The Administrative Center for China's Agenda 21

A REPORT ON CO_2 UTILIZATION TECHNOLOGIES ASSESSMENT IN CHINA

Science Press
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Brief Introduction

This report provides scientific assessment on 25 CCU technologies and explores the functions and potential of these technologies in promoting economic and social development, resolving resource and energy constraints, reducing greenhouse gas emissions and other goals. More importantly, on the basis of evaluating the current status and development trends of these technologies and analyzing and identifying technical bottlenecks, barriers and development needs, this report gives informed advice for the development of CCU in China.

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Preface

Climate change is one of the most serious challenges facing the world today, affecting the survival and development of human being. Tackling climate change serves the common interest of the world and has a bearing on China's future development and Chinese people's wellbeing. The ever-increasing pressure for emissions reduction domestically and internationally has significantly affected energy security, economic development and livelihood improvement in China. Among the technologies that can reduce greenhouse gas emissions, Carbon capture and storage (CCS) is an emerging one that has the potential to achieve the large-scale use of fossil fuels in a low-carbon manner. However, currently CCS is still in the phase of R&D and demonstration, and it is facing many constraints including high energy penalty, high costs, safety issues of long-term storage and unverified reliability.

Carbon capture and utilization technologies (CCU) can reduce CO_2 emissions while creating remarkable economic benefits. Its strategic importance lies not only in offsetting the extra cost incurred in the CO_2 capture process, but also in providing technical, policy and legal basis and valuable engineering experience for the demonstration and promotion of CCS. More importantly, it offers a feasible strategic method that can help to ensure energy security, break regional development bottlenecks and promote the incubation of low-carbon industries.

CCU can increase energy supply, reduce CO_2 emissions and turn waste to treasure. Therefore, in the Chinese context it can deliver triple benefits, i. e. economic, social and environmental benefits while meeting the need of China to reduce emissions. This report conducts scientific assessment on 25 CCU technologies and explores the functions and potential of these technologies in promoting economic and social development, resolving resource and energy constraints, reducing greenhouse gas emissions and other goals. More importantly, on the basis of evaluating the current status and development trends of these technologies and analyzing and identifying technical bottlenecks, barriers and development needs, this report gives informed advice for the development of CCU in China.

As a developing country that relies heavily on traditional energy resources, China has a huge population, and its economic development is still lagging behind the developed countries. Therefore, it is significant to choose CO_2 emission reduction technologies wisely. China should pay great attention to these technologies, arrange the R&D and promotion of CCU with unconventional and strategic foresight and address technical bottlenecks, policy issues, high cost and other challenges confronting the technologies. It is our sincere hope that this report can provide scientific basis for China's policy-making on developing CCU and effectively promote the R&D and application of the technologies, so as to enhance China's capacity of tackling climate change.

WANG Weizhong

Vice Minister of Science and Technology of China

Foreword

Climate change interweaves international policy, economy, and energy, interacting two overall situations nationally and internationally. The Eighteenth National Congress of the CPC has come up with ideas on ecological civilization construction and strategy of innovation-driven development. Climate change works have been added new values as well as raised demands. On one hand, further comprehension for climate change has been put forward. On the other hand, analysis for continuous new up-coming hot and difficult problems and investigation for a better solution are needed.

Base on two successful experiences before *China Third National Assessment of Climate Change* has investigated and broadened context and form of the outcome as well as made further efforts to edition work for better adapting to new strategy and request. Special reports, method databases and example analyses had been added for multiple supporting of climate change field study and decision making.

As supplement of main report, special reports are mainly focusing on below aspects:

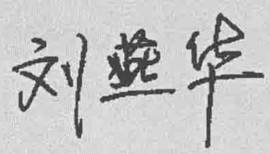
Firstly, emphasize on climate change hot issues including strengthen publish advertising or enhance hot issues comprehension so as to deepen understanding and build for common sense.

Secondly, concern on special tasks′ systematical evaluation especially on which cannot be embedded invested limited by space or form on main report.

Thirdly, take Chinese problems into consideration, compared to other countries our unique national condition decides China need a special perspective and resolution.

As a potential large-scale carbon emissions reduction technology, carbon collection, utilization, and storage (CCUS) have gained growing attention from all sides in recent years. Due to different comprehensions, various development challenges have been faced. At the same time carbon utilization technology especially differs from Country, Region and Industry. However, in China there is no systemically analysis on status and potential of this technology. Therefor carbon utilization has been chosen for the first experiment on China Third National Assessment of Climate Change special reports with hoping of laying foundation for the development of this study filed.

This special report is not only the first experiment but also a beneficial exploration for climate change national evolutional work method and achievement explanation, and it also revealed the flexibility principle in our work. We had an embedded comprehension on the variety and difficulty of this work. Despite the limitless, we would like to think it as a new beginning and though hard working and experiences accumulation making contributions to the national climate change work and advancing the development of ecological civilization construction.



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Abstract

CO_2 utilization (CCU) technologies refer to the industrial and agricultural utilization technologies that apply physical, chemical or biological functions of CO_2 to produce products with commercial value, which can reduce emissions compared to like products or similar processes. CO_2 utilization technologies must be used in industrial and agricultural production, rather than on purely natural processes. These technologies can directly utilize CO_2, bring economic benefits, and reduce CO_2 emissions. This report is a systemic assessment of the role, significance, potential and benefits, current situation and challenges of CO_2 utilization technologies, and early stage opportunities of and deployment suggestions for China.

Ⅰ. Background of the Assessment and Technological Orientation

ⅰ. CCU Can Break the Bottlenecks of CCS, Which Has High Energy Penalties, High Costs and High Risks

With emission reduction pressure mounting internationally, CCS is regarded as one of the pillar emission reduction methods in the future because it enjoys great CO_2 emission reduction potential. But it is also criticized sometimes for it is energy-intensively, costly and risky. The development of CCS hindered, the international community set their eyes on CO_2 utilization technologies, start to explore the feasibility of offsetting the incremental cost of CCS with economic benefits brought by CO_2 utilization, and try to develop relevant CO_2 utilization technologies to provide engineering and project experiences for CO_2 storage so as to reduce energy consumption and risks. Currently, CCU has become a widely recognized stepping-stone on the way towards the ideal CCS technology that can realize massive CO_2 emission reduction.

ⅱ. There Is No Systemic Assessment of CO_2 Utilization Technologies to Date

With an aim to improve CCS and reduce its cost, the international community has switched its research focus towards economically efficient CCU. In 2011, GCCSI issued the report *Accelerate the Development of CCS: Industrial Utilization of Captured CO_2*. According to the report, the revenues brought by the utilization of captured CO_2 can make up for part of the CCS cost so as to facilitate the development of CCS that enjoys massive emission reduction

potential. Since 1990s, the R&D of utilization technologies has been on the rise in the scientific and technological community, and there have been more and more research outputs and international platforms for academic communication. Developed countries like America, Britain, Australia and Canada have not only recognized CCUS's importance in CO_2 emission reduction, but also set their eyes on the considerable technology market, and pushed forward the R&D and commercialization of CCU technologies. For example, America has announced an investment of 106 million dollars into the development of CCU technologies including mineralization, algae to biofuel or chemicals (CO_2-AB) and production of polycarbonate ester (CO_2-CTPC).

Currently, the assessments of CCU technologies in the world are mostly based on direct emission reduction capacity. In 2005, the IPCC issued a special report on CCS, which assessed the mineralization and industrial utilization of CO_2, and came to the conclusion that they would not produce obvious effect on direct emission reduction. In July 2013, the IEA issued the updated CCS Roadmap, which pointed out that utilization technologies had a limited capacity for emission reduction, and therefore was not highlighted.

Developing CCS for the purpose of advancing CCS, and taking directemission reduction capacity as the sole assessment criterion both show the idea of the international community that the only value of CO_2 utilization technologies is emission reduction. It ignores the economic, social and environmental benefits brought by utilization technologies and the indirect emission reduction realized through the replacement of coal by clean energies recovered with the help of CO_2. Therefore, the above-mentioned conclusion does not provide significant guidance for China.

iii. Accurately Assess CO_2 Utilization Technologies Based on National Conditions

The correct assessment and positioning of CO_2 utilization technologies should be based on our national conditions, emission reduction potential (especially substitutive emission reduction potential) in our country, and its contribution to multiple goals of economic development and environmental protection. China is in an important phase of industrialization and urbanization, and our basic national conditions including the economic structure and energy mix are a lot different from those in developed countries. The fact that China is rich in coal but poor in oil, natural gas and uranium determines that the assessment and positioning of CO_2 utilization technology should be different from that in developed countries:

Attention should be paid to the substitutive emission reduction capacity of CO_2 utilization technologies. China's energy mix is dominated by coal and the heavy industry takes up a big share in the economic structure. Although some CO_2 utilization technologies can not isolate CO_2 from the atmosphere forever, they can help to recover green energies to replace coal and other fossil fuels, and thus enjoying great substitutive emission reduction capacity in China.

Contribution to various goals related to China's economic development should be taken into consideration. Apart from CO_2 emission reduction and climate mitigation, other contributions of CO_2 utilization technology should also be noticed. In particular, it can enhance the recovery of energy resources, promote industrial development and improve energy utilization pattern.

We should view CO_2 utilization technology as a strategic technical reserve. Many CO_2 utilization technologies are parts of CCS. The development of utilization technologies can facilitate the transition towards CCS.

Based on thestated considerations, this report presents a comprehensive assessment of various utilization technologies. It explores the potential contribution of utilization technologies to social and economic development, alleviation of resource and energy constraint, greenhouse gas emission reduction and other goals, evaluate the current status and development trend of these technologies, analyze their technical bottlenecks, barriers and development needs, and put forward some suggestions for the development of CO_2 utilization technologies in China. Based on different subjects and principles, CO_2 utilization technologies in this report are divided into three categories (geological utilization, chemical utilization and biological utilization) and five fields (energy efficiency enhancement, mineral resources recovery efficiency enhancement, synthesis of organic chemicals, synthesis of inorganic chemicals and production of consumer goods).

Ⅱ. Development Potential and Benefits

CO_2 utilization technologies can deliver such multiple benefits as ensuring our national energy security, improving the environment, reducing emissions, creating new sources of economic growth, cultivating strategic emerging industries, enhancing national competitiveness, and promoting the sustainable development of the society.

ⅰ. Great emission reduction Potential

- The theoretical emission reduction potential of CO_2 utilization technologies in China is huge.

With maximum resource supply supplement and maximum market capacity, the theoretical emission reduction potential of CO_2 utilization technology is expected to be 5.078Gt/a in 2020 and 5.357Gt/a in 2030.

- Based on the current development status of CO_2 utilization technologies, they will play an important role in emission reduction in the coming two decades.

It is estimated that by 2020, there will be a series of large-scale industrial CO_2 utilization facilities that can reduce CO_2 by 49.79Mt/a, and create an industrial output of 120.9billion

Yuan/a.

By 2020, the CO_2 emission reduction in the three major production fields, namely CO_2 to synthesized gas/liquid fuel (CO_2-CDR/CTL), CO_2 to methanol (CO_2-CTM), CO_2 to organic carbonate ester and high polymer materials (CO_2-CTPC), is expected to exceed 40 Mt/a. And the emission reduction capacity of enhanced oil recovery (CO_2-EOR) and CO_2 to carbonate and inorganic materials (CO_2-CTC) is expected to reach 8Mt/a. Other CO_2 utilization technologies are still under research in laboratories, so it is difficult to estimate their applicability and emission reduction potential.

It is expected that by 2030, major CO_2 utilization technologies will have been commercialized, with an estimated CO_2 emission reduction capacity of 200 Mt/a, and an industrial output of over 300.8 billion Yuan/a.

By 2030, energy efficiency and recovery enhancement technologies including CO_2 to synthesized gas/liquid fuel (CO_2-CDR/CTL), CO_2 to methanol (CO_2-CTM), CO_2 enhanced oil recovery (CO_2 EOR) are expected to reduce CO_2 emissions by 125 Mt/a; and the emission reduction capacity of CO_2 to organic carbonate ester and high polymer materials (CO_2-CTPC) and CO_2 to carbonate products and materials (CO_2-CTC) will reach about 25Mt/a. Other CO_2 utilization technologies will also contribute to emission reduction.

- With strengthened policy and investment support, CO_2 utilization technologies will be able to contribute more to emission reduction at an early date.

If we can promote the R&D and demonstration in unconventional ways and create a more enabling market environment, over 20 CO_2 utilization technologies that are still in the demonstration and R&D phase will mature quickly and be applied in production, which means they can play bigger roles. In this scenario, the following goals may be achieved:

It is expected that by 2020, larger-scale industrial CO_2 utilization facilities will be built, with a CO_2 emission reduction capacity of 250 Mt/a and an industrial output of 375.6 billion Yuan/a.

By 2030, major CO_2 utilization technologies will have been commercialized, with a CO_2 emission reduction capacity of 880 Mt/a and an industrial output of 904.1 billion Yuan/a.

ii. Considerable Economic Benefits

CO_2 utilization technologies can bring considerable economic benefits. The end products of these technologies are of various types with high added-value. CO_2 utilization technologies can enhance the recovery efficiency of energy resources, extract rare mineral resources, and enhance crop output. They can also synthesize with other substances to become chemical materials, chemicals, biological and agricultural products and other necessary consumer goods.

Prediction based on the current development status of CO_2 utilization technologies shows that these technologies will bring China considerable economic benefits.

Energy recovery efficiency enhancement CO_2 utilization technologies are expected to realize an output of roughly 5. 8 billion Yuan/a in 2020, and 45. 2 billon Yuan/a in 2030 if the market share of these technologies is 10%.

As to mineral resource recovery enhancement technologies, their industrial demonstration projects are estimated to realize an output of over 30 Million Yuan, and over 700 Million Yuan in 2030.

The products of CCU technologies to produce organic chemicals are mostly chemicals that are in great demand (like methyl alcohol) and valuable high polymer materials that are widely used. It is estimated that by 2020, industrial projects using these technologies will have an output of 105. 75 billion Yuan. The number will exceed 192. 02 billion in 2030 after large scales of application.

The output of massive industrial demonstration projects of utilizationtechnologies that are used to produce inorganic chemicals and process materials is estimated to be 6. 26 billion Yuan by 2020, and 39. 2 billion Yuan by 2030, with an expected market share of 30%.

Without benefits from carbon trade or subsidies, the industrial facilities of agricultural utilization technologies are estimated to realize an output of 900 million Yuan by 2020, and this number is expected to increase to 11. 5 billion Yuan by 2030.

iii. Remarkable Environmental Benefits

CO_2 utilization technologies not only enjoy great emission reduction potential in China but also can help to improve and protect our ecological environment. It can enhance the production efficiency of chemical and agricultural products, facilitate recycling of industrial waste, reduce industrial water consumption and ensure agriculture water supplement, and reduce the discharge of sulfides, nitrides, solid waste and other pollutants. Steel slag, ardealite and red mud of aluminum oxide are all typical solid waste from the metallurgy and chemical industries that feature high emissions, low energy efficiency and serious pollution. Mineralization of CO_2 can reduce the discharge of such waste by a large margin. It is estimated that large-scale industrial demonstration projects of CO_2 mineralization will utilize over 5 million tons of industrial solid waste in 2020, and 30 million tons in 2030 after popularization of these technologies. CO_2 utilization technologies related to agricultural production enhancement use microorganisms to sequestrate CO_2, which is totally environmentally friendly, because in the whole conversion and utilization process no chemicals are involved. They do not generate secondary pollution to the soil and are conducive to soil improvement.

iv. Summary

CO_2 utilization technologies have strategic significance to China because they offer a choice that can meet our multiple needs including economic development, energy security, emission reduction and environmental protection. With accelerated industrialization and modernization, China is faced with serious challenges in energy and resource supply as well as emission reduction. At the same time, as we maintain balanced and sound economic and social development, we have to meet the emission reduction target that carbon intensity shall be cut 16%-17% in the 12^{th} Five Year Plan period, and that the CO_2 emissions per unit GDP in 2020 should be 40% to 45% down from the 2005 level. To this end, we should strike a balance between economic development, energy supply, readjustment of energy mix and CO_2 emission reduction. Since CO_2 emission reduction can bring economic benefits and is better to be implemented at an early date, CCUS will provide technical support for China's medium and long-term efforts against climate change and facilitate economic development.

CCUS can break the bottlenecks for regional economic development. CO_2 technologies cover a wide range and have a lot to offer to different regions. It can realize in-situ utilization of CO_2 emissions and create new sources of economic growth in the region. Geological utilization technologies can be applied to Central China, Western China and Northeastern China. Chemical utilization technologies can be applied to Eastern China and Southern China. The northwestern region, including Xinjiang, is China's important energy base, but it has been suffering from water shortage in energy recovery and economic development. We can produce substitute natural gas (SNG) in this region and transmit the gas from the west to the east through pipelines. The high concentration CO_2 emitted can be used to displace deep saline water and is then stored underground. The saline water, after treatment, will become industrial water. In this way, not only can we increase the natural gas supply, we can also solve the water shortage in the region. CO_2 utilization technologies can break the resource constraint in some parts of China, and help to bring about leapfrogging development.

The development of CO_2 utilization technology will give birth to new industrial forms. Some CO_2 utilization technologies can share capture and transport system and integrate products and energies to jointly bring down the cost and energy consumption. For example, integrating chemical utilization technology with renewable energy technology can store low grade renewable energy in the form of chemical energy, breaking the wall between chemicals and energy. The integration of different technologies will lead to development of interdependent industrial parks. And the rapid rise of these technology-backed, market oriented low-carbon industries will attract private capital and create a new situation featuring diversified investors and operation forms.

Ⅲ. Current Situation, Prospect and Early Stage Opportunities of the Technologies

ⅰ. Current Situation of the Technologies

The output of scientific research in the area of CO_2 utilization technologies has been rising