Norway grants
Programme Kappa
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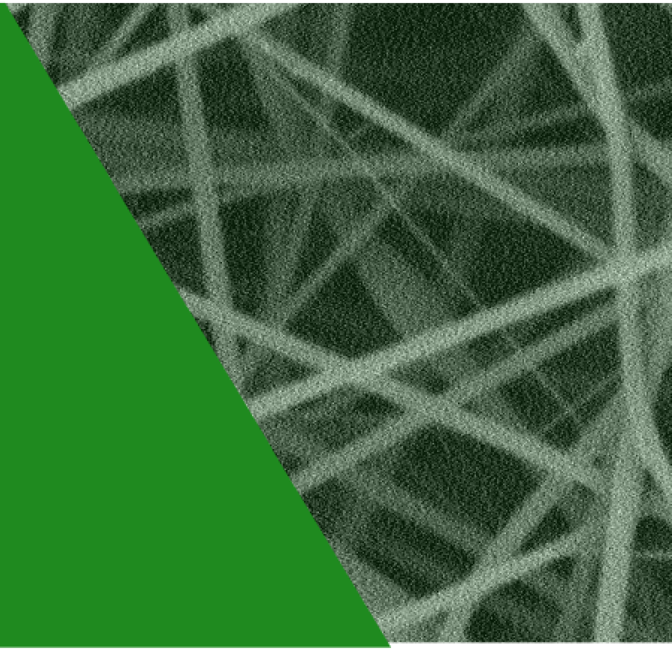
metaMORPH: advanced hybrid organic-inorganic nanofibers for CO2 capture and photocatalysis



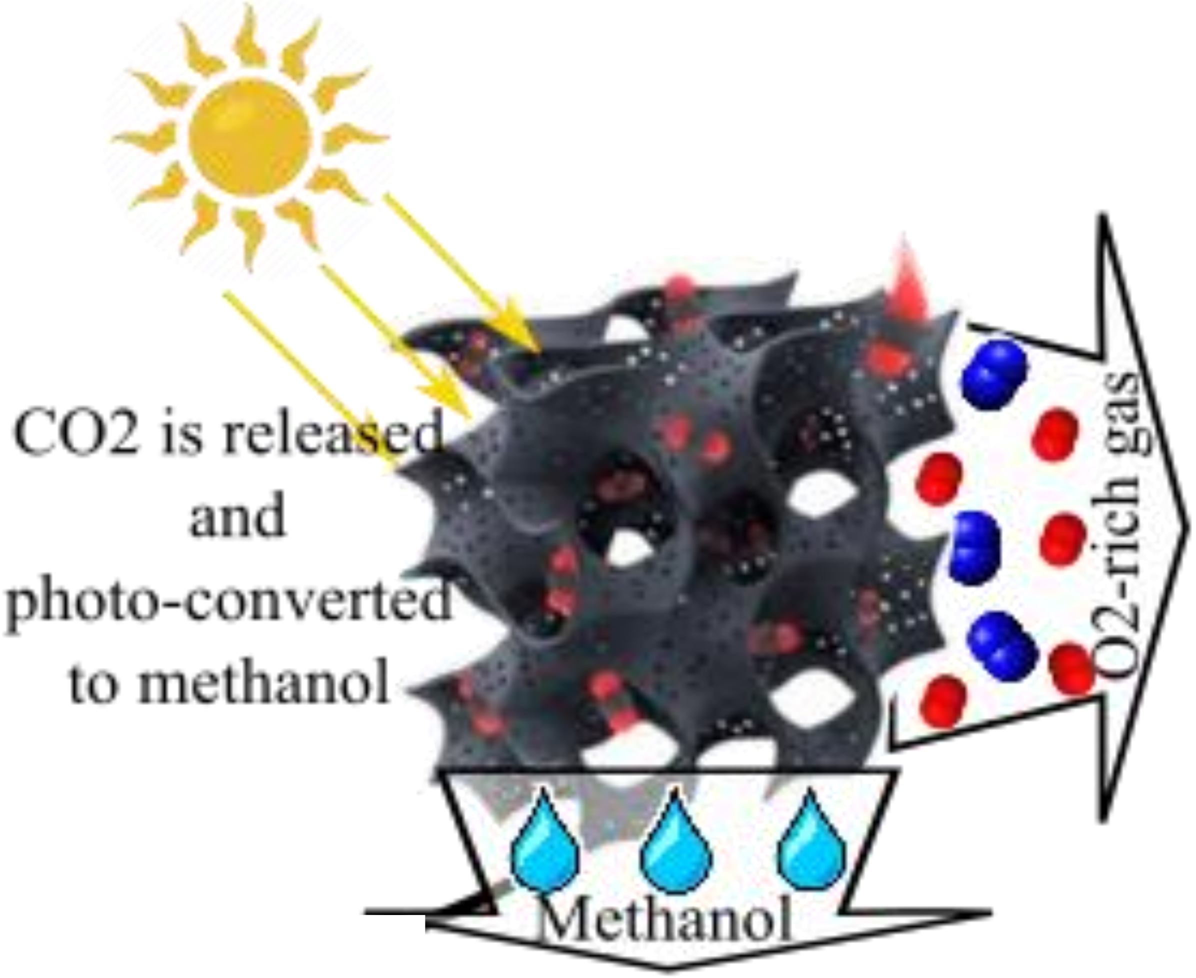
Aiva Simaite (InoCure s.r.o.)

March 2021

INOCURE
SINTEF
UNIVERSITY OF CHEMISTRY AND TECHNOLOGY PRAGUE
JAN EVANGELISTA PURKYNĚ UNIVERSITY IN ÚSTÍ NAD LABEM

Introduction to metaMORPH: contents

- Introduction
  - Carbon Capture and Utilization
  - Direct Air Capture
  - metaMORPH's aims
- MetaMORPH approach
  - Consortium
  - Hybrid carbon capture materials
  - Hybrid photocatalysts
  - Photoreactors



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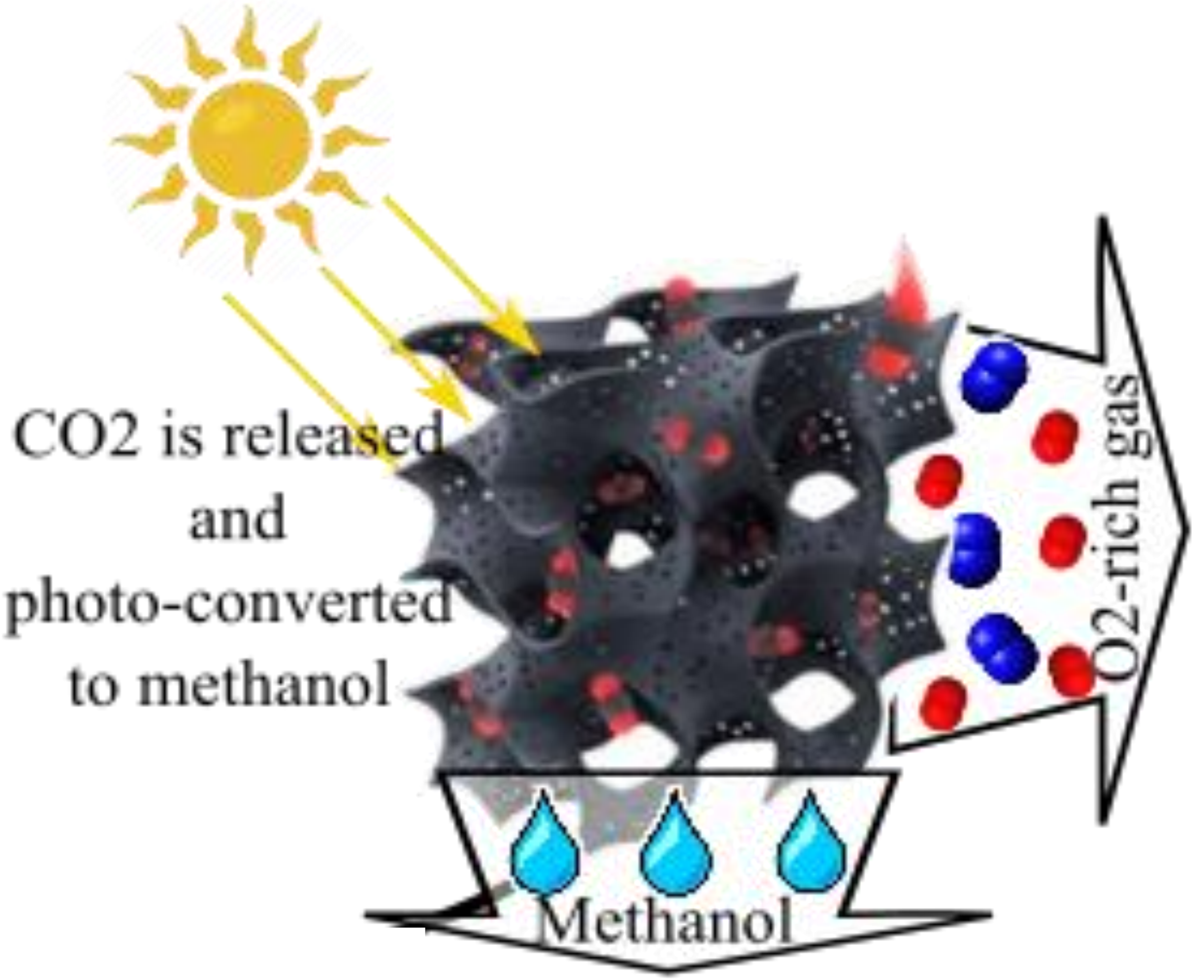
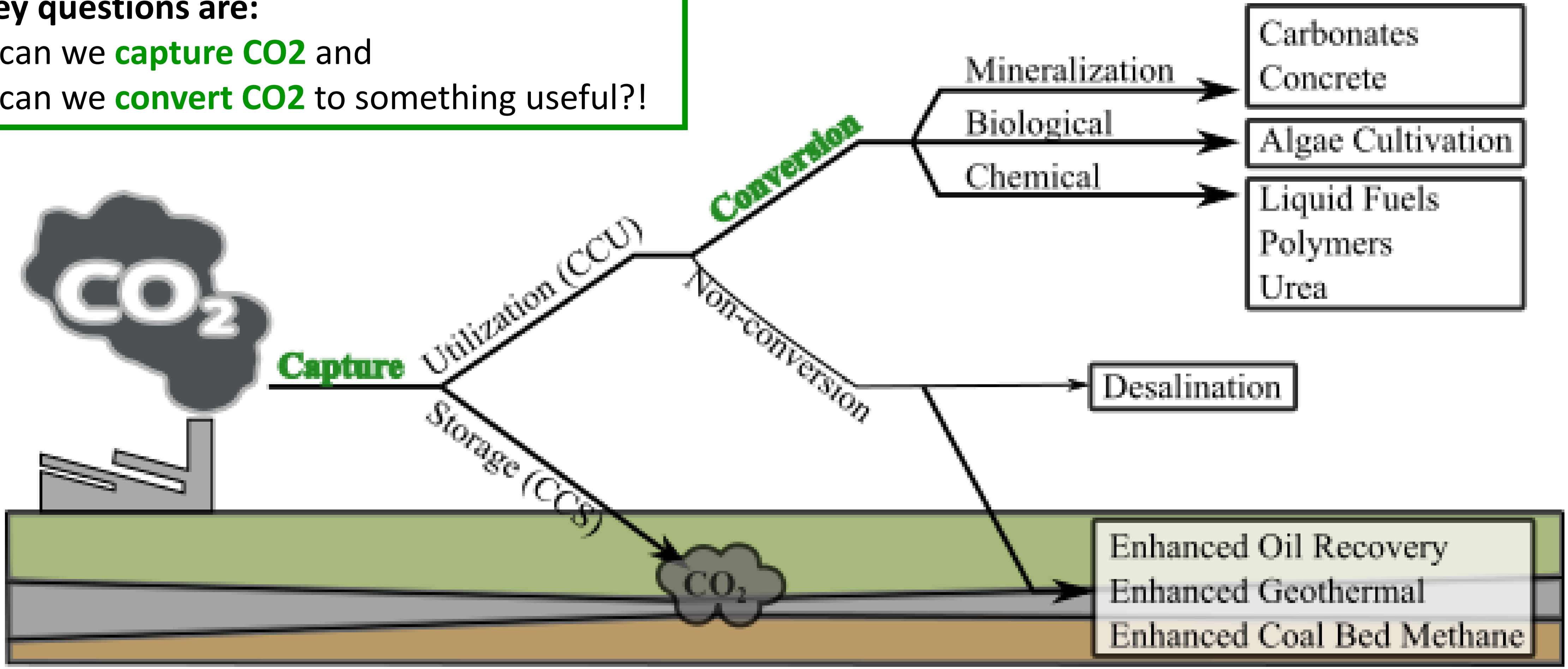


Two routes towards carbon neutrality: Carbon Capture and Utilization

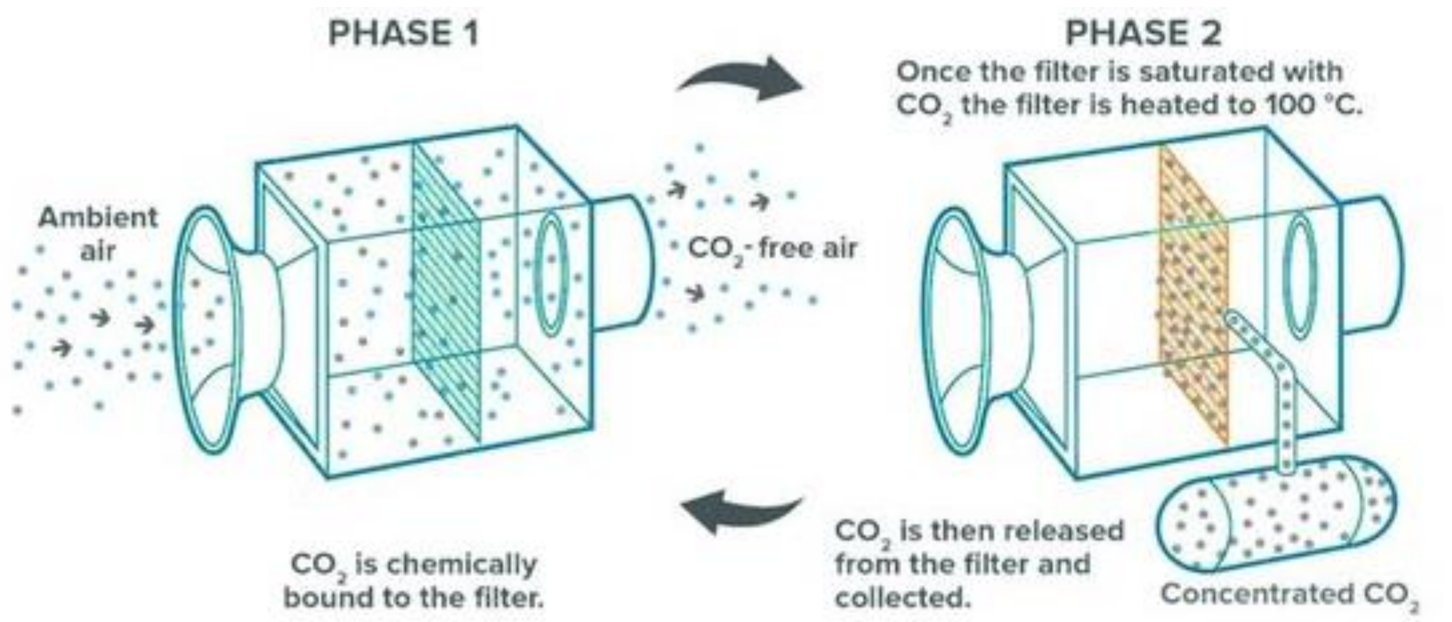
The key questions are:
HOW can we **capture CO2** and
HOW can we **convert CO2** to something useful?!



Schematic illustration of the carbon storage and utilization strategies. *Adapted from Pekdemir (2012)*

Direct Air Capture (DAC) aims to remove the CO2 from air leading to negative carbon emissions

Company	Technology	Capacity	Cost
ClimeWorks	Sorption membrane	900 tCO2 /year /plant	>600 $/tCO2
Carbon Engineering	Potassium hydroxide	1 MCO2 /year /plant	>95 $/tCO2
Global Thermostat	Sorption membranes	50 tCO2/year /plant	> 120 $/tCO2



Climeworks carbon capture units and schematic illustration of Climeworks direct air capture process. (from climeworks.com)

Direct Air Capture (DAC) is still an expensive technology with high carbon cost

DAC advantages

- **significant amounts of carbon** can be removed
- **can be sited anywhere** which reduce the cost of transporting CO2 to the sequestration sites
- **can be scaled** easily and has a relatively small land footprint

DAC challenges

- **Energy Intensive**
- **Very Expensive**
- **Water consumption** concern
- **Revenue**

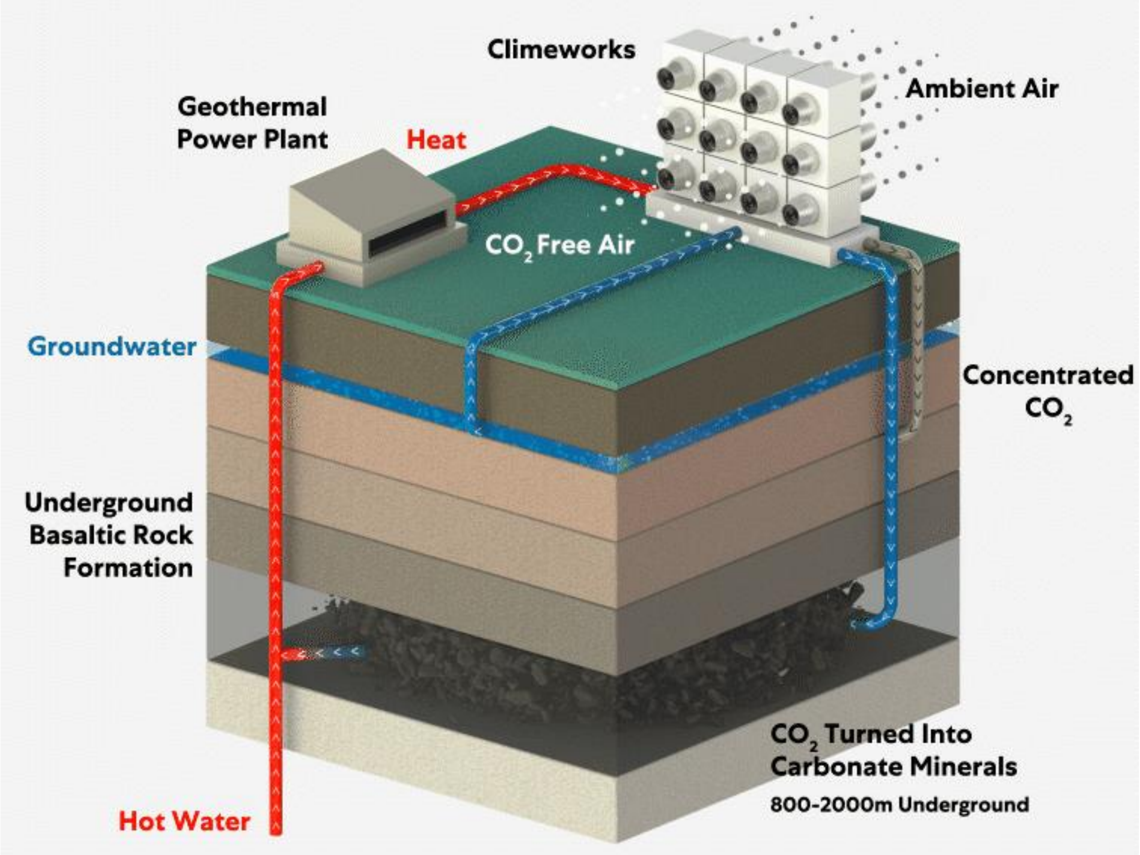
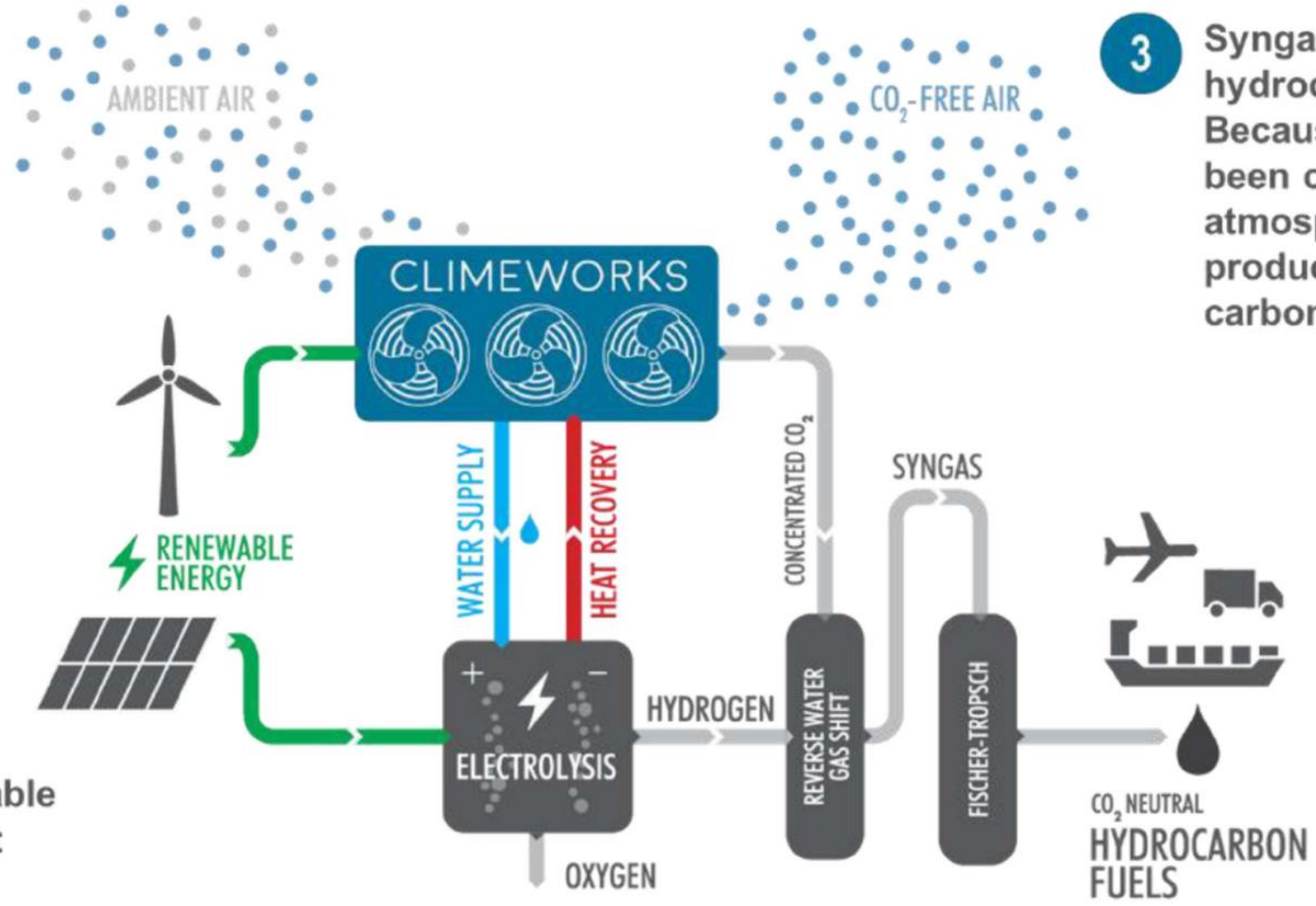


Illustration of the ClimeWorks/Carbofix plant in Iceland utilizing geothermal energy for DAC and storage. (from climeworks.com)

Direct Air Capture and Utilization is an ultimate objective for carbon negative economy

1 CO_2 is captured directly from ambient air using renewable energy.



3 Syngas is turned into hydrocarbon fuels. Because the CO_2 has been captured from the atmosphere, the produced fuels are carbon neutral.

2 CO_2 and water is provided to the electrolysis unit. The Climeworks plant is able to run on excess heat from the electrolysis.

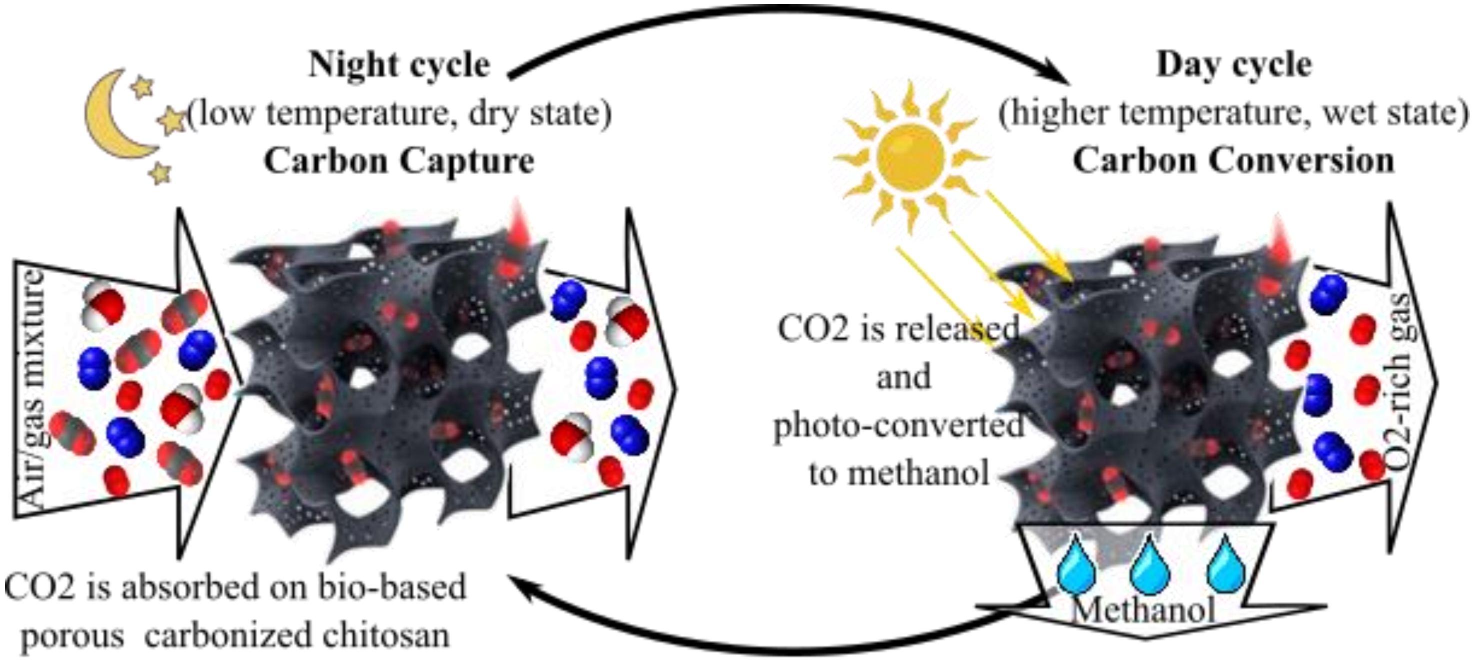
metaMORPH aim: combination of carbon capture and conversion in one material and one photoreactor

Direct capture from air

- High carbon sorption
- High selectivity for CO2
- High cycling capacity
- Low water consumption
- Low energy need

Continuous conversion to hydrocarbons

- Solar light catalysis
- High conversion efficacy
- Conversion to useful materials (methanol)



Schematic illustration of metaMORPH's aim: continuous production of the hydrocarbons (methanol) from carbon dioxide adsorbed from air.

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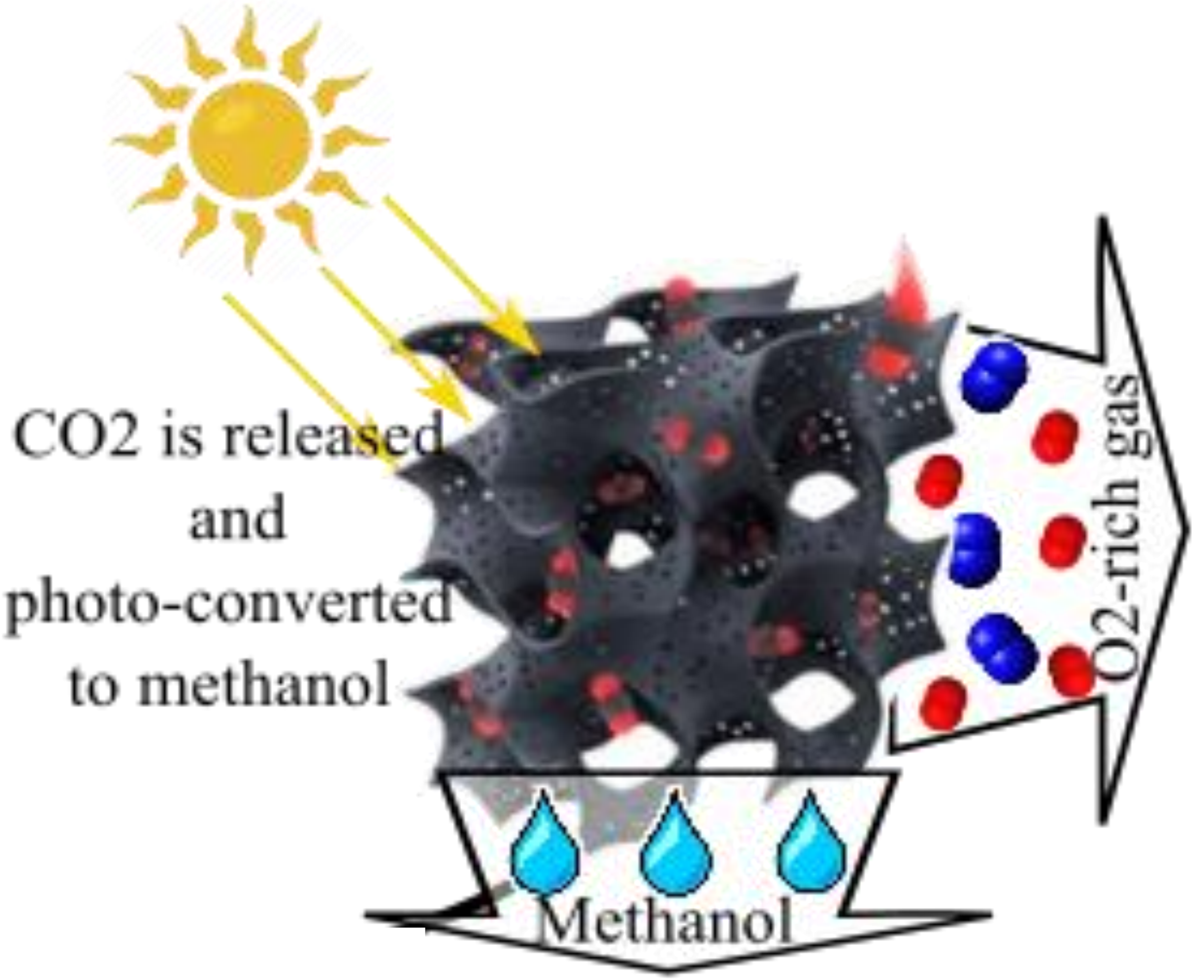
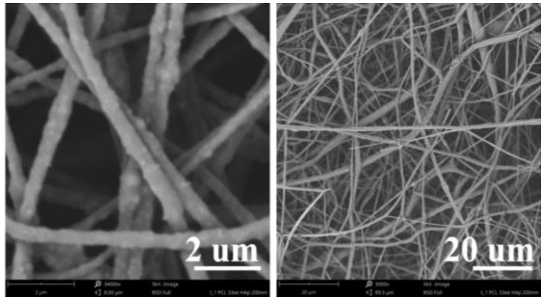


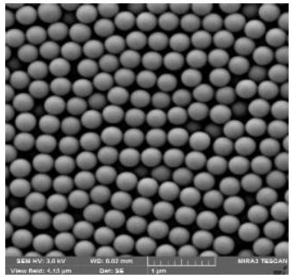
metaMORPH consortium: experts in nanofibrous, carbon capture, and photocatalytic materials

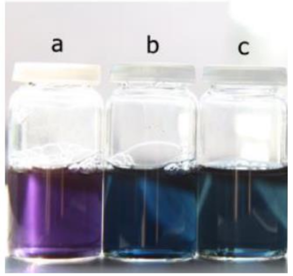
Nanofibers and electrospinning technology

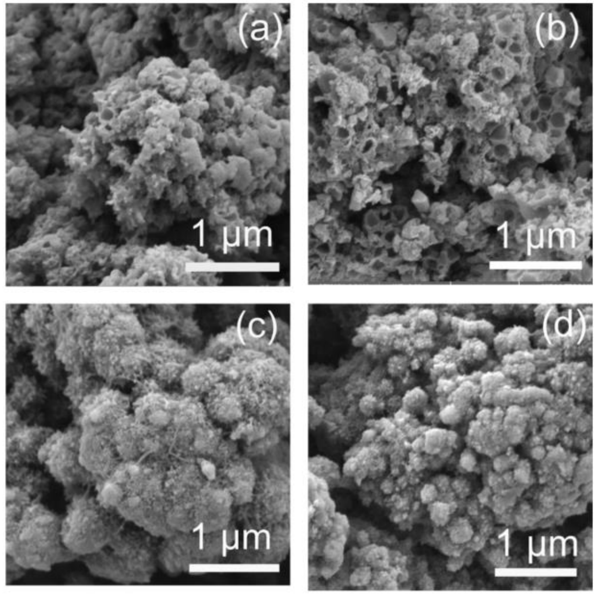


- R&D team at **InoCure (CZ)**
- Prof. Pavla Capkova team at **University of Jan Evangelista (CZ)**

Colloid engineering and advanced materials

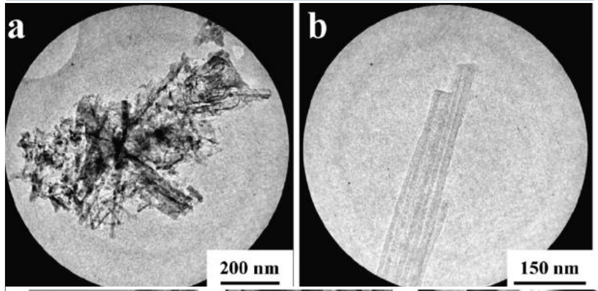


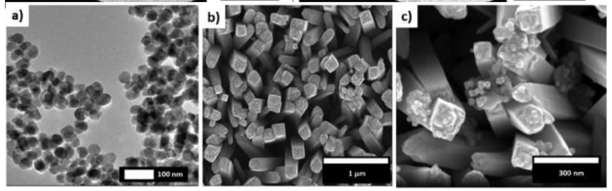




- Team of prof. Miroslav Soos at **University of Chemistry and Technology (CZ)**

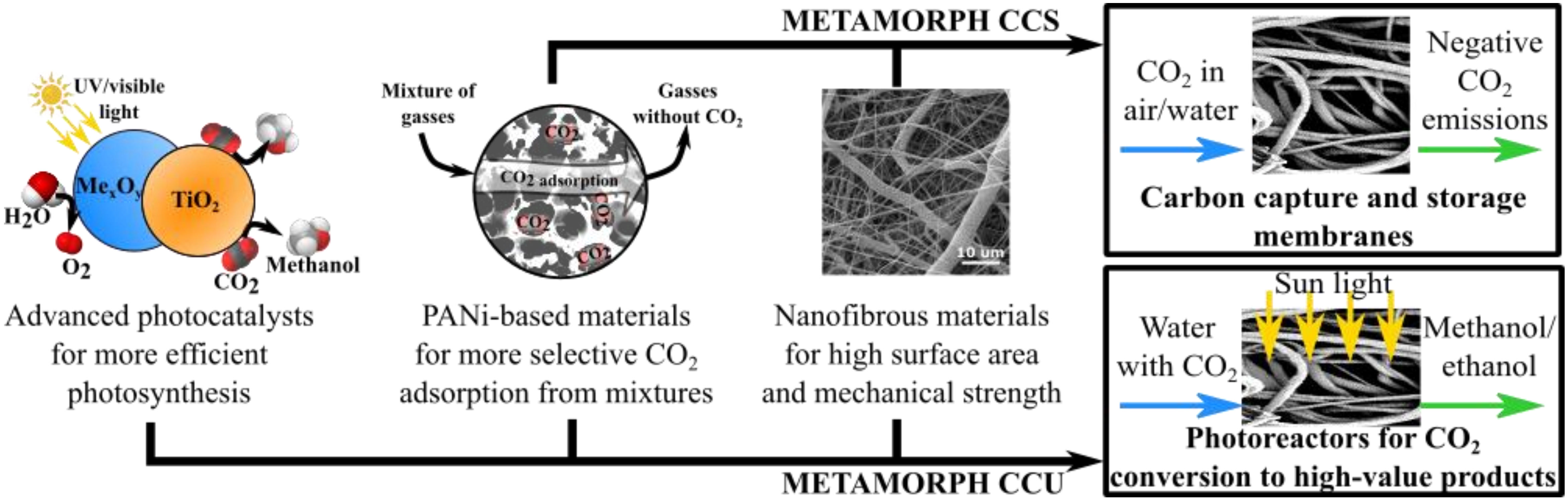
Photocatalysts and advanced materials





- Dr. Mathieu Grandcolas at **SINTEF (NO)**

metaMORPH: hybrid materials for CCS and CCU



1. Sorption materials based on carbonized polyaniline (PANi).

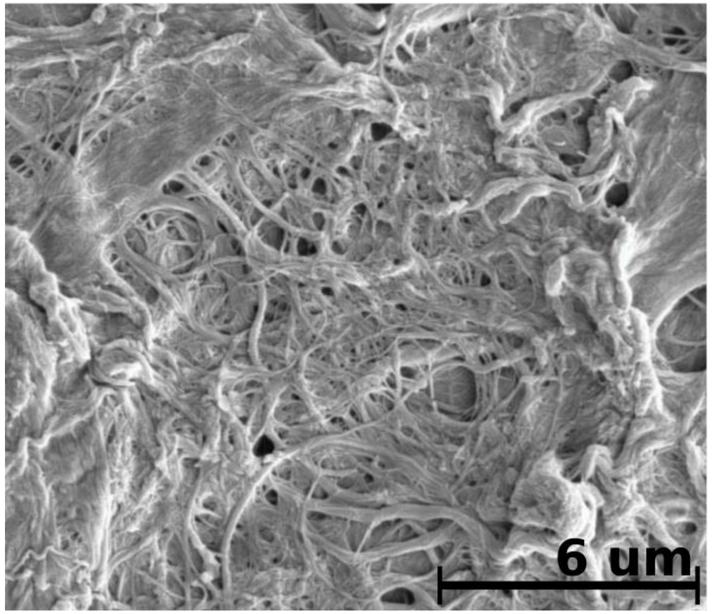
2. Combination of sorption materials with photocatalysts, for CO2 conversion to carbohydrates.

3. Combination of hydrid materials with electrospun scaffolds to provide mechanical support.

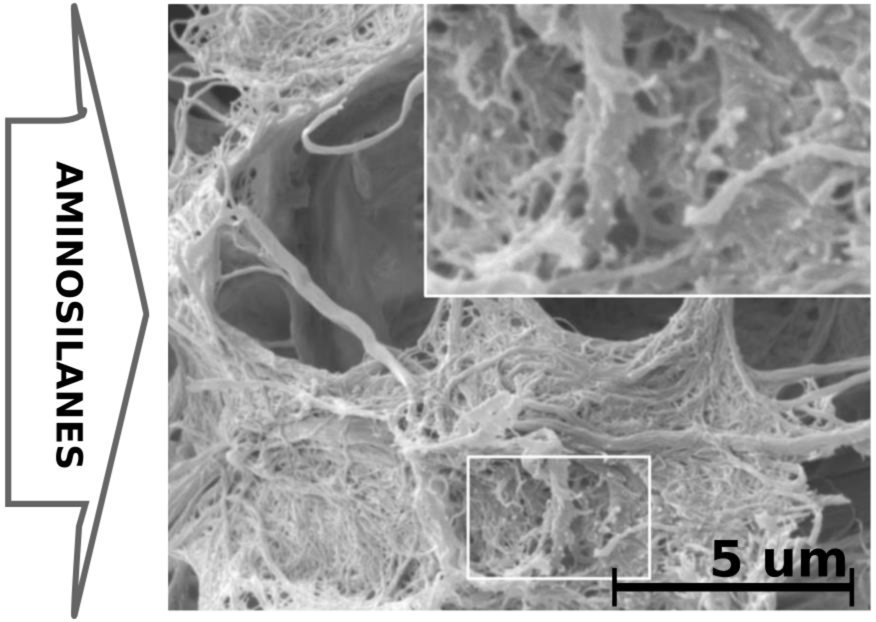
State-of-the-art materials used for the DAC: amine-modified fibers and absorbants

The state-of-the art reusable absorbers used in DAC are based on membranes and sponges modified with amines. ClimeWorks membranes can absorb up to **1.4 mmolCO2/gr** of material

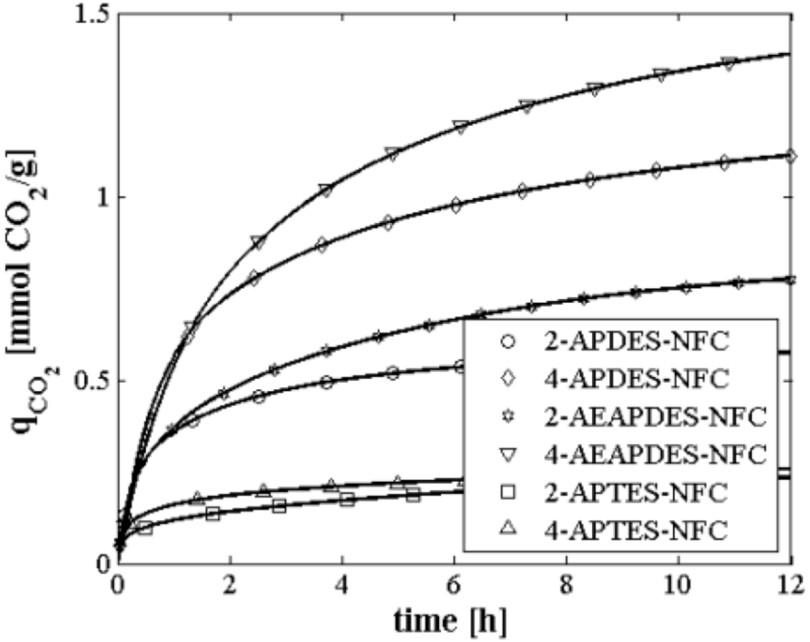
Cellulose fibers



Modified cellulose fibers

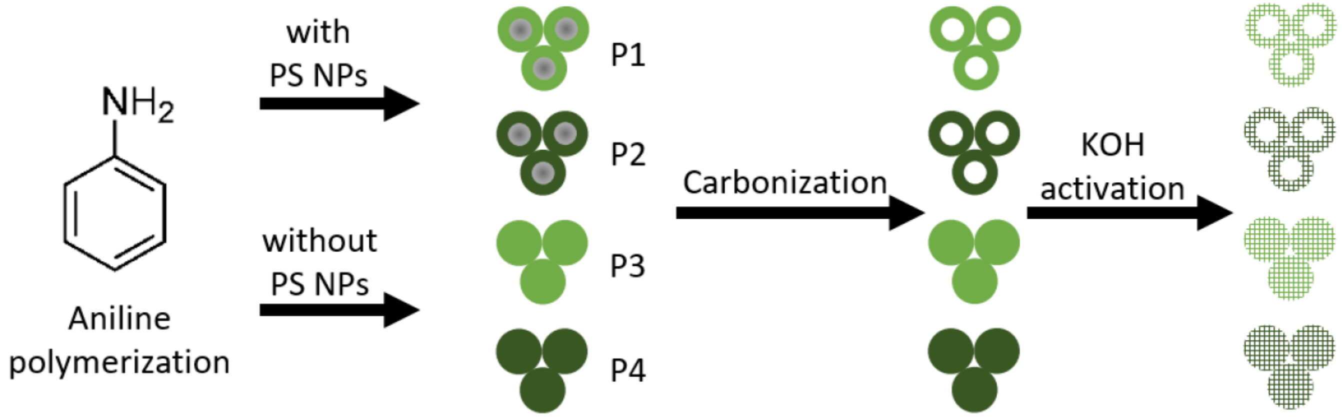


Modified cellulose fibers

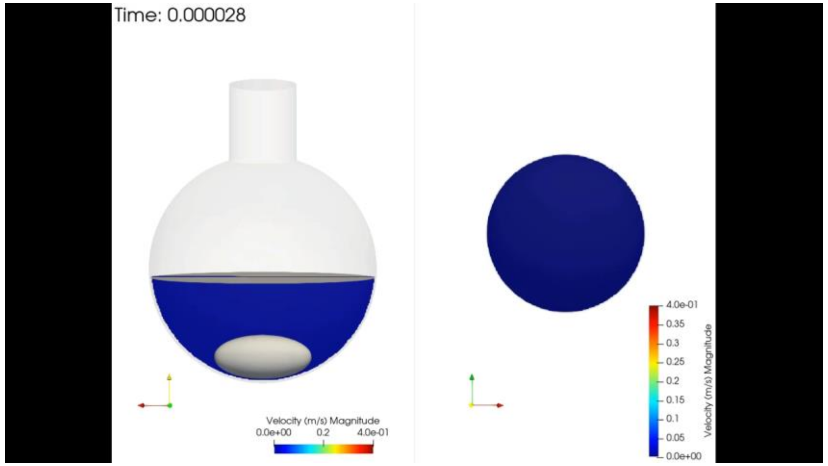


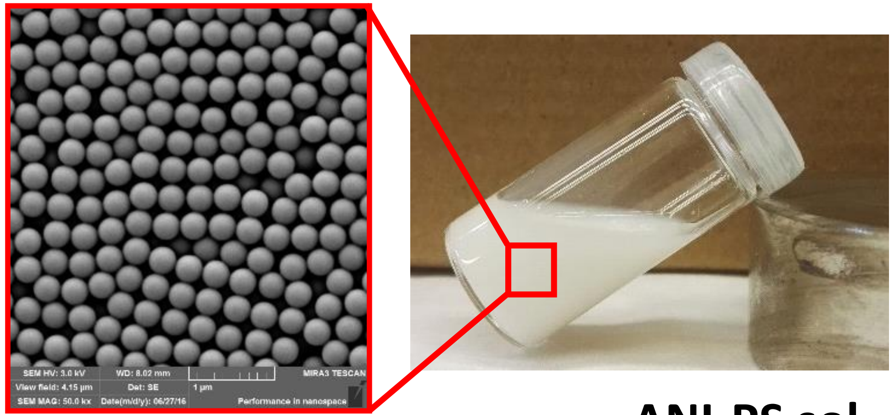
SEM images of the cellulose fiber support and the cellulose fibers functionalized with aminosilanes introducing active amino groups. (right) Carbon sorption capacity of the modified cellulose fibers)

Even better CO2 sorption materials have been developed by UCT



(P1) PANI-coated PS NPs; (P2) Crosslinked PANI-coated PS NPs; (P3) PANI; (P4) Crosslinked PANI

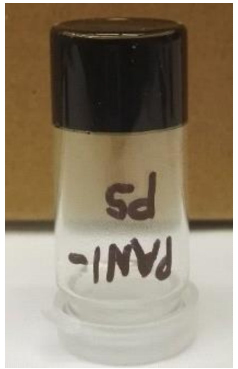


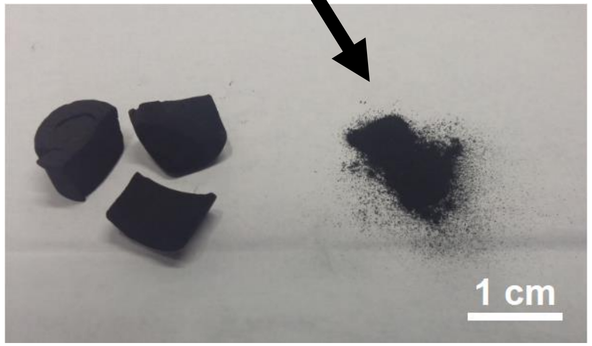


ANI-PS sol

Polymerization

Stagnant cond.





Porosity > 80%

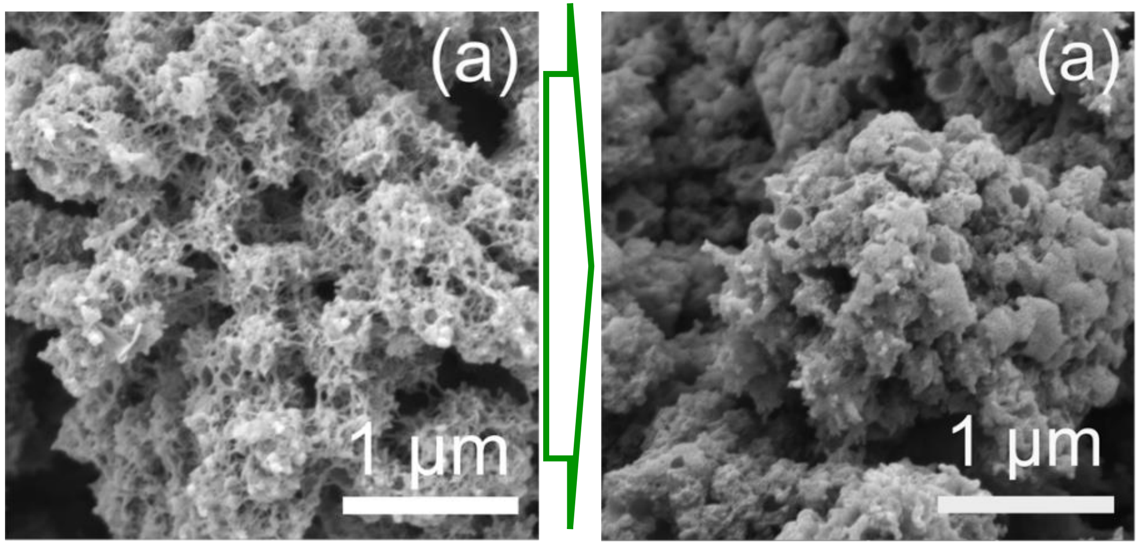
- **Kutorglo et al., Chem. Eng. Journal (2019, 2020)**

10x better CO2 sorption materials have been developed by UCT

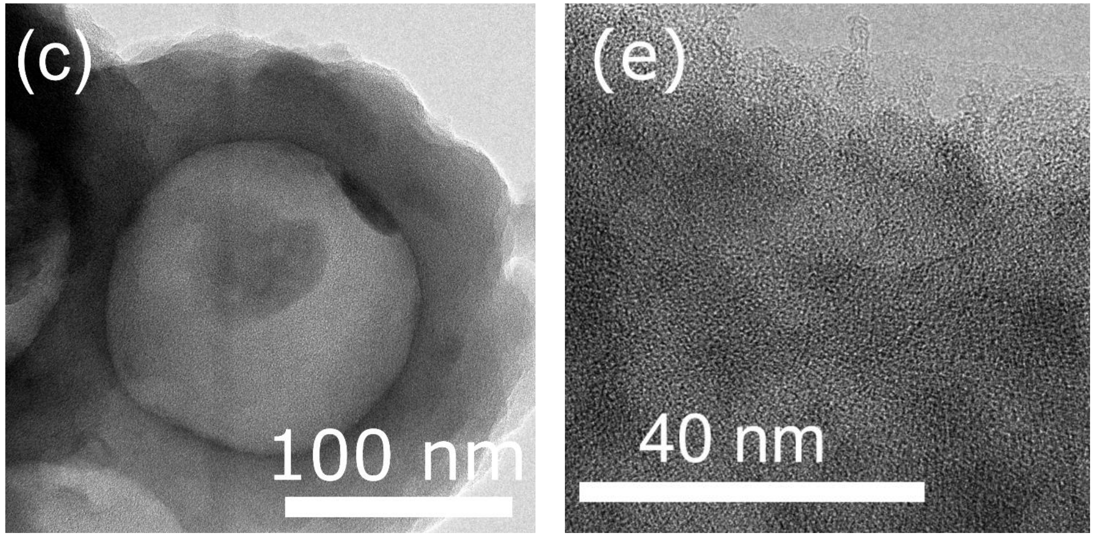
Nanostructured materials with high surface area and porosity are obtained after the templated synthesis, carbonization and activation of PANi.

As synthesized

After carbonization (500 °C) and activation (750 ° C)



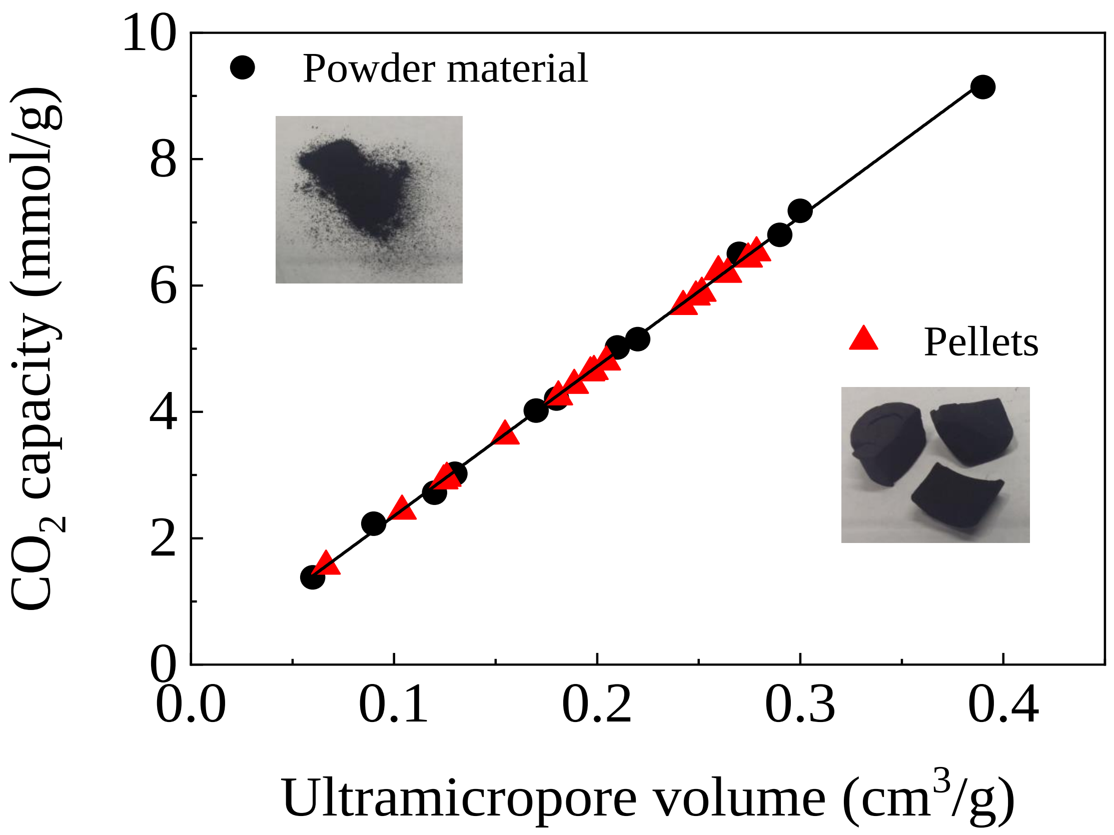
SEM images of the synthesized PANi materials for carbon capture



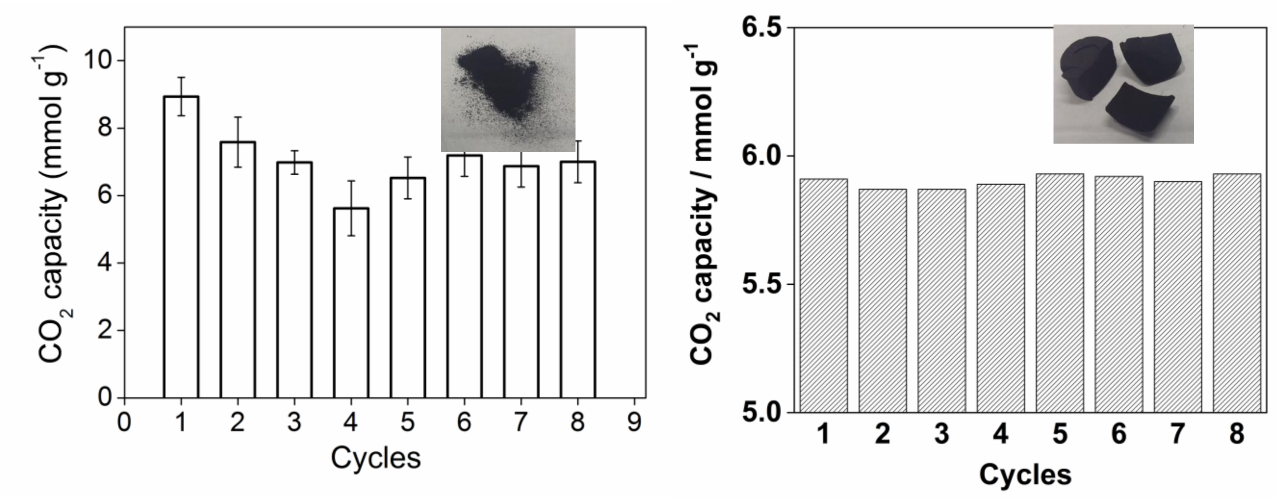
TEM images of the synthesized PANi materials for carbon capture

Kutorglo et al., Chem. Eng. Journal (2019)

10x better CO2 sorption materials have been developed by UCT



- Carbon sorption capacity correlates with the volume of the ultramicropores in the material and does not depend on the macrostructure.
- Material is reusable.



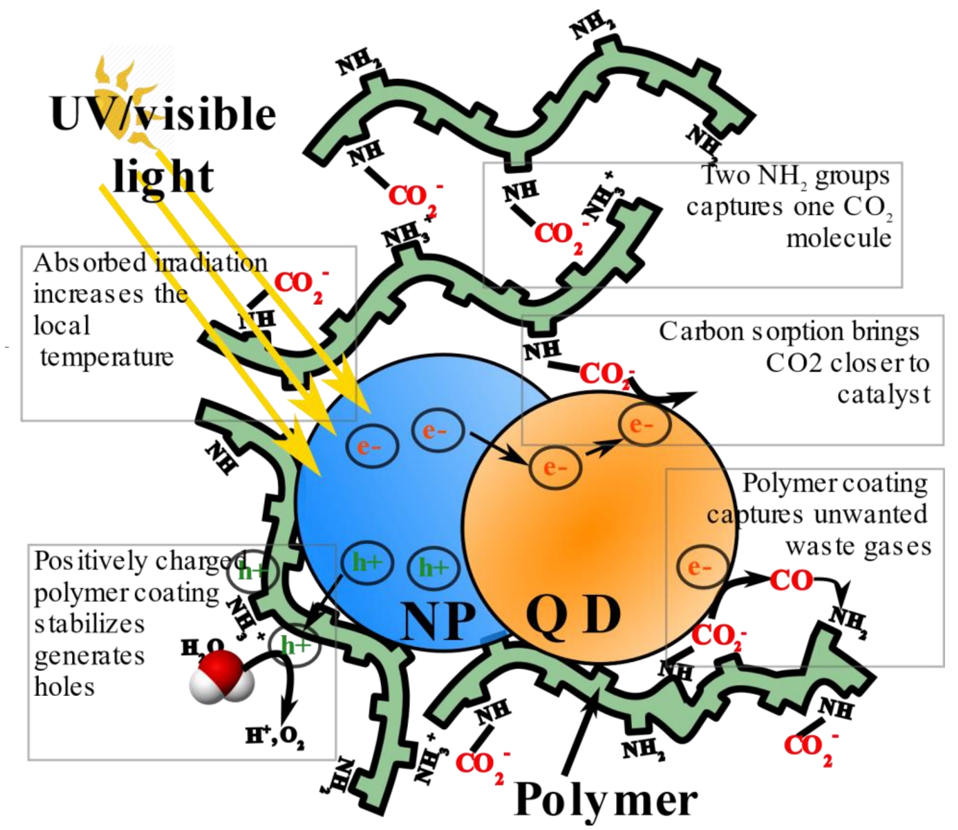
- **Kutorglo et al., Chem. Eng. Journal (2019, 2020)**

Carbon capture capacity and reusability of UCT PANi materials in powder and pellet macrostructure.

MetaMORPH: combination of carbon sorption and photocatalytic materials

1. Hybrid nanoparticles for CO2 capture/ photocatalysis

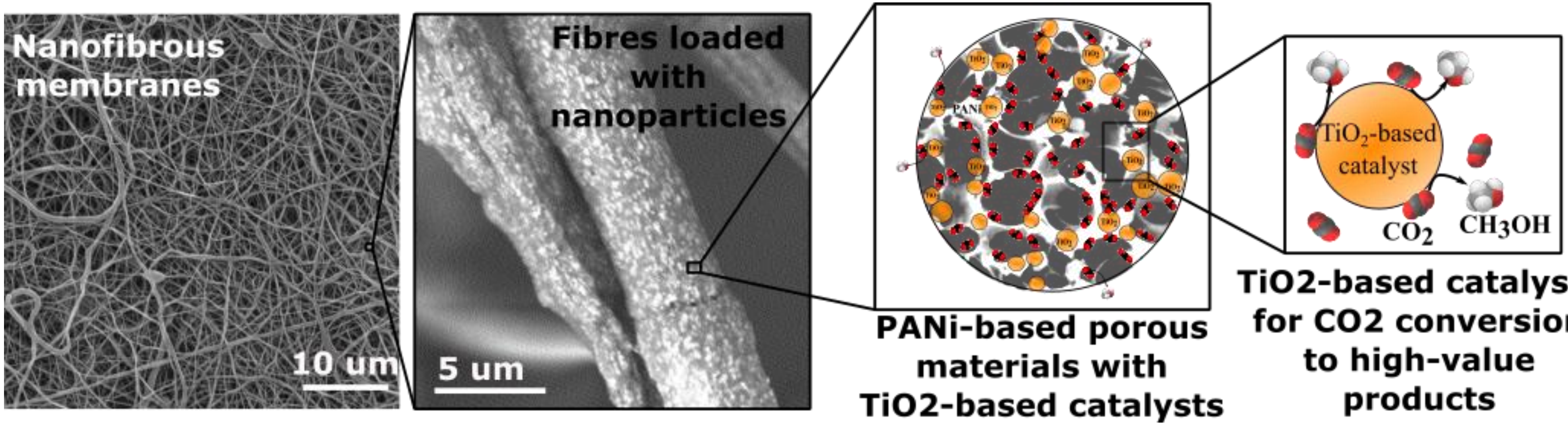
1. Improved carbon sorption by photocoatalytic removal of adsorbed CO2.
2. Improve photocatalytic conversion of the CO2 to methanol by increasing the local concentration of the CO2.
3. Stabilization of the photocatalysts in the polymer matrix.



Schematic illustration of the benefits of cambined carbon capture and carbon sorption materials

MetaMORPH: expected results

2. **Electrospun membranes with photocatalytic/ carbon-capture nanoparticles**
   1. Further increased carbon capture capacity by combining PANi materials with nanofibrous membranes.
   2. Increased mechanical stability of the hybrid nanomaterials that allows easier handling and integration in the photoreactors.



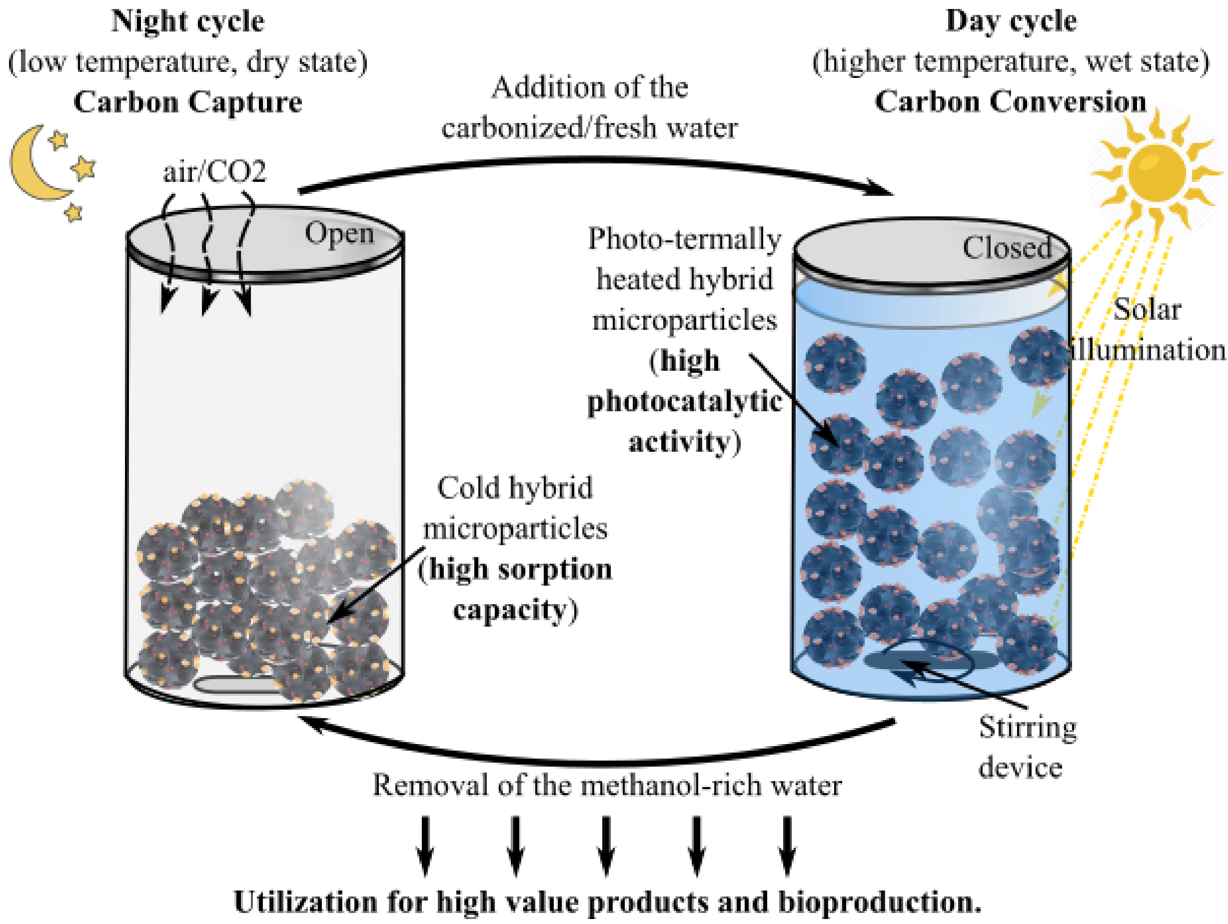
PANi-based porous materials with TiO2-based catalysts

TiO2-based catalysts for CO2 conversion to high-value products

MetaMORPH: expected results

3. Photoreactor with METAMORPH membranes with photocatalytic/ carbon-capture nanoparticles

1. Materials for carbon capture and utilization combined in one step bioreactor.
2. Photocatalytic conversion is driven by solar energy minimizing the energy consumption.



Thank you for your attention.

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