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Physical solvents and techno-economic analysis for pre-combustion CO_2 capture: A review

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ABSTRACT

This manuscript reviews the use, development, and economic performance of physical solvents for pre-combustion CO_2 capture from high pressure H_2 rich syngas streams. Commercially available physical solvents are presented, followed by an assessment of the ideal properties that are important for development of novel solvents for CO_2 capture from high-pressure syngas streams. To compare the technical and economic performance of traditional and novel physical solvents, a review of the methods, assumptions and models used in techno-economic analysis (TEA) studies was conducted. It was found that, although some novel solvents show promising technical performance in the laboratory (e.g., high CO_2 absorption capacity and low vapor pressure), other issues (e.g., solvent viscosity and cost) may limit their industrial applications. Process simulations were useful tools for modeling the technical performance of processes using traditional and novel solvents. However, model predictions are most reliable when the methods and correlations used to develop the process simulation are validated with representative experimental data, in particular highly accurate baseline models are required for fair comparison among physical solvents. The key inputs and assumptions in pre-combustion CO_2 capture TEAs have also been summarized. Some studies showed that the promising technical performance of novel physical solvents can be offset by the high and often unknown costs of these solvents. Future development of novel physical solvents for pre-combustion CO_2 capture will benefit from more studies that conduct in-depth techno-economic analysis, specifically with validated process simulations and transparent economic models.

1. Introduction

As reported in the latest IPCC assessment report, in order to limit global warming, “strong, rapid, and sustained reductions in carbon dioxide, methane and other greenhouse gases are necessary” (IPCC, 2021). The primary sources of greenhouse gas (GHG) emissions in the United States in 2019 were transportation (29%), electricity production from fossil fuels (25%) and industries that burn fossil fuels for energy or produce GHG emissions from chemical processes (23%) (EPA, 2021). Carbon capture and storage (CCS) technologies are considered critical for reducing fossil fuel sourced carbon dioxide (CO_2) emissions in order to meet global climate targets (Global CCS Institute, 2020). In the first step of CCS, CO_2 emissions are captured using a gas separation process, such as solvent absorption, membrane separation, adsorption or cryogenic separation, and the resulting CO_2 rich gas stream is then compressed, transported, and stored geologically in depleted oil and gas fields or deep saline formations.

Many forms of CO_2 capture will be required to achieve global climate goals, including but not limited to: (a) direct air capture, (b) post-combustion capture from large power plants and similar point sources, and (c) pre-combustion capture from mid-stream facilities, gasification plants and chemical refineries. The demand for clean or near-zero emissions hydrogen produced from fossil fuels with CCS, also known as clean hydrogen or ‘blue hydrogen’, is increasing due to its potential to make a significant contribution to emissions reduction in the power generation, transportation, and industrial sectors (Global CCS Institute, 2021). Blue hydrogen is produced from fossil fuels (e.g. steam methane reforming (SMR) from natural gas or gasification from a solid fuel like coal) with carbon capture and storage (Lau et al., 2021; NETL, 2021). As such, this review will be important for future implementation of blue

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