A Research of Carbon Dioxide Capture and Storage

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Abstract: Researchers believe that the emission of CO_2 is the main factor causing the greenhouse effect, which has further exacerbated the climate change. According to the report, carbon capture and storage (CCS) technology should be promoted to effectively reduce carbon emissions and store sustainable energy. The paper delves into the basic and latest progress of CCS technology, focusing on the application and advantages of each step, and provide a comprehensive understanding of the potential of CCS technology in ecological protection and energy transition. In the report, CCS technology is divided into three parts: carbon dioxide capture technology, transportation technology and storage technology. The capture is divided into pre-combustion capture, post-combustion capture and after-oxidation combustion capture. Storage technology can be used for geological capture or marine storage. In recent years, many industries, such as transportation, power and chemical industries, have adopted or are preparing to adopt CCS technology. Studies have shown that this will have a significant impact on emissions reduction and energy conservation in these industries. Globally, the International Energy Agency says that CCS will achieve 14% of the cumulative emissions reductions needed to limit warming. Due to the impact of the epidemic, China will increase economic construction recently. Therefore, CCUS (carbon capture, utilization and storage) technology should be widely used. However, because the cost is too expensive, it will not be used majorly.

1 INTRODUCTION

In recent years, the problem of global climate change has become more and more serious, mainly manifested in the greatly intensified greenhouse effect, the annual average temperature has significant rising trend, and the frequent occurrence of extreme weather events. Researchers believe that the emission of greenhouse gases is the main factor leading to global warming, especially carbon dioxide, which has increased by 25% in the past 125 years, and has become the main culprit of the greenhouse effect (Li et al., 2023). A growing number of studies show that human activity is the main factor that causes the most carbon emissions. Researchers have simulated various external climate strength, and the results show that factitious strength, such as greenhouse gas emissions, factitious aerosols, and land use change, have a greater impact on extreme temperature changes (Balcerak, 2013).

Carbon capture and storage is an authoritative method for reducing greenhouse gas emissions (Figueroa, 2023). It is divided into three processes: CO_2 capture, transport and storage, including three capture technologies: pre-combustion capture, post-combustion capture and oxidation capture, and two storage methods: geological storage and Marine storage. The researchers focused on promoting the development of CCS technology in different areas and levels to reduce carbon emissions and achieve sustainable energy production. In the past few years, research on CCS technology has covered a variety of capture and storage methods, including chemical absorption, physical adsorption, membrane separation and other capture technologies, as well as underground reservoir injection, mineralization storage and other storage methods (Benson, 2008). The technologies' continuous innovation and optimization offers new possibilities for achieving the low-carbon economy and sustainable development goals.

Therefore, the capture and storage of carbon is necessary for the development of humanity. This paper delves into the latest advances in CCS technology and focus on the applications and advantages of different technological approaches.

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The full text will be divided into three aspects: introduction of CCS process, application examples and development prospects. The second part will describe the application of CCS in transportation, power and chemical industries, and the third part will show the measures taken by the world and China in the promotion of CCS technology. Through a comprehensive analysis of the relevant literature, this text will gain a comprehensive understanding of the potential of CCS technology to mitigate climate change, protect the environment and drive the transition to renewable energy.

2 CARBON DIOXIDE CAPTURE TECHNOLOGY

Carbon dioxide capture in CCS technology is significant, and so much literature is devoted to the research of capture technology, including pre-combustion capture technology, post-combustion capture technology, and oxidation combustion technology.

2.1 Pre-Combustion Capture Technology

The basic principle of pre-combustion capture technology is the conversion of carbon-containing fuels into hydrogen and carbon dioxide, followed by the separation of pure hydrogen through an absorbent (Benson, 2008). It is usually described in the literature as the separation of carbon from the fuel in gaseous form prior to the combustion process. It has been shown that the selection of a suitable absorbent can significantly improve the separation efficiency, but it also brings problems of energy consumption and equipment corrosion with higher separation efficiency. Primary amines are the most commonly used absorbents in the carbon dioxide capture industry because of their excellent CO_2 removal capability, which produces >99% pure -CO_2. Even though primary amines have a proven ability to capture carbon dioxide, drawbacks remain, the most common of which is that they are susceptible to degradation, and the substances produced by this degradation will result in, for example, solvent loss. The most common drawback is their easy degradation, which results in a number of problems such as solvent loss, fouling and equipment corrosion (Leung et al., 2014 & Chai, Hgu and How, 2022).

2.2 Post-Combustion Capture Technology

Post-combustion capture technology mainly absorbs carbon dioxide from the post-combustion flue gas through chemical solutions, such as ammonia or amine absorbers. This technology is currently the most industrialized CCS technology, which absorbs CO_2 from the combustion flue gas by using a chemical absorber (usually an amine solution) (Benson, 2008). Although such technologies can be applied to many types of industrial emission sources, energy consumption is still one of the main obstacles.

2.3 Oxidation Combustion Technology

Oxidation combustion technology uses pure oxygen instead of air to burn fuel, thereby obtaining CO_2-rich flue gas and simplifying the separation process of CO_2 (Metz et al., 2005). This technology can significantly reduce the energy required to separate CO_2 from flue gas, but at the same time requires that combustion units must be resistant to corrosion to adapt to high temperatures and high oxygen concentrations. In addition, because the technology is relatively new, its long-term reliability and large-scale application potential need further study and validation.

3 CARBON DIOXIDE TRANSPORT RESEARCH

Literature in this area generally focuses on the transportation of CO_2 from the capture point to the storage point. Pipeline transportation is the most commonly used mode of transportation (Chai, Ngu and How, 2022), so most studies have focused on the selection of pipeline materials, safety during transportation, and environmental impacts in the event of a CO_2 leak. In addition, there is also literature exploring the feasibility of using ships or tankers as an alternative. After CO_2 is captured, it is mainly transported through pipelines, ships or tankers. In order to evaluate these transportation methods, researchers need to consider not only the cost and efficiency, but also the safety and environmental impacts of transportation, and the environmental risks and monitoring issues associated with pipeline leakage are also factors to be considered (Wilberforce et al., 2021). For safety the main focus is on preventing CO_2 leakage and emergency response in case of leakage. In addition, there is a focus on transportation safety under extreme weather conditions or geological activity, as well as regulations and standards to ensure the safety of the transportation process. The assessment of environmental impacts during the transportation phase of CCS involves impacts on ecosystems, water resources, and land use. Researchers analyze the potential direct and indirect environmental impacts of transporting CO_2 through a life cycle assessment (LCA) approach. This includes an assessment of possible ecological disturbances from the construction of transportation infrastructure and the potential impacts of possible CO_2 leakage during transportation on the surrounding environment.

4 CARBON DIOXIDE STORAGE TECHNOLOGY

Storage is the last link of CCS technology, and it is also one of the hot spots of current research, including geological storage and Marine storage.

4.1 Geological Storage

Geological sequestration involves the injection of CO_2 into underground oil and gas fields, saline formations, or coal seams (Leung et al., 2014). Studies of geological sequestration in the literature have focused on the long-term stability of sequestration, monitoring techniques, and potential environmental risks.

Storage efficiency, capacity assessment, leakage risk and monitoring methods are the main aspects of geological storage evaluation methodology. The study shows that although geological storage has a large amount of potential storage space, its long-term storage stability is still an unsolved mystery, and long-term geological monitoring and simulation are needed to ensure the safety of the storage.

4.2 Marine Storage

Marine sequestration is a method of injecting CO_2 directly into the deep ocean, but due to its potential impact on Marine ecosystems, the literature in this area has focused on environmental impact assessments and related legal and regulatory studies.

5 USE OF CCS TECHNOLOGY

Currently, carbon capture and storage technology has been widely applied globally, spanning various sectors including environmental governance, chemical industry, power industry, construction engineering, materials science, and transportation.

5.1 Transportation Industry

In 2019, the global aviation industry emitted 915 million tons of carbon dioxide, or about 2% of global anthropogenic carbon emissions. If no action is taken, international aviation is projected to become the second largest source of emissions by 2050 (Almena et al., 2024). Sustainable Aviation Fuel (SAFs) is a short-term solution: Fischer-Tropsch synthetic paraffin kerosene (FT-SPK) extracted from forest residues, converted into a pathway that allows for the integration of carbon capture and storage (CCS) technology. The FT-SPK and CCS processes were modelled and the study showed that the use of A certified mixture resulted in a 37% reduction in Jet A/A1 fossil emissions and a positive net carbon flux.

5.2 Power Industry

On the one hand, the electric power energy industry has been the largest carbon emission industry; On the other hand, the traditional power generation method of energy consumption is huge, and industrial transformation is imperative. In recent years, CCS technology has become increasingly widely used in the power industry. For example, the literature surveyed Bangladesh in Southeast Asia, which has about 2.7 billion metric tons of high-quality coal reserves. Yet, coal only accounted for 6.21% of electricity generation in the 2020-21 fiscal year. Therefore, the use of CCS in existing large-scale power plants in Bangladesh will be a highly feasible pulverized coal power generation technology (Hossain et al., 2023).

5.3 Chemical Industry

The traditional chemical industry is also at the top of the list of industries producing carbon emissions. The literature shows that the CCUS (Carbon Capture, Utilization and Storage) process can be used for the final stage of the carbon dioxide and flue gas mineral carbonization process of cement kiln dust, which can reduce the CO_2 emissions of the plant by 0.42% (Sun et al., 2024). Also in the oil and gas industry, CCS can be used as an alternative to reservoir water injection, which involves injecting carbon dioxide into the reservoir for enhanced oil recovery while storing the carbon dioxide underground. CCS technology includes various capture methods in petroleum engineering, such as post-combustion capture, pre-combustion capture, and oxygen-fuel combustion (Yasemi et al., 2023).

6 CURRENT STATUS OF CCS TECHNOLOGY DEVELOPMENT

CCUS is critical in shifting the world to more sustainable and low-carbon energy production, as it is a temporary "band-aid" to reduce the impact of humanity's high dependence on fossil fuels.

6.1 World CCS Technology Application Prospects

According to the International Energy Agency, 14% of total cumulative emissions reductions by 2050 will need to come from CCS. Especially in the industrial sector, CCS and CCUS are the only technologies that can reduce emissions from steel, gas, refining, paper and other industries. If CCS is used with biomass, CCS can extract carbon dioxide from the atmosphere (Kapetaki, Simjanović and Hetland, 2016)

6.2 Application Prospect of CCS Technology in China

The Chinese government recently committed to becoming carbon neutral by 2060, and CCUS technology will be a key building block in achieving this ambitious goal. Post-covid-19, as the Chinese government prioritizes economic growth over sustainable energy security, a large number of fossil fuel power plants will remain operational, and the CCUS strategy will need to minimize their impact as much as possible. Fortunately, implementing CCUS technologies and strategies could reduce China's CO_2 emissions by 60% by 2050, but this would cost about $450 billion. Therefore, the Chinese government does not view it as a viable primary technology but as an "alternative technology." As a result, according to the concerns of investors and policymakers, committing to the development of this project is a costly and risky endeavor (He, 2023).

7 CONCLUSION

The paper specifically describes the process of CCS technology, application examples and development prospects of three aspects. This paper finds that, the process of CCS technology is divided into three steps: CO_2 capture, transportation and storage, while the capture technology includes three methods: pre-combustion capture, post-combustion capture and oxidation combustion capture. The storage technology is divided into two means: geological capture or Marine storage. In the introduction of CCS application examples, the article selects three aspects: CCS treatment of aviation fuel, coal-fired power generation and application of CCS in chemical industry, showing the characteristics that CCS technology can be widely used to achieve energy saving and emission reduction. Finally, the article expounds the CCS technology in China The international and domestic application prospects, the advantages and existing limitations of this technology are objectively analyzed. Through the introduction of CCS in the above three parts, readers can better realize the important role of CCS technology in saving energy and reducing greenhouse gas emissions in the world when greenhouse effect is greatly intensified and environmental problems are frequent.

However, our research on the project is still not deep enough. Therefore, readers could only learn the technology itself, but will fail to comprehensively understand the benefits it has by contrasting to other techniques for solving the greenhouse effect. In the next step, the three different methods used by the CCS technology will be studied to screen for more effective solutions, such as the monitoring of the data of the CO_2 transportation pipeline, which is studied to achieve the most effective way for CO_2 transportation. The CCS technology can also be compared with other emission-reduction production technologies in emissions, efficiency, cost and so on, such as the hydrogen technology, this will be beneficial to offer insights about future low-carbon production pathways.

AUTHORS CONTRIBUTION

All the authors contributed equally and their names were listed in alphabetical order.

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