DYNAMIC MODELLING AND OPTIMIZATION OF A FIXED BED DIRECT AIR CAPTURE SYSTEM

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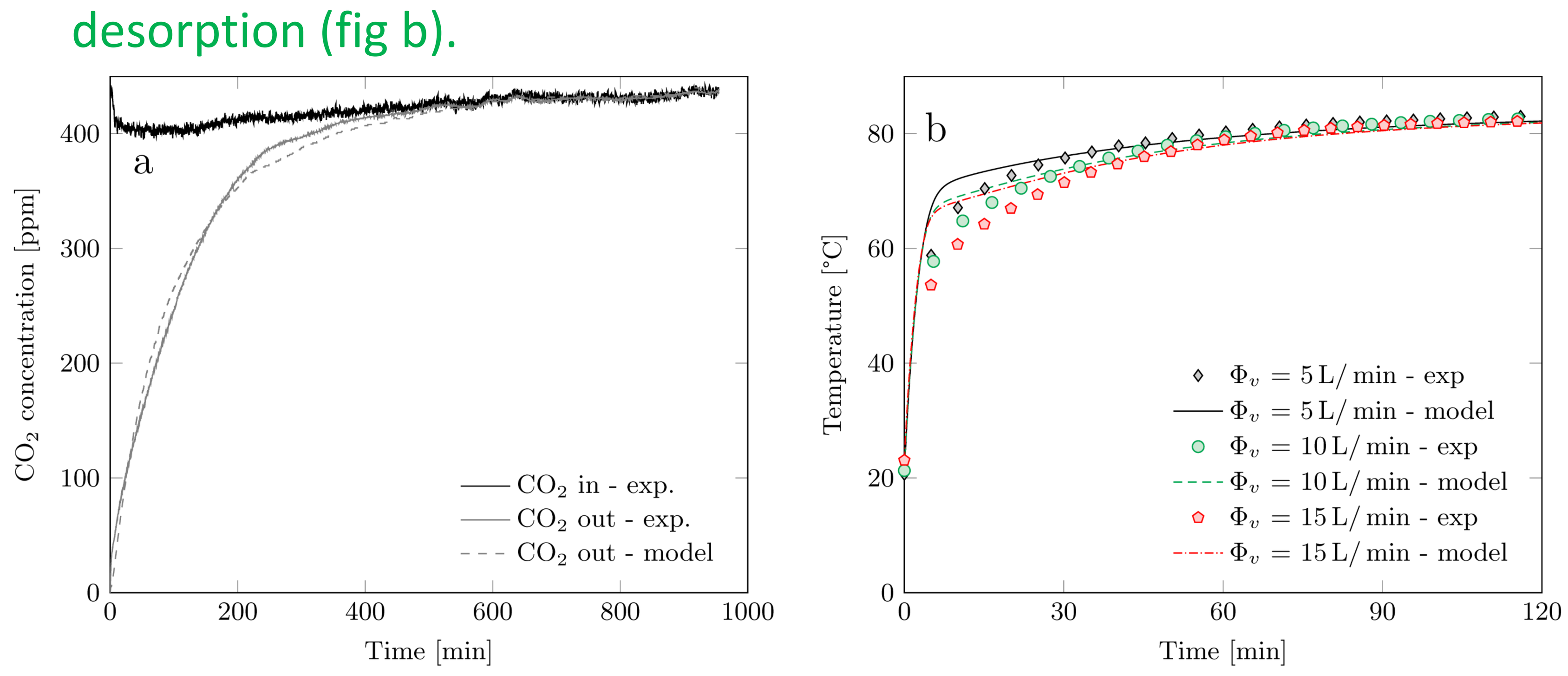
INTRODUCTION

Direct air capture (DAC) is the extraction of CO_2 from the atmosphere. It is the ultimate form of CO_2 recycling when combined with CO_2 utilization processes, for example microalgae cultivation. Adsorption using amine-based sorbents is a promising DAC technology. In this research, such a process is designed and a dynamic model is constructed. The goal of this research is to find the optimal operation parameters with respect to energy requirement, CO_2 productivity and overall cost of capture.

MODELLING

The complete adsorption-desorption cycle of this fixed bed system is described by a dynamic model.

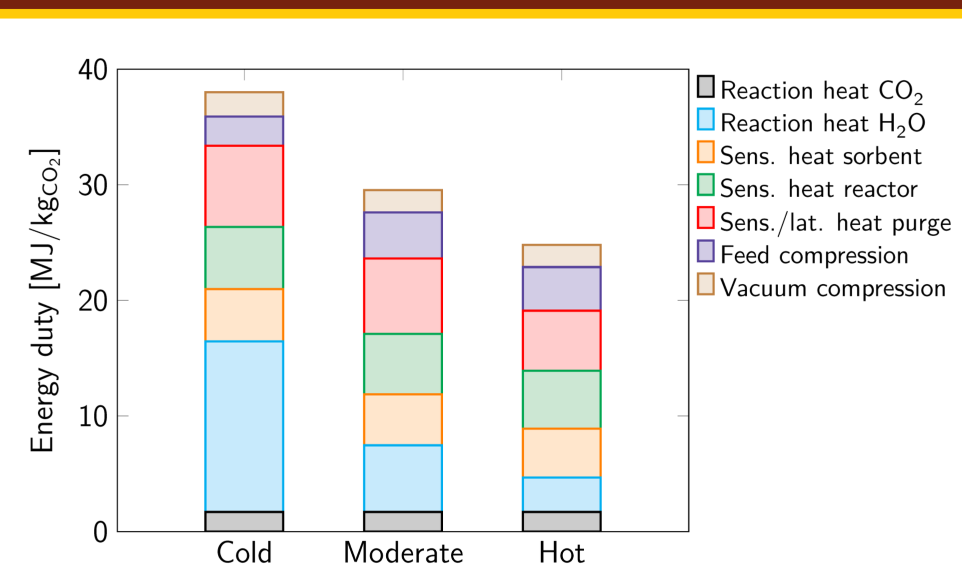
- This model is validated by experimental data on a kg-scale DAC setup.
- Model results are validated with experimental results for CO2 outlet concentration for adsorption (fig a) and for temperature during desorption (fig b).



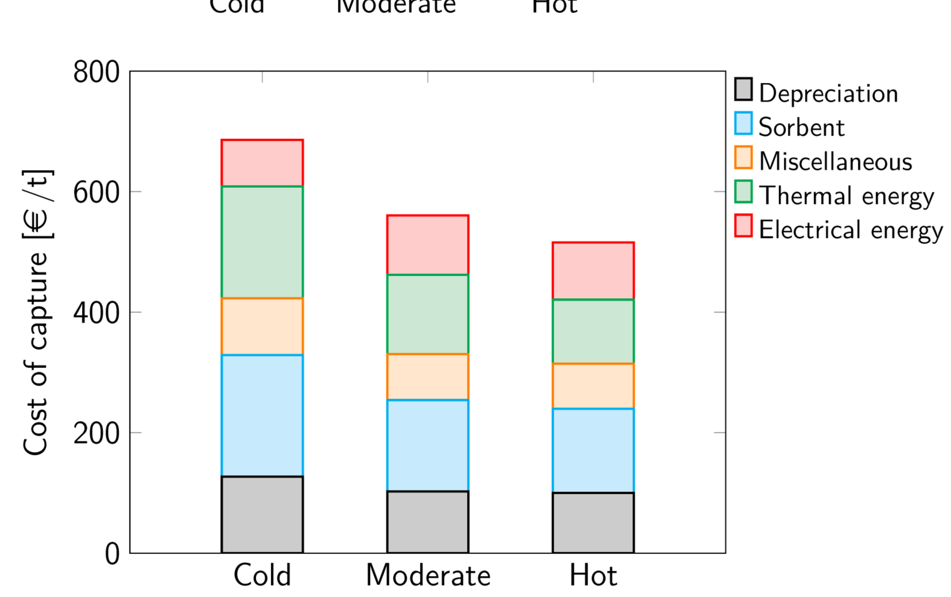
PROCESS OPTIMIZATION

The objective of the optimization is to minimize the total costs of capture for different weather conditions:

- Cold (10°C/80% RH)
- Moderate (20°C/50% RH)
- Hot (30°C/30% RH)

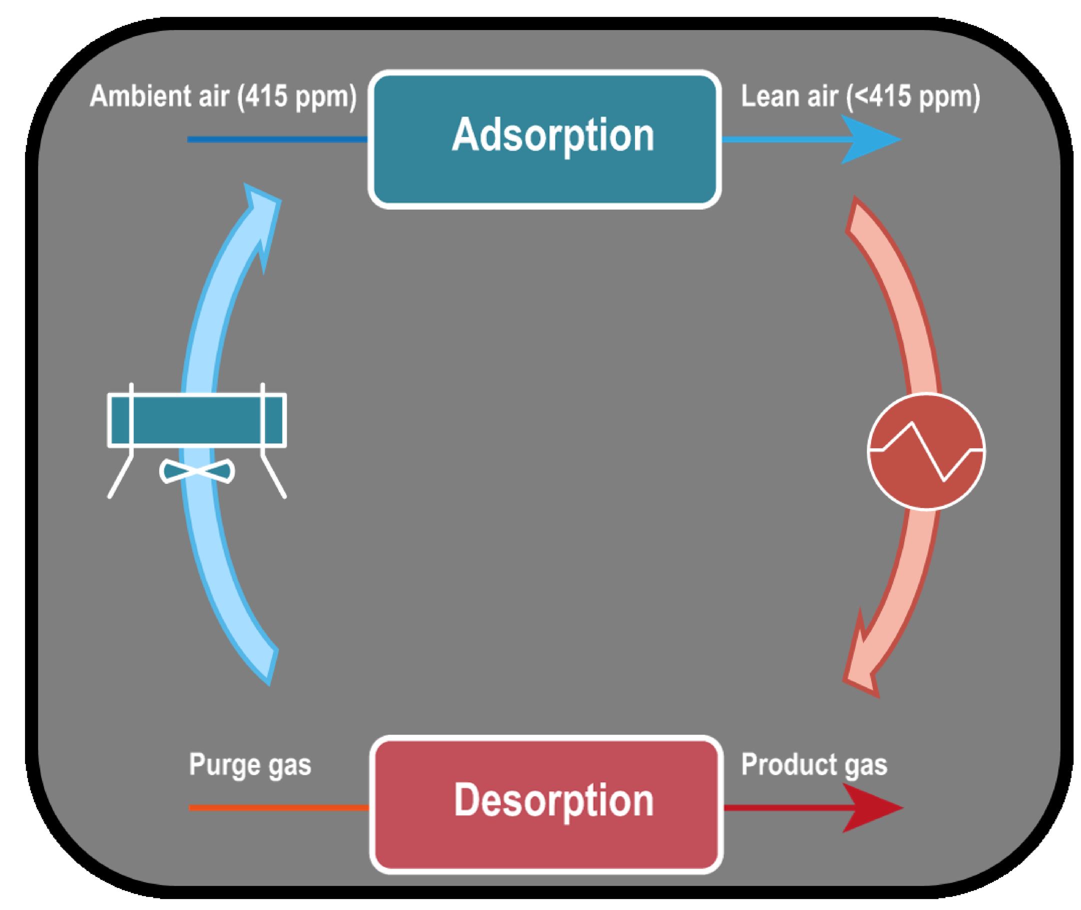


- Weather conditions have a large effect on the cost of DAC.
- Water co-adsorption is an important aspect
  - At cold conditions it accounts for 40% of the energy duty



ADSORPTION-DESORPTION CYCLE

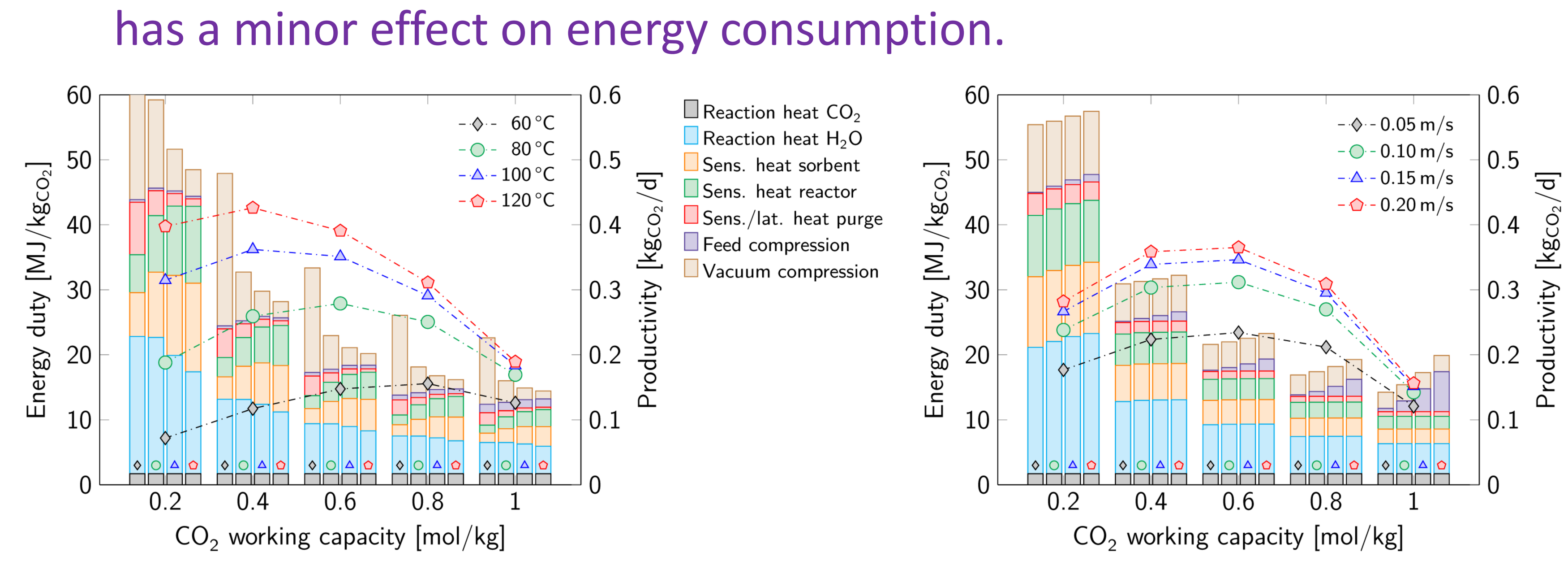
Adsorption is a two-step process. First, CO_2 is adsorbed by the porous solid material. Once the sorbent is saturated it requires regeneration. This desorption step is carried out at increased temperature and/or reduced pressure. In this step, the CO_2 product gas is collected.



SENSITIVITY ANALYSES

Sensitivity analyses show effect of certain process variables on process performance. The figures show the effect of desorption temperature (left) and adsorption gas velocity (right) on the productivity (symbols) and the energy duty (bars) as function of working capacity, which is a measure of the adsorption time. We conclude that:

- Desorption temperature is preferably as high as possible
- Gas velocity significantly influences productivity up to 0.15 m/s, but has a minor effect on energy consumption.



CONCLUSIONS

- A fixed bed adsorption system for DAC was designed, modelled and optimized
- Sensitivity analyses show a trade-off between productivity and energy consumption, however desorption temperature should always be as high as possible
- Economic analyses show a cost of capture of 500-700 €/ton
- Weather conditions significantly influence a DAC process

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