Proceeding of ICSPHS 2026 Symposium:Ethics, Law, and Psychology: Interdisciplinary Reconstruction of Humanities in Medicine
DOI: 10.54254/2753-7048/2026.ZJU31283

# Current Status, Challenges and Improvements of Direct Air Capture Technology

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***Abstract.*** Against the backdrop of escalating global climate change, countries have reached a consensus on carbon neutrality, and negative emission technologies, as a key support for achieving this goal, have attracted much attention. Direct air capture (DAC) technology, with its unique advantages of not relying on fixed emission sources and flexible deployment, together with carbon capture, utilization, and storage (CCUS) technology, constitutes a diversified carbon reduction technology system. This paper systematically elucidates the core concepts and working logic of DAC technology, reviews the current status of domestic and international technology research and development, project progress, and policy support, analyzes the core challenges it faces in terms of technology, economy, policy, and environment, and proposes targeted development suggestions from three dimensions: technology research and development, economic market, and policy promotion. Finally, it looks ahead to the future development trend of DAC technology, aiming to provide a reference for the large-scale application and promotion of DAC technology and contribute to the achievement of the global carbon neutrality goal.

***Keywords:*** DAC, Negative emission technology, Carbon neutrality, "Dual carbon" target.

## 1. Introduction

Global warming has led to frequent extreme weather events, posing a serious threat to ecosystems and human societal development. The Paris Agreement explicitly sets a target of limiting the increase in global average temperature to above pre-industrial levels [1]. In response, various countries have formulated carbon neutrality timelines: China has pledged to peak carbon emissions before 2030 and achieve carbon neutrality before 2060; the EU has set a target of achieving carbon neutrality by 2050; and developed countries such as the United States and Japan have also successively proposed clear carbon neutrality timelines and targets [2,3].

Relying solely on traditional emission reduction methods such as energy structure optimization and industrial emission reduction is insufficient to offset historically accumulated carbon dioxide emissions. Traditional emission reduction technologies are mainly limited to stationary emission sources, and the cost of modifying mature industries is high, and they cannot cover dispersed emissions and historical carbon stock [4]. In contrast, net emission reduction technologies (NETs)—technologies that remove carbon dioxide from the atmosphere and store or convert it for long-term use—have significant advantages: their scope extends beyond point source limitations, targeting atmospheric carbon sinks, adapting to diverse geographical environments, and filling gaps in areas with difficult-to-reduce emissions. In terms of cost, traditional point source capture costs approximately $30-100 per tonne of carbon dioxide, while net emission reduction technologies, such as forest carbon sinks, cost $10-50 per tonne of carbon dioxide, and current direct air capture (DAC) costs $232-600 per tonne of carbon dioxide [5]. The International Energy Agency (IEA) predicts that by 2050, the world will still need to store 7.6 billion tons of carbon dioxide through net emission reduction technologies, highlighting their irreplaceable role in the carbon neutrality process [6].

As a core negative emission technology, direct air capture (DAC) differs significantly from traditional point source capture technologies in several dimensions. Regarding the target pollutant, traditional point source capture targets high-concentration flue gas from stationary sources (typically 5%-15%), while DAC focuses on low-concentration atmospheric carbon dioxide (approximately 420 ppm) [7]. In terms of technical difficulty, DAC, due to its lower carbon dioxide concentration, requires more efficient adsorbents and regeneration processes, while point source capture benefits from a higher concentration gradient [1]. In terms of cost, the current capture cost of DAC (US$232-600/ton of carbon dioxide) is significantly higher than that of point source capture (US$30-100/ton of carbon dioxide), but this gap is expected to narrow with material innovation and scale expansion [6]. In terms of application scenarios, traditional carbon capture is limited by the location of emission sources, while direct air capture (DAC) can be flexibly deployed near storage sites or demand centers, enabling carbon removal in remote areas, islands, and decentralized emission sectors [8]. Notably, DAC is the only technology capable of actively removing historical carbon emissions that have already diffused into the atmosphere, making it crucial for achieving net-zero or even negative emissions [7].

The primary objective of this study is to systematically review the current development status and mainstream technological paths of Direct Air Capture (DAC) technology both domestically and internationally, and to identify its core challenges at the technological, economic, and policy levels. It also aims to specifically identify key directions for technological improvement and industrial advancement, providing theoretical and practical references for enhancing the energy efficiency, reducing costs, and promoting large-scale application of DAC technology. At the academic level, this paper clarifies the intrinsic connection between the development trajectory and core bottlenecks of DAC technology, supplementing the systematic analysis of technological challenges and improvement strategies in existing research. At the practical level, it aligns with the urgent global demand for negative emission technologies for carbon neutrality, providing decision-making support for enterprise technology research and development, government policy formulation, and industrial layout, helping to overcome difficulties in areas requiring emission reduction and promoting the achievement of carbon reduction goals.

## 2. Basic understanding of Direct Air Capture (DAC) technology

### 2.1. Core concepts

Negative emission technologies refer to the general term for technologies that remove carbon dioxide from the atmosphere through human intervention and store it for a long period of time, thereby reducing the concentration of carbon dioxide in the atmosphere [8].Direct air capture (DAC) technology is one of the negative emission technologies.DAC refers to an industrial process that uses specific materials to adsorb or absorb carbon dioxide from the atmosphere, and then separates and purifies the carbon dioxide through heating, depressurization, or other methods, ultimately achieving carbon dioxide storage or reuse [6]. This technology can directly extract carbon dioxide

DOI: 10.54254/2753-7048/2026.ZJU31283

from the atmosphere, and its capture efficiency is not limited by the concentration of emission sources. It can be deployed at any location and is the only negative emission technology that can actively remove carbon dioxide from the atmosphere [7].

In addition to DAC, common technologies include forest carbon sinks and biomass combined with carbon capture and storage (BECCS).Forest carbon sinks absorb carbon dioxide through plant photosynthesis and convert it into biomass for storage; BECCS technology captures and stores carbon dioxide generated during the utilization of biomass energy, realizing the combination of energy production and carbon emission reduction [8].

### 2.2. Basic working logic of DAC technology

The core workflow of DAC technology mainly includes three stages: First, carbon dioxide in the air is selectively adsorbed by contacting the adsorbent material (such as amine adsorbents, metal-organic framework materials, etc.) with the atmosphere; second, the adsorbed material is regenerated by heating, depressurization, or washing to separate the carbon dioxide from the adsorbent material and obtain high-purity carbon dioxide; finally, the separated carbon dioxide is compressed to a supercritical state and transported through pipelines to geological storage sites for storage, or used to synthesize methanol, synthetic fuels and other chemical products, thus completing resource recycling [6].

Traditional point source capture technology mainly targets stationary emission sources, and the target of capture is carbon dioxide in high-concentration flue gas. It has the characteristics of high capture concentration and relatively low cost, but it is limited by the location of the emission source and cannot capture dispersed emissions and carbon dioxide already present in the atmosphere [9]. Direct Air Capture (DAC) technology targets low concentrations of carbon dioxide in the atmosphere (approximately 420 ppm), does not rely on stationary emission sources, and can be deployed near carbon dioxide demand sites or storage sites [10].

## 3. Current status of Direct Air Capture (DAC) technology

### 3.1. Development status (international + domestic)

#### 3.1.1. Internationally

##### 3.1.1.1. Chemisorption method

Chemisorption captures $CO_2$ in the air by reacting it with adsorbents such as amine solvents and solid amines to form stable compounds. It boasts advantages such as high adsorption selectivity and strong affinity for low concentrations of $CO_2$, making it one of the most mature DAC technologies in industrial applications [3]. Its core problem lies in the high-temperature heating required for adsorbent regeneration (typically 80-120℃), leading to high energy consumption, and the risk of corrosiveness and degradation of liquid amine solvents [7].

Current research focuses on novel amine-based adsorbent modification technologies. For example, loading amine groups onto porous supports to form solid amine adsorbents, combined with microwave or ultrasonic-assisted regeneration, can reduce regeneration energy consumption by more than 30% [1]. Simultaneously, the development of mixed amine systems and functionalized ionic liquids aims to balance adsorption capacity and regeneration efficiency [2]. Future development directions include optimizing integrated adsorption-regeneration processes and low-

DOI: 10.54254/2753-7048/2026.ZJU31283

temperature regeneration technologies coupled with renewable energy sources to further reduce life-cycle energy consumption [4].

#### 3.1.1.2. Physical adsorption method

Physical adsorption utilizes the porous structures of materials such as activated carbon, zeolite, and metal-organic frameworks (MOFs) to physically adsorb $CO_2$. It features mild regeneration conditions (low-pressure or temperature-increase desorption) and strong adsorbent stability, making it suitable for wide temperature range conditions [8]. However, this method has limited adsorption capacity for low-concentration $CO_2$ and is easily affected by impurities such as water vapor, requiring further improvement in adsorption selectivity.

Research progress focuses on exploring novel high-performance adsorbent materials, such as metal-doped MOFs, which, by controlling pore size and surface functional groups, can increase $CO_2$ adsorption capacity to 2-3 times that of traditional materials [6]. Furthermore, biomass-based porous carbon materials have become a research hotspot due to their low cost and renewability; activation modification can enhance their physical adsorption affinity for $CO_2$ [2]. Future key directions include the development of large-scale preparation technologies for adsorbent materials and the miniaturized design of integrated adsorption-separation devices to adapt to distributed DAC applications [7].

#### 3.1.1.3. Membrane separation method

Membrane separation achieves $CO_2$ separation based on the difference in permeation rates of different gases in membrane materials. It offers advantages such as simple process, no chemical reagent consumption, and low operation and maintenance costs, making it suitable for continuous capture [1]. Existing problems mainly include insufficient selectivity in separating $CO_2$ and $N_2$, and the membrane materials' susceptibility to performance degradation due to high temperatures and moisture. Furthermore, membrane module costs are high for large-scale applications.

Recent research focuses on improving membrane selectivity and stability. For example, developing hybrid matrix membranes (embedding MOFs or graphene and other nanomaterials into a polymer matrix) can increase $CO_2/N_2$ selectivity to more than twice that of traditional polymer membranes [6]. Simultaneously, research on the modification of inorganic ceramic membranes and carbon molecular sieve membranes aims to broaden the membrane's operating temperature range [2]. Future development directions include high-flux design and modular integration of membrane modules, as well as mass production technology for low-cost membrane materials, reducing unit capture costs through economies of scale [4].

#### 3.1.1.4. Cryogenic distillation

Cryogenic distillation achieves $CO_2$ separation by cooling air to the $CO_2$condensation temperature (-78.5°C), offering advantages such as high capture purity (up to 99.9% or higher) and no adsorbent loss [2]. However, its main problems are extremely high refrigeration energy consumption, strict control of water vapor content to avoid ice blockage, and high system complexity.

Current research focuses on optimizing mixed working fluid refrigeration cycles, which, combined with waste heat recovery technology, can reduce refrigeration energy consumption by 25%-30%; simultaneously, research on the application of novel cryogenic heat transfer materials aims to improve heat exchange efficiency and reduce equipment size [7]. Future development

DOI: 10.54254/2753-7048/2026.ZJU31283

directions include coupling with low-grade cold sources such as LNG cold energy, as well as the development of staged condensation processes to reduce energy consumption while ensuring purity and expand application scenarios in cold regions [6].

### 3.1.2. Project progress

Several DAC demonstration projects have been built internationally and are gradually being commercialized. Climeworks built an industrial-scale DAC plant in Hinwil, Switzerland, in 2017 with an annual capture capacity of 900 tons. Subsequently, it collaborated with Reykjavik Energy on the Carbfix project, which injects the captured carbon dioxide into underground basalt for mineralization and storage, gradually increasing the annual capture capacity [6]. Global Thermostat in the United States has a DAC facility in Huntsville with an annual capture capacity of 40 - 50,000 tons, claiming a capture cost as low as $120/ton, and has already collaborated with companies such as Coca-Cola and ExxonMobil [6]. Soletair Power in Finland integrated DAC technology with building ventilation systems and showcased the "Power to X" demonstration device at the Dubai Expo, using captured carbon dioxide to produce synthetic methane [6].

Domestic DAC projects are still in their infancy, mainly consisting of small-scale demonstration projects. Energy companies such as State Power Investment Corporation and China Huaneng have begun to explore the combined application of DAC technology with other energy technologies. Some universities and research institutions have built laboratory-scale DAC devices to conduct performance testing of adsorption materials and system optimization research [8].

## 3.2. Main application scenarios of current technologies

The large-scale application and industrial practice of direct air capture (DAC) technology have validated its technical feasibility and scenario adaptability through numerous typical projects worldwide, providing key practical references for industry development.

Globally, DAC projects exhibit characteristics of diversified technical paths and tiered scale. Climeworks, a Swiss company, is a benchmark enterprise for the commercialization of DAC technology. Its industrial-scale DAC plant in Hinville, which began operation in 2017, has an annual $CO_2$ capture capacity of 900 tons. Its core innovation lies in utilizing the waste heat from the local waste incineration plant to reduce adsorbent regeneration energy consumption, while simultaneously supplying the captured $CO_2$ to surrounding greenhouses to increase crop yields [3]. The company's Carbfix project, a collaboration with Reykjavik Energy, is even more groundbreaking. It mixes $CO_2$ captured by the DAC (Diverterless Hydrogen Depletion) system with water and injects it into Icelandic basalt formations, achieving permanent storage through mineral carbonization. This has an annual storage potential of 4 million tons of $CO_2$, validating the technological maturity of coupling DAC with geological storage [6].

Carbon Engineering of Canada focuses on the synergy between DAC and fuel conversion. Its pilot plant in British Columbia, since its operation in 2015, has captured an average of 1 ton of $CO_2$ per day. Using a potassium hydroxide solution adsorption system, it combines the concentrated $CO_2$ with hydrogen production from renewable energy sources to convert it into synthetic fuel. Calculations show that its $CO_2$ removal cost has dropped to $94-232 per ton, providing empirical evidence for the economic feasibility of DAC technology [7]. Global Thermostat, a US company, has achieved a capture scale of 40-50,000 tons/year in its Huntsville project using amine-functionalized carbon sponge adsorbent technology, with costs controlled at $120/ton. Its innovation

DOI: 10.54254/2753-7048/2026.ZJU31283

lies in directly supplying the captured $CO_2$ to Coca-Cola for beverage production, creating a short-process value chain of "capture-utilization" [1].

Soletair Power, a Finnish company, has pioneered the integration of DAC (Chemical Degradation Capacitor) with building applications. Its DAC system, integrated into building ventilation systems, can both remove indoor $CO_2$ to improve air quality (each 400 ppm $CO_2$ removal can improve cognitive function by 20%) and convert the captured $CO_2$ into synthetic methane fuel. The flexibility of this model was successfully demonstrated in the Power to-X demonstration unit at Expo 2020 Dubai [2]. These cases cover diverse scenarios such as industrial waste heat utilization, geological storage, fuel conversion, and building integration, demonstrating that DAC technology can be customized according to resource endowment and market demand. They also reveal that reducing energy consumption, optimizing adsorption materials, and expanding application scenarios are the core directions for the technology's scaling up.

## 4. Key challenges facing Direct Air Capture (DAC) technology

### 4.1. Technical challenges

#### 4.1.1. Efficiency needs improvement

Slow Capture Rate Makes Large-Scale Processing Difficult. DAC technology faces the problem of low capture efficiency for low-concentration carbon dioxide. The atmospheric carbon dioxide concentration is only about 420 ppm, far lower than the concentration in industrial flue gas (typically 5%-15%), which limits the contact efficiency between the adsorbent material and carbon dioxide, resulting in a slow capture rate and making large-scale processing difficult [7]. Furthermore, the recycling efficiency of the adsorbent material needs improvement. After multiple adsorption-regeneration cycles, the adsorption capacity of the material gradually decreases, affecting the overall capture efficiency [8].

#### 4.1.2. High energy consumption

The regeneration process of adsorbents in DAC technology requires a significant amount of energy, such as heating and depressurization, resulting in high overall energy consumption [7]. Currently, the unit energy consumption of DAC technology is approximately 1316 kWh/t$CO_2$, far exceeding that of traditional point source capture technologies (approximately 64-133 kWh/tCO) [7]. If the energy source is primarily fossil fuels, DAC technology will generate additional carbon emissions, affecting its negative emission performance; if renewable energy is used, it will be limited by the stability and cost of renewable energy supply [1].

#### 4.1.3. Material shortcomings: high material costs

Adsorption materials are the core of DAC technology, and their performance directly affects capture efficiency and cost [8]. Currently, mainstream adsorbent materials suffer from high cost, limited adsorption capacity, and high regeneration energy consumption. Although amine-based adsorbents have high capture efficiency, they require high regeneration temperatures (approximately 120-150 ℃), resulting in high energy consumption and easy degradation. Metal-organic frameworks (MOFs) materials have high adsorption capacity and high selectivity, but their synthesis process is complex, production costs are high, and they are difficult to scale up for application [6]. In addition, the long-term stability and corrosion resistance of adsorbent materials need to be improved. In

DOI: 10.54254/2753-7048/2026.ZJU31283

complex atmospheric environments, they are easily affected by factors such as humidity and pollutants, reducing their service life [1].

### 4.2. Economic challenges

DAC technology currently faces severe cost pressures, significantly limiting its large-scale application [7]. According to industry data, the current capture cost of DAC technology is approximately \$600-232/ton $CO_2$, far exceeding that of traditional point source capture technologies (approximately \$30-100/ton $CO_2$) and forest carbon sinks (approximately \$10-50/ton $CO_2$) [6]. The high cost stems primarily from three factors: high cost of adsorption materials, high energy consumption, and high equipment investment costs [1].

The profit model for DAC technology remains unknown, and achieving market-based operation faces difficulties [1]. Currently, the revenue of DAC technology mainly comes from carbon trading, government subsidies, and revenue from carbon dioxide utilization. However, given the current state of the carbon trading market, carbon prices are generally low (below \$50/ton $CO_2$ in most regions), making it difficult to cover the high costs of DAC technology. While government subsidies can alleviate cost pressures to some extent, the sustainability and stability of subsidy policies are difficult to guarantee. In terms of carbon dioxide utilization, the market for synthetic fuels and chemical products is highly competitive, and carbon dioxide products produced by DAC technology lack cost competitiveness [6].

### 4.3. Policy and environmental challenges

#### 4.3.1. Insufficient policy support

Although countries have begun to pay attention to DAC technology, policy support still has many shortcomings [8]. First, there is a lack of specific policies. There are a few specific policies for DAC technology, such as R&D subsidies, market incentives, and standards and regulations. Most policies include it in the carbon capture, utilization, and storage (CCUS) or negative emission technology category, which lacks specificity. Second, there is poor policy coordination. DAC technology involves multiple links, such as capture, transportation, storage, and utilization, which require policy coordination from multiple departments, such as energy, environmental protection, finance, and industry. However, the policies of various departments lack effective coordination, forming policy barriers [7]. Third, there is insufficient international policy coordination. The development of DAC technology requires global cooperation, but the policies of different countries vary greatly, and there is a lack of unified technical standards and market rules, which affects international cooperation and technology promotion [6]. Fourth, there is insufficient policy stability. The subsidy policies and tax incentives of some countries have time limits, and the uncertainty of policies increases the investment risk of enterprises [1].

#### 4.3.2. Low public awareness

Most people do not understand DAC technology, making it difficult to create a supportive social atmosphere. Currently, most members of the public lack understanding of the principles, functions, and safety of DAC technology, and are concerned about the unknown environmental risks it may pose. This low public awareness leads to significant social resistance in the site selection and construction of DAC projects; some projects have been delayed or canceled due to resident opposition, hindering the large-scale adoption of the technology [8]. Furthermore, public

DOI: 10.54254/2753-7048/2026.ZJU31283

understanding of DAC technology and the lack of attention given to technology make it difficult to encourage governments and businesses to increase their investment in it [1].

#### 4.3.3. Lack of supporting facilities

Inadequate supporting resources, such as $CO_2$ storage sites and transportation channels. First, there is a shortage of carbon dioxide storage sites. The exploration, assessment, and development of geological sequestration sites require substantial financial and technological investment. Currently, the number of sites suitable for large-scale carbon dioxide sequestration that have been discovered globally is limited and unevenly distributed [6]. Second, transportation channels are inadequate. Carbon dioxide captured by DAC facilities needs to be transported to storage or utilization sites via pipelines, ships, trucks, etc. However, the construction of carbon dioxide transportation infrastructure is lagging, especially the severe lack of long-distance pipeline transportation networks, resulting in high transportation costs and low efficiency [8]. Third, there is a lack of detection and monitoring facilities. Long-term monitoring of carbon dioxide after storage requires specialized detection equipment and technology. Currently, the accuracy and reliability of monitoring technology need to be improved, and the monitoring network coverage is insufficient, making it difficult to ensure the safety of storage [7].

## 5. Recommendations for promoting the development of Direct Air Capture (DAC) technology

First, at the materials level, the focus is on developing high-efficiency adsorbents and membrane materials, promoting the implementation of technologies such as amine-based adsorbent modification and MOF material doping optimization to reduce regeneration energy consumption and material loss; simultaneously optimizing the integrated adsorption-regeneration process, exploring low-temperature regeneration solutions coupled with renewable energy, and improving technological energy efficiency [1,6].

Second, at the cost and policy level, a long-term and stable fiscal subsidy and carbon price incentive mechanism should be established, providing investment subsidies and tax breaks for DAC projects, and incorporating them into the carbon market trading system; encouraging government-enterprise cooperation, sharing initial investment risks through public-private partnerships, and promoting large-scale technology deployment to reduce costs [2, 7].

Then, at the industry chain level, it should coordinate the capture, transportation, and storage of DAC materials, build a regional CCUS (Collection-Utilization-Storage) cluster network, prioritize the deployment of DAC plants based on industrial waste heat resources, and reduce energy costs; promote the coupling of DAC with geological storage, synthetic fuel production, and other scenarios, expand the "capture-utilization-storage" value chain, and improve the commercial viability of the technology [1].

Finally, at the international cooperation level, it should strengthen transnational technology research and development cooperation, jointly build a DAC technology joint laboratory, and share core technologies such as adsorption material formulations and process design; unify technical standards and monitoring specifications, promote global DAC project data sharing, and accelerate technological iteration and upgrading [6].

DOI: 10.54254/2753-7048/2026.ZJU31283

## 6. Conclusion

First, as a flexible and efficient negative emission technology, DAC technology plays an irreplaceable role in achieving carbon neutrality and has enormous development potential. However, DAC technology currently faces many challenges: technically, the capture efficiency needs to be improved, energy consumption is high, and there are shortcomings in adsorption materials; in terms of economics, the cost is high, profitability is difficult, and large-scale development is challenging; in terms of policy and environment, there is insufficient policy support, low public awareness, and a lack of supporting facilities.

Second, DAC technology cannot achieve carbon neutrality on its own and needs to be developed in conjunction with other emission reduction and negative emission technologies. In terms of emission reduction technologies, it should be combined with traditional emission reduction methods such as energy structure optimization, industrial energy conservation, and transportation electrification to jointly reduce new carbon emissions; in terms of negative emission technologies, it should complement technologies such as forest carbon sinks and BECCS to form a diversified negative emission technology system.

First, technologically, with the continuous advancement of materials science and engineering technology, the performance of adsorption materials and membrane materials will continue to be optimized, and the development of plasma modification and electrochemical synthesis technologies will further improve capture efficiency and reduce costs. Furthermore, the large-scale application of new, highly efficient adsorption materials will improve the capture efficiency of DAC technology and reduce energy consumption.

Second, in terms of applications, DAC technology will be combined with renewable energy in the future to reduce energy costs and carbon footprint. Driven by both policy and market forces, coupled with the improvement of public acceptance through effective communication, DAC technology will gradually achieve large-scale and commercial applications, becoming a key technological support for the global carbon neutrality process.

## References

[1] Becattini, V., Gabrielli, P., Antonini, C. et al. (2022) Carbon Dioxide Capture, Transport and Storage Supply Chains: Optimal Economic and Environmental Performance of Infrastructure Rollout. International Journal of Greenhouse Gas Control, 117, 103-635.
[2] Bose, D., Bhattacharya, R., Kaur, T. et al. (2024) Innovative Approaches for Carbon Capture and Storage as Crucial Measures for Emission Reduction within Industrial Sectors. Carbon Capture Science & Technology, 12, 100-238.
[3] Gabrielli, P., Charbonnier, F., Guidolin, A. et al. (2020) Enabling Low-carbon Hydrogen Supply Chains through Use of Biomass and Carbon Capture and Storage: A Swiss Case Study. Applied Energy, 275, 115-245.
[4] IPCC (2018) Global Warming of 1.5°C. Intergovernmental Panel on Climate Change.
[5] METI (2021) Strategic Energy Plan. Ministry of Economy, Trade and Industry.
[6] Nagireddi, S., Agarwal, J.R. & Vedapuri, D. (2024) Carbon Dioxide Capture, Utilization, and Sequestration: Current Status, Challenges, and Future Prospects for Global Decarbonization. ACS Engineering Au, 4, 22-48.
[7] Otsuki, T., Shibata, Y., Matsuo, Y. et al. (2024) Role of Carbon Dioxide Capture and Storage in Energy Systems for Net-zero Emissions in Japan. International Journal of Greenhouse Gas Control, 132, 104-165.
[8] Song, X., Wang, F., Ma, D. et al. (2023) Progress and Prospect of Carbon Dioxide Capture, Utilization and Storage in CNPC Oilfields. Petroleum Exploration and Development, 50, 229-244.
[9] Mohammed, S., Eljack, F., Al-Sobhi, S. et al. (2024) A Systematic Review: The Role of Emerging Carbon Capture and Conversion Technologies for Energy Transition to Clean Hydrogen. Journal of Cleaner Production, 447, 141-506.
[10] Tolstrup, S., Ladenburg, J. & Lex, S. (2025) A Qualitative Analysis of Key Stakeholders' Perception of CCS and its Value Chain in a Danish North Sea Storage Context - Through a Socio-economic Lens. International Journal of

DOI: 10.54254/2753-7048/2026.ZJU31283

Greenhouse Gas Control, 144, 104-363.