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Joule-heated reactor structures for the electrification of direct air capture

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Abstract

To reach the goal of limiting global warming to 1.5 °C, the IPCC predicts that negative emission technologies (also called carbon dioxide removal) will be needed. These technologies enable us not only to reduce CO_2 production but also to remove CO_2 from the air and either store it or utilize it as a reagent to produce useful chemicals, such as methane, methanol, or syngas, in a carbon-neutral manner. Of interest among these methods is direct air capture. By removing CO_2 from the air instead of flue gas, the point of emission becomes irrelevant, and the technology is therefore not bound to one specific location, unlike carbon capture and storage.

Currently, solid adsorption is the most promising method for capturing CO_2 from the air due to its lower specific energy cost compared to liquid adsorption. However, this method remains expensive, primarily due to the high energy requirements needed to regenerate the sorbent. Other limitations arise from the heat supply method: pushing steam through the bed reduces the purity of the CO_2, while using a heating jacket limits the potential for scale-up.

This research explores ways to reduce energy costs through electrification, specifically Joule heating. We incorporate an electrically conductive material within the reactor to produce heat in the solid phase, enabling quick temperature adjustments and improved heating efficiency. However, the best reactor structure for Joule heating is still uncertain: options like packed beds, monoliths, foams, and other configurations may all be viable.

Different reactor structures were therefore compared based on adsorbent holdup, thermal efficiency, and pressure drop. This demonstrated that the most promising approach was a novel method to prepare structured sorbent materials with integrated resistive wires. However, the created structures were quite fragile, so several methods to reinforce the material were tested. At the conference, the resulting structures will be presented, along with performance tests, including heating rates, heat distribution within the sample, modeling of scaled-up reactors, and other relevant data.