proposed a four-stage outlook for China's CCUS development pathway: First, in 2030, all kinds of mature technologies will be pushed to commercialization; second, in 2035, the new generation of technologies will have the conditions for large-scale application; third, in 2040, key breakthroughs will be achieved in system integration and risk management technologies; fourth, in 2050, the large-scale promotion layout of CCUS technology will be completed [6].

3. Development challenges in the commercialization of CCS

3.1. Insufficient economic incentives

The carbon market is the core channel for CCS projects to achieve economic returns. Even so, China's carbon price is still too low to drive private-sector investment in CCS. IPCC calculated that to promote the large-scale implementation of CCS, the carbon price needs to reach $25–30 per ton of CO_2 (roughly 180–210 RMB/t). Domestic carbon prices have been running at a low level for a long time, and it is difficult for enterprises to establish a stable price expectation [1, 9]. In 2024, the domestic carbon price briefly broke through 100 yuan per ton, but this trend was not maintained, and the market quickly fell. In a short period of time, the fluctuation of carbon prices has exceeded 40%, making it more difficult for enterprises to commit to long-term investment plans [10]. The trend of carbon prices is directly influenced by institutional factors such as quota carryover mechanisms, quota scarcity expectations, and penalty intensity for violations.

An effective connection linking CCS projects to carbon markets has yet to be built. Chinese CCUS schemes are still excluded from the China Certified Emission Reduction (CCER) system. Even if the enterprise invests in the CCS project, the emission reduction benefits generated by the project cannot be realized into actual economic benefits in the carbon market [11]. The United States' 45Q policy offers a useful reference. Tax credits of $85 are granted for each tonne of CO_2 securely stored. By comparison, China lacks well-defined, quantifiable fiscal and tax incentives of this kind. Viable business models remain absent. CCS projects are primarily demonstration initiatives led by state-owned enterprises, lacking a clear profit model and risk-sharing mechanisms [2].

3.2. Technical cost constraints

The main technical problem that hinders the commercialization of CCS is the high capture cost. In the power industry, the cost of capture per ton of carbon dioxide is roughly in the range of 200-600 yuan. The cost level of the cement industry will be higher, with the cost of carbon dioxide capture per ton of about 300-730 yuan [11]. CCUS also competes with other types of emission reduction paths; Take coal-fired power plants as an example, relying on improving energy utilization efficiency to reduce emissions will generate lower expenses than using CCUS technology. The cost advantage is directly reflected, and enterprises also have lower-cost emission reduction options.

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The shortcomings of technical maturity and system integration ability also restrict the promotion of CCS. Post-combustion chemical absorption technology still lags behind international commercialization levels. The large-scale pipeline transmission system of carbon dioxide has not been completed, and tanker transportation is still the mainstream. Integrated optimization work such as network optimization and cluster hub layout is greatly needed in the construction of CCUS clusters, but practical experience for reference is still lacking.

3.3. Lack of policies and regulations

The reduction of technical costs depends not only on research and development investment but also on policy frameworks that provide stable market expectations and institutional safeguards. However, China's CCS policy and regulatory system still has significant gaps. More than 90 policy documents related to CCS/CCUS have been issued in China. Systematic legislation specifically for the industrialization of CCS has not been established. Special regulations such as the U.S. 45Q Act and the EU Net Zero Industry Act can be used for reference. A clear CCS industry development roadmap is absent, and supporting medium- and long-term targets have not been established.

There are still major gaps in the legal framework of CO_2 geological storage, including ownership, long-term liability and regulatory rules that have not been clarified. It is not clear who will bear the liability compensation after the leakage and the monitoring costs after the closure; this uncertainty will increase the risk of the project, and the willingness of enterprises to participate will be inhibited. Non-technical obstacles should also not be underestimated. First, the early exploration and evaluation licensing process is too lengthy and cumbersome, and second, the public has always been concerned about the safety of CO_2 transportation and storage [11].

3.4. Risk transmission mechanism

Chen Yuan and others classified the risks of CCS projects into four categories, namely environmental, economic, social and technological, with a total of 25 specific risks. Among these risks, technical cost risk, CO_2 leakage risk, site selection risk and policy and regulatory risk are recognized as key nodes. The average path length of the entire risk network is only 2.156, which shows that one risk event triggers other risks, and only two nodes can be passed through the middle on average to complete the conduction. What is more special is the policy and regulatory risk. The node has the highest degree of exit among all factors, but the degree of entry is zero, which makes it the most upstream source factor in the whole network [12].

Carbon price fluctuations just prove the root cause of policy and regulatory risks in the whole system. The factors affecting carbon prices can be reduced to three specific elements at the level of institutional design. First, the quota carryover mechanism, second, the expectation of quota scarcity, and third, the intensity of punishment for violations [9]. Once the policy orientation becomes blurred, the price signals transmitted by the market will be distorted. In this environment, it is difficult for enterprises to judge how high the compliance costs they will bear in the future, and they can't figure out what level of subsidy support the government will provide, and even the boundaries of responsibility after violation can't be grasped. These uncertainties are superimposed, and the end result is that enterprises have to significantly raise the high-risk premium when making investment decisions.

China's CCS commercialization faces an interrelated bottleneck network. High technology cost is the bottom constraint, but cost reduction depends not only on technology research and development, but also on scale. The formation of the scale effect depends on whether three conditions are in place:

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first, the policy gives clear and stable return expectations; second, the carbon market provides tradeable carbon assets, and third, the law clearly defines long-term responsibility.

4. Development strategies for CCS to overcome commercialization barriers

4.1. Prioritizing western cluster projects

China's carbon storage resources are mainly distributed in the western basin, while the emission sources are concentrated along the east coast. This spatial misalignment between the sources and sinks directly increases the cost of transportation. In the face of this reality, a feasible strategy is to prioritize the CCUS industrial cluster in the western energy base. Take the Junggar Basin in Xinjiang as an example, where more than 380,000 tons of carbon dioxide have been injected and 120,000 tons of incremental oil production has been brought about [3]. Regarding the Ordos Basin, it possesses abundant coal chemical carbon sources and favorable storage conditions, fully demonstrating the potential to establish a million-ton CCUS industrial base. As for the eastern coastal areas, attention should be turned to offshore storage, and the Enping 15-1 project has provided preliminary verification in this regard [7].

Gao et al. selected 10 CCUS projects and asked them to be prioritized by 2030. These projects are distributed in eight provincial administrative regions, such as Xinjiang, Shandong, Ningxia and Shaanxi. The total annual carbon dioxide emissions are close to 103.73 Mtpa, and the cumulative emission reduction potential can reach 2,058.29 Mt by 2060. Among them, the proportion of emissions in Xinjiang and Shandong is particularly prominent, totalling 47%. Specifically, Xinjiang is 24.68%, and Shandong is 22.38%. Based on the emission scale and geographical distribution, these projects can form four clusters for the next step of deployment [13].

4.2. Advancing trunk pipeline construction and experience dissemination

China has not yet established a large-scale CO_2 pipeline network. Priority should be given to planning main trunk lines and regional distribution hubs in areas with favorable source-sink matching conditions, gradually building up the transportation system. The Jilin Petrochemical–Jilin Oilfield CO_2 pipeline project (over 280 kilometers in length, designed for an annual transport capacity of 3.3 million tons) could serve as a starting point for regional pipeline network development [14].

The Shengli Oilfield's million-ton-scale CCUS project has demonstrated that capture energy consumption can be reduced by 19% and costs by over 30% through integrated process optimization [8]. The technical expertise and management model of Shengli Oilfield should be promoted nationwide to accelerate the transition of CCS technology from demonstration to commercialization.

4.3. Improving the carbon market and CCER mechanism

To overcome the challenges in carbon pricing, two approaches are needed: gradually tightening the total quota supply by shifting the allocation baseline from "balance between surplus and deficit" to "yearly reduction"; and introducing a paid allocation mechanism and auctions so that carbon prices more accurately reflect marginal abatement costs [9]. Stable expectations of quota tightening are more important than the absolute level of carbon prices, as long as enterprises are confident that carbon prices will rise progressively in the future, long-term emission reduction investments can still be initiated.

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It is even more critical to establish a pathway connecting CCUS with carbon markets. The methodology for calculating CCUS carbon emission reductions should be improved as soon as possible, and CCUS projects should be included in the national certified voluntary emission reduction (CCER) registration scope, enabling captured and stored CO_2 to become tradable carbon assets. The approach of Alberta, Canada, which grants double certified volume credits for CCUS projects, offers a valuable reference.

During the transitional phase when carbon market mechanisms are still underdeveloped, direct fiscal and tax incentives remain essential. After the U.S. 45Q policy raised its sequestration subsidy from $50 per ton to $85 per ton, it directly spurred the commercialization of numerous CCS projects [2, 5]. China could explore the introduction of phased CCS investment tax credits or direct subsidy policies, with clearly defined phase-out pathways and timelines. At the same time, efforts should be made to include CCUS projects in the green bond and green credit support catalogs.

4.4. Enacting specialized CCS regulations

China currently lacks specific legislation targeting CCS. There is an urgent need to accelerate the introduction of dedicated regulations for CCS, clearly defining ownership rights over subsurface CO_2 injection spaces, assigning responsibility for long-term monitoring of storage sites, and establishing mechanisms for liability determination and compensation in the event of leaks. The certainty of the law is more important than its stringency. Enterprises can endure stringent standards, but they cannot cope with unknown rules.

In early 2026, the State Administration for Market Regulation and the National Standardization Administration released 12 national standards for CCUS, covering the entire process of capture, transportation, and storage. These standards will take effect on July 1, 2026. This marks the transition of China's CCUS standards system from fragmented and dispersed to systematically integrated.

A one-stop approval channel for CCS projects should be established, with a clearly designated lead department to avoid fragmented management. To address public concerns and uncertainties, a transparent information disclosure mechanism and community participation system should be put in place [11].

Policy and regulatory risks are the root of the risk network. The primary task in risk prevention and control is to stabilize policy expectations—by publicly announcing in advance the path for quota tightening, carbon price regulation mechanisms, and the timeline for subsidy phase-outs [9].

4.5. Establishing a full-process monitoring and early warning system

At the technical risk level, a leakage monitoring and risk early warning system covering the entire process of capture, transport, and storage should be established. China has limited experience in monitoring saline formation storage, and 4D seismic monitoring technology has only been applied in the Gao 89 block of Sinopec's Shengli Oilfield. The deployment of proven monitoring technology combinations—including wellhead monitoring, downhole fluid monitoring, and time-lapse seismic monitoring—should be accelerated, and new projects should be mandated to include full-lifecycle monitoring plans [2]. Regarding site selection risks, it is necessary to improve screening criteria for storage sites and strengthen assessments of geological caprock integrity and long-term stability [12].

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5. Conclusion and outlook

5.1. Conclusion

This paper analyzes the core bottlenecks in the commercialization of carbon capture and storage (CCS) in China from four dimensions: technology, economy, policy, and risk.

First, CCS commercialization in China faces an interconnected and self-reinforcing set of bottlenecks. The combination of high capture costs and low carbon prices renders CCS projects economically unviable; volatile carbon prices reflect uncertainty in policy signals; and the absence of a legal framework pervades all aspects of technology deployment, market transactions, and risk management. Addressing any single dimension alone is insufficient.

Second, China's breakthrough in CCS must be advanced through coordinated efforts. The four dimensions—technological innovation, carbon market mechanisms, policies and regulations, and risk management—are interdependent and indispensable.

Third, the timing of China's "dual carbon" goals differs from the stage at which developed countries reached their carbon peaks. While developed nations face large-scale upgrades of aging infrastructure, a significant portion of China's infrastructure is still in the new construction or expansion phase, which theoretically presents the possibility of incorporating CCS technology integration at the planning stage.

5.2. Outlook

Although this paper has established a relatively systematic framework for identifying bottlenecks in the commercialization of CCS in China, the analysis is primarily based on literature review and lacks primary field data; the analysis of specific capture technologies and storage techniques may not be sufficiently in-depth. Future research should further focus on assessing the dynamic impact of carbon market expansion on CCS economics, the tracking of CCUS industrial cluster development in western regions, and the analysis of the synergistic emission reduction potential of CCUS with technologies such as hydrogen and renewable energy.

References

[1] IPCC. (2005). *Carbon dioxide capture and storage: Summary for policymakers*. Cambridge: Cambridge University Press. Retrieved from https://www.ipcc.ch/report/carbon-dioxide-capture-and-storage/summary-for-policymakers/

[2] Tang, J. R., Guo, J. F., Wang, H., et al. (2025). Development status and key challenges of the full industrial chain of carbon capture and storage (CCS) in China. *China Mining Magazine, 34*(9), 3-14.

[3] Wang, K. X., Wu, J. W., & Han, G. D. (2026). Opportunities, challenges and future development pathways of CCUS in Xinjiang under the background of carbon peaking and carbon neutrality. *Journal of Arid Land Resources and Environment, 40*(2), 82-90.

[4] Leung, D. Y. C., Caramanna, G., & Maroto-Valer, M. M. (2014). An overview of current status of carbon dioxide capture and storage technologies. *Renewable and Sustainable Energy Reviews, 39*, 426-443.

[5] Dou, L., Sun, L., Lyu, W., et al. (2023). Trend of global carbon dioxide capture, utilization and storage industry and challenges and countermeasures in China. *Petroleum Exploration and Development, 50*(5), 1246-1260.

[6] Yao, J., Han, H., Yang, Y., Song, Y., & Li, G. (2023). A review of recent progress of carbon capture, utilization, and storage (CCUS) in China. *Applied Sciences, 13*(2), 1169.

[7] Wang, G. F., Lyu, W. F., Cui, K., et al. (2025). Global technological progress and application prospects of carbon capture, utilization and storage industrial clusters. *Petroleum Exploration and Development, 52*(2), 478-487.

[8] Zhu, X. Q., Wang, W. D., & Jia, Y. T. (2026). China's key CCUS technology and equipment reach internationally leading level. *China Petrochemical News*. Retrieved from http://www.sinopecnews.com.cn/xnews/content/2026-04/08/content_7145563.html

DOI: 10.54254/2755-2721/2026.37447

[9] Lyu, C., Liu, Y., Song, X. H., et al. (2025). Analysis of carbon price trends and influencing factors in the national carbon market. *Environmental Economics Research*, (4), 3-18.
[10] Wang, K., & Lyu, C. (2025). Global and Chinese carbon market review and outlook (2025). *Journal of Beijing Institute of Technology (Social Sciences Edition), 27*(2), 19-36.
[11] Lyu, J. N., Zhang, S., & Chen, W. Y. (2026). China's CCUS development progress and international experience implications under the carbon neutrality target. *Advances in Climate Change Research, 22*(1), 70–83.
[12] Chen, Y., Chen, T. F., & Xu, Y. H. (2025). Identification and analysis of key risks in carbon capture and storage (CCS) projects. *Journal of Tianjin University (Social Sciences), 27*(3), 222–230.
[13] Gao, X., Zhang, K., Ji, D., et al. (2025). A proposed layout of CO_2 capture utilization and storage for coal fired power plants in China. *Fuel, 401*, 135723.
[14] Sang, W. J., Song, G. G., Yuan, Z. G., et al. (2026). Development status and recommendations for CCUS-EOR projects in China. *International Petroleum Economics, 34*(3), 55–64.