

The Key Role of Measurement, Monitoring and Verification of CO₂ Emission Reduction in the CCS Project

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Abstract—In order to mitigate climate change, China did a lot to improve the development of CCS technology in recent years and made some great progress in this period. However, how many CO₂ emission reductions are achieved by those companies using CCS technology is hard to say. There is almost no scholar concentrating on this field. Therefore, the purpose of this paper is to study the importance of measurement and verification of CO₂ emission reductions for the development of CCS projects in the future. By collecting and analyzing figures and articles, we find that the measurement and verification of CO₂ emission reductions is very important. At the same time, this paper also finds some issues through analyzing the current status of measurement and verification of CO₂ emission reductions in CCS projects in China. Besides, based on CCS technology advanced countries' experiences of developing measurement and verification of CO₂ emission reduction, combined with the actual situation in China, suggestions are put forward on how to improve measurement and verification of CO₂ emission reductions in China's CCS project.

Keywords—CO₂ emission reductions; CCS; Measurement; Verification; China

I. THE DEVELOPMENT OF CCS IN CHINA

Because of the fact that China will still use coal as the main source of energy for a long time, and responding to the global climate change is the inherent requirement and obligation of China's sustainable development, CCS technology has become the important technical path for China to fulfill the responsibility of controlling the climate change and meet the goal of reducing carbon emission. CCS(CO₂ capture and storage technology)refers to the process of separating CO₂ from emission sources of industrial or related energy industries, transporting and storing it into geological structures, and permanently isolating it from the atmosphere. Since the first CCS-EOR project has completed in the Jilin oilfield in 2007,

China has made a lot of progress in many aspects related to CCS projects such as technology, policies, regulations, environment and economic support.

A. *The Number of Projects and the Scale of Investment*

The development of China's CCS project started late. The first CCS-EOR project was completed in 2007 in Jilin oil field. But this project has developed rapidly in recent years. By the end of 2017, there were 13 large integrated CCS projects in different stages of development or planning in China.

In 2008, China built the CO₂ capture demonstration project of Huaneng Beijing Gaobeidian thermal power plant, which is China's first flue gas CO₂ capture demonstration project of coal-fired power plant. The cost of this project is 28.5 Million Yuan, which is supported by the self-raised funds of Huaneng and the national science and technology program. It is estimated that the CO₂ recovery rate is more than 85% and the annual capture capacity is 3000 tons. In December 2009, Huaneng Group's CCS demonstration project of Shanghai Shidongkou second power plant was officially launched. This project can capture 120 thousand tons of high purity CO₂ per year. The huge capture capacity of this project shows that the CO₂ capture "demonstration" project can be developed into "scale" project. In January 2010, China Electric Power Investment Group invested 12.35 million Yuan to Chongqing Hechuan shuanghuai power plant. This project is the first ton class carbon capture device of coal-fired power plant in China, which can capture 10000 tons of high purity CO₂ per year. In June 2010, China's Shenhua Group set up a demonstration project of CO₂ capture and storage in Ordos, Inner Mongolia. This project is the first full-chain CO₂ capture and storage industrial demonstration project in China. It is the largest CCS project in Asia, which is mainly to store CO₂ in salty water layer. The total investment of this project is about 210 million

Yuan. This project is expected to store about 100 thousand tons of CO₂ per year.

TABLE I. LARGE INTEGRATED CCS PROJECTS IN CHINA

Project Name	Location	Scale	Demonstration Content
Clean Coal Energy Power Investigation Facility In Lianyungang	Lianyungang, JiangSu	Capture Capacity: 500, 000t/a(first stage) 1, 000, 000t/a(second stage)	Pre-Combustion Capture
CO ₂ -EOR Research and Demonstration, PetroChina	JiLin Oil Field	Storage Capacity: about 100, 000 t/a	CCS-EOR
Huaneng Green-gen IGCC CCS Pilot	Binhai New Area, Tianjin	Capture Capacity: 60, 000 to 100, 000 t/a	Pre-Combustion Capture, CCS-EOR
Yanchang CCS Project	JingBian Oil Field	Capture Capacity: about 40, 000 t/a	Coal Chemical Industry, CCS-EOR
CO ₂ Capture and Storage Displacement Demonstration Project of Sinopec Group	ShengLi Oil Field	Capture and Utilization Capacity: 500, 000 to 1, 000, 000 t/a	Pre-Combustion Capture, CCS-EOR
CO ₂ Capture and Utilization Demonstration Project of Datang Company	Daqing, Heilongjiang	Capture Capacity: 1, 000, 000 t/a	Oxygen Enriched Combustion and Geological Storage and EOR
CCUS Project of Shanxi International Energy Group	Shanxi	Capture Capacity: 1, 000, 000 t/a	Oxygen Enriched Combustion and EOR

B. The Number of Policies

In 2009, the Chinese government issued a CO₂ reduction target and decided that the national CO₂ emissions per unit of GDP will drop by 40% -45% from 2005 levels by 2020. The Chinese government pays high attention to and actively tackles global climate change. Since 2006, China had clarified the importance of this CO₂ emission reduction technology in a number of policy documents. By 2017, the State Council, the National Development and Reform Commission, the Ministry of Science and Technology, the Ministry of Finance, the Ministry of Foreign Affairs and the Ministry of Environmental Protection have issued more than 20 national policies and development plans related to CCS technology, such as "China's Science and Technology Action plan for Climate Change", "The 12th Five-Year Subject Plan for National Carbon Capture, Utilization and Storage Technology Development ", "The 13th Five-year Special Plan for Science and Technology Innovation on Climate Change" promulgated in 2017 and so on.

Since 2012, the relevant polices of CCS projects has increased obviously, and the policies and regulations are more detailed than before. For example, in March 2017, "The National Key Energy-saving and Low-carbon Technology Promotion Catalog -2017", promulgated by the National Development and Reform Commission, clearly proposed that the "comprehensive utilization technology of carbon monoxide-rich gaseous secondary energy" should be promoted vigorously.

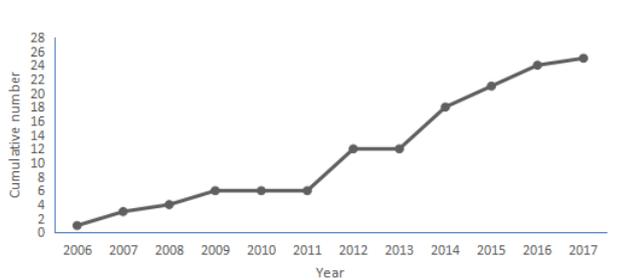


Fig. 1. The cumulative number of policies related to CCS technology in China.

China has made great progress in the investment, policies and regulations of the CCS project, but it is undeniable that there are still so many problems in the process of promoting CCS project. Due to the fact that the technologies of capture, transportation and storage related to CCS are not mature enough, the cost of CCS project is still very high[1]. Without government's funding and the support of policy, it is difficult to achieve commercialization and dissemination of CCS project in China; in the aspect of legislation, China has not achieved a breakthrough yet and has not formed the specialized CCS legislation and policy[2]; on the other hand, the public's awareness and acceptance of CCS technology are still very low[3]. Besides, only a few scholars can'tice the significance of the verification and report of CO₂ emission reduction for commercializing the CCS demonstration project in China.

II. THE IMPORTANCE OF VERIFYING CO₂ EMISSION REDUCTION

At present, there are two kinds of measurement standard of mitigating climate change internationally: one is the carbon emission reduction; another is the CO₂ emission reduction. These two kinds of measurements can be transformed to each other, which mean that one ton of carbon emission reduction (liquid or solid carbon) is equivalent to 3. 67 tons of CO₂ emissions reduction. Most power plants in China are coal-fired power plants, and the main greenhouse gas produced by these power plants is CO₂. Therefore, it is more appropriate to choose the CO₂ emission reduction as the measurement standard of the enterprise's emission reduction results. The verification of CO₂ emission reduction means that the state or the local environmental protection bureau or the specified third party verification organization measure, monitor and verify the real CO₂ emission reductions and the reports of controlled companies (such as the large coal-fired power station) or the enterprises that reduce CO₂ emission by their own accord. At present, there is no standard accounting method and procedure to verify CO₂ emission reductions achieved by CCS technology yet. Most China's local environmental protection bureaus use the emission reduction data reported by enterprises to evaluate and check the results of the emission reduction achieved by those enterprises carrying out CCS projects. It can be said that these local environmental protection bureaus do very little work on verification of enterprise emission data and even have

not carried out substantial work. Therefore, many enterprises have to rely on themselves to explore the methods of calculating the CO₂ emission reductions. The last step is to calculate the amount of CO₂ emission reduction, including: confirming the accounting boundary of companies' verification of emission reductions, recognizing the baseline amount of emissions under the baseline scenario to minus the real amount of CO₂ emission and the amount of CO₂ leakage. Enterprises' reports of CO₂ emission reductions are required to be authentic and effective, the reports should meet the standard; enterprises should provide all kinds of information and data in a transparent way, such as the accounting boundary, the scheme of identifying the baseline scenario, the selection of methods for verification and so on. All these information and data should be given full explanation in the report to make sure that these can be verified in the future. Additional CO₂ emissions and the increased energy consuming which are produced by installing emission reduction devices also need to be included into the accounting system. For example, when calculating the net carbon emission reductions in the CCS-EOR process, enterprises should take all increased CO₂ generated by using energy during the process of CO₂ capture, transportation, injection and recovery of gas into account[4]. Because of the imperfection and non-standard of measuring and verifying CO₂ emission reduction, some enterprises often choose the schemes which are beneficial for themselves to measure CO₂ emission reduction. For example, in the actual carbon verification process, some enterprises often find various reasons to narrow down the boundary of the project activity and eliminate some emission units for avoiding the environmental responsibilities that need to be undertaken. Therefore, if we want to know how much CO₂ emission has been reduced by the enterprises using CCS technology, it is very important to verify CO₂ emission reduction.

A. Implementing the Goal of Using CCS Technology to Reduce CO₂ Emissions

Mitigating climate change and reducing CO₂ emissions are the initial goal of developing CCS technology. Carrying out CCS projects need to undergo rigorous process, including project design, project validation, project operations, the implementation of measurement and monitoring, reporting emission reductions and verification. It can be said that in the process of using CCS technology, capturing CO₂ successfully is only half done; the ultimate goal of the project is to store the captured CO₂ in the geological structure. Therefore, how successful the operation of an enterprise's CCS project is should be assessed by the amount of the stored CO₂. In the whole process of CCS project, the verification of CO₂ emission reductions is the key point to generate qualified emission reductions. Therefore, in order to implement the goal of CCS project and avoid false data, it is necessary to verify the carbon emission reduction reports and data submitted by enterprises using CCS technology. In this way, the authenticity of the data on CO₂ emission reduction can be guaranteed.

B. Contributing to the Commercialization of CCS Technology in China

Influenced by China's own energy structure, consumption structure, economic development stage and the responsibility

of coping with global climate change, CCS technology has become one of the important technological paths for China to mitigate climate change and achieve its goal of reducing CO₂ emissions in the coming decades. From the prognostic map we can see that CCS is becoming more and more important in mitigating climate change and reducing CO₂ emissions in China. By 2040, the cumulative CO₂ emission reductions achieved by using CCS technology can up to 15% of the total emission reductions[5]. However, technologies of capturing, transporting and storing CO₂ are not very mature, the cost of operating CCS projects are very high, so it is still hard for CCS to attract investment. In order to promote the commercialization of CCS in China and ensure the success of the following prognostic map, it is necessary to increase the investment attraction of CCS technology. On December 18, 2017, China announced the establishment of a nationwide carbon emissions trading market in the power sector. It means that the companies using CCS technology can sell their excess carbon emission permits to other companies to get profit after they have reduced CO₂ emissions. So it is very important to regulate the measurement and verification of CO₂ emission reductions in CCS projects, which is related to how much carbon quota the enterprises that use CCS technology can get and how much carbon emission right they can sell. Therefore, standardized measurement, monitoring and verification of carbon emission reductions can bring huge economic benefits to enterprises applying CCS technology and increase the investment attractiveness of CCS projects, so as to further promote the commercialization of CCS in China.

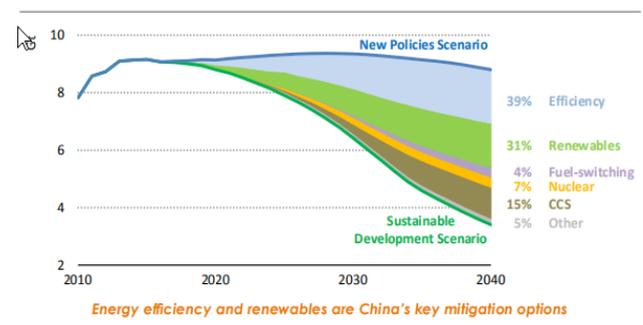


Fig. 2. China CO₂ emissions in the Sustainable Development and New Policies Scenarios

C. Improving China's Carbon Emission Trading System

In order to reduce CO₂ emissions and fulfill the emission reduction obligations, China has invested a lot of money in developing CCS technology. According to the IEA statistics, as of 2017, China's investment in a series of technologies such as electric vehicles, CCS technology, wind power generation, solar photovoltaic power generation and nuclear power account for large proportion of the global total investment. China's accumulated investment in CCS technology account for 40% of the world's cumulative investment[6]. However, at present, using captured CO₂ to enhance oil recovery is the only source of profit of CCS technology. Influenced by oil recovery rate and oil price, the profit of using this method is highly uncertain. If China wants to promote the development of CCS technology, it can only rely on the establishment of China's carbon market.

Combining carbon trading market and the use of CCS technology can stimulate the vitality of CCS. By the end of 2017, China established a carbon emissions trading market in the power market. So once the differences in carbon stock and carbon sequestration among enterprises happened, power plants that are integrated into the carbon market can sell the excess carbon emission right, which are achieved by using CCS technology, in carbon market to get some profit. How many the company can sell in the end depends on the measurement, monitoring and verification of CO₂ emission reduction. It can be said that the strict and normative measurement and verification of CO₂ emission reductions can ensure the accuracy of the emission reduction data and can ensure the fairness when companies trading in the carbon trading market. In this way, the measurement and verification of emission reductions can promote the improvement of the newly established national carbon trading market gradually, and the improvement of the carbon trading market will in turn promote the further development of CCS technology and the commercialization of CCS projects. In a world, the carbon trading market and the measurement and verification of CO₂ emission reduction are mutual development conditions and they can promote each other.

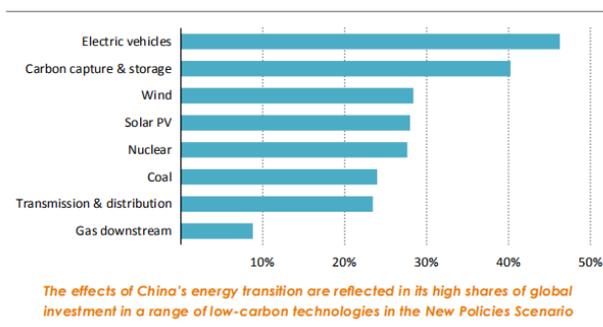


Fig. 3. China's share of cumulative global investment in selected fuels and technologies in the New Policies Scenario, 2017-40

D. Establishing the Foundation of International Cooperation and Mutual Trust of CCS Technology

The scale of the CCS project is judged by the amount of captured or stored CO₂. Countries that build international cooperation in CCS technology not only want to learn capture and storage technologies, reduce operation costs, but also want to exchange information on the capture and storage capacity of CO₂, namely, the amount of CO₂ emission reductions. It can be said that the input-output ratio of CCS emission reduction technologies-the comparison between the cost of development and utilization and emission reductions of CO₂ -is an important consideration when developing international cooperation in CCS technologies. In order to ensure the accuracy and authenticity of the CO₂ emission reductions reported by the enterprises applying the CCS technology, the measurement and verification of CO₂ emission reduction needs to be done well.

III. PROBLEMS IN THE MEASUREMENT AND VERIFICATION OF CO₂ EMISSION REDUCTION

A. The Measurement and Verification of CO₂ Emission Reduction Are Nonstandard.

China's measurement, monitoring and verification system of CO₂ emission reduction is still in the initial stage of establishment. Unified standard for the measurement and verification of carbon emission reduction has not been established. Guidance on verification of CO₂ emission reductions in CCS projects is scarce. There are some problems in carbon verification guideline. For example, the division of industries does not correspond to the reality of the enterprises; the calculation formulas do not match the actual technological processes of the enterprises, and so on[7]. Many enterprises that develop and utilize CCS technology rely on themselves to study and calculate the emission reductions of their own enterprises. As a result, the emission reductions of these enterprises are largely calculated and reported by the enterprises themselves, and the authenticity and accuracy of the data can't be guaranteed. For example, when calculating the net carbon emission reductions in the CCS-EOR process, enterprises should take all increased CO₂ generated by using energy during the process of CO₂ capture, transportation, injection and recovery of gas into account. However, in order to reduce costs, some enterprises also count the leakage of CO₂ at the wellhead as emission reduction. In addition, many enterprises that use CCS technology in China are coal-fired power plants, and the carbon emission coefficient of CO₂ is closely related to the coal consumption of coal-fired power plants. Without standard carbon verification system, the different positioning of individual power plants for their own carbon emission coefficient can lead to the different CO₂ emission reductions when accounting.

B. The Third-Party Verification Agencies Are in Short Supply and Their Verification Capabilities Are Uneven

At present, the verification of China's greenhouse gas emissions is mainly conducted by the third-party verification agencies(organized by local department)to verify the annual emission reports and supplementary data sheets and review the emission monitoring plan submitted by the enterprises. However, the verification on CO₂ emission reductions achieved by those companies participating in the emission reduction has not been carried out. The enterprises measure their own CO₂ emission reductions and report them to the local environmental protection bureau. At present, only about 300 third-party verification agencies have been selected in 24 provinces and pilot areas. There are only eight third-party verification agencies awarded by the National Development and Reform Commission for reviewing China's Greenhouse Gas Voluntary Emission Reduction Project (CCER), including China Classification Society Certification Company(CCSC), China Quality Certification Center(CQC), Central Joint Certification Center Co. Ltd. (CEC), Cerberus Certification Center(CEPREI) and so on[8]. Therefore, once the full promotion of CCS technology is started in the future, the number of existing verification agencies and inspectors is far from enough to complete the measurement and verification tasks of CO₂ emission reduction on time. In addition, the

verification capability of these third-party verification agencies is also uneven. The reason is that some places incorporate some unrelated institutions such as research institutes, carbon asset management companies and engineering consulting firms into the verification system. At the same time, different verification agencies have different verification capacity; different inspectors have different verification experience and sense of responsibility. All these factors can affect the authority and equity of verification.

C. Lack of Supervision System of Carbon Verification Agencies

At present, China is still in the initial stage of building a system for measuring and verifying the CO₂ emission reduction, and the CCS technology has not been included in the CDM project team. Therefore, the supervision system of carbon verification agency is still not established yet. At present, China has only established the carbon emission verification agency. Since the verification system is still imperfect and has not promulgated any certification standards, there is no relevant standard for enterprises and local environmental protection bureaus to verify the verification capability and market credit of these verification agencies, which leads to the uneven verification capabilities of various verification agencies in the market. In addition, in Liu's report, it can be seen that the source of verification costs is not clear. Some of these costs are supported by local governments; some are paid by enterprises themselves. The second method of payment may affect the independence of verification agencies and the authenticity of emission reduction data[8]. In the future commercialization of CCS technology promotion process, carbon emissions and verification of CO₂ emission reduction are bound to be included into the same system. It can be said that the problems existing in current supervision system of carbon emission verification are also the problems in supervision system of carbon emission reduction verification in the future. In order to ensure the perfection of supervision system of CO₂ emission reduction verification in the future, it is necessary to solve the problems existing in the supervision system of carbon emission verification now.

IV. SOLUTIONS AND RECOMMENDATIONS

A. Standardizing the Methods and Standards for Measuring CO₂ Emission Reductions

The amount of CO₂ emission reduction is an important indicator to measure the success of CCS projects, so the methods of measuring CO₂ emission reductions should be regulated gradually in the commercial process. At the early stage of developing the measurement system of CO₂ emission reduction, the government can reference the methods used by the NDRC in formulating the guidelines and methods for accounting and reporting enterprises' greenhouse gas emissions. On the other hand, companies can voluntarily study the standard accounting methods of CO₂ emission reductions in their industry. Comparing the measurement method formulated by the government with the method specified by the enterprise can avoid the situation where the method developed by the NDRC is not suitable for the enterprise and can't be used, and the situation where the enterprise select the most advantageous calculation method for maximizing its own interests. At the

early stage of development, due to the limited number of third-party carbon inspection agencies, the government can draw some lessons from the EU carbon market. For example, the emission reduction companies can measure and verify their CO₂ emissions reductions by themselves.

B. Improving the Rules for Admittance of Carbon Emission Reduction Verification Agencies

Although the number of third-party carbon verification agencies in China can't meet the requirements of national carbon emission reduction verification at present, its access rules can't be relaxed, because the third-party verification agencies' verification capabilities and market credit will affect the future development of CCS technology and will promote the development of carbon trading market. Therefore, the verification agencies that do not meet the requirements in the current market should be eliminated with the improvement of the access rules. The government can encourage these agencies to improve their own capabilities and upgrade their ranks by dividing the credit level of the verification agencies. In the aspect of qualification examination, the government should collect the agency in the whole society. Experts and related sectors should select and verify these agencies in accordance with the principle of just, fair and open.

C. Improving the Verification System of Carbon Emission Reductions and Increasing Financial Support for Carbon Emission Reduction Verification

The government should promulgate the detailed rules of managing carbon emission reduction and clarify the key tasks and management mechanisms in measuring, monitoring and verifying of the CO₂ emission reduction. When the verification system of CO₂ emission reductions and the access rules of third-party verification agencies become more standardized, third-party agencies can start to review the emission reduction data and reports submitted by the enterprises to ensure the accuracy and authenticity of the reports and data. The government can also learn some experiences from EU carbon market: in the process of monitoring and verification of carbon emission reductions, the government can use different third-party agencies so as to establish a mechanism for mutual restraint among third-party carbon emission agencies to ensure their fairness[9]. In addition, without government's financial support, it will be very difficult to improve and promote the verification of carbon emission reduction. Therefore, the Chinese government should add its financial support for establishing the verification CO₂ emission reduction and management mechanism, especially at the initial stage of the commercialization of CCS technology. Such as developing the greenhouse gas emission accounting standards and data reporting platform, developing third-party verification agency management approach, carrying out the third-party verification agencies record and so on.

D. Improve the Supervision System of Third-party Carbon Emission Reduction Verification Agencies

The government can refer to China's own experience in the supervision system of carbon emission verification agencies to establish and improve the supervision system of carbon emission reduction verification agencies so that these two systems can be mixed together in the future. The government

can ensure the effectiveness of supervision policies and the clarity of policy content by legislation. Governments can also learn some experiences from the United States or the European Union. They can set up a technical support platform to record and track the carbon emission reduction of enterprises using CCS technology and reduce the possibility of seeking rent-seeking from verification agencies. In addition, public supervision can be innovatively incorporated into the supervision system of carbon emission reduction verification agencies to increase regulatory transparency. The public can inspect about the progress of verification by the regulatory authorities through the regulatory platform, and can also make complaints or report on any illegal activities in the regulatory or verification work[10].

V. SUMMARY

Reducing CO₂ emissions is the original intention for China to develop CCS technology. In order to ensure that CCS technology can maximize its capacity in reducing CO₂, Chinese government have to pay much attention on the monitoring and verification of CO₂ emission reductions achieved by enterprises applying CCS technology.

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