STEM for BRITAIN

# A HYBRID SYSTEM FOR CAPTURING $CO_2$ DIRECTLY FROM THE AIR

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ONASSIS FOUNDATION


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**Direct air capture using a two-stage hybrid system can be a cost competitive way for reducing $CO_2$ emissions**

## INTRODUCTION

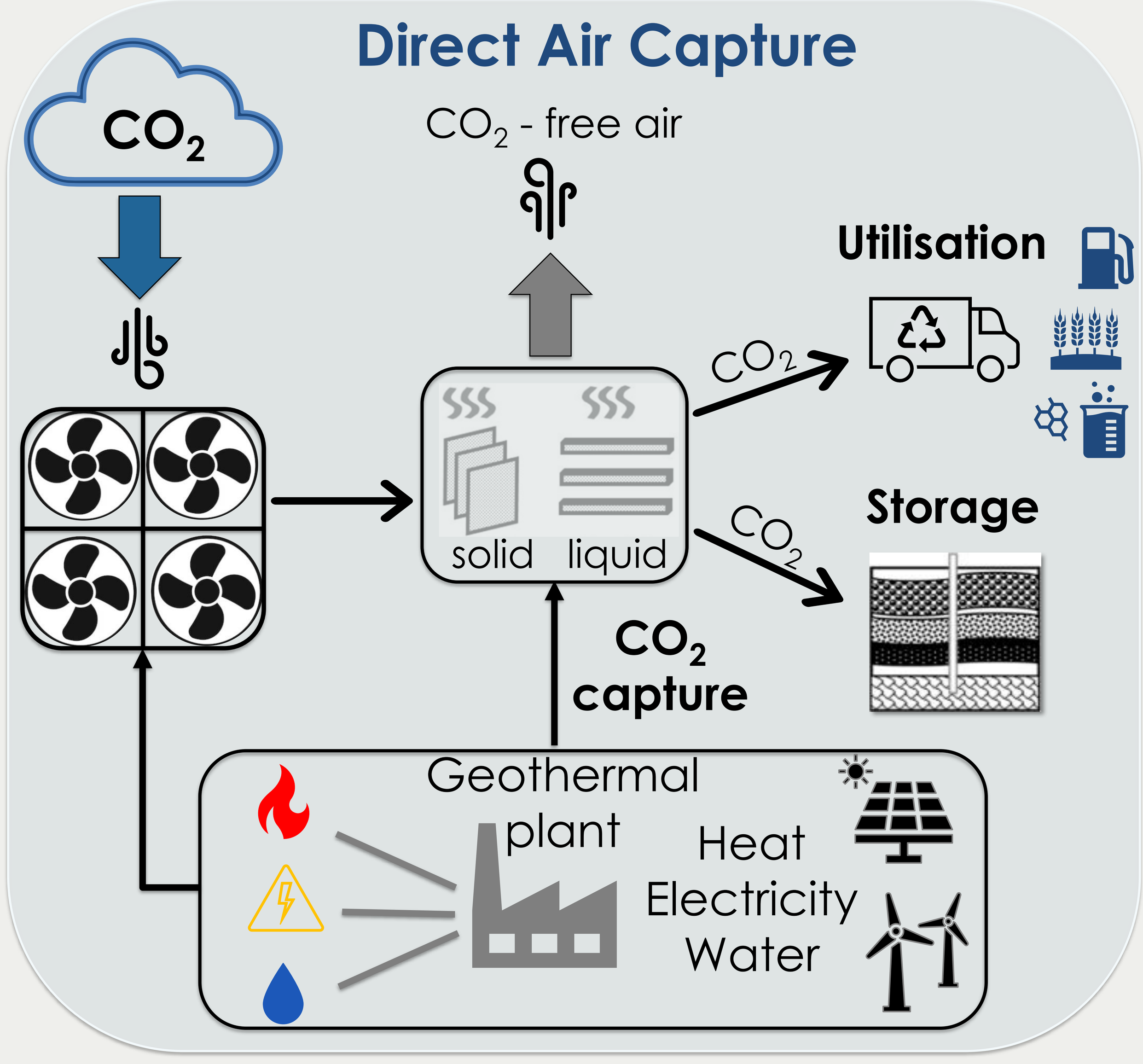
**Climate change** is the biggest challenge humanity has ever faced. The concentration of carbon dioxide ($CO_2$) has increased from a pre-industrial value of **280 ppm** to **412 ppm** in 2020, the highest value in at least 2 million years. The Paris Agreement aims at keeping global warming to well-below 2°C.

### How can we combat climate change?

- Reduce energy demand
- Renewables
- Carbon capture and storage
- $CO_2$ removal

### What is Direct Air Capture (DAC)?

- DAC is a removal process that captures $CO_2$ from the air and concentrates it, so that it can be stored or utilised
- Other removal technologies : Bioenergy with carbon capture & storage, afforestation /reforestation, soil carbon sequestration




### Why DAC ?

- ☑ DAC can offset emissions from hard-to-abate sectors
- ☑ DAC facilities do not need to be located close to $CO_2$ source
- ☑ DAC has a low carbon footprint

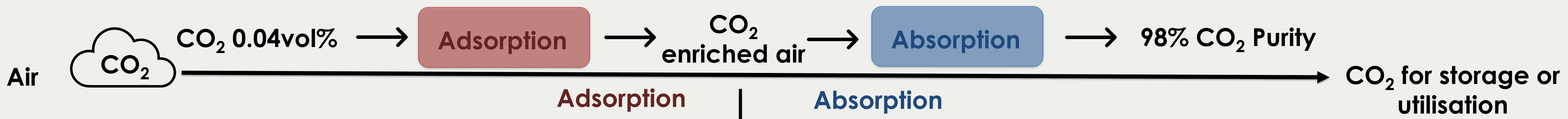
### What are the challenges of DAC?

- ☒ Very low concentation of $CO_2$ in the air
- ☒ Large volumes of air must be processed
- ☒ High energy consumption
- ☒ High cost ($250-$1000 per tonne of $CO_2$)

## METHODOLOGY

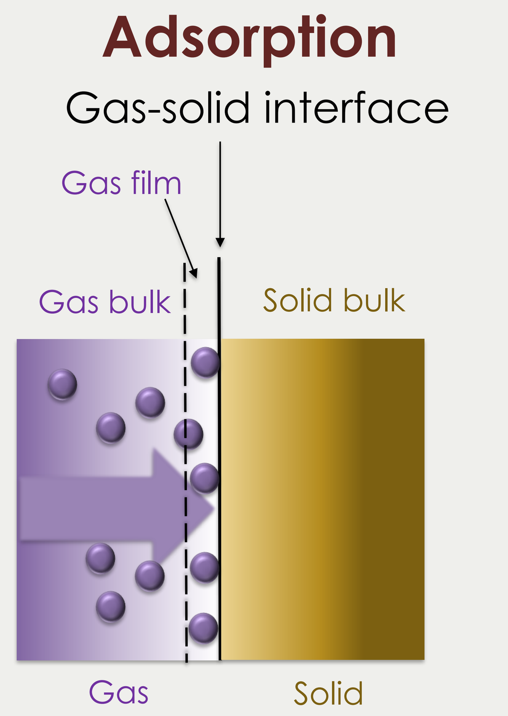
**Research Challenge:** Today, DAC is using a single stage technology to capture $CO_2$. However, achieving high purity (>98%) from the air (400 ppm - parts per million - level) is very energy and cost demanding.

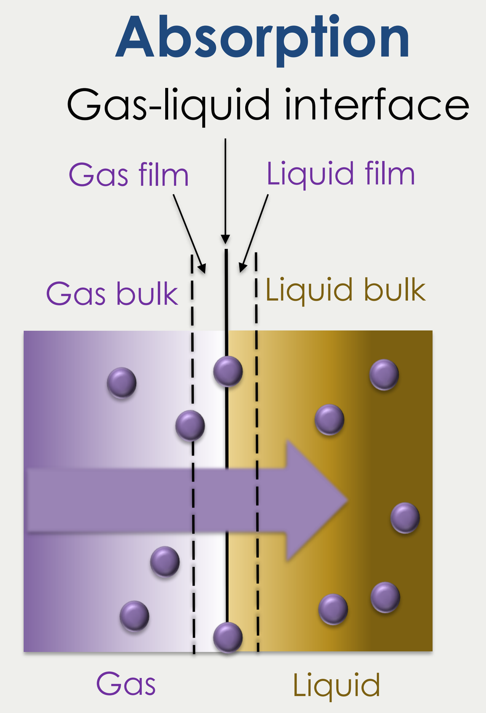
**Possible Solution:** I have developed a two-stage hybrid concept for capturing $CO_2$ directly from the air and concentrating it high purity (>98%). The hybrid concept integrates two technologies, adsorption onto solids and absorption into liquid solvents.




**1 Adsorption:**

- Attachment of $CO_2$ molecules to the surface of a porous solid (adsorbent)
- $CO_2$ is liberated by decreasing pressure and/ or by heating
- Versatile technology (many adsorbents available)



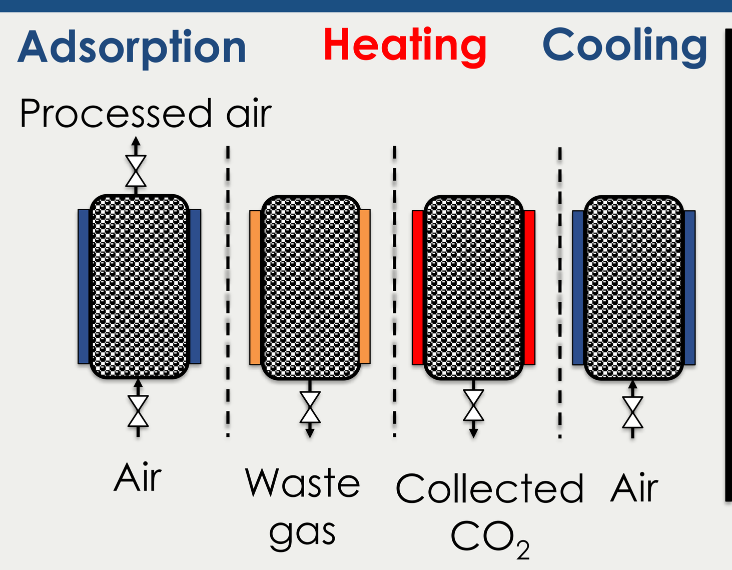




**2 Absorption:**

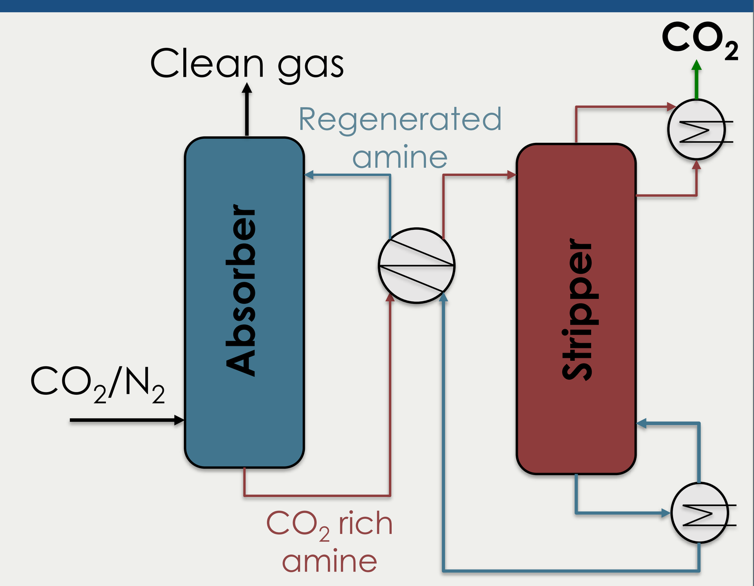
- Dissolution of $CO_2$ in a liquid solvent, such as aqueous amines and forms a solution
- $CO_2$ is liberated from the liquid solution by heating
- The most mature technology for $CO_2$ capture and delivering high of $CO_2$ purity

## RESULTS

**First Stage:** $CO_2$ is captured from the air using solid materials such as Zeolite13X, MOFs or activated carbon. **Starting from 400 ppm, $CO_2$ can be enriched to between 0.5 % and 12% purity.** A mathematical model is used to simulate the process.




**Second Stage:** $CO_2$ from the first stage is concentrated to **98% purity** using liquid solvents, such aqueous monoethanolamine (MEA). This stage was modelled in the *Aspen Plus* process simulator. A mathematical *meta model* was developed from the detailed simulation model.




**My hybrid model with 2 stages:** our preliminary estimation of the total cost is $230 to $450 per tonne of $CO_2$

## CONCLUSIONS

- A hybrid model for capturing $CO_2$ 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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