Journal of Environmental Chemical Engineering 9 (2021) 105644

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

Advances in recovery and utilization of carbon dioxide: A brief review

Jessica Godin [b], Weizao Liu [a,*], Shan Ren [a], Chunbao Charles Xu [b,*]

[a] College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China
[b] Department of Chemical and Biochemical Engineering, Western University, London, Ontario, Canada N6A 5B9

ARTICLE INFO

Editor: Dr. Z. Wen

Keywords:
Carbon dioxide
Carbon capture and utilization
Climate change
Mineralization
Greenhouse gases

ABSTRACT

The continued warming of the planet resulting from anthropogenic CO_2 emissions requires immediate action to meet climate change mitigation targets. The utilization of CO_2 from waste streams and ambient air has attracted increasing attention as a powerful emission mitigation tool. This review aimed at exploring the current state of carbon capture and utilization technologies. Various separation techniques, including absorption, adsorption, membrane, cryogenics, and chemical looping were explored in this review, with their challenges and future prospects identified. Utilization of CO_2 via conversion to fuels and chemicals, as a green solvent and enhanced oil recovery, as well as through mineral carbonation were explored. Conversion of CO_2 to synthetic fuels appears to be the very promising pathway to scaling up carbon capture technologies due to the value of the products. The costs and sustainability aspects of capture and utilization technologies, as well as the challenges and future prospects for CO_2 utilization were discussed.

1. Introduction

The average temperature of the planet has increased by more than 1 °C since before the industrial revolution, with the ten warmest years recorded occurring since 1998 [1]. The global temperature increase is attributed primarily to anthropogenic greenhouse gas (GHG) emissions. According to the Intergovernmental Panel on Climate Change, carbon dioxide (CO_2) is the largest anthropogenic contributor to GHG emissions, accounting for more than 70% of global emissions, with the remainder comprised of methane, nitrous oxide, and various fluorinated gases [2].

Human activities are causing an accumulation of CO_2 in the atmosphere at a rate of 33 Gt CO_2/year, as the carbon cycle is unable to accommodate the anthropogenic emissions through natural sinks such as forests, and influencing the carbon storing ability of soils [3–5]. There is a global consensus that immediate intervention is required to reduce the rate of global warming by minimizing CO_2 emission sources or enhancing GHG sinks. Despite the implementation of policies for the mitigation of climate change, the global surface temperature is predicted to reach 1.5 °C before 2052 if CO_2 emissions remain at their current level [1]. Global CO_2 concentrations have always cycled through peaks and valleys, however the concentration of CO_2 in the atmosphere has reached more than 410 ppm, the highest it has been in over 800,000 years [6–8].

Fossil fuel combustion for power generation, transportation, and industry account for the majority of anthropogenic emissions, as depicted in Fig. 1. Despite the growth of more renewable energy technologies such as wind and solar power, the Energy Information Administration (EIA) predicted that fossil fuels would remain the dominant energy source for at least the next 30 years, suggesting CO_2 emissions will continue to grow [9]. A proposed route to reduce carbon dioxide emissions is to implement carbon capture technologies, primarily: Carbon Capture and Storage (CCS), and Carbon Capture and Utilization (CCU). CCS refers to the capture of waste CO_2 through various technologies, then transporting it to a location where it is stored typically by geological, oceanic and mineral sequestrations [10,11]. CCS suffers from several limitations, primarily the energy required to separate, transport and store CO_2, thereby increasing fossil fuel use, as well as the uncertainty regarding the permeance of CO_2 storage [4]. Conversely, during CCU, once the waste CO_2 is captured, it is recycled for further uses rather than storage. CCU will be the focus of this work.

While both approaches result in a reduction in atmospheric CO_2 levels, CCU has the added benefit of potential energy and resource recovery, through utilizing the CO_2 as a renewable resource. CCU has been demonstrated to be a viable route to reducing emissions by mimicking the natural carbon cycle to produce compounds from spent CO_2. Recently, the focus on renewable energy sources such as solar, wind and geothermal energy has indicated the potential to utilize carbon-free

* Corresponding authors.
E-mail addresses: liuwz@cqu.edu.cn (W. Liu), cxu6@uwo.ca (C.C. Xu).

https://doi.org/10.1016/j.jece.2021.105644
Received 29 December 2020; Received in revised form 1 May 2021; Accepted 5 May 2021
Available online 10 May 2021