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The Current Research Progress on CO_2 Capture and Storage Technology

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Abstract. Carbon dioxide is considered as a particularly significant greenhouse gas affecting the rate of global warming and climate change in the world today. As a greenhouse gas that is primarily emitted through various activities such as industrial production, energy production and transportation, it is vital to reduce emissions. This is now regarded as an important environmental challenge. This study systematically reviews CO_2, especially CO_2 carbon capture and storage technologies, to examine how these can play a significant role in sustainability and green development. It will focus on three main aspects of carbon capture storage, namely physical absorption, compression and separation, and chemical absorption. From the analysis, it indicates how physical absorption depends on pressure differences to trap carbon dioxide. On the other hand, compression and separation methods prepare the carbon dioxide to be trapped and stored in underground storage. Through research, research has found that carbon capture storage technologies can successfully decrease carbon emissions from sources of release including manufacturing facilities and power plants. These effectively address the need for environmental protection while taking into account the need to balance economic activity, in contributing to green development overall. The paper concludes that for green development to be plausible in the long-term and in the interest of sustainable development, carbon capture storage is essential. In this way, it can contribute to mitigating the effects of climate change and supporting long-term green growth, while facilitating green development.

Keywords: CO_2 capture, storage technology, chemical absorption, research progress

1. Introduction

Carbon dioxide capture and storage technology has been highlighted as a significant way through which it may be possible to reduce greenhouse emissions to benefit the environment and move towards a sustainable future. Given the decrease in the carbon sinks globally, experts are concerned with the possibility of removing and storing carbon dioxide (CO_2) through the use of carbon capture and storage technology [1]. From the perspective of experts specialising in research relating to energy and the environment, there is a need to consider how carbon dioxide can be captured and stored, alongside countries' commitments to 'net-zero' emissions. In relation to sustainable development, experts have also highlighted the need to pivot towards carbon neutrality, while still being able to cater for people's energy needs. These are especially in industries, transport and

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communications, and domestic use, which often still require significant energy use relying on either fossil fuels, despite potentially 'cleaner' alternatives. In terms of its characteristics, the stability of carbon dioxide as a gas makes it difficult to remove and store from the environment, also allowing it to remain in the atmosphere for a long time [2].

Researchers are currently looking into how carbon capture and storage works and the different types of technology that can be used to capture carbon. One way to do this is called "direct air capture" (DAC), which means pulling carbon dioxide directly from the air. Another way is to try to do it from a factory's smokestack to focus on capturing it at the source. Experts are currently investigating more efficient and cost-effective methods to facilitate these [3]. These have been accomplished by analysing diverse materials that have not been previously utilised, particularly filters and innovative liquids, or sorbents, a novel solid that may reduce energy consumption in recycling while retaining greater carbon dioxide.

Current research has also included possibly using advanced polymers and metal-organic frameworks for selective effective carbon capture. Other than carbon capture, storage research focuses on safety and alternate forms of storage in addition to the current ones. The current ones focus on underground storage, to last for over 1000 years in saltwater aquifers, gas reservoirs, or empty oil fields. This is done through deep underground injection [4]. However, it remains significant and important to consider alternatives which could be better, in terms of being more efficient, effective, and cheaper.

Other things to look at are how carbon dioxide gets trapped in rock minerals and how to make it more permanent so that it doesn't leak or pollute the environment. These include using imaging and sensors to keep an eye on things all the time. Researchers are still worried about how many of these sites need to exist for them to work and last. Direct air capture makes sense, but it is still costly and requires a lot of energy. This has led to suggestions to combine use with capture to make useful products or life-cycle assessments. In the future, research will seek to investigate this aspect.

This article will examine the technology, potential, and impacts of carbon dioxide (CO_2) capture and storage technologies, with the objective of summarising and assessing their various characteristics, principles, and contributions to sustainable development. The article will look at the most important and widely used carbon capture and storage technologies, focussing on how they work, how well they work, and how useful they are in different areas of industry. This article will examine prevalent studies regarding the challenges and efficacy of various carbon capture and storage technologies. It will also look into the potential for future growth. This sets the stage for the promotion of potential advancements in carbon capture and storage technologies, as well as the necessary considerations for their implementation.

2. Sources of CO_2

CO_2 sources range from various aspects of daily activities and contemporary life. These can be categorised into industrial and domestic aspects. The most significant is the release of CO_2 by the energy demands and needs which forms the global energy system that all countries depend on to some extent. These are required as part of industrial and domestic needs, which include fuel for transport, heat, electricity generation, that can often come from combustion processes from oil, gas, and coal. These demands meant a need for energy released roughly 37.4 billion tons of CO_2 estimated according to the International Energy Agency reports in terms of CO_2 release from energy demands alone [5]. Other forms of CO_2 release can come from varied industrial processes in the form of manufacturing sectors, like the conversion of clinker from limestone, chemical manufacturing, steel manufacturing, and cement production. These are instances when CO_2

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emissions can result from chemical reactions that remain an important part of many countries' industries. In terms of global industrial CO_2 these comprise a significant portion globally.

Other uses of land and agriculture are also sources of CO_2 release based on the release of the carbon as a result of soil disturbance release, cleared land, deforestation which play a role in terms of CO_2 release. The CO_2 release is from the original amount of CO_2 stored in soil and trees. Some practices of agriculture also employ fertilizer production and energy thus contributing to overall CO_2 release. This results in a majority of the CO_2 emissions from according to research groups, based on land use, industrial processes, and energy systems. While households contribute to these, they are not directly responsible.

Emissions can also be divided based on how they are released and the scale of the emissions. Emissions can either be diffused in terms of dispersed sources, small industries and transport making it harder to capture in terms of CO_2 storage. However, there is also the use of larger facilities which are stationary, which can be described as point-source meaning it is possible to capture the emissions at the stack rather than for this to be diffused. This means that the current carbon capture storage technology is more suitable for carbon capture for this kind of point-source emissions rather than diffused ones. Another question remains of whether the CO_2 carbon capture storage is tackled through technology and policy since a number of the CO_2 release is also due to countries and fossil-fuel producers.

3. CO_2 capture and storage methods

Taking CO_2 out of the air and putting it away (CCS) is a very important way to lower the amount of greenhouse gases that come from big factories and power plants. CCS has three main parts: taking CO_2 out, moving it to another place, and keeping it stored safely. For the last twenty years, scientists have come up with many ways to take CO_2 out well, and each way has good things and problems. Overall, the ways are using materials to soak it up, squeezing it and taking it apart, and using chemicals to soak it up [6]. Knowing about these ways helps us decide which one is best for different kinds of factories, from ones that burn coal to ones that use natural gas.

3.1. Physical absorption

Physical absorption traps CO_2 by getting it to dissolve into a liquid without any chemical changes. This approach is most effective when there's a lot of pressure and the gases have a lot of CO_2 in them. Liquids like Selexol and Rectisol are often used because they soak up CO_2 when squeezed and let it go when the squeeze is lessened. This works because gases dissolve better when pressed, so CO_2 goes into the liquid naturally, and can be taken out later to be stored or used [7].

A good thing about physical absorption is that it uses less energy to refresh the liquid compared to chemical ways. Physical liquids break down slowly, so they can be used again and are affordable in factories. But, this way isn't as good for exhaust gases with not much CO_2, like those from coal power plants after burning. Physical absorption is often used before burning in gas plants and to clean up natural gas, where there's lots of CO_2.

3.2. Compression and separation

After collecting it, CO_2 usually needs to be squeezed tightly into a special condition for moving and keeping it. This part means pushing CO_2 to a pressure of 80–150 bar, so it can move easily through

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pipes or be put deep in the ground. Squeezing it takes power and is often one of the most power-hungry parts of CCS.

Ways of separating things come before squeezing to make sure the CO_2 is very clean. These ways are using filters, very cold separation, and sticking to hard things like zeolites or metal–organic frameworks. Filters are small and can be put together easily, good for small factories; very cold methods are good for very clean CO_2, but use lots of power; hard materials are good for picking up and reusing CO_2 [8]. These ways make sure CO_2 is ready to be moved and kept while using as little power as possible.

3.3. Chemical absorption

Chemical absorption employs liquids that interact chemically with CO_2, creating substances that can be broken down later to extract pure CO_2. Substances like monoethanolamine (MEA) are the most often used chemical liquids. This method uses an absorber tower where CO_2 interacts with the liquid, and a stripper that warms the liquid to extract CO_2 and renew it [9].

The benefits are that it can grab small amounts of CO_2 well, so chemical absorption is great for changing old coal and gas power plants. But the bad parts are that it uses a lot of energy to renew, the liquid breaks down, it causes rust, and it lets out gases from the broken-down components [10]. Chemical absorption is still the most common way to capture after burning and is used in test projects such as the Boundary Dam CCS project in Canada.

4. Prospects for CO_2 capture and storage

Though there remain economic, technological, and policy challenges to a full utilisation of carbon capture and storage technologies, there is a generally promising outlook in this field.

The increase in emerging technologies have provided key opportunities for CO_2 capture and storage. This is notably in the use if direct air capture meaning to remove CO_2 directly from the air or the surrounding atmosphere, as well as the use of bioenergy carbon capture and storage (BECCS). The use of BECCS allow for a combination of CO_2 capture with biomass energy use, with the goal of successful net negative emissions. Other possible new technologies comprise hybrid methods, meaning the use of chemical absorption integrated with membrane separation, successfully improving efficiency and reducing consumption. Other innovations include selective permeable membranes, porous absorbents, and advanced solvents. These can then be applied to industry to allow for flexible applications with energy-efficient systems. Furthermore, the confidence public has in carbon capture storage operations is also evident in potential applications of advanced sensors and satellite tracking, which also benefits storage security.

For large-scale deployment and applications, it is crucial to reduce the cost of CCS. This can be done through shared infrastructure and technological improvements. The use of coordinated transport systems, centralised storage hubs, and standardised pipeline networks allows multiple industries to employ the same facilities, in the process reducing cost. Financial incentives can be offered by governments in the form of carbon pricing mechanisms and tax credits. This will motivate more private investment. There is also the projection of decreased energy use during capture, comprising the biggest proportion of costs. This can be facilitated through advancements in process design and improvements in capture materials. Larger, repeated projects allow more economies of scale, making carbon capture storage more competitive, and decreasing unit costs.

A multi-stage pathway can be seen in future development trends of carbon capture storage technologies. Short-term efforts are currently focused on industries like fossil power generation,

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steel, and cement, with limited alternatives and concentrated emissions. Medium-term efforts include a projection of expanding into possible carbon capture storage hubs, meaning there can be a combination of storage, transport, and capture for industries. Among countries, the US, Norway, and Canada are considering these on a demonstration scale at the moment. Long-term efforts would project the implementation and application of carbon capture technologies together with renewable energy, also considering aspects relating to efficiency and lifestyles. These could then help contribute to working towards net-zero targets as part of a comprehensive strategy. Overall, even though carbon capture storage technology cannot fully resolve climate issues on its own, it can provide additional green jobs in green development, industrial opportunities, and reduce emissions, all at the same time.

5. Conclusion

Through analysis and systematic research, this study and article have found that carbon capture and storage technologies play a critical role in allowing for sustainable development and promoting carbon neutrality. There are pros and cons to each of the current methods, and they can only be used in certain situations. The most common ways to do this right now are chemical absorption, compression separation, and physical absorption. New technologies like bioenergy carbon capture and storage and direct air capture have made it easier to capture carbon from the air. There have also been suggestions for different ways to use hybrid systems that would cut costs and energy use. To make things bigger and cheaper, the government needs to help by making policies and building infrastructure. Carbon capture storage is an example of how carbon emissions can be cut back in a planned way, especially since there is still the question of whether there are other ways to do this. These are mostly in making steel, cement, and fossil fuels. It can also create chances for green development.

The article gives an overview of the research on carbon capture storage, including the problems that have been found and the progress that has been made so far. This helps to understand the research's effects. This helps to fill a gap by looking at the future possibilities and real-world uses of current scientific principles and methods for carbon capture and storage, as well as current technological progress. The overview it gives can help answer questions about research and policy, which can be helpful for professionals in the field, researchers, and policymakers who want to know how to connect carbon capture storage to climate strategies.

In the future, research should focus on lifecycle assessments, cost-effective hybrid systems, and enhancing material performance. This would make it easier to judge how well carbon capture storage projects are working overall. For practical, large-scale applications, partnerships between the public and private sectors, as well as research, will be essential in this regard. This research supports the shift towards sustainability and green development by explaining the social, economic, and technological factors that affect carbon capture and storage technologies.

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