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A review of research progress on CO_2 capture, storage, and utilization in Chinese Academy of Sciences

Lei Li [a,b], Ning Zhao [b,*], Wei Wei [b,*], Yuhan Sun [b,c,*]

[a] Graduate University of the Chinese Academy of Sciences, Beijing 100049, China
[b] State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences, Taiyuan 030001, China
[c] Low Carbon Conversion Center, Shanghai Advanced Research Institute, Chinese Academy of Sciences, Shanghai 201203, China

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ABSTRACT

This article reviews the progress made in CO_2 capture, storage, and utilization in Chinese Academy of Sciences (CAS). New concepts such as adsorption using dry regenerable solid sorbents as well as functional ionic liquids (ILs) for CO_2 capture are thoroughly discussed. Carbon sequestration, such as geological sequestration, mineral carbonation and ocean storage are also covered. The utilization of CO_2 as a raw material in the synthesis of chemicals and liquid energy carriers which offers a way to mitigate the increasing CO_2 buildup is introduced.

1. Introduction

The control of greenhouse gas is arguably the most challenging environmental policy issue facing China and other countries [1–6]. CO_2 is considered to be the major greenhouse gas (GHG) contributing to global warming. Since the beginning of the industrial revolution in about 1850, the average atmospheric concentration of CO_2 has increased from 280 ppm to 370 ppm and as a result, the average global temperature has increased between 0.6 °C and 1 °C in the same time period [7]. The International Panel on Climate Change (IPCC) predicts that, by the year 2100, the atmosphere may contain up to 570 ppm CO_2, causing a rise in the mean global temperature of around 1.9 °C [8]. Continued uncontrolled greenhouse gas emissions may contribute to sea level increases and species extinction.

Fossil fuel combustion systems such as coal-fired power plants are one of the major sources of CO_2 emissions, which accounts for about 33–40% of the total anthropogenic emissions of carbon worldwide [8,9]. It is generally accepted that a reduction of the GHG emissions that promote climate change is necessary globally [1–10]. In order to reduce CO_2 emissions into the atmosphere, several options have been suggested, which are reducing energy consumption by increasing the efficiency of energy conversion, switching to less carbon intense fuels, and using renewable energies [11]. These options, however, may not be enough to mitigate global warming in the future, so the technology of CO_2 capture, storage, and utilization (CCSU) provides a mid-term solution to mitigate environment impacts and allows human continue to use fossil energy until renewable energy technologies are ready for application.

According to the International Energy Outlook 2005 (IEO2005) prepared by the Energy Information Administration (EIA) of the US Department of Energy (DOE), China was the world's second largest emitter of CO_2 after the United States in 2002, which contributes 13.6% of total world CO_2 emissions [12]. Fig. 1 is a map showing the location of the 1623 CO_2 point sources that each emits at least 0.1 Mt CO_2/yr in China end at 2009. The combined annual CO_2 emissions from these sources are estimated at over 3890 MtCO_2 [13]. In China, power generation accounts for 73% of the total carbon emissions from these sources. Cement plants contribute 14%, followed by iron and steel (7%), ammonia (3%), refineries (2%), ethylene (1%), hydrogen (<1%), and ethylene oxide (<1%). The majority of the sources are concentrated along the coastal zones, with 58% of the sources being located within the east and south central regions. The contributions of large point sources in each sector to total CO_2 emissions in China are listed in Fig. 2 [13]. With rapid development of energy technologies in the 21st century, fossil fuels, especially coal, will still remain the dominant energy

* Corresponding authors. Address: State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences, Taiyuan 030001, China (Y. Sun). Tel.: +86 351 4049612; fax: +86 351 4041153.

E-mail addresses: zhaoning@sxicc.ac.cn (N. Zhao), weiwei@sxicc.ac.cn (W. Wei), yhsun@sxicc.ac.cn (Y. Sun).

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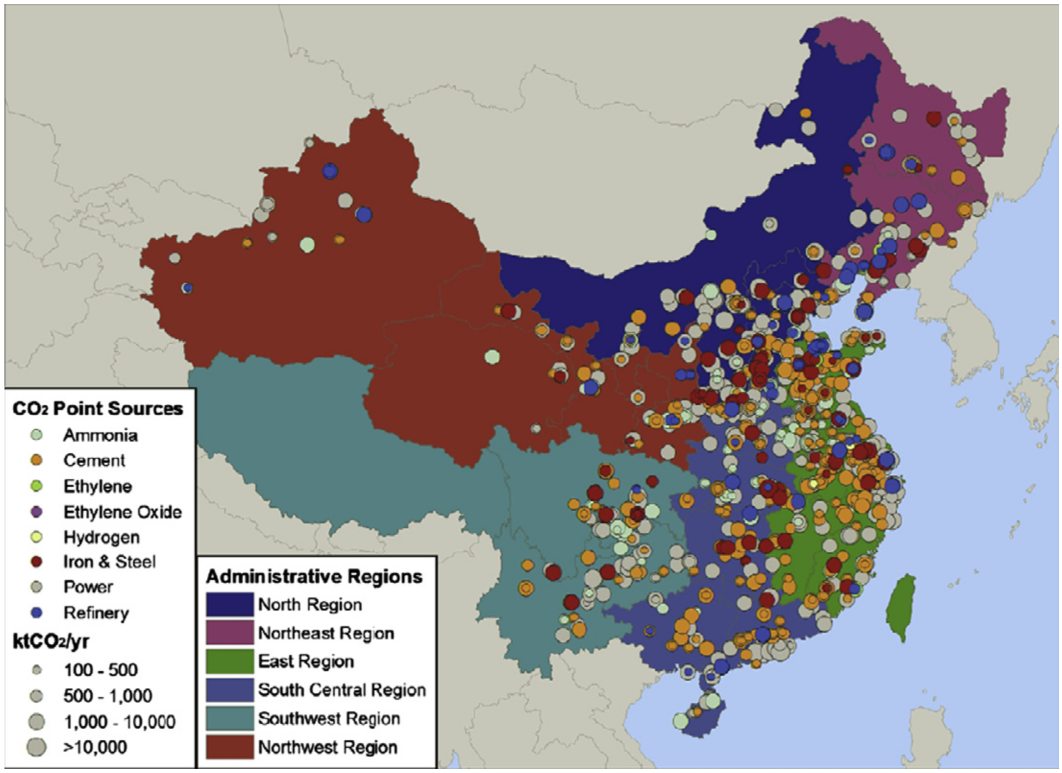

Fig. 1. Map of large CO_2 point sources by type, size, and administrative region in China [12].

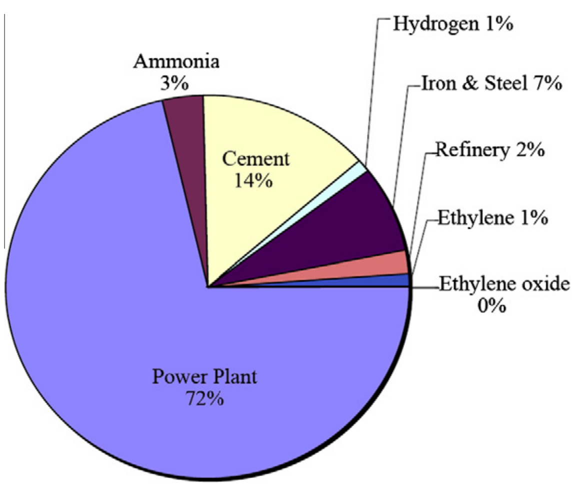

Fig. 2. The contributions of large point sources in each sector to overall total CO_2 emissions in China [12].

source in China for decades to come. Chinese government had recognized the huge challenge of CO_2 abatement while satisfying an ever-increasing energy demand. In the light of this situation, on November 26, 2009, China officially announced action to control CO_2 emissions per unit of GDP by 40–45% by 2020, based on 2005 levels [14]. To address this, China is undertaking a range of technical research and development projects on CCSU, including the national fundamental research and high-tech programs, as well as a large number of international programs. The CCS projects, fundings, and research institutes in China is shown in Table 1.

Since 1990, China had carried out a series of climate change projects under framework of national programs, such as China's National Climate Change Program (CNCCP), National Hi-tech R&D Program (863 Program), National Basic Research Program of China (973 Program), Natural Science Foundation of China (NSFC). Furthermore, CCSU was integrated into a National Medium and Long-term Science and Technology Development Plan towards 2020 as a leading-edge technology (State Council). Within this framework, in 2007, the Ministry of Science and Technology (MOST) published the 'Scientific and Technological Actions on Climate Change', including global climate change prediction and its impacts, future trends of the living environment changes in China, global environmental change, response strategy and technologies in response to climate change, technologies for use of clean and efficient energies, for energy saving and efficiency, for exploitation of new and renewable energies, progress on CO_2 capture, storage, and utilization technologies, etc. [15,16].

Meanwhile, Chinese government also conducted the international incorporation with the US, Australia, Canada, Japan, the EU, and the UK in CCS demonstration and R&D projects, such as Cooperation Action within CCS China–EU (COACH), the UK–China Near Zero Emissions Coal project (NZEC), World Climate Research Programme (WCRP), International Geosphere–Biosphere Programme (IGBP), International Global Change Human Dimension Programme (IHDP), the Intergovernmental Coordination Organization on Global Earth Observation (GEO), and the Global Climate Observing System (GCOS), which covered the key elements and processes of CCS from carbon capture, transportation, and storage [15,17].

CAS have launched Knowledge Innovation Program, Strategic Priority Research Program-Climate Change, and encouraged the cooperation with international on CCSU. On the basis of the finical support of both Chinese government and CAS, a lot of progresses were obtained in several academic institutes in CAS including CO_2 capture; enhanced oil recovery (EOR) and enhanced coal bed methane (ECBM) projects as well as CO_2 chemical utilizations. This brief review has covered the research progress in CO_2 capture, storage, and utilization in CAS.