Optimizing the Tier 2 Carbon Capture Process

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Background/Objectives. Increased deployment of carbon capture, utilization, and storage (CCUS) technologies is one pillar of the U.S. Department of Energy's Industrial Decarbonization Roadmap ("Industrial Carbonization Roadmap," U.S. Department of Energy, September 2022). Unfortunately, current CCUS deployments are primarily for "Tier 1" industries that produce high-purity CO_2 streams (e.g., ethanol, ammonia, and natural gas production), which account for only about 10% of U.S. industrial CO_2 emissions. Deployment to the much larger Tier 2 segment, which includes the likes of cement, steel, chemical production, fossil-fuel burning power plants, and refineries, is slowed by the prohibitive cost of capturing CO_2 from these industries' low-purity CO_2 streams.

The current method for capture of CO2 at Tier 2 sites uses an absorbing column containing an amine solution, desorption of CO_2 and regeneration of the amine, and finally CO_2 compression and transport for utilization or sequestration. The presented work focuses on the absorption and desorption portions of this process, seeking to lower cost by identifying opportunities to optimize the process through insertion of novel technologies and developing a low-energy desorption method that significantly reduces the cost of this portion of the capture process.

Approach/Activities. Our approach to optimizing the Tier 2 capture process consists of a model-based analysis of the performance, cost, and opportunities for improvement of the process, along with experimental research and development of a novel desorption material. The analysis models the capture process from introduction to the low-purity emission to compression of the CO_2 for transport and allows variation of the system design, operating conditions, sorbent solution properties, and component and material properties. Performance of the modeled system is evaluated in terms of overall CO_2 capture efficiency against lifecycle costs that include capital costs, energy costs, other operational costs such as maintenance and sorbent solution life, and cost of waste disposal.

To address one of the major cost elements of the capture process, the thermal energy required to desorb CO_2 from the sorbent solution, our team is working to transfer low-energy desorption technology developed for a separate industry to the CCUS market. Our approach began with conducting coupon tests of the desorption efficiency of a novel desorption material at different temperatures. Following demonstration of effective desorption in the coupon tests, we prepared the material in a configuration for a prototype packed-bed desorption column. Current efforts focus on evaluating the efficiency of new prototype desorption column, modeling the thermal characteristics of the column, and evaluating the long-term stability of the material.

Results/Lessons Learned. The results of the coupon tests of the new desorption material indicate that effective desorption is achieved at a temperature of approximately 80^{o}C, as opposed to needing to heat the sorbent solution to greater than 120^{o}C with a traditional desorption column. Applying this temperature change in the model indicates that the energy savings alone from the new desorption material can lower the overall cost of carbon capture by 20% or more. Further analysis will include the effects of ancillary component changes and longer sorbent life which should increase the savings. Future analysis will also address combining the new desorption material with other technology advances such as new sorbent solutions.