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Carbon Capture and Sequestration in China-An Overview

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Abstract: If deep reductions in anthropogenic greenhouse gas emissions are to be achieved, the introduction of CO_2 capture and storage in geological reservoirs is likely to be necessary. Several CO_2 storage demonstration projects are needed in a variety of geological formations worldwide to prove the viability of CO_2 capture and storage as a major option for climate change mitigation. A number of studies have been performed to identify potential worldwide opportunities for early application of CO_2 sequestration. China has several low-cost CO_2 sources at sites that produce NH_3 from coal via gasification. These CO_2 sources would potentially be economically interesting candidates for storage demonstration projects if there are suitable storage sites nearby. This study reviews the efforts that have been made in the area of geologic storage of CO_2 in China and what measures the government is putting in place to contribute to the reduction in the emission of greenhouse gases.

Key words: Carbon capture and sequestration, greenhouse gases, carbon dioxide

INTRODUCTION

The IEA World Energy Outlook (WEO) Reference Scenario projects that, based on policies currently in place, by 2030 CO_2 emissions will have increased by 63% from 2004 levels, which is almost 90% higher than 1990 levels. Even in the WEO 2004's World Alternative Policy Scenario-which analyses the impact of additional mitigation policies up to 2030-global CO_2 emissions would increase 40% on today's level, putting them 62% higher than in 1990. Fossil fuels will be used extensively and CO_2 emissions will rise over the next half century, if no new policies are put in place. It is clear that such a development is not sustainable (IEA, 2004).

According to the International Energy Outlook (EIA, 2005), prepared by the Energy Information Administration of the US Department of Energy, China was the world's second largest emitter of CO_2 after the United States in 2002, contributing 13.6% of total world CO_2 emissions or 3322 megatonnes (Mt) of CO_2. In its Reference Case scenario, the IEO (2005) projected that China's CO_2 emissions will grow 4.0% per year (the highest rate in the world), reaching 8133 Mt CO_2 by 2025, at which point China's share of world CO_2 emissions is projected to reach 21%. By contrast, the US share of world CO_2 emissions will decrease from 24-21% during 2002-2025 and that in 2025, US emissions will be 98% of China's (IEO, 2005).

Abatement of carbon dioxide emissions: Various courses of action could be taken to reduce greenhouse gas emissions. They vary in the scale of their effect, their cost and potential contribution. Three options are typically considered for reducing carbon dioxide emissions from power generation:

- Improvements in energy efficiency in power generation or in end-use.
- Switching to fuels containing less carbon (e.g., natural gas instead of coal).
- Substitution of electricity from carbon-free sources (e.g., renewables or nuclear) (Freund, 1997).

A fourth option has now been established as a viable approach to reducing carbon dioxide emissions. This is the removal and storage of carbon dioxide. In practice it is unlikely that any single approach would be used alone-instead, combinations of these four options would be used to meet particular needs. The advantage of removing carbon dioxide from flue gases is that it would enable society to continue to enjoy the benefits it has come to expect from fossil fuel derived power whilst minimizing the impact on the environment, although the cost would be significant (Freund, 1997).

WHAT IS CO_2 CAPTURE AND STORAGE?

CCS refers to the capture of CO_2 from emissions, followed by storage, thereby preventing it from entering the atmosphere. To be useful for climate change mitigation, storage should be for at least many hundreds of years until well past the end of the fossil fuel era (Gale, 2004). CCS involves three stages: CO_2 capture, transport and storage.

CO_2 capture: Carbon capture is best applied to large stationary sources such as power stations and industrial plants, where CO_2 can be separated from the flue gases at some stage of the process. There is a range of capture technologies at different stages of development. The most developed has been used in the petroleum and gas industry for almost a century and has already been applied to a few small power plants abroad producing CO_2 for Enhanced Oil Recovery (EOR) or industrial uses. In principle, subject to scale-up issues, this technology could be retrofitted to the UK's existing power stations as well as included in new build. All capture technologies consume energy and reduce the efficiency of the power station. Further research and development will lead to cost reductions and increased efficiency, although capture will inevitably add to process costs (Gale, 2004).

CO_2 transport: CO_2 is captured as a gas. Its transport generally needs it to be compressed and/or cooled, requiring energy input decreasing net CO_2 emission reduction. Bulk transport may be by tanker or pipeline. Tankers may have a role in smaller projects but for larger volumes pipelines are the only practical option. CO_2 transport by pipeline is an established commercial technology. Over 3000 km of pipelines are currently used to transport several Mt of CO_2 per year for EOR in the US and Canada (Gale, 2004).

CCS in geological formations: There are several potential options for storing captured CO_2. The most viable and environmentally acceptable is geological storage. CCS in geological formations involves capturing CO_2 and then injecting it into rock layers. According to Postnote (2005), there are 3 main storage options:

- Depleted or near-depleted oil and gas fields.
- Deep saline aquifers (porous rock layers containing salty water deep underground).
- Unmineable coal seams.
- Carbon Capture and Storage (CCS) in China.

Meng *et al.* (2007) observed that although detailed assessments have not been made of the CO_2 storage capacity in China, a large number of suitable CO_2 storage sites are plausibly available within China's numerous sedimentary basins. They make note of Friedmann (2003) who pointed out that China's rich Mesozoic-Cenozoic tectonic and stratigraphic history suggest a significant CO_2 storage potential. There are possible opportunities for storage in China in all three geological formations that have been recognized as major potential CO_2 sinks: deep saline aquifers, depleted oil and natural gas reservoirs and unminable coal-seams. The geology also suggests possibilities for CO_2 enhanced oil recovery (CO_2-EOR) and CO_2 enhanced coal-bed methane recovery (CO_2-ECBM) projects in China. As China's geology continues to be explored and characterized, its CO_2 storage potential will be further clarified.

In 1998, China began its first CO_2 storage project for CO_2-EOR in the Liaohe oil field, one of China's largest oil fields in the Bohai Basin (IEA, 2004a). Meng *et al.* (2007) also noted that a joint venture was formed between the China United Coal Bed Methane Corporation and the Alberta Research Council of Canada to develop technology for extracting coal-bed methane via CO_2 injection (CO_2-ECBM). Neither of these projects was motivated by climate change concerns. Rather they were designed to use CO_2 to assist in fossil fuel recovery. Nevertheless, these projects are giving China some experience with CO_2 storage. In addition, China, in 2003, joined the Carbon Sequestration Leadership Forum (CSLF), a ministerial-level organization initiated by the United States that aims to foster cooperation for CO_2 storage projects among the 17 signatory countries.

Sources of CO_2 in China: According to Meng *et al.* (2007), Effective storage of CO_2 requires a relatively pure stream of CO_2. Most of the world's large-volume point CO_2 sources come from fossil fuel power plants. At these sites, CO_2 is generated during combustion, mixed with the nitrogen used as combustion air and then vented at low concentrations as flue gas. Separating and capturing this CO_2 is costly.

They further state that China is one of the few countries where large streams of relatively pure CO_2 are available as a result of precombustion CO_2 capture. Most of these large point sources of relatively pure CO_2 are at coal-fed ammonia plants that use modern Texaco and Shell gasifiers. Because these CO_2 streams have already been separated, capturing and using this CO_2 for storage demonstration projects is much less costly than CO_2 that would be recovered from flue gases of fossil fuel power plants.

CHINA'S AQUIFERS

Deep saline aquifers: Gale (2004) stated that although saline aquifers do not have proven 'tightness', the Norwegian Sleipner project results are promising. CO_2 volumes estimated from monitoring measurements are consistent with the known injected volume. One recognized method for locating deep saline aquifers appropriate for CO_2 storage is to look for oil-and natural gas-bearing sedimentary basins. It is known that pockets of hydrocarbon form typically during the folding, plugging and faulting of aquifers (Hitchon *et al*., 1999). Therefore, brine-filled media will typically be found near pockets of known hydrocarbons in sedimentary basins.

China has more than 420 sedimentary basins having areas of 2000 km^2 or greater. There are numerous sedimentary basins in eastern and central China, such as Songliao, Bohai Bay, Ordos, North Jiangsu and Sichuan basins located on land and Yellow Sea, East China Sea, Pearl River Delta, Beibuwan and Yinggerhai basins located on the continental shelf.

Oil and gas fields: Oil and gas have been 'stored' underground for millions of years demonstrating that buoyant fluids can certainly be retained in these structures over long timescales. While depleted oil and gas fields obviously had this 'tightness', the extraction process may have damaged it. This is mainly due to potential leakage through abandoned production and exploration wells, but the possibility that the rock structure itself may have been weakened has also been suggested. The effective capping of wells is a mature technology although it might need some optimizing to seal CO_2 (Gale, 2004).

The oil and gas fields of the sedimentary basins in China are major potential geological storage sites of CO_2, especially depleted or depleting oil and gas reservoirs. Ping (2007) estimates the potential capacity of oil and gas reservoirs to be about 7.2 billion tones of CO_2. The usage of CO_2-Enhanced Oil Recovery (CO_2-EOR) and CO_2-Enhanced Gas Recovery (CO_2-EGR) not only stores a large amount of CO_2 in oil and gas fields, but also increases the recovery of oil and natural gas which can offset the cost of CO_2 capture and storage

Coal seams: CO_2 can be stored in beds of unminable coal and in some instances CO_2-Enhanced Coal Bed Methane (ECBM) might be feasible. China's coal bed methane (CBM) potential is estimated to be one of the world's largest-between 16,000 and 35,000 GNm^3 (Zhang and Zhang, 1996). However, the CO_2-ECBM potential is uncertain. Stevens and Kuuskraa (1998) identified the Ordos Basin and the Northeast China Coal Region as regions with the greatest CO_2-ECBM potential. The Ordos Basin has a coal-bed methane resource of 445 GNm^3, a possible CO_2-recovery potential of 180 GNm^3 (about a 2 year natural gas supply at the average rate expected for China during 2001-2025) and a corresponding CO_2 storage potential of 660Mt CO_2. The NE China Coal Region is estimated to have a coal-bed methane resource of 55GNm^3, a CO_2-ECBM recovery potential of 5.5GNm^3 and a CO_2 storage potential of 21 Mt CO_2.

Ping (2007) estimates the total geological storage capacity of CO_2 in China to be 1454.8 Gt (10^9 t), of which the CO_2 storage capacity in deep saline aquifers, coalbeds and gas and oil fields is estimated to be 1.435×10^{11} t, 1.2×10^{10} t and 7.8×10^9 t, respectively.

Governmental support: Ping (2007) states that China participated in the negotiations on the Charter of the Carbon Sequestration Leadership Forum (CSLF) and signed the Charter later to be one of the initiating Parties to CSLF. The government pays much attention to Carbon Capture and Storage (CCS) technologies. CCS was integrated into a National Medium and Long-term Science and Technology Development Plan towards 2020 as a leading-edge technology. In the 11th 5-Year Plan period (2006-2010), the National High Tech. Program (863 Program) will support the development of CCS.

CONCLUSION

The Chinese Government will support the research of CCS in China and expect Chinese CCS technology development roadmap to be planned in line with China's energy structure, e.g., to be combined with R and D of clean coal technology, because coal dominates Chinese energy supply in future. However, in the near future, the scope and scale of CCS activities in China will mainly depend on such aid as fund and technologies from the international community (Ping, 2007).

In the near future, China plans to pay special attention to relevant capacity building issues, such as information sharing, exchange of professionals and introduction of measures, tools and models, etc., to areas that can bring direct economic returns. This includes areas that support the implementation of the Nation's key energy policies, such as ECBM exploitation and recovery with CCS (Ping, 2007).

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