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A GAP ANALYSIS OF CHINA'S REGULATORY FRAMEWORK FOR CO_2 GEOLOGICAL STORAGE

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1.0 EXECUTIVE SUMMARY

Carbon Capture, Utilisation and Storage (CCUS) has emerged as a pivotal component of China's carbon neutrality strategy.

Momentum has been building since the country's commitment in 2020 to peak CO_2 emissions by 2030 and achieve carbon neutrality before 2060.

Both state-owned and large-scale private enterprises are rapidly advancing CCUS projects across various sectors, from power generation to petrochemicals, coal-chemicals, and cement production.

China now stands among the major economies with integrated megaton-scale CCUS projects in operation.

Nonetheless, the absence of a clearly defined legal and regulatory framework for CO_2 geological storage in China adds uncertainties to this progress.

This regulatory gap analysis for China's CO_2 geological storage draws on lessons from the US, the EU and Australia, and the work of the International Energy Agency, the World Resources Institute and the Global CCS Institute.

It will assist international project developers in understanding China's regulatory landscape for CO_2 geological storage projects and provide domestic policymakers and researchers with insights to enhance and refine regulatory frameworks.

The success of CCUS implementation in China will not only determine the success of the country's climate commitments but also impact the global deployment of this critical climate mitigation technology.

MOMENTUM HAS BEEN BUILDING SINCE THE COUNTRY'S COMMITMENT IN 2020 TO PEAK CO_2 EMISSIONS BY 2030 AND ACHIEVE CARBON NEUTRALITY BEFORE 2060.

2.0 INTRODUCTION

China accounted for 27% of global carbon dioxide (CO_2) emissions in 2019 and is a critical player in the pursuit of global climate goals (Larsen et al., 2021). The transition to a low-carbon economy in China is imperative, requiring the country to continue improving energy efficiency, achieve a greater reliance on renewables, and decarbonise its existing fossil-based energy and industrial infrastructure. CCUS is central to the last of these three requirements. (Zhang et al., 2023) summarised the role of CCUS in various scenario studies, underscoring the escalating need for CO_2 emissions reductions through CCUS in China to meet its 2060 target, reaching around 2,350 Mt annually in 2060.

Within this urgency, CCUS development was put into high gear in 2021 after the 30/60 announcement.[1] Since then, China has accomplished many milestones, including the first integrated megaton-scale CCUS project, the first offshore CO_2 storage project, the first 1.5 Mt-scale coal power CCUS project, and the first commercial-scale CO_2 pipeline.

CCUS demonstrations have also been gathering unprecedented pace in China. As of July 2023, there were around 100 CCUS pilots and demonstration projects with various scales and in different phases in the country (Zhang et al., 2023). It is worth noting that most of the 100 CCUS projects are not integrated commercial projects but rather technology RD&D projects. The key milestones since 2021 are summarised in Table 1.

TIMELINE	PROJECT DEVELOPER(S)	PROJECT DESCRIPTION
June 2022	CNOOC, Shell, and Exxon	CNOOC, Shell, Exxon, and Guangdong government signed an MOU to explore China's first 10 Mt-scale CCUS hub in Guangdong province.
August 2022	SINOPEC	SINOPEC's Qilu-Shengli CCUS project became China's first integrated megaton-scale project, capturing CO_2 from a petrochemical plant for use in enhanced oil recovery.
November 2022	SINOPEC, Baowu, Shell, and BASF	SINOPEC, Baowu, Shell, and BASF began to jointly explore a second 10 Mt-scale CCUS hub in East China.
December 2022	Huaneng	Huaneng started construction of the country's first 1.5 Mt-scale coal power CCUS project.
May 2023	China National Energy, CNPC	Construction started on a 3 Mtpa integrated CCUS project in the Ningxia region by China National Energy, with the first phase to realise 500 ktpa. Part of the captured CO_2 from a coal-to-liquids facility will be transported to CNPC 's oil field for enhanced oil recovery.
June 2023	China National Energy	China Energy's 500 ktpa coal power CCUS project commenced full operation in Jiangsu province, becoming Asia's largest operational CCUS project in the power sector.
June 2023	China United Cement Group (CUCG)	CUCG, a subsidiary of China National Building Material, inaugurated construction of the world's largest oxyfuel CCUS project in the cement industry at a scale of 200 ktpa in Shandong.
June 2023	SINOPEC	China's first commercial-scale CO_2 transport pipeline with a length of 109 km started full operations, serving SINOPEC's Qilu-Shengli CCUS project in Shandong.
June 2023	Huaneng	China's first carbon capture facility at a NGCC facility commenced operation on Hainan Island, developed by Huaneng Group. This pilot plan aims to capture 2,000 tonnes of CO_2 per year with Huaneng's own post-combustion capture technology.

Table 1: Key milestones in China's CCUS development since 2021 (compiled by author)

[1] China's 30/60 target was outlined by President Xi during the 75th session of the United Nations General Assembly in September 2020, indicating that China will reach a peak in carbon emissions before 2030 and become carbon neutral before 2060. https://news.un.org/en/story/2021/09/1100642

The policy signal is clear. Approximately 10 new macro- or sectoral-level policy documents referencing CCUS have been published since 2022 (Zhang et al., 2023). Furthermore, various sub-national governments, including Guangdong, Shandong, Sichuan, and Shaanxi, have demonstrated their commitment to CCUS by incorporating it into their climate action plans. Some significant developments include the People's Bank of China's Carbon Reduction Facility (CERF), which facilitates financial institutions in providing low-cost loans to decarbonisation projects, including renewables, energy conservation, and CCUS, contingent upon carbon reduction disclosure.[2]

Notably, foreign financial institutions like Deutsche Bank China, Societe Generale China, and DBS Bank China have been selected to participate in this program. President Xi Jinping during a meeting of the Central Commission for Deepening Reform on 11 July 2023 underscored China's shift from controlling both the maximum volume and intensity of energy consumption to focusing on the maximum volume and intensity of carbon emissions.[3]

These developments mean that provinces, sectors, and manufacturing plants may eventually face an emissions cap. CCUS is poised to become an even more crucial tool for China's major emitting industries in adapting to this policy shift.

While there has been substantial progress in several areas, the absence of a viable business model and a well-defined legal and regulatory framework still hinders the widespread expansion of CCUS in China (Ghaleigh, 2018). To sustain the positive trajectory, it is imperative for China to develop a comprehensive national CCUS strategy in alignment with its 30/60 targets. In addition, China should also establish a regulatory and legal framework, explore incentive policy mechanisms, and strengthen its commitment to international collaboration on CCUS in the years ahead. This report highlights the gaps within China's legal and regulatory landscape to a CO_2 geological storage project and proposes solutions to address these issues.

[2] https://english.www.gov.cn/statecouncil/ministries/202201/28/content_WS61f341b2c6d09c94e48a464b.html

[3] In presiding over the second meeting of the Central Committee for Comprehensively Deepening Reform, General Secretary Xi Jinping emphasised that China has entered a critical period in which carbon reduction has become a key strategic direction, and needs to improve the regulation of the total amount and intensity of energy consumption, and gradually shift to a dual-control system for the total amount and intensity of carbon emissions. http://www.ce.cn/cysc/stwm/gd/202307/14/t20230714_38631471.shtml (in Chinese)

3.0 ANALYTICAL FRAMEWORK

This research aims to identify the missing components within China's legal and regulatory framework concerning industrial-scale CO_2 geological storage activities and to offer recommendations informed by the regions that have already developed and implemented these regulations. For the purposes of this study, an industrial-scale CO_2 geological storage project is defined as an industrial project involving the processing of at least 100,000 tonnes of CO_2 annually over multiple years. Such projects typically necessitate approval from various regulatory authorities at different administrative levels in China.

The gaps within the existing framework are explored through two key questions: 1) to what extent do China's current regulatory procedures encompass key stages of a CO_2 geological storage project; and 2) what are the missing components in China's current regulatory landscape? A CO_2 geological storage project is defined as "the carbon is stored deep underground in geological formations" (IPCC, 2005). This study does not cover carbon capture and transport components.

This analysis commences with the construction of a conceptual regulatory framework, drawing upon essential components gathered from a selection of classic works, which includes the "Guidelines for Carbon Dioxide Capture, Transport, and Storage (2008)" by the World Resources Institute, the "Carbon Capture and Storage: Legal and Regulatory Review (2016)" and the "Legal and Regulatory Frameworks for CCUS (2022)" by the IEA, and the Global CCS Institute's CCS Legal and Regulatory Indicator (2023).

Subsequently, this research proceeds to compare the conceptual regulatory framework with China's existing legal and regulatory documents, which are substantially associated with large-scale industrial project development and the mining and energy production industry (Table 2). A CO_2 geological storage project shares many similarities with mining, and oil & gas exploration activities in China. The names of these Chinese documents are listed below and described in the subsequent section.[4] It is worth noting that the 10-page 2016 guideline was China's first attempt to provide an official framework to identify, assess, and manage environmental risks of CCUS projects. The last phase of this study involves delivering recommendations for China's policymakers.

[4] This legislation and regulation can be accessed at https://flk.npc.gov.cn/index.html.

NAME	LEVEL	RELEASED BY
《中华人民共和国矿产资源法》(1996, 2018) “Chinese Mineral Resources Law”	Legislation	National People’s Congress
《中华人民共和国土地管理法》(1986, 1988, 1998, 2004, 2019) “Chinese Land Administration Law”	Legislation	National People’s Congress
《中华人民共和国物权法》(2009) “Chinese Property Law”	Legislation	National People’s Congress
《企业投资项目核准和备案管理条例(2017)》” Regulations on the Administration of Enterprise Investment Projects by Verification and Approval and Record-filing (2017)”	Regulation	State Council
《矿产资源法实施细则(1994)》 “The Rules for the Implementation of the Mineral Resources Law”	Regulation	State Council
《矿产资源勘查区块登记管理办法(1998)》 “Regulations for Registering to Explore for Mineral Resources Using the Block System”	Regulation	State Council
《矿产资源开采登记管理办法(1998)》Procedures for Administration of Registration of Mining of Mineral Resources.	Regulation	State Council
《探矿权采矿权转让管理办法》 (1998, 2014) “Measures for the Administration of the Transfer of Exploration and Mining Rights”	Regulation	State Council
(《关于加强碳捕集、利用和封存试验示范项目环境保护工作的通知(2013)》"Strengthening Environmental Protection of Carbon Capture, Utilization, and Storage Pilot Projects"	Notice	Ministry of Ecology & Environment
《二氧化碳捕集、利用与封存环境风险评估技术指南(试行)(2016)》”Technical Guidelines for Environmental Risk Assessment of Carbon Dioxide Capture, Utilization, and Storage (Trial)(2016)"	Technical Guideline	Ministry of Ecology & Environment

Table 2: Chinese legal and regulatory documents examined in this study

3.1 A conceptual framework

A typical CO_2 geological storage project has a lengthy timeline that spans several decades, covering phases such as site characterisation and selection, injection operations, closure, and post-closure management (IPCC, 2005; WRI, 2008; the US EPA, 2024). GCCSI (2022) also indicates that establishing a new CCS facility or retrofitting CCS into an existing facility is a substantial industrial undertaking that necessitates a comprehensive suite of studies, starting from conceptualisation through pre-feasibility and feasibility studies before embarking on detailed engineering assessments. A well-established regulatory framework for CO_2 geological storage can accommodate this multi-phase process, and clearly define regulatory requirements from relevant authorities.

The following concept design is mainly drawn from WRI (2008) and IEA (2016, 2022). Before entering the injection phase, comprehensive site characterisation and selection must be conducted to evaluate potential storage sites, as a prerequisite for a permit for CO_2 storage. The prerequisites might also involve environmental impact assessments, risk assessments, a monitoring and verification plan, and consultations with stakeholders. These steps are vital in ensuring the safe and effective implementation of a CO_2 storage project and in complying with regulatory requirements. They set the stage for the subsequent phases of the project, including injection and post-injection activities.

The injection phase of a CO_2 storage project can have a significant duration, typically spanning from 20 to 50 years, depending on various factors, including the site's characteristics and operational considerations (IEA, 2022). At the end of injection, a gradual transition towards site closure begins, with certain wells being plugged and abandoned before the project's final closure. Injection activities cease during the site closure phase, and most injection wells are securely sealed, except for those designated for ongoing monitoring purposes.

Monitoring protocols after injection are implemented to ensure that the project poses no risks to human health or the environment. Once a project is certified for closure, management responsibility might shift to the State, depending on domestic law. In this study, the conceptual framework categorises a completed project into three distinct phases: pre-injection, during-injection, and post-injection, with each encompassing crucial regulatory requirements (as detailed in Table 3).

	PRE-INJECTION	DURING INJECTION	POST-INJECTION
KEY LEGAL & REGULATORY ISSUES	• Permitting process • Site characterisation and selection • Ownership of pore space • Interaction with other surface and subsurface resources • Risk assessment • Environmental impact assessment • Measurement, reporting, and verification (MRV)	• Storage site inspections • Defining operational liabilities and financial security • Measurement, reporting, and verification (MRV)	• Site closure process and certification • Long-term responsibility post-closure (e.g. maintenance and monitoring of storage site and addressing long-term liabilities) • Finance assurances of long-term site stewardship

Table 3: A proposed conceptual Legal and Regulatory Framework for a CO_2 storage project for this study (created by author)

4.0 ANALYSIS

Building upon the conceptual framework and the key issues identified in Table 3, this section assesses the extent to which China's existing legal and regulatory can accommodate the requirements of CO_2-geological storage activities. It also outlines potential subsequent actions for consideration, including lessons from the experiences of the US, Australia, Norway, etc. All these selected countries are ranked in the top ten in the GCCSI's 2023 CCS Legal and Regulatory Indicator (Havercroft & Raji, 2023).

4.1 Permitting Requirements

In China, large-scale construction or industrial projects follow one of three pathways to receive approval: the registration-based system, and approval-based systems I and II, as outlined in the "Regulations on the Administration of Enterprise Investment Projects by Verification and Approval and Record-filing (2017)". The choice of pathway is determined by the project's nature and characteristics. Projects related to national security, strategic resource development, or significant public interest are subject to the approval-based systems.[5]

The difference between the two approval-based systems is whether public funds are involved. Projects supported by the State typically undergo a more rigorous approval process under approval-based system II and applies to projects like petrochemical plants, pipeline construction, and oil & gas production projects. Large-scale CO_2 geological storage projects may also be subject to this approval-based system II, given their inherent nature and importance.

The process for obtaining a project permit in China typically follows a three-step procedure consisting of a project proposal, feasibility report, and preliminary design report (Figure 1). These reports, including the feasibility and preliminary design reports, are required to address crucial aspects like site selection, environmental assessment, land use considerations, geological hazards, soil and water conservation measures, and energy conservation.[6] They are submitted to the relevant authorities for review. Ultimately, the final decision is reached through a review process led by the national and provincial Development and Reform Commissions. These commissions will also consider inputs and recommendations from peer departments in this process. In addition to a permit for construction, the Chinese government has established a comprehensive oversight framework that covers other stages of a project, encompassing construction, operation, site closure, and post-closure. The primary gap at present lies in integrating regulatory topics and relevant authorities related to CO_2 geological storage into this existing process, particularly by clarifying the level and type of government agencies and incorporating storage-related site characterisation and environmental and risk assessment within this permitting process.

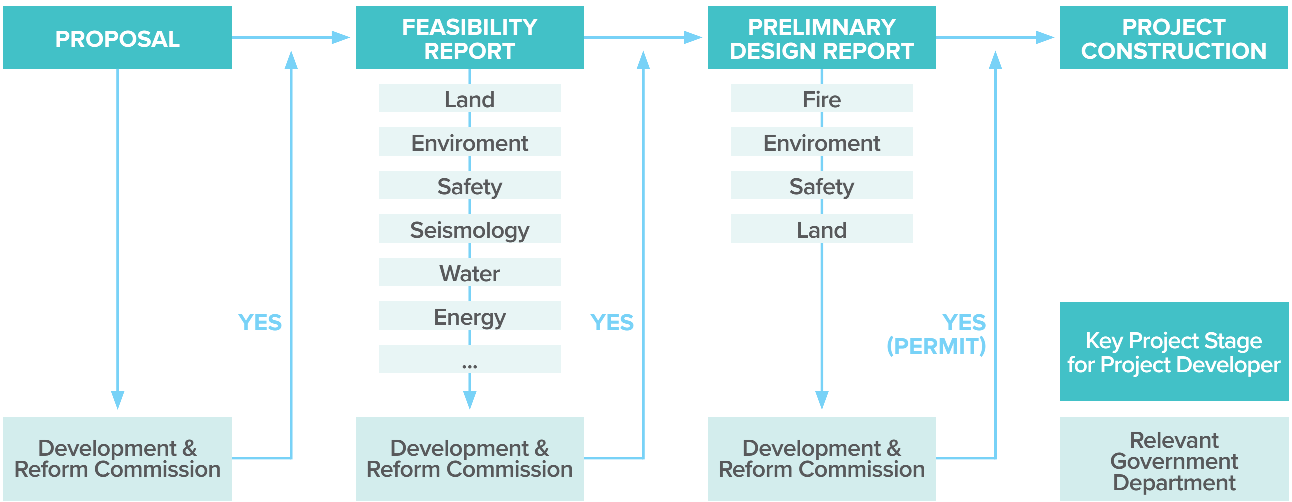

Figure 1: A typical permitting process for an industrial project in China (created by author)

[5] "Regulations on the Administration of Approval and Filing of Enterprise Investment Projects (2017)" https://www.gov.cn/zhengce/content/2016-12/14/content_5147959.htm

[6] "Regulations on the Administration of Approval and Filing of Enterprise Investment Projects (2017)" removed site selection and environmental impact assessment reports from the pre-feasibility study phase. However, an environmental impact assessment is still required before project construction. The site selection requirement for a regular project usually involves land use planning, infrastructure & accessibility, and potential environmental pollution, etc.

4.2 Site characterisation and assessment

Site selection for CO_2 geological storage in China is guided by two fundamental regulations. The first, Article 3 paragraph 3 of the Mineral Resources Law of the People's Republic of China [1996], stipulates that "the exploration and production of mineral resources require the application and authorisation to obtain exploration rights and mining rights, respectively."

The second regulation, known as the Regulations for Registering to Explore for Mineral Resources Using the Block System (1998) states that "exploration for various mineral resources must be approved and registered by the competent geological and mineral authorities of the State Council, which will issue exploration licenses" in Article 4, paragraph 1.

These two regulations cover all major mineral resources such as oil, gas, coal, and metal ores, requiring exploration permits for their development. However, China's Mineral Resources Law (Box 1) only defines "the natural resources with value for utilisation, which are formed through geological function and exist under solid, liquid or gaseous state" as resources. Pore space for CO_2 geological storage has not been defined as a resource in any Chinese legal and regulatory documents; therefore, site assessment for CO_2 geological storage is still not required.

Some countries and regions have enacted site assessment requirements for proposed CO_2 geological activities that can provide some lessons to Chinese regulators. In December 2010, the US EPA published the Federal Requirements under the Underground Injection Control (UIC) Program for CO_2 Geologic Sequestration Wells Final Rule (Class VI Rule). To obtain a UIC Injection Class VI permit, CO_2 storage site operators must demonstrate that the site candidate has a suitable injection zone capable of receiving CO_2 and a confining zone that will effectively prevent fluid movement out of the injection zone (US EPA, 2010). This process requires applicants to collect the necessary data to prove site suitability and submit it with a Class VI permit application for evaluation by the EPA.

Norway and the European Union have similar processes for determining the suitability of a storage location through a set of criteria.[8] All these regulations require the submission of sufficient data to demonstrate that the proposed storage site poses minimal environmental, health, or leakage risks.

The Mineral Resources Law of the People's Republic of China, enacted in 1986 and revised in 1996 and 2019, governs the exploration and exploitation of mineral resources within China. It outlines the following key principles and regulations:

1. Ownership: Land and mineral resources in urban and suburban areas belong to the state, while those in rural areas are owned collectively by farmers, with exceptions for state-owned land. This law sets the framework for mineral rights ownership.

2. Licensing and rights: The law defines the procedures for obtaining exploration and mining rights for minerals. It distinguishes between different types of mining projects based on size and nature, specifying different periods for large-scale, medium-sized, and small mining projects.

3. Exploration and mining: The law addresses the rights and obligations of exploration and mining rights holders. It outlines environmental protection measures, safety regulations, and mine closure requirements.

4. Transfer and termination: The law provides guidance on the transfer of mineral rights and the process for mine closure and land reclamation.

5. Legal sanctions: It outlines penalties for violations, including environmental damage, illegal mining, and unauthorised transfer of mineral rights.

6. Compensation and fees: Provisions related to compensation for land expropriation, royalties, and other financial considerations are included.

7. State regulation: The state has regulatory authority over the mineral resources sector, and various government agencies oversee the issuance of permits, inspections, and environmental impact assessments.

8. Protection of mineral resources: The law emphasises the importance of rational and efficient utilisation of mineral resources and sustainable development.

Box 1: A high-level introduction to China's Mineral Resources Law [7]

[7] https://en.cgs.gov.cn/laws/ps/201603/t20160309_266132.html

[8] https://www.sodir.no/en/regulations/regulations/exploitation-of-subsea-reservoirs-on-the-continental-shelf-for-storage-of-and-transportation-of-co/;https://climate.ec.europa.eu/eu-action/carbon-capture-use-and-storage/legal-framework-safe-geological-storage-carbon-dioxide_en#:~:text=The%20CCS%20Directive%20lays%20down,human%20health%20or%20the%20environment.

4.3 Pore Space rights

Pore space rights are also referred to as "the right to utilise underground space" in China. Article 8 of the Land Administration Law establishes that "urban land is state-owned, while land in rural and suburban areas belongs to farmers' collectives unless otherwise stipulated by law. Homesteads, private plots, and private hills are collectively owned by farmers." Article 136 of the Property Law specifies that "the right to use construction land can be established on the surface, above the ground, or underground." This provision marked the first legal differentiation of land use rights in China, but it remains unclear whether the rights to underground and above-ground land are exercised by the same owner.

More recently, certain sub-national governments at the provincial and municipal levels have indicated that all underground spaces should be state-owned. Nevertheless, the Land Administration Law, the Land Registration Rules No. 184 [1995], and the Measures for Land Registration No. 40 [2007] have not yet established clear provisions for the registration of land use rights in underground spaces.[9]

Internationally, pore space rights are managed differently in different jurisdictions. In many European countries, the subsurface geology, which includes the pore space where CO_2 is injected, is typically owned by the national government (Havercroft et al., 2018). In the US, the allocation of subsurface property rights on non-federal lands is subject to state jurisdiction and can vary. In most states, when subsurface minerals are depleted, the surface owner typically gains exclusive possession of the space that was once occupied by these minerals (Ivory-Moore, 2022).

China's Mineral Resources Law Chapter VII Article 2 states "Mineral resources belong to the State. The rights of State ownership in mineral resources are exercised by the State Council." Therefore, subsurface ownership defaults to the state in China, and the challenge lies in legislating this ownership structure, providing legal clarity, and establishing access procedures for CO_2 geological storage project developers. This also leads to the next challenge – when CO_2 geological storage occurs in an area where exploration and mining rights are already allocated.

4.4 Competition with other resources

Once pore space is clearly defined, the next challenge is resolving situations where pore space overlaps with other resource claims for a suitable site. In China, according to the "Measures for the Administration of the Transfer of Exploration and Mining Rights (2016)", the exploration right is inherently exclusive. This exclusivity means that a second exploration right cannot be established within an approved block and timeframe. Furthermore, the standard duration for an exploration right is typically three years, but for resources such as oil and gas, it can extend up to 15 years. Therefore, even if pore space is officially recognised as a resource by the Ministry of Natural Resources, a new player cannot obtain an exploration right for CO_2 geological storage once a specific block is allocated.

Article 7 of the Procedures for Administration of Registration of Mining of Mineral Resources (the State Council Order [2014] No.653) stipulates that the mining period for mining rights can extend up to 30 years for large-scale projects, 20 years for medium-sized enterprises, and 10 years for smaller ones. The mining right holder has the option to renew their license with the registration authority within 30 days before its expiration. Consequently, under the current regulatory framework, it is virtually impossible for a new entrant to establish a presence in this sector in areas designated for exploration or production. This practical challenge is further reflected in the current landscape, as nearly all CO_2 storage projects are initiated by owners who already possess mining or exploration rights in the respective regions.

Some efforts to address issues related to overlapping mining rights have been made by sub-national governments in China. In 2016, Shanxi province introduced policies aimed at promoting coalbed methane exploration in coal production areas, encouraging parties to engage in consultations, and facilitating administrative mediation.[10] To encourage these efforts, in 2017, the former Ministry of Land and Resources implemented a policy that allowed for the coexistence of oil and gas mining rights with non-oil and gas mining rights.[11] This policy required all mining rights holders to enter into mutual non-interference agreements to govern their activities. Despite these

[9] Both the Land Registration Rules and the Measures for Land Registration are released by the Ministry of Land and Resources.

[10] https://www.gov.cn/xinwen/2016-12/16/content_5148813.htm

[11] https://www.gov.cn/xinwen/2018-01/05/content_5253518.htm

initiatives, they have not yet been formalised or proven sufficient to pave the way for CO_2 geological storage activities.

Examples of successful resolution of overlapping underground resource issues can be found in regions like Alberta, Canada. Alberta's regulatory framework assessment clarifies property rights, manages conflicts, and supports the responsible development of both hydrocarbon resources and CO_2 geological storage (Ettinger, 2022). Learning from these experiences, China can pass legislation or establish regulations that specifically address overlapping underground resources, defining the rights, responsibilities, and processes for resolving conflicts. Additionally, it is highly recommended that Chinese governments develop a comprehensive inventory of storage-quality pore space, along with an assessment of potential interactions with other subsurface resources. This database can facilitate informed decision-making regarding subsurface resources.

4.5 Measurement, Report and Verification Plan

A measurement, reporting, and verification (MRV) requirement is an essential component for a CO_2 geological storage project, ensuring its safety, environmental integrity, and alignment with climate goals. MRV is also a prerequisite for CCUS to be incorporated in any carbon market or to be supported by public money.

In 2013, China's Ministry of Environmental Protection took an initial step by issuing a notice titled "Strengthening Environmental Protection of Carbon Capture, Utilization, and Storage Pilot Projects (2013)." This notice proposed the exploration of an "environmental risk prevention and control framework" and encouraged the development of environmental standards and specifications.

Subsequently, the Science & Technology Standards Department of the Ministry of Environmental Protection released China's first "Technical Guidelines for Environmental Risk Assessment of Carbon Dioxide Capture, Utilization, and Storage (Trial) (2016)." However, these technical guidelines only briefly mentioned MRV, suggesting the need to "develop an environmental monitoring plan, including routine pollutant monitoring, pollutants monitoring, and carbon dioxide monitoring," without offering specific implementation details. To date, China has made limited progress in developing an MRV framework, primarily due to the relatively slow development of CCUS projects in the country in previous years. Since 2021, with an increasing number of commercial CCUS projects being announced, there has been a growing call for the Ministry of Ecology and Environment to establish a comprehensive MRV framework.

A well-established MRV framework can be observed within the US EPA's Underground Injection Control Class VI (UIC Class VI) requirements for CO_2 injection and storage projects, coupled with the Greenhouse Gas Reporting Program. This framework includes two core requirements – a. the UIC Class VI's own MRV requirements focusing on the subsurface and potential drinking water impacts, and b. subpart RR, part of the EPA's Greenhouse Gas Reporting Program with a focus on the tracking and quantification of CO_2. Subpart RR requires project developers to implement an EPA-approved MRV plan. Approved projects are mandated to institute monitoring systems, gathering data on various parameters such as CO_2 injection, the integrity of geologic formations, wellbore stability, pressure differentials, and the potential for CO_2 leakage (US EPA, 2010). This continuous monitoring process serves to promptly detect any issues or irregularities during the injection phase. In addition to monitoring, project operators are obligated to submit regular reports to regulatory authorities. These reports play a pivotal role in demonstrating compliance with the conditions stipulated in the UIC Class VI permit.

The verification process is another critical component, involving an assessment to ensure that the injected CO_2 remains securely contained within the designated storage site and poses no risks to human health or the environment. Verification activities are designed to confirm compliance with permit conditions and the maintenance of safety and environmental standards. Furthermore, the MRV framework includes provisions for taking corrective actions in the event of any identified issues, deviations, or potential risks uncovered during monitoring and verification activities. Operators must respond promptly to address these concerns, maintaining safety and compliance. Even after injection activities have concluded and the site has been closed, post-closure monitoring remains ongoing. This long-term monitoring phase is indispensable for ensuring the continued integrity of the storage site and identifying any potential issues that may arise over time. At the time of writing, the EPA has approved 24 MRV plans[12], which can provide extremely valuable lessons for other countries.

[12] https://www.epa.gov/ghgreporting/subpart-rr-geologic-sequestration-carbon-dioxide

4.6 Closure & post-closure

China's existing procedures for closing a mining field can be adapted for use in a CO_2 storage project, but certain critical aspects, such as post-closure monitoring, long-term liability, and site responsibility transfer, remain unaddressed. The Rules for the Implementation of the Mineral Resources Law (Articles 33 and 34) outline the steps for mine closure. Initially, the mine owner is required to submit a geological report concerning the closure of the pit. Following approval of this geological report, the mining right holder must prepare a comprehensive report on mine closure. The department that originally granted the mining right collaborates with the geological and industry departments to jointly approve the closure report.

Once the closure report receives approval, the owner undertakes the necessary measures related to labour safety, soil and water conservation, land reclamation, and environmental protection, or covers the associated costs for land reclamation and environmental protection. After the completion of these tasks, the government cancels the mining license. While this process provides a framework for closing a mining field, it does not adequately address several key issues pertaining to CO_2 geological storage, including post-closure monitoring, long-term liability, and the transfer of site responsibility.

The EPA's UIC Class VI, WRI's guidelines and Alberta's regulatory framework assessment provide some valuable examples. According to the WRI's guidelines, the successful closure of a site should exhibit the following characteristics:

- There must be no migration or release of CO_2 from closed sites due to geological or engineering hazards that could endanger human health or safety.
- CO_2 retention levels should be sufficiently high to prevent adverse impacts on health and safety and to make a significant contribution to achieving atmospheric stabilisation goals.
- Closure should be achieved through reasonable, established, and cost-effective methodologies.
- After a site is officially certified as closed, it should remain safe, efficient, and secure over time (WRI, 2008).

Within the UIC Class VI, closure refers to the structured process of concluding injection operations, involving the proper sealing of wells and implementing measures to ensure the containment and isolation of stored CO_2. Post-injection activities focus on continued monitoring and verification to assess the long-term effectiveness of closure measures. This phase aims to confirm the integrity of the storage site, assess potential environmental impacts, and address any unforeseen challenges that may arise after injection ceases. After this post-injection phase, and once the regulatory authority is satisfied that the permit conditions have been met, the site can be officially closed(US EPA, 2010).

In addition to creating a process to close a storage site, Alberta's regulatory framework assessment defines that liability for CO_2 credits is transferred to the Crown when a closure certificate is issued (Alberta Government, 2013). The Alberta Energy Regulator is also responsible for working with project operators to set project-specific fees for a post-closure stewardship fund that covers the costs of long-term monitoring and maintenance, CO_2 credits liability, and costs associated with unforeseen events. The specific procedures and requirements for setting these fees are typically outlined in the regulatory framework. The aim is to ensure that adequate financial provisions are in place to address potential liabilities and long-term stewardship obligations for CCS projects in Alberta.

4.7 Transfer of site responsibility

As per the Rules for the Implementation of the Mineral Resources Law, once mining closure is certified and the mining right is deregistered in China, the project owner is relieved of further responsibilities for the site. However, this existing setup may result in unclear responsibilities and a lack of clarity regarding who will be responsible for ensuring the continued security and environmental soundness of CO_2 geological storage after well closure. Additionally, in cases of accidents or environmental damage during the project, it is crucial to define the responsibilities and compensation mechanisms for all involved parties to safeguard the public interest.

Australia, Norway, and the UK follow a similar approach, where long-term responsibilities and liabilities are eventually transferred to the state. However, there are differences in the timing of this transfer among these jurisdictions. The EU Directive 2009/31/EC requires that the state assumes liability after 20 years from the date of storage site closure, provided that the operator provides evidence indicating the complete and permanent containment of the stored CO_2. In the EU context, financial requirements are a crucial criterion for the transfer of long-term liability. In Norway, the operator is required to make a financial contribution that should cover anticipated monitoring expenses for a minimum period of 30 years (Norwegian Petroleum Directorate, 1997).

5.0 LESSONS LEARNED FROM CHINA'S FIRST CO_2 GEOLOGICAL STORAGE PROJECT

The Shenhua Ordos CCS demonstration project was China's pioneering integrated CCS project featuring a component for CO_2 geological storage, partially supported by China's Ministry of Science and Technology. The project focused on capturing CO_2 emissions from a coal-to-chemical facility. The captured CO_2 was then transported approximately 11 kilometres to a designated storage site in Jinhoro Banner, Erdos City, Inner Mongolia. The injection phase of the project commenced in 2011 and concluded in 2015, during which a total of 0.3 Mt of CO_2 was injected.

The entire project incurred a total cost of approximately $40 million, with Shenhua Group contributing over $30 million for the engineering and construction of capture and storage facilities. Of this amount, more than 41% was invested in subsurface storage. China's Ministry of Science and Technology and the National Energy Administration provided approximately $6 million and $1 million, respectively, to support monitoring and research associated with the project (Zhang et al., 2016).

The project was officially launched in 2007, with the pre-feasibility study report completed in 2009. Shenhua began to apply to various departments for approvals in March 2010, and received the last approval from provincial Environment Department in April 2011. During the initial stages of the project, CCS was a relatively novel industrial concept spanning various industries. As a result, there was no clearly designated authority at the national and sub-national levels to approve or guide such projects. To navigate this, the project's developer Shenhua Group engaged with the provincial Development and Reform Commission. The demonstration project was temporarily put on record and approved at the provincial level. The legal aspects, including the right to use saline aquifers for storage, were areas of legal ambiguity. However, Shenhua Group already owned the coal mining rights in the area; therefore, the application for land use was primarily focused on surface land, guided by the provincial government.

Moreover, at the project's inception, there were no specific government guidelines related to safety and environmental protection evaluation standards for CCS projects. Safety and environmental evaluations initially followed the content evaluation criteria of ordinary chemical projects. The Shenhua Ordos CCS Project highlighted the challenges and legal ambiguities faced by early CCS initiatives in China. Given the limited interest in CCUS development between 2015 and 2020, there are still significant legal and regulatory gaps, creating uncertainties for project developers in China years after the completion of Shenhua Ordos CCS Project.

6.0 CONCLUSION & RECOMMENDATIONS

Following an assessment of China's existing legal and regulatory framework and an analysis of a real project, it is evident that there are some gaps that must be addressed to enable the successful development of commercial-scale CO_2 geological storage projects in the country.

A regulatory framework capable of supporting the development of CO_2 geological storage activities should be considered and established by 2030.

Key priority areas within this framework include the establishment of a permitting process and authority, defining pore space rights, implementing site characterisation, measurement, monitoring, and verification mechanisms, resolving potential conflicts with other resources, and creating a management framework for closure and post-closure phases.

The good news is that China has gradually built a comprehensive regulatory framework for oil and gas exploration and production since the introduction of the Mineral Resources Law in 1996. The state has accumulated valuable experience in implementing a licensing system for the mining industry and establishing a holistic management framework. These lessons provide a solid foundation upon which China can develop the regulatory components related to CO_2 geological storage.

International practices offer valuable insights that China can take into consideration. For instance, the US EPA oversees the Underground Injection Control (UIC) Program, which features Class VI regulations specifically tailored for CO_2 geologic storage. The European Union has introduced the Carbon Capture and Storage Directive to regulate the geological storage of CO_2. In Canada, Alberta stands out with its comprehensive regulatory frameworks, encompassing rules for permitting, monitoring, and liability management, along with mechanisms for addressing long-term liability and financial assurance. Similarly, Norway has laid down a comprehensive legal and regulatory framework for CCS. These international references contribute knowledge regarding critical aspects identified for China's legal and regulatory framework development.

China has expressed a clear commitment to achieving commercial readiness for CCUS by 2030 in its "1+N" climate policy framework, leaving a six-year window for the development of an essential legal and regulatory framework for CO_2 geological storage. This requires a collaborative, multidisciplinary approach, uniting legal experts, scientists, environmental advocates, government officials, and industry stakeholders.

To facilitate this, it is advisable to establish a public-private coalition dedicated to the task, co-led by the national and provincial Development and Reform Commissions, the National Energy Administration Bureau, the Ministry of Natural Resources (specifically, the Chinese Geological Survey), the Ministry of Emergency Management, the Ministry of Ecology and Environment, the Ministry of Commerce, and the Ministry of Housing and Urban-Rural Development. These government agencies all play pivotal roles in managing China's exploration and production of underground resources.

While this study has highlighted some specific areas for intervention, it is essential that this proposed government taskforce conduct a comprehensive review of existing national laws, regulations, and policies concerning CO_2 geological storage, starting with defining pore space rights and resolving conflicts with other resources. These two issues might be the most difficult components within this CO_2 geological storage-oriented regulatory framework given the number of interested parties.

This review would need to be completed as soon as possible, as the findings from this holistic review should serve as the foundation for the development of new regulations and policies, or the amendment of existing ones, to accommodate CO_2 geological storage. The framework should address various facets of the entire process of a CO_2 geological storge project, including legal, technical, financial, and environmental considerations. Within this improved framework, well-defined roles and responsibilities for regulatory bodies for CO_2 geological storage should be clearly defined.

Once the implementation of the new legal and regulatory framework begins, continuous monitoring and enforcement to ensure compliance with the regulations are needed. Regular reviews and updates of the framework are also recommended to suit evolving technology, scientific knowledge, and changing needs over time. Finally, it is important for Chinese policymakers to actively engage in international discussion, working with other countries to harmonise standards and regulations.

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