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A comprehensive review on recent trends in carbon capture, utilization, and storage techniques

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ABSTRACT

This review highlights the latest trends in carbon capture, utilization, and storage techniques. The recent advances in the current carbon capture techniques, i.e., post-combustion carbon capture, pre-combustion carbon capture, and oxyfuel combustion systems, have been deliberated. Human exploitation of natural resources is leading to an immense rise in the concentration of greenhouse gas (GHG), i.e., primarily carbon dioxide (CO_2) in the atmosphere. This boosted quantity of CO_2 by human intervention leads to increased global temperatures and climate change. Hence there is a crucial need for fixing CO_2 to control global climate change and meet the pledges of the Paris Agreement. The global CO_2 emission hit an all-time high in 2018, emitting 32.7 billion tons of CO_2 into the atmosphere, whereas the current scenario for global CO_2 utilization constitutes a tiny amount, i.e., 0.2 billion tons/year. Hence various CO_2 utilization techniques, such as CO_2 deployment in reforming techniques and its direct conversion into fuels, have been emphasized. Finally, the CO_2 storage methods have been underlined, and the recent advancements along with the outlook in DAC technique have been discussed at the end. The DAC technique shows the most promise for future CO_2 capture and utilization, pending resolution of initial investment and techno-economic feasibility challenges. However, it's important to note that no single technique is universally applicable, and governments worldwide must address specific ground-level issues for practical solutions.

1. Introduction

Due to swift industrialization, due to the rising global population and increasing energy demands, the global concentration of greenhouse gases (GHGs, i.e., mainly CO_2) is intensifying, thus disturbing the ecosystem [1–3]. The world population is estimated to be about 7.98 billion in 2022 and is expected to cross 10 billion by 2050. This will lead to the increased demand for energy and water in the near future raising their scarcity [4,5]. Still, more than 84% of global energy demand is met by fossil-based fuels, which puts great pressure on the rising global GHG trajectory emissions [6,7]. This, in turn, is responsible for the ever-increasing CO_2 quantity worldwide [8]. The CO_2 concentration, i.e., mainly responsible for global warming due to its infrared rays trapping nature, has escalated from 315 parts/million to 415 parts/million in just the past six decades, as shown in Fig. 1 [9]. This is due to the fact that the fossil-based hydrocarbon fuel that has been formed in millions of years under the earth's crust has been exploited at an enormous rate by humans after the industrial revolution. Hence to achieve the pledges

Abbreviations: GHG, Greenhouse Gas; DAC, Direct Air Capture; COP26, Climate Change Conference of Parties; COP27, Conference of Parties; UNFCCC, United Nations Framework Convention on Climate Change; CCS, Carbon capture and sequestration/storage; CCUS, Carbon Capture, Utilization, and Storage; DFT, Density Functional Theory; NOAA, National Oceanic and Atmospheric Administration; IPCC, Intergovernmental Panel on Climate Change; WGS, Water-Gas-Shift; PPs, Power Plants; CHPPs, Combined Heat and Power Plants; IGCC, Integrated Gasification Combined Cycle; HRSG, Heat Recovery Steam Generator; AGR, Advanced Gas-cooled Reactor; MEA, Monoethanolamine; DEA, Diethanolamine; MDEA, Methyl Diethanolamine; MOFs, Metal-Organic Frameworks; PSA, Pressure Swing Adsorption; VSA, Vacuum Swing Adsorption; TSA, Temperature Swing Adsorption; PTSA, Pressure-Temperature Swing Adsorption; CLC, Chemical Looping Combustion; CLP, Calcium Looping Process; LNG, Liquified Natural Gas; AMD, Acid Mine Drainage; DRM, Dry Reforming of Methane; BRM, Bi-Reforming of Methane; ORM, Oxy-CO_2 Reforming of Methane; THF, Tetrahydrofuran; TBAB, Tetra-n-Butyl Ammonium Bromide; TBAF, Tetrabutylammonium Fluoride; ECBM, Enhanced Coal Bed Methane; EOR, Enhanced Oil Recovery; MMP, Minimum Miscibility Pressure; NET, Negative Emission Technique; HER, Hydrogen Evolution Reaction; CO2RR, Carbon Dioxide Reduction Reaction; OER, Oxygen Evolution Reaction.

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