# DACS Talks

Within the interdisciplinary talk series **DACS Talks**, young DACStorE scientists present their recent findings.

The DACS Talks are hosted by the DACStorE Transformation Hub and are part of the NETs@Helmholtz Research School.

The talk will be recorded and published on our website (www.dacstore-project.com).

Next Level Ramp Up of Direct Air Capture and Storage DACStorE NETs@Helmholtz DACStorE Transformation Hub

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DACS Talk 5

# Solid Sorbent Design for DAC – Challenges and Approaches

Patrick Behr
Forschungszentrum Jülich GmbH – IMD-2
05.09.2024

FZJ | GFZ | Hereon | HZB | KIT | TUB | UFZ

# From geological fieldwork to carbondioxide removal

## Potential of layered oxides for DAC

Sustainable and abundant materials

Foto von Courtney Cook auf Unsplash

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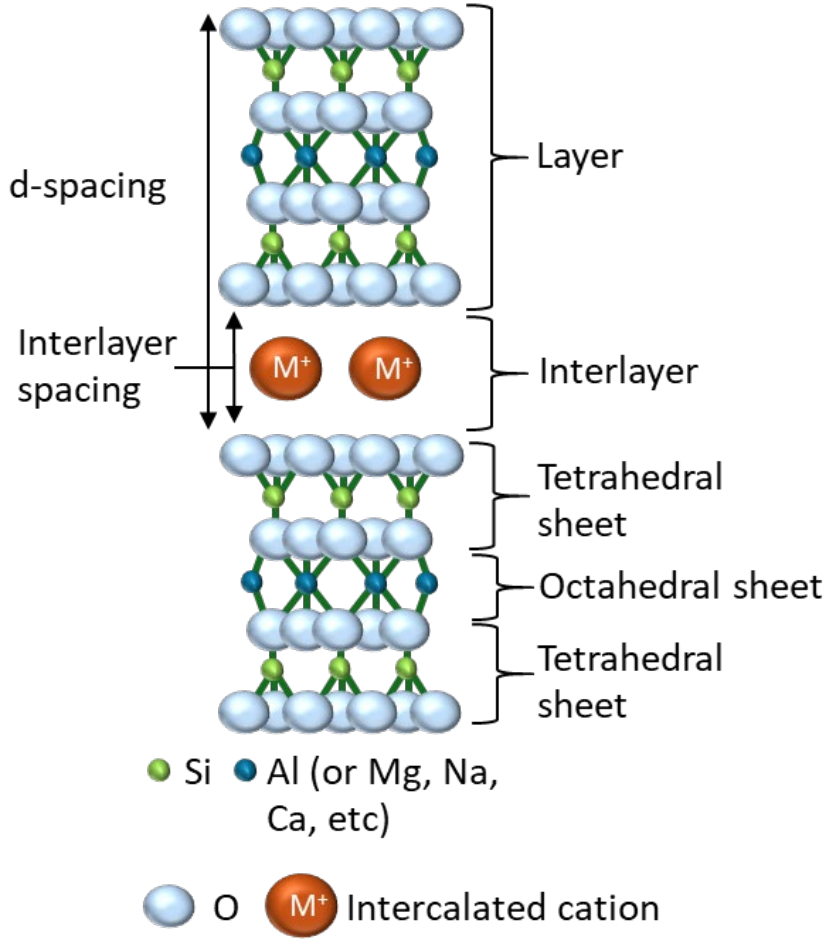
# From geological fieldwork to carbondioxide removal

## Potential of layered oxides for DAC

Sustainable and abundant materials

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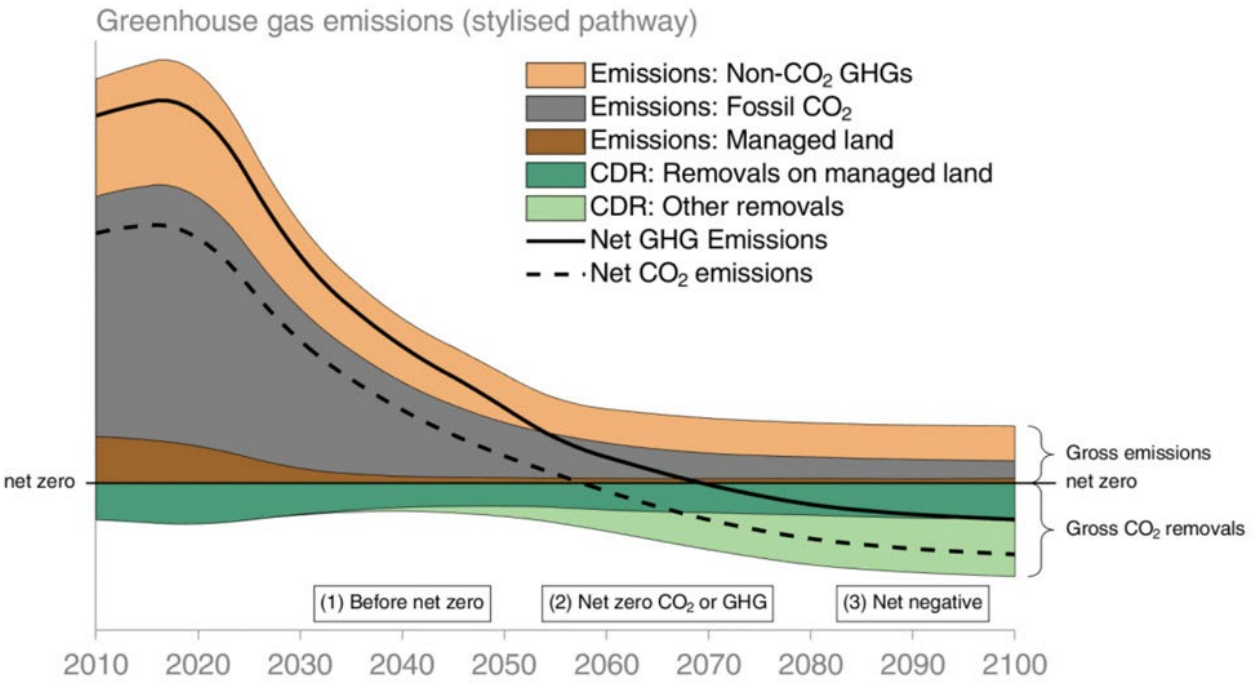
# Do we need negative emission technologies (NETs)?

## IPCC Report

- Implementation of NETs needed to reach net zero
- Net negative emissions needed at least temporary to reach climate goals




IPCC (2022) Cross-Chapter Box 8, Figure 2. *1

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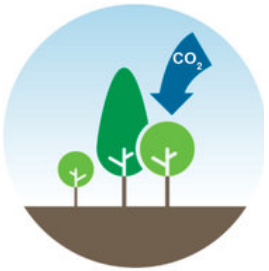
“Yes, we need to implement
a significant amount of NETs”

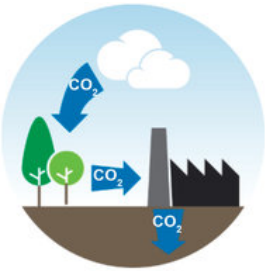
# Why focus on Direct Air Capture (DAC)?

## Overview

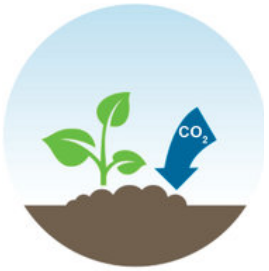
- Most NETs are slow and only feasible at certain locations
- DAC offers dezentralized, controllable capture on industrial scale




**Reforestation**

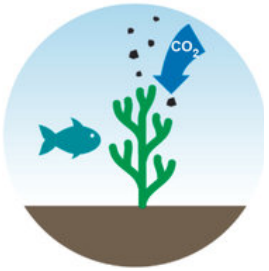



**Bioenergy**

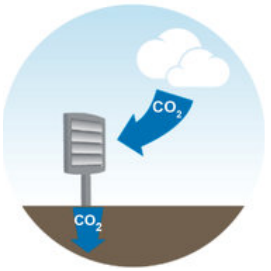



**Biochar**


**Enhanced Weather-ing**




**Ocean Fertilisation**




**Direct air capture (DAC)**

https://www.researchgate.net/figure/Different-groups-of-negative-emission-technologies-exist-Some-are-rather-recent_fig1_313425382

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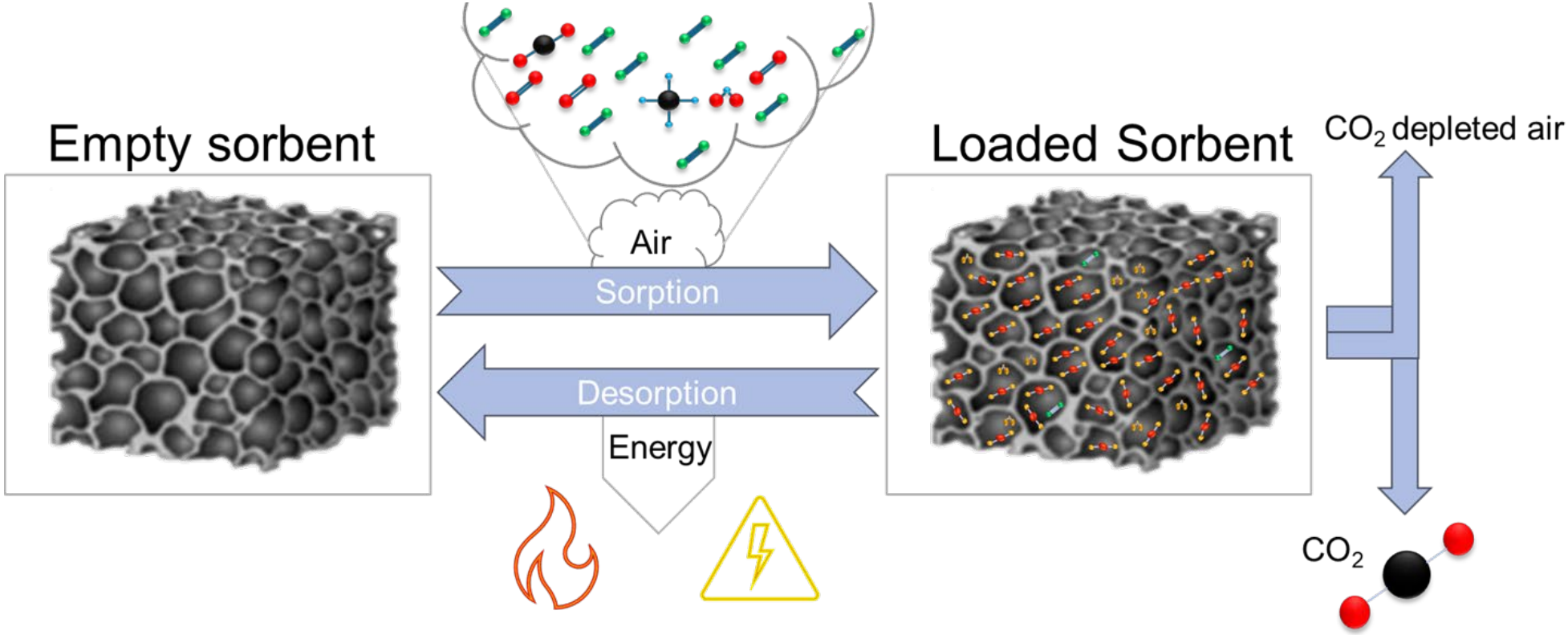
# How do solid sorbents capture $CO_2$ ?

## Simplified scheme

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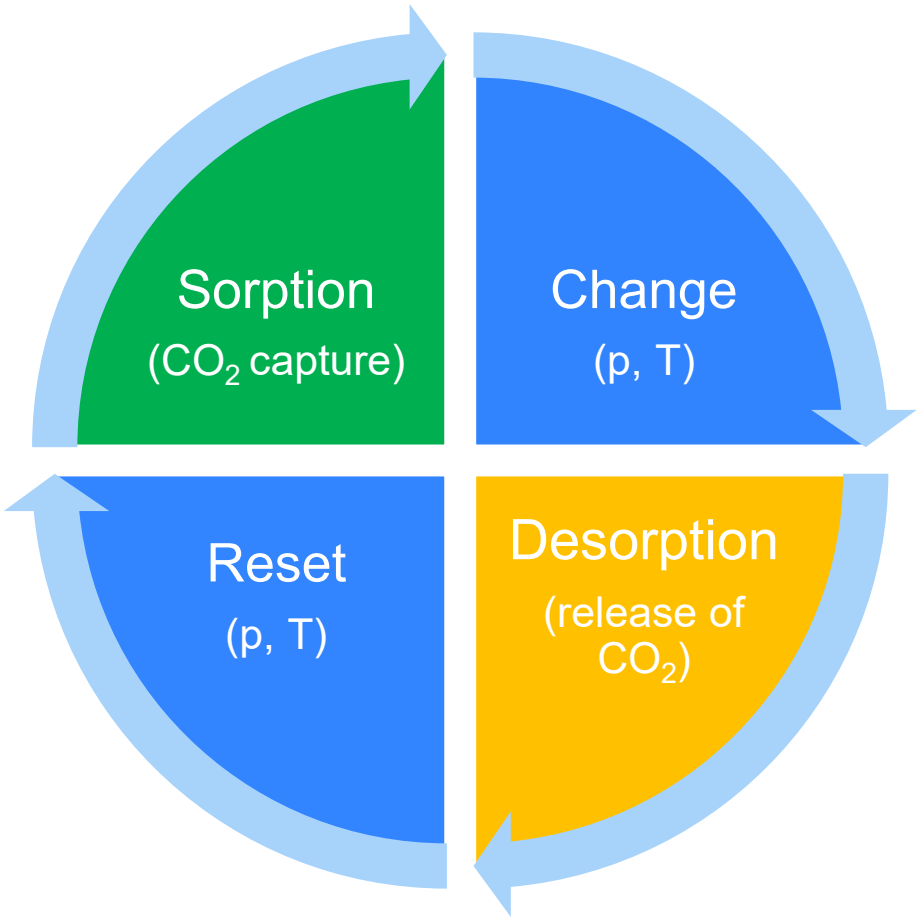
# How do solid sorbents capture $CO_2$ ?

## Swing Adsorption

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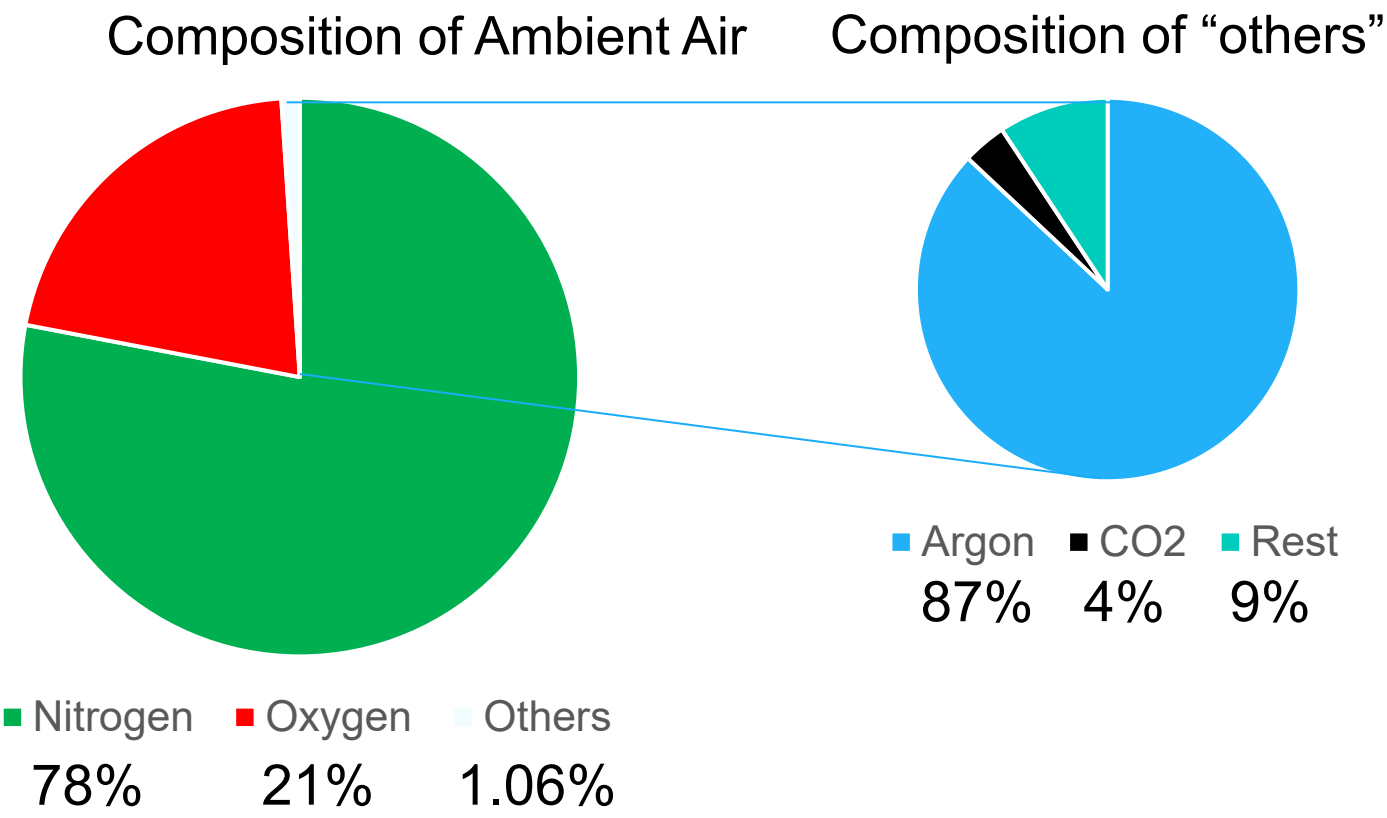
“Direct air capture offers
decentralized and scalable $CO_2$ removal.

Solid sorbents can remove $CO_2$
by swing adsorption”

# What are the challenges in designing solid sorbents for DAC?

## Composition of ambient air

- Low concentration of $CO_2$ makes adsorption unfavorable
- Presence of competing gases hinders sorption of $CO_2$

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# What are the challenges in designing solid sorbents for DAC?

## Composition of ambient air

- Roughly 75.000 seats
- 400 ppm equals 30 people in the Olympiastadion

https://olympiastadion.berlin/de/start/ aufgerufen am 30.08

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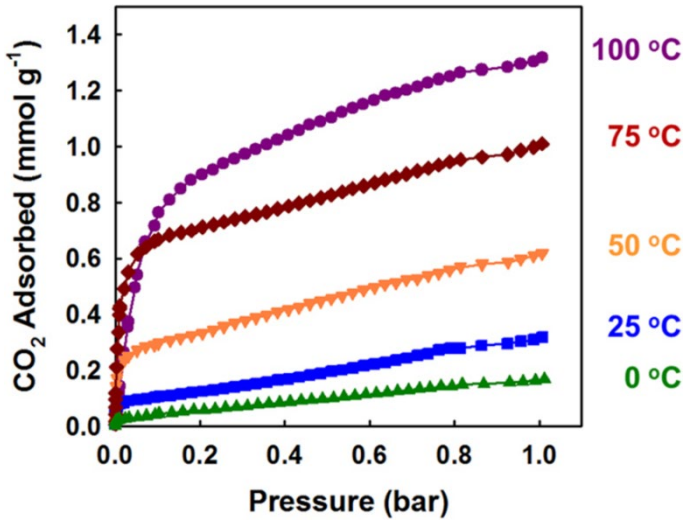
# What are the challenges in designing solid sorbents for DAC?

## Different climate conditions over the world

### Influence of temperature…




Crystal-Size Effects on Carbon Dioxide Capture of a Covalently Alkylamine-Tethered Metal-Organic Framework Constructed by a One-Step Self-Assembly - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/CO2-adsorption-isotherms-of-MOFNH2-obtained-at-the-various-temperatures_fig6_290478602 [accessed 18 Aug 2024]

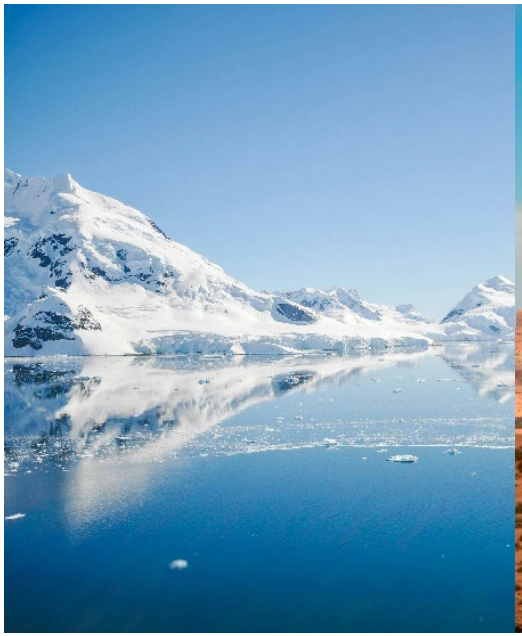


Foto von Ganapathy Kumar auf Unsplash

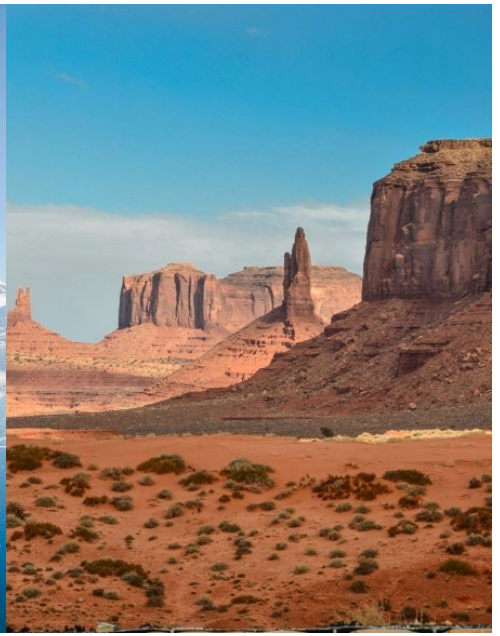


Foto von henrique setim auf Unsplash

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# What are the challenges in designing solid sorbents for DAC?

## Different climate conditions over the world

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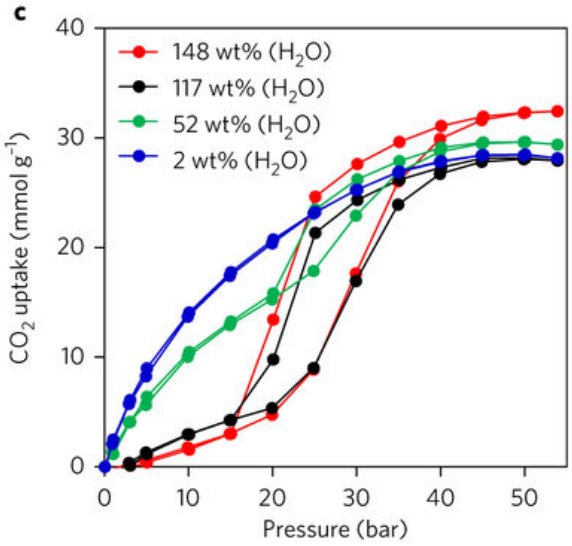


Increased CO2 selectivity of asphalt-derived porous carbon through introduction of water into pore space - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Effects-of-temperature-equilibration-time-water-content-and-sorption-desorption-cycling_fig2_321683256 [accessed 18 Aug 2024]

Foto von Parsing Eye auf Unsplash

Foto von Paulius Dragunas auf Unsplash

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HELMHOLTZ

“The main challenges
for direct air capture sorbents are
Low concentration of $CO_2$ in air and
different conditions (T, RH) around the globe”

# What makes a good sorbent?

## DAC Checklist

- ❑ Capacity

https://olympiastadion.berlin/de/start/ aufgerufen am 30.08.24

https://www.europlan-online.de/erftstolz-stadion/stadion-17476.html aufgerufen am 03.09.24

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# What makes a good sorbent?

## DAC Checklist

✓ Capacity

❑ Selectivity

Foto von Ginger Jordan auf Unsplash

Foto von Kate Remmer auf Unsplash

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# What makes a good sorbent?

## DAC Checklist

- ✓ Capacity
- ✓ Selectivity
- ❑ Heat of Adsorption

Foto von Adhitya Sibikumar auf Unsplash

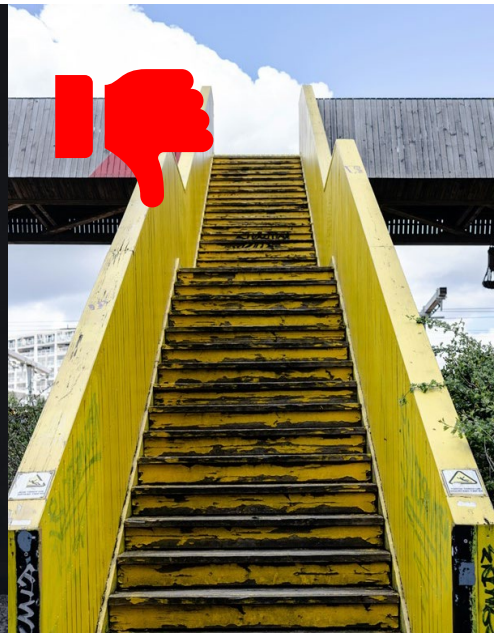

Foto von micheile henderson auf Unsplash

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# What makes a good sorbent?

## DAC Checklist

- ✓ Capacity
- ✓ Selectivity
- ✓ Heat of Adsorption
- ❑ Cost

- ❑ Material and Setup
- ❑ Energy for regeneration
- ❑ Transport/Storage of $CO_2$

More infos in DACSTALK #4

Early Business Cases for a fast industrialization of DACs technologies

*Robin Koch (KIT IMVT / Mercedes-Benz)*

Tuesday, 09. July 2024 | 09:00 – 10:00 AM | online-event

Direct Air Capture (DAC) will be an integral part of the urgently needed Carbon Dioxide Removal (CDR) methods, to deal with humanities residual emissions. One of the main hurdles for DAC is currently its high costs compared to other nature based or hybrid methods. This creates a chicken and egg problem where high costs slow down investment and less investments slows down cost reduction.


Early business cases need lower costs which could be provided through using synergetic effects. For example, integration into HVAC-systems of office of factory buildings could provide such effects. First simulation results are promising for integration of DAC into HVAC Systems of a production plant in Germany.

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# What makes a good sorbent?

## DAC Checklist

- ✓ Capacity
- ✓ Selectivity
- ✓ Heat of Adsorption
- ✓ Cost
- ❑ Sustainability

- ❑ Solvents and problematic or toxic substances for some materials
- ❑ Organic chemicals into the atmosphere possible

More infos in DACSTALK #X
By Phillip Kahl

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# What makes a good sorbent?

## DAC Checklist

- ✓ Capacity
- ✓ Selectivity
- ✓ Heat of Adsorption
- ✓ Cyclability
- ✓ Cost
- ✓ Sustainability
- ❑ Stability

- ❑ Thermal expansion of the solid sorbent
- ❑ Delamination of amines (functional groups with high $CO_2$ affinity)
- ❑ Poisoning of sorbents (e.g. $H_2S$) possible

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“A good sorbent for DAC can capture
a high amount of $CO_2$ in a sustainable way
at low cost and with minimal co-sorbtion”

# How can we solve these problems with solid sorbents?

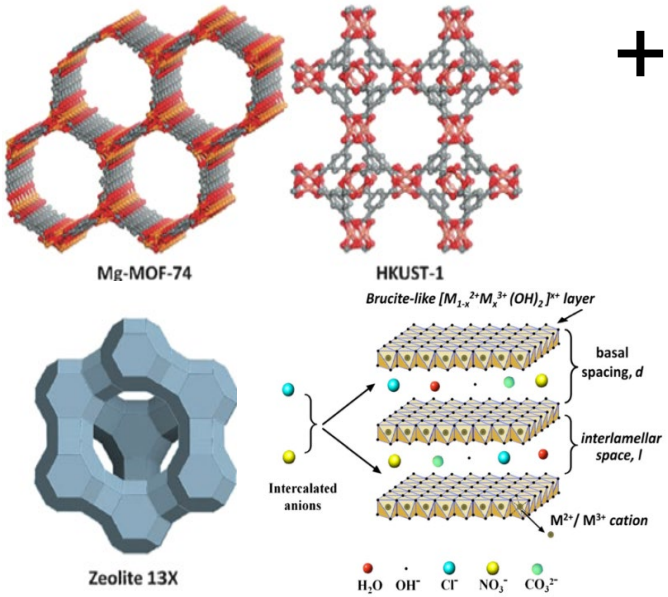
## Advantages of solid sorbents

**Amine functionalized solid sorbents**

- ✓ Surface area
- ✓ Affinity for $CO_2$
- ✓ Selectivity
- ✓ Potentially cheap, sustainable and stable

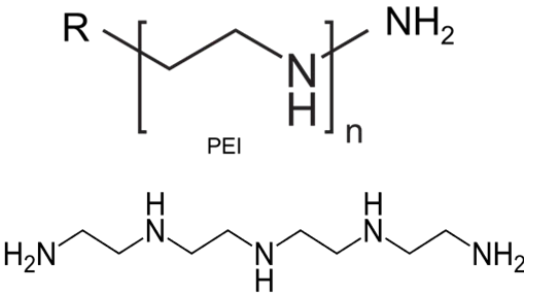
- ❑ Find best material combination and synthesis route
- ❑ Make sorbents more stable

Solid Sorbents




+

Amines

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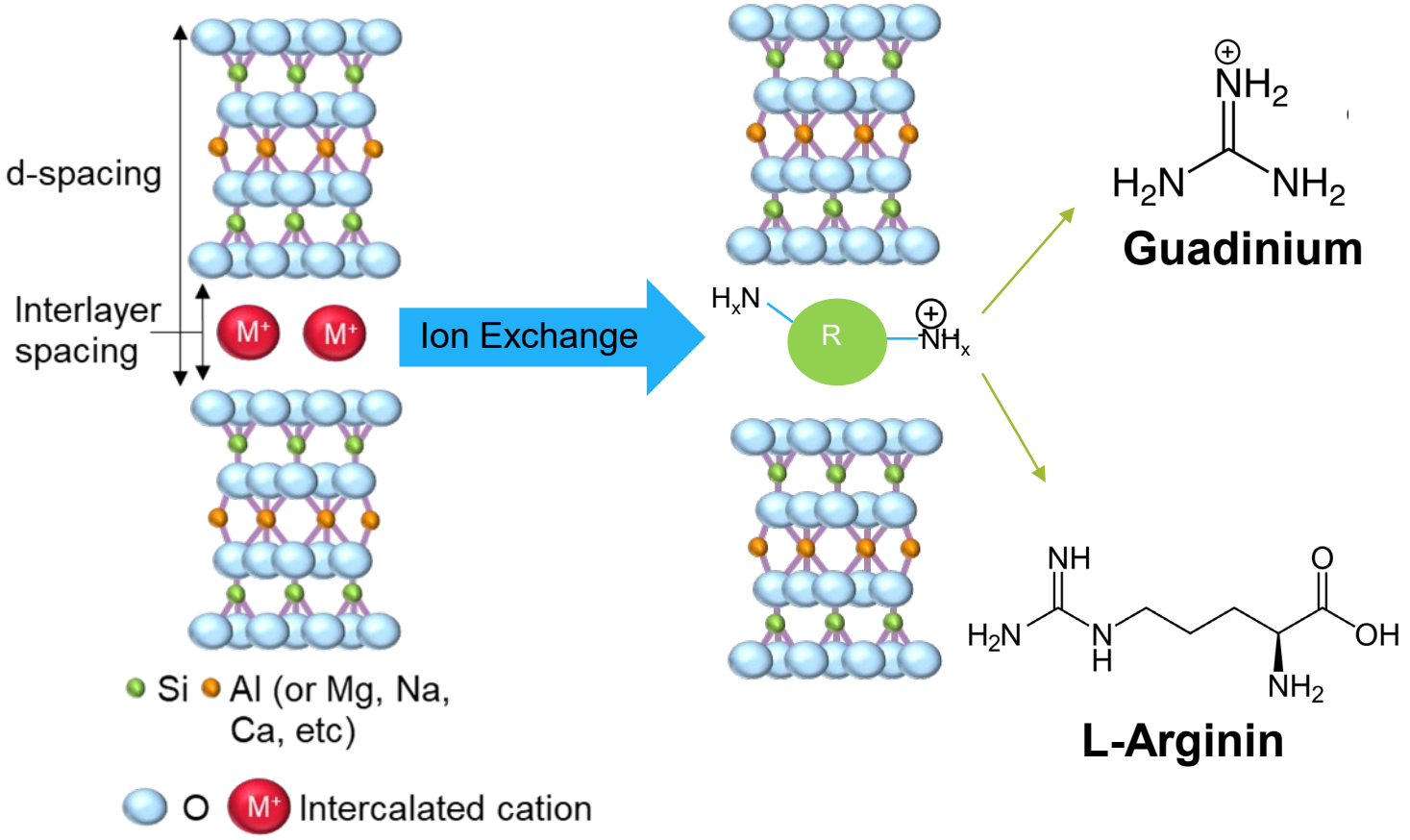
# So what do I do?

## Potential of layered oxides for DAC

**Amine intercalated clay**

- Repeating layers of silicate
- Interlayer cation for charge balance
- Exchange cation with amine

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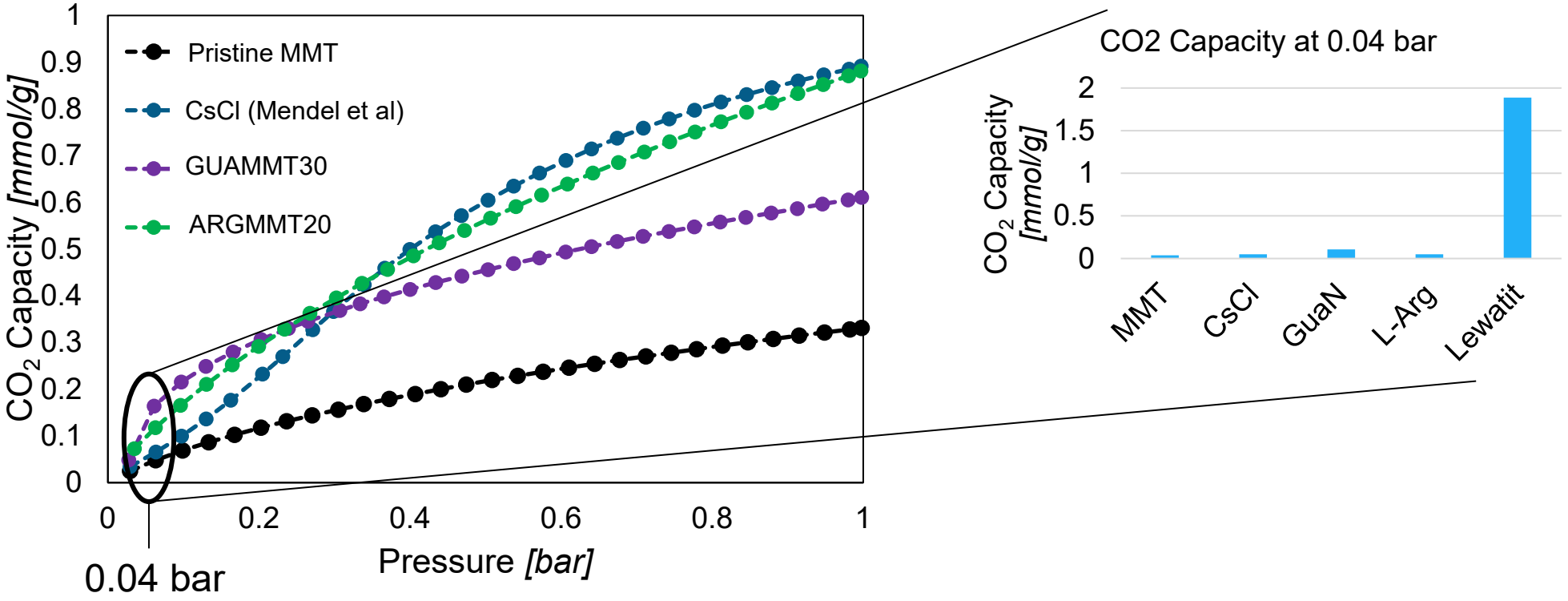
# And does it work?

## First results

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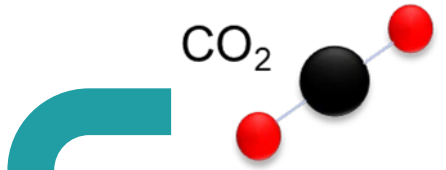
# So what do you need to remember?

## Summary and take home




- NETs strictly necessary
- DAC as major contributor
  - decentralized, scalable
- Solid sorbents show good performance
  - Sustainability and cost to be improved
- Challenges for solid sorbent design
  - low partial pressure of $CO_2$
  - Competing gases
  - Different conditions (varying by day and season)
  - stability and energy demand

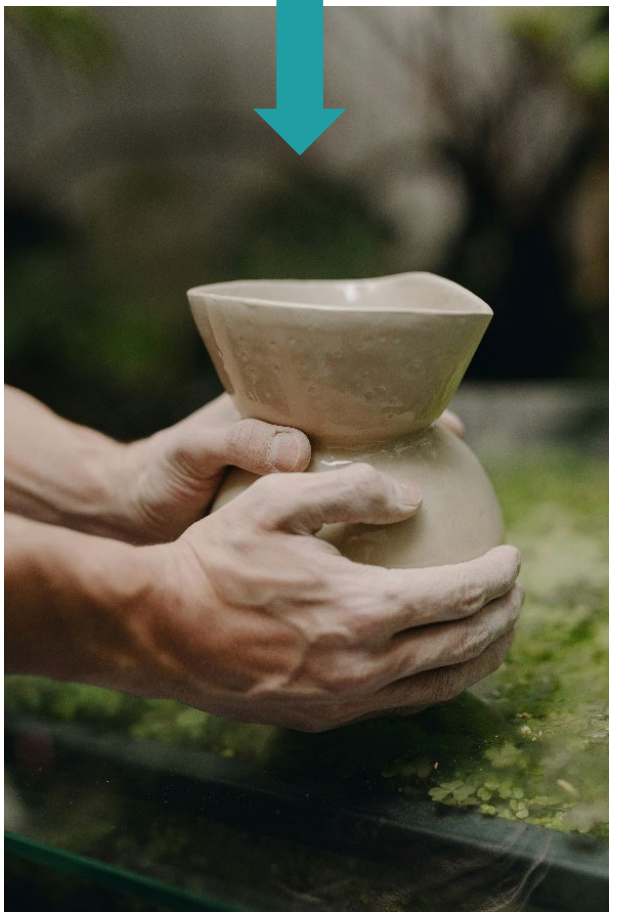


Foto von Mariana Beltrán auf Unsplash

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“We are working on naturally abundant and safe substances for DAC to fight climate change in a sustainable way”

# DACS Talks

**Upcoming DACS Talk 2024:**

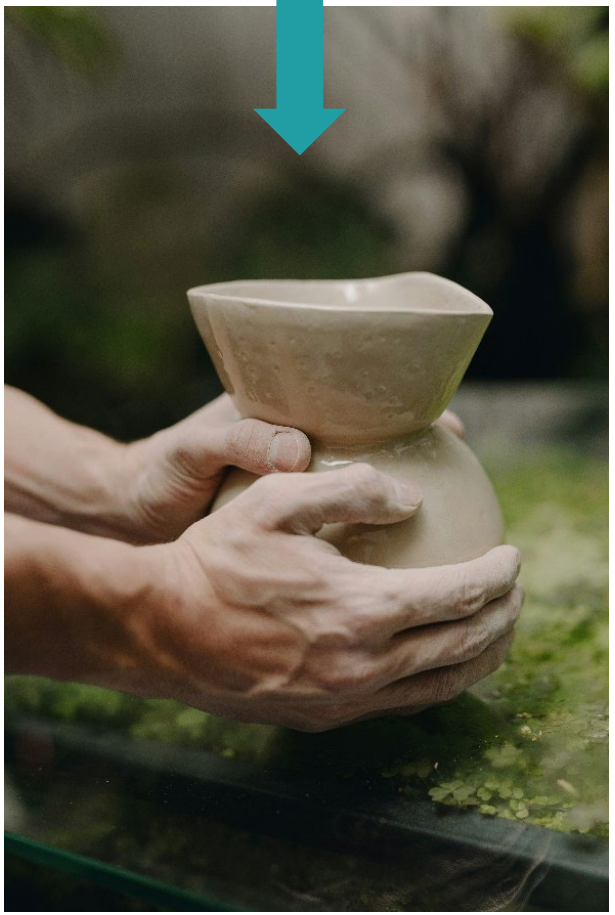
**20.11.2024**
Lutong Lu, KIT IMVT
*"Electrochemical $CO_2$ capture with solid adsorbers based on electroactive polymers."*

DACS Talks

www.dacstore-project.com
dacstore-info@fz-juelich.de

This work is performed as part of the project DACStorE, funded by the Initiative and Networking Fund of the Helmholtz Association (grant agreement number KA2-HSC-12).

# Thanks a Lot!
# Any Questions?

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