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Investigation of Technology Development Progress for Post Combustion Capture in Department of Energy Funded Research

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Abstract

Over the past 20 years, the U.S. Department of Energy has conducted research on carbon capture technologies through a variety of programs. R&D efforts of the DOE's Office of Fossil Energy and Carbon Management Point Source Capture (PSC) program since 2015 have focused on the development of 2nd generation and transformational solvents, sorbents, membranes and novel and hybrid systems for both post-combustion and pre-combustion carbon capture. These efforts have culminated in the development of advanced capture systems that have increased in scale, improved in terms of cost and efficiency, increased technical readiness and have been applied to a widening variety of flue or process gas sources. This paper aims to summarize the efforts to date through examination of the decreases in technology capture cost and improvements in technical performance.

Solvent based research has focused on chemisorptive or phisisorptive liquid materials. Materials-level R&D has focused on new solvent materials (e.g., phase-changing solvents and water-lean solvents) that outperform 1st generation solvents (e.g., monoethanolamine (MEA)) by lowering regeneration energy requirements, increasing the CO_2 absorption capacity and improving solvent tolerance to impurities present in flue gas. Additionally, process intensification has been investigated to improve overall efficiency and lower CO_2 capture costs. Sorbent based research has focused on chemical and/or physical adsorption of CO_2 in solid materials. Sorbent material research has primarily focused on advanced sorbents that are low-cost, have a high CO_2 selectivity, high CO_2 adsorption capacity and exhibit cyclic stability and resistance to oxidation and impurities. Examples include metal organic frameworks (MOFs), porous polymer networks and functionalized resins. Additonally, sorbent based process intensification and new reactor designs and configurations. Membrane based research has focused on selective transport and separation of CO_2 from gas streams through permeable or semi-permeable materials. Materials research in this area has investigated low-cost, durable membrane materials (e.g., polymeric membranes, mixed matrix membranes, sub-ambient temperature membranes) with improved permeability and selectivity for CO_2, thermal and mechanical stability, along with improved tolerance to gas contaminants. Novel membrane systems have been evaluated to utilize low-pressure drop membrane modules, membrane modules developed for additive manufacturing and module configurations that allow for increased carbon capture rates. Novel/hybrid capture processes have also been investigated that either

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combine two of the aforementioned technology types in a single system or aim to separate CO2 in a manner that does not quite fit the above categories (e.g. cryogenic).

Early efforts focused on lab and bench scale testing to improve the performance of carbon capture processes. Performance targets were established to reduce CO_2 emissions by 90+% and more recently by 95+% at new and existing power plants. Pilot-scale tests of solvent-, sorbent- and membrane-based technologies were initiated in the early 2010s. Since 2009, testing at up to 1 MWe scale has been conducted at the National Carbon Capture Center (NCCC). To date, 63 technologies have undergone pilot-scale testing at NCCC with an additional 13 currently in planning, and capture costs over that time have been reduced by approximately one-third. In addition, a subset of technologies have been tested at large pilot scale (~10 MWe) at Technology Center Mongstad in Norway, and construction has been completed for two purpose-built large pilot scale test facilities in the US.

Results from techno-economic analysis will show reductions in CO_2 capture costs associated with PSC Program lab and bench scale efforts from 2015 to present. As shown, capture costs have decreased from 2015 ($50/tonne) to the present ($38/tonne) based on continuing R&D and while using a common basis and financial parameters. It is also worth noting that numerous projects have achieved a TEA-based capture cost of under $40/tonne (2025 target, coal-based electric generation) in the last 2 years. Additional results to be shown include the improvement of process/material parameters (regeneration energy, selectivity, etc.) over time, as a function of the technology type, and as a function of the R&D scale.

Keywords: carbon capture, cost analysis, membranes, solvents, sorbents

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