Journal of Cleaner Production 362 (2022) 132300

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Large scale application of carbon capture to process industries – A review

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ARTICLE INFO

Handling editor: Prof. Jiri Jaromir Klemeš

Keywords:
Carbon capture
Post-combustion
Oxyfuel-combustion
Cement
Iron and steel
Oil refinery

ABSTRACT

Carbon capture (CC), along with the efforts to reduce carbon emissions at the source, is a major action toward the mitigation of climate change and global warming due to emissions of greenhouse gases (GHGs). Carbon emissions amount to 36.3 Gt-CO_2 in 2021 from 31.5 Gt-CO_2 in 2022, with a drop of about 1.5 Gt-CO_2 in 2020 relative to 2019 due to the COVID-19 pandemic. The carbon emissions originate from heat and power, transportation, process industries, and residential activities constitute 47.7, 24.9, 18.9, and 8.5% of the total emissions, respectively. The process industries represent the second large-scale point-source of carbon emissions next to heat and power. Additionally, the process industries have high-intensity carbon emissions up to 0.6–0.8 t-CO_2/t-cement, 1.4–2 t-CO_2/t-steel, and 2.7–99.2 kg CO_2/bbl, with flue gas streams having high CO_2 concentration up to 30%. In comparison to 0.4 t-CO_2/MWh and 3–16% CO_2 in the flue gas from heat and power facilities, these process industries present a highly effective target for CC application. This work reviews and critically discusses the large-scale application of CC to different process industries, namely, cement, iron and steel, oil refinery, and chemicals. CC can be achieved by three main approaches, i.e., post-combustion, pre-combustion, and oxyfuel combustion. Post-combustion and chemical-looping are the common CC approaches utilized in process industries, with the first being widely applied due to its ease of incorporation, and the latter is commonly used in the cement industry. CC with the capacity in the range of 0.4–2 Mt-CO_2/yr is planned for cement plants relative to current capacities of 75 kt-CO_2/yr. Similarly, CC capacity up to 0.8 Mt-CO_2/yr has been integrated into iron and steel plants, in which captured CO_2 is utilized for enhanced oil recovery (EOR) applications. In the oil and gas industry, CC has been widely utilized, in the context of gas purification, being an essential gas processing unit, with CC capacities up to 1.4 Mt-CO_2/yr, and plans to reach 4 Mt-CO_2/yr. CC cost is the main challenge for the widespread implementation of CC in process industries with a wide range of reported costs of USD9.8-250/t-CO_2 depending on the process industry and the CC technology used.

1. Introduction

Owing to human activities, the rise in energy demand and subsequent greenhouse gases (GHGs) emissions have contributed to several climate changes and global warming impacts (Wilberforce et al., 2021). These impacts vary from environmental, ecological, physical, and economic to health, including severe weather patterns such as heatwaves, rising sea levels, and changing rainfall rates in both trend and timing leading to erratic floods and droughts, hence alteration of crop cycles (Zheng et al., 2019). CO_2 emissions account for about 76% of the GHGs emissions, followed by 16% for methane, and finally 6% for nitrogen oxides (NO_x), hence GHGs are usually expressed as CO_2-equivalent (Intergovermental Pannel on Climate Change IPCC, 2014). There are three main approaches to reducing atmospheric CO_2: 1) emissions reductions at the source, by improved process performance and efficiency (Elsaid et al., 2020; Olabi et al., 2021b); 2) introducing alternate low- and zero-carbon energy sources (Ahmed et al., 2021; Montoya et al., 2021); and 3) carbon capture and storage or utilization (CCUS) (Pokhrel et al., 2021; Wang et al., 2021). The first approach looks into replacing

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https://doi.org/10.1016/j.jclepro.2022.132300
Received 18 September 2021; Received in revised form 15 May 2022; Accepted 17 May 2022
Available online 21 May 2022
0959-6526/