18th International Conference on Greenhouse Gas Control Technologies **GHGT-18**

25th -29th October 2026, Perth Australia

DAC integration in building technical systems: a novel approach to sustainable CO_2 capture

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Abstract

Direct Air Capture (DAC) technology faces significant economic challenges, as CO_2 capture requires substantial energy inputs and associated operational costs. Current state-of-the-art approaches focus on minimizing capital and operational expenditures through large-scale installations. However, an alternative strategy involves identifying synergies with existing energy systems to reduce both energy consumption and costs. This research presents a novel approach to DAC implementation by integrating CO_2 capture systems into the technical infrastructure of buildings, specifically targeting ventilation and HVAC systems.

Buildings of sufficient scale possess technical systems, such as ventilation and climate control, that present opportunities for DAC integration. These buildings also have diverse operational needs including heating, cooling, and increasingly stringent Environmental, Social, and Governance (ESG) objectives. If a DAC system can be successfully integrated into building infrastructure while simultaneously reducing operational expenditures and meeting ESG criteria, this concept has the potential to be deployed across thousands of buildings, creating significant cumulative impact on atmospheric CO_2 reduction.

This research pursues two complementary objectives: designing an optimized DAC contactor and re-engineering building HVAC systems for integrated operation. The DAC contactor design builds upon the liquid absorbent approach pioneered by Carbon Engineering [1], utilizing a caustic solution to convert gaseous CO_2 into a liquid carbonate solution. The conceptual framework for CO_2 capture and absorbent regeneration is based on the work of Luis Rincon et al. [2], which establishes several critical principles: (1) temporal decoupling between CO_2 capture and solvent regeneration processes, (2) the exothermic nature of the capture reaction, and (3) the potential for integrating DAC reactor inputs and outputs into external value chains.

Based on these established principles, this research advances three key hypotheses. First, the CO_2 capture process can

be integrated as a component of building air conditioning systems, contributing useful thermal energy to the building's overall energy balance. Second, the chemical absorbent can be incorporated into a profitable value chain, reducing net system costs. Third, absorbent regeneration can be strategically scheduled during summer periods when green electricity from photovoltaic systems is abundant and grid curtailment is necessary, thereby utilizing otherwise wasted renewable energy.

The research methodology employs modelling of the DAC reactor as a combined mass and heat exchanger operating as a counter flow exchanger between the building ventilation air stream and the liquid absorbent solution. Modelling results demonstrate successful CO_2 capture capability while simultaneously generating meaningful thermal energy from the exothermic absorption reaction. This recovered heat can be utilized for building space heating, reducing overall energy demand. Furthermore, the same reactor design exhibits potential to function as an adiabatic cooling system during summer operation, providing additional energy efficiency benefits.

The second part of this research focuses on comprehensive redesign of building technical systems to accommodate DAC integration. Dynamic system modelling is employed to minimize total annual energy consumption while maintaining or improving indoor air quality standards. This holistic approach considers the interdependencies between ventilation requirements, thermal loads, DAC operation, and renewable energy availability.

Preliminary results indicate that building-integrated DAC systems offer several advantages over standalone DAC installations. The utilization of exothermic reaction heat for space heating creates a direct economic benefit that improves the business case for DAC deployment. The integration with existing ventilation infrastructure reduces capital costs compared to dedicated DAC facilities. The ability to time-shift absorbent regeneration to periods of renewable energy surplus addresses both cost and carbon intensity concerns associated with the regeneration process.

This research represents a paradigm shift in DAC deployment strategy, moving from centralized large-scale facilities toward distributed building-integrated systems. If successful, this approach could unlock DAC deployment at scale by aligning CO_2 capture with the existing economic motivations of building operators—reducing energy costs and meeting sustainability targets. The distributed nature of this approach offers advantages in terms of potential valorisation scenarios for the carbonate. The timing decoupling for the absorbent regeneration is contributing to stabilizing the grid, especially in winter when the exothermal reaction is reducing the load. It fits with the concept of local production/consumption.

This presentation will detail the modelling methodology, present quantitative results on energy recover, CO_2 capture efficiency, and yearly building energy balance.

Keywords : Direct Air Capture, Building Integration, HVAC Systems, Exothermic CO_2 Capture, Energy Recovery, Distributed Carbon Capture, Sustainable Buildings

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From Environ. Sci.: Adv., 2023, 2, 957

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