A HYBRID SYSTEM FOR CAPTURING CO₂ DIRECTLY FROM THE AIR

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Direct air capture using a two-stage hybrid system can be a cost competitive way for reducing CO₂ emissions

INTRODUCTION

Climate change is the biggest challenge humanity has ever faced. The concentration of carbon dioxide (CO₂) has increased from a pre-industrial value of 280 ppm to 412 ppm in 2020, the highest value in at least 2 million years. The Paris Agreement aims at keeping global warming to well below 2°C.

How can we combat climate change?
- Reduce energy demand
- Renewables
- Carbon capture and storage
- CO₂ removal

What is Direct Air Capture (DAC)?
- DAC is a removal process that captures CO₂ from the air and concentrates it, so that it can be stored or utilised
- Other removal technologies: Bioenergy with carbon capture & storage, afforestation, soil carbon sequestration

Why DAC?
- DAC can offset emissions from hard-to-abate sectors
- DAC facilities do not need to be located close to CO₂ source
- DAC has a low carbon footprint

What are the challenges of DAC?
- Very low concentration of CO₂ in the air
- Large volumes of air must be processed
- High energy consumption
- High cost ($250-$1000 per tonne of CO₂)

METHODOLOGY

Research Challenge: Today, DAC is using a single stage technology to capture CO₂. However, achieving high purity (>98%) from the air (400 ppm - parts per million - level) is very energy and cost demanding.

Possible Solution: I have developed a two-stage hybrid concept for capturing CO₂ directly from the air and concentrating it high purity (>98%). The hybrid concept integrates two technologies, adsorption onto solids and absorption into liquid solvents.

RESULTS

First Stage: CO₂ is captured from the air using solid materials such as Zeolite13X, MOFs or activated carbon. Starting from 400 ppm, CO₂ can be enriched to between 0.5% and 12% purity. A mathematical model is used to simulate the process.

My hybrid model with 2 stages: our preliminary estimation of the total cost is $230 to $450 per tonne of CO₂

Second Stage: CO₂ from the first stage is concentrated to 98% purity using liquid solvents, such as aqueous monoethanolamine (MEA). This stage was modelled in the Aspen Plus process simulator. A mathematical meta model was developed from the detailed simulation model.

CONCLUSIONS

- A hybrid model for capturing CO₂ directly from the air is developed. The hybrid concept with two stages is shown to be feasible and cost competitive for DAC compared to current single stage technologies.
- Future work includes the integration and the optimisation of the overall performance of the hybrid system.

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