TU Delft

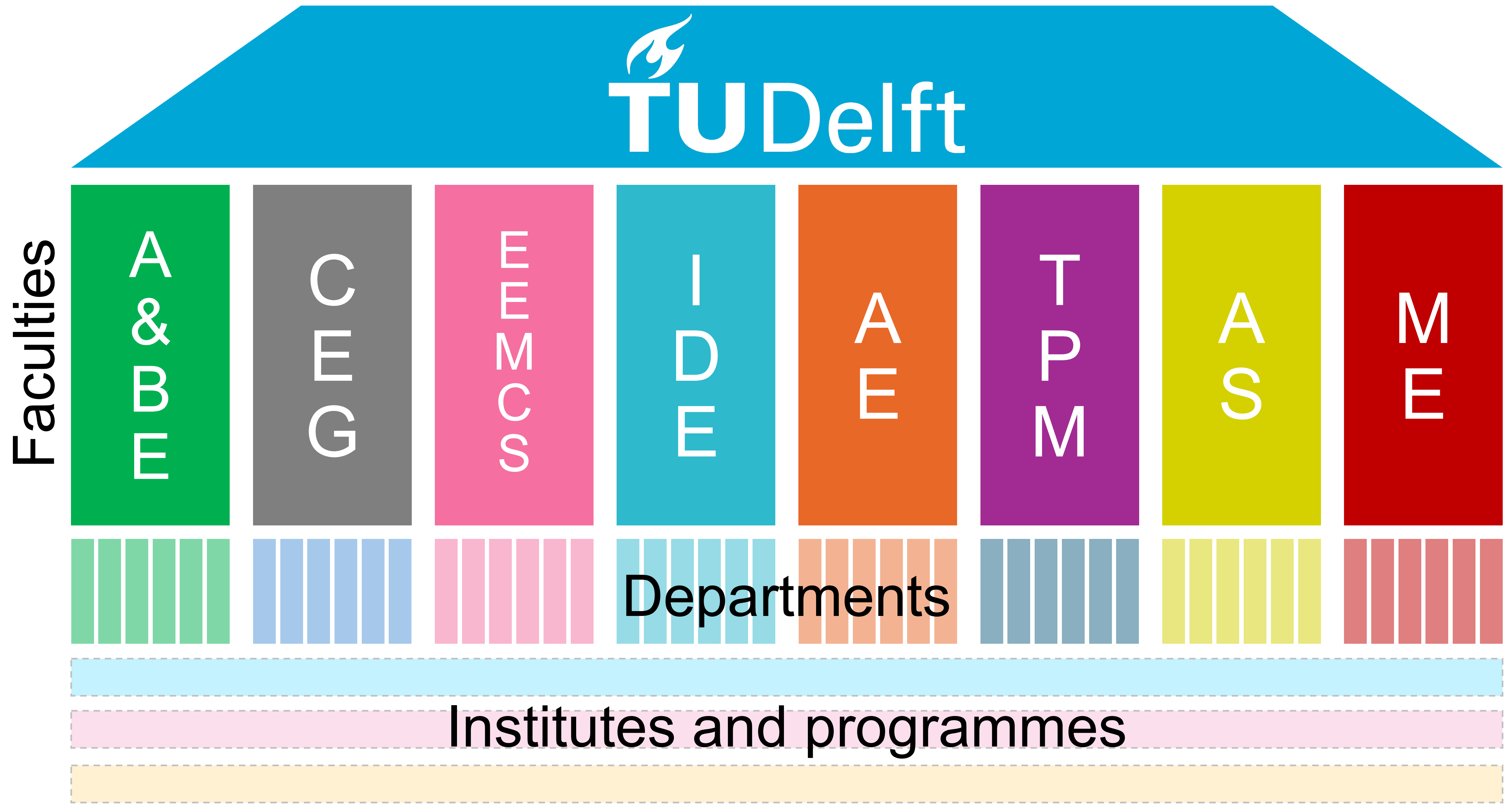
CCUS research at TU Delft

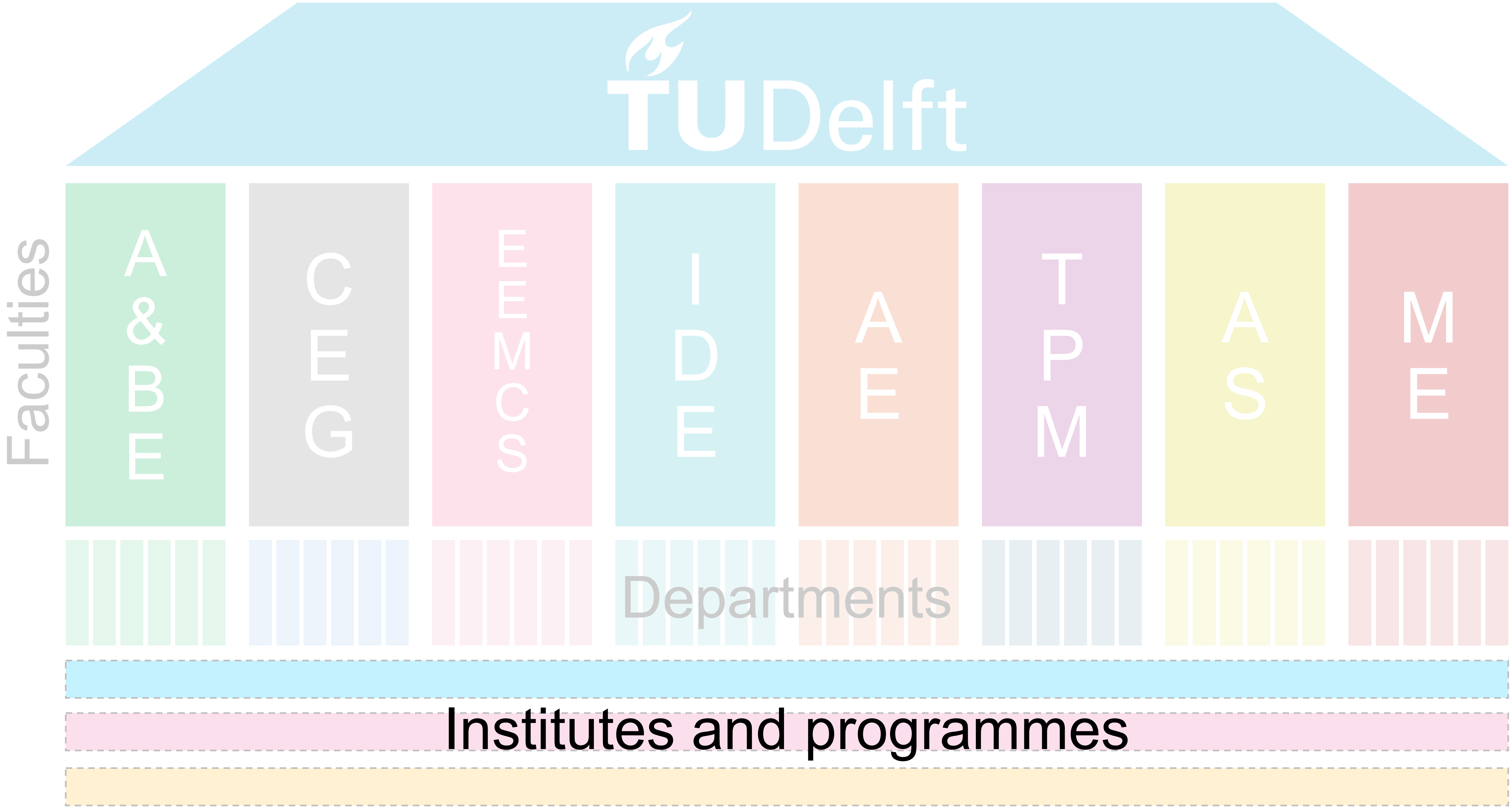
Tim M.J. Nijssen | CATO Spring event 2026

23-4-2026

TU Delft in numbers

8,870	FTE staff members (1,378 faculty, 3,516 PhD candidates)
56	Education programmes (16 BSc, 40 MSc)
25,774	Students (13,330 BSc, 12,444 MSc, 5,451 first year)
544	PhD defences
4,801	Publications


TU Delft
Faculties
A&BE
CEG
EEMCS
IDE
AE
TPM
AS
ME
Departments
Institutes and programmes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CLIMATE ACTION PROGRAMME

OVERVIEW

April 2026

RESEARCH

- Climate Science
- Mitigating Climate Change
- Climate Change Adaptation
- Climate Change Governance

EDUCATION

- Climate Fresk
- Course Development
- Learning Communities
- Climate Action Pedagogies

INNOVATION

- Innovation in labs, pilots & beyond
- Engagement of End-Users in research, education & innovation
- Development of initiatives with societal stakeholders
- Sharing of learnings, knowledge & solutions

CLIMATE ACTION COMMUNITY

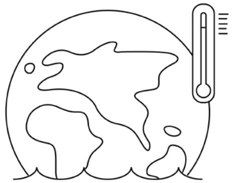
CLIMATE ACTION RESEARCH FLAGSHIPS

CLIMATE SCIENCE

- Urban flow and climate
- Regional sea level rise
- Machine learning for regional climate
- Radiation management for climate engineering

MITIGATING CLIMATE CHANGE

- CO_2 capture, removal, and management: towards net-zero
- Scaling the circular economy: an integral design approach
- Circularity of plastic & non-fossil energy carriers
- Materials for circular renewable energy technologies



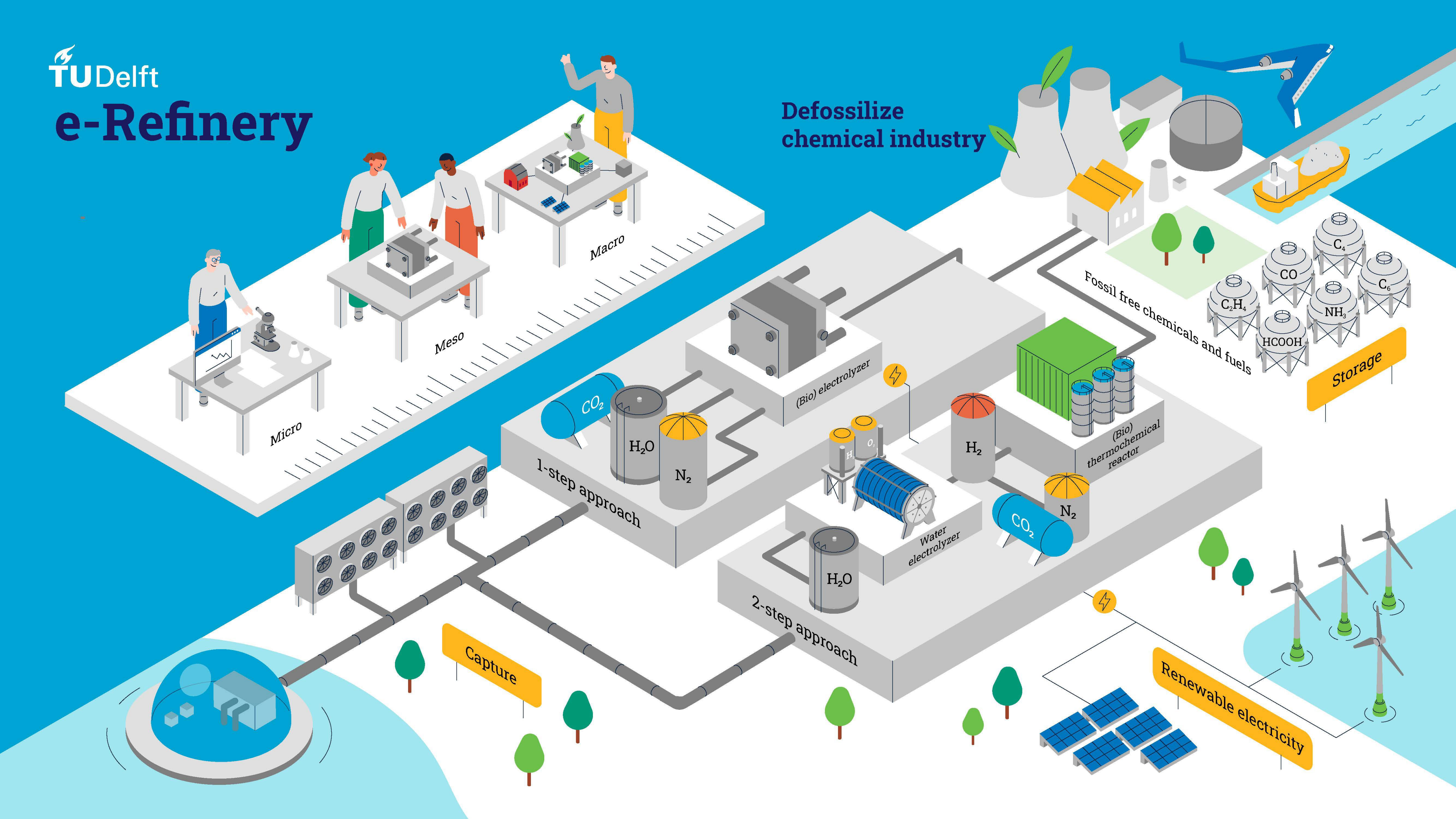
CLIMATE CHANGE ADAPTATION

- Cool and clean buildings
- Transformative urban adaptation
- Cool cities
- Spatial Planning of future deltaic systems

CLIMATE CHANGE GOVERNANCE

- Behavioral insights for climate action
- Climate finance for climate resilient infrastructure
- Integrated Assessment Modelling for Climate Policy
- Modelling future deltaic systems

e-Refinery


TU Delft
e-Refinery
Defossilize chemical industry
Micro
Meso
Macro
CO_2
H_2O
N_2
1-step approach
(Bio) electrolyzer
H_2
Water electrolyzer
H_2
N_2
CO_2
H_2O
2-step approach
(Bio) thermochemical reactor
Fossil free chemicals and fuels
C_2H_4
CO
C_4
C_6
NH_3
HCOOH
Storage
Capture
Renewable electricity

We develop:

Knowledge & Technology for a disruptive change to electricity based systems for sustainable chemicals and fuels.

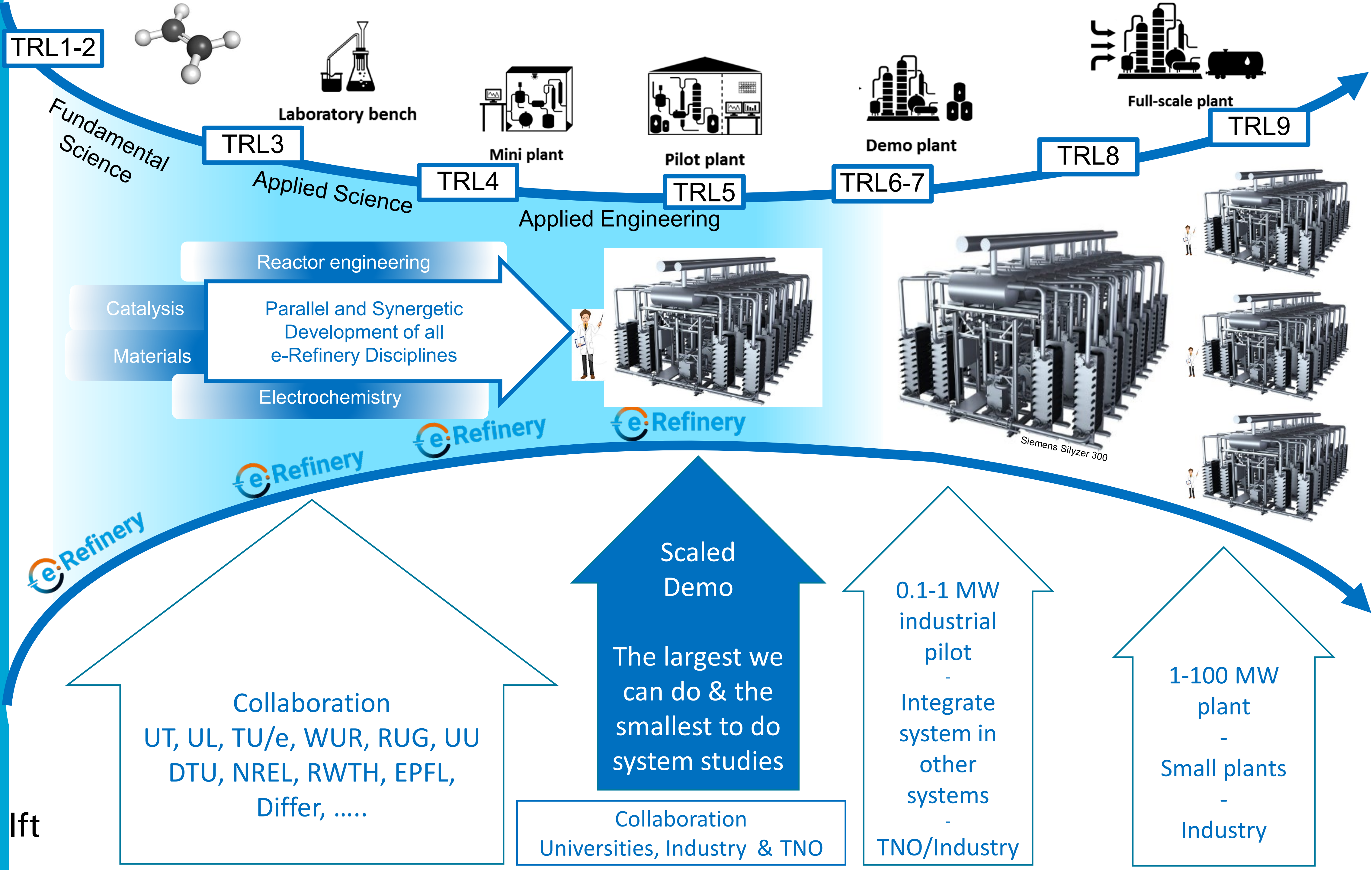
We educate:

Next generation of scientists and engineers to implement and maintain future fossil free industry.

We provide:

An open innovation hub to realise multidisciplinary collaboration with leading R&D institutes and industrial partners.

Boundaries of e-Refinery



TUDelft lft

Clockwise—Time-Explicit LCA for CDR

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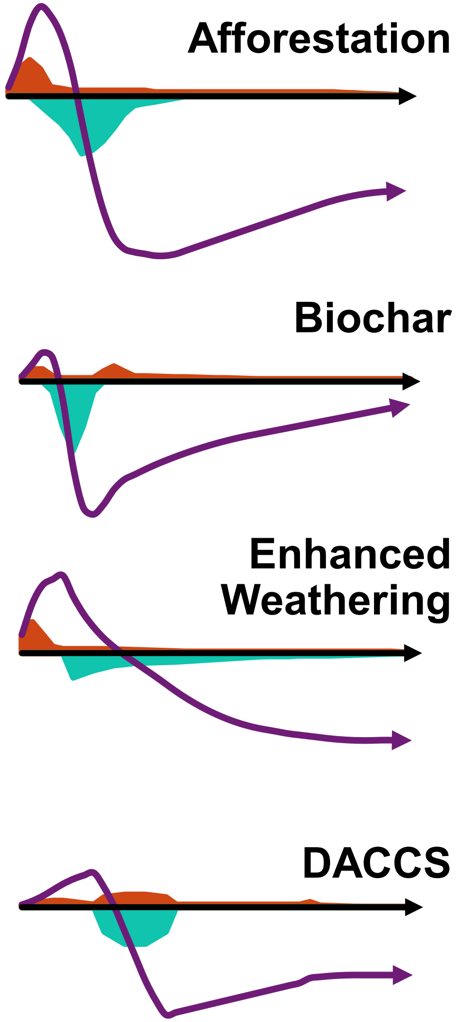
Improving Models and Metrics for Carbon Management

Faculty Technology, Policy and Management
Department Engineering Systems and Services

TU Delft

A two-year project to evaluate time-explicit benefits, risks, and impacts of nature-based and technological CDR systems.

- Conventional evaluation of carbon dioxide removals focus on estimating how much removals occur
- But different CDR systems exhibit different behaviour over time
- So, when does CDR actually occur?
- And is that the right question to ask?



Prior work:
Time-explicit CDR in the concrete sector: 10.1039/D0FD00139B
Time compression in LCA for CDR: 10.5287/ora-o1yjzd6vx

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Department Engineering Systems and Services

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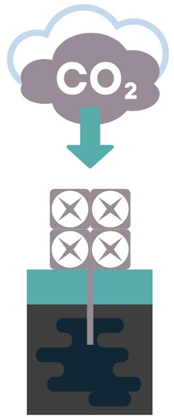
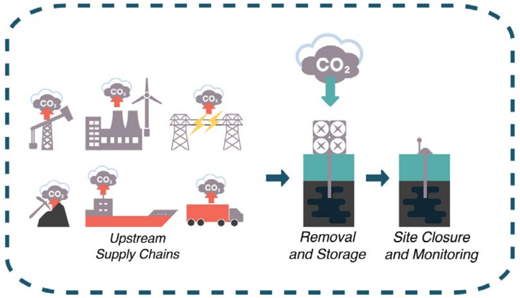
Fair Trade—Moral Transactions in CDR Crediting, from MRV to offsets



This project reveals the chain of moral decisions that are made in the process of creating CDR credits.

- Offsetting emissions means accepting that the social value of the emissions' source is worth the resources to compensate rather than prevent damage.
- But what values are we accepting when we simplify and financialise carbon removal systems into carbon credits?
- Are different crediting schemes making different moral decisions?



Related work:
System boundaries in CDR abatement costs:10.1016/j.ijggc.2023.103864
EU Policy Landscape for BioCCS: 10.1088/2515-7620/add3d5

Prof. Andrea Ramírez Ramírez
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Department Chemical Egineering

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Ex-Ante Technology Assessment & System Analysis

Develop and test methodologies to assess the impacts, synergisms & bottlenecks of deploying novel low-carbon technologies in industrial clusters

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Ex-Ante Technology Assessment & System Analysis

Develop and test methodologies to assess the impacts, synergisms & bottlenecks of deploying novel low-carbon technologies in industrial clusters

- Focuses on processes that use alternative carbon sources (CO_2, biomass, waste)
- Combines process design, techno-economic analysis, life cycle assessment, value chain design, uncertainty analysis
- Example of current projects:
  - Evaluating the performance of CO_2-based Methanol as Marine fuel (M2ARE project)
  - Role of (bio)CCS in defosilization pathways for refineries (Ecopetrol)
  - Modeling impacts of using alternative carbon sources in existing industrial clusters (VICI)
  - Assessing the level of flexibility of current and new industrial processes under different scenarios (OranjeWind program and DEFLAME)

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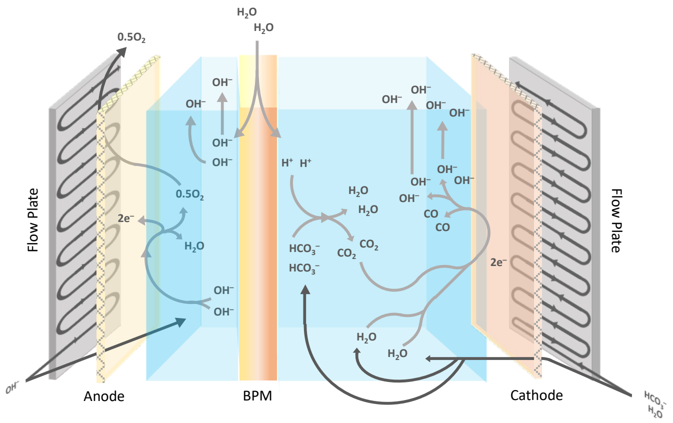
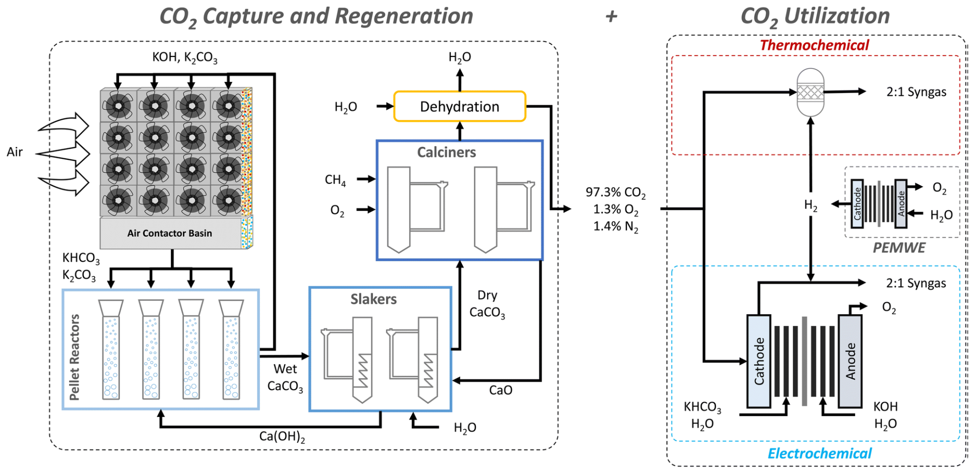
Modelling and assessing CCU processes

- Process modelling, assessment and optimization of emerging technologies, including CCUS.
  - Combined models: commercial simulators, first principles and custom data-driven.
  - Techno-economic, life cycle assessment, and social LCA.
  - Optimization of the design and operation of CCUs under uncertainty.
- Focus on the integration of CO_2 capture, reduction, and downstream purification of products.





Further reading: 10.1039/D3EE02589F

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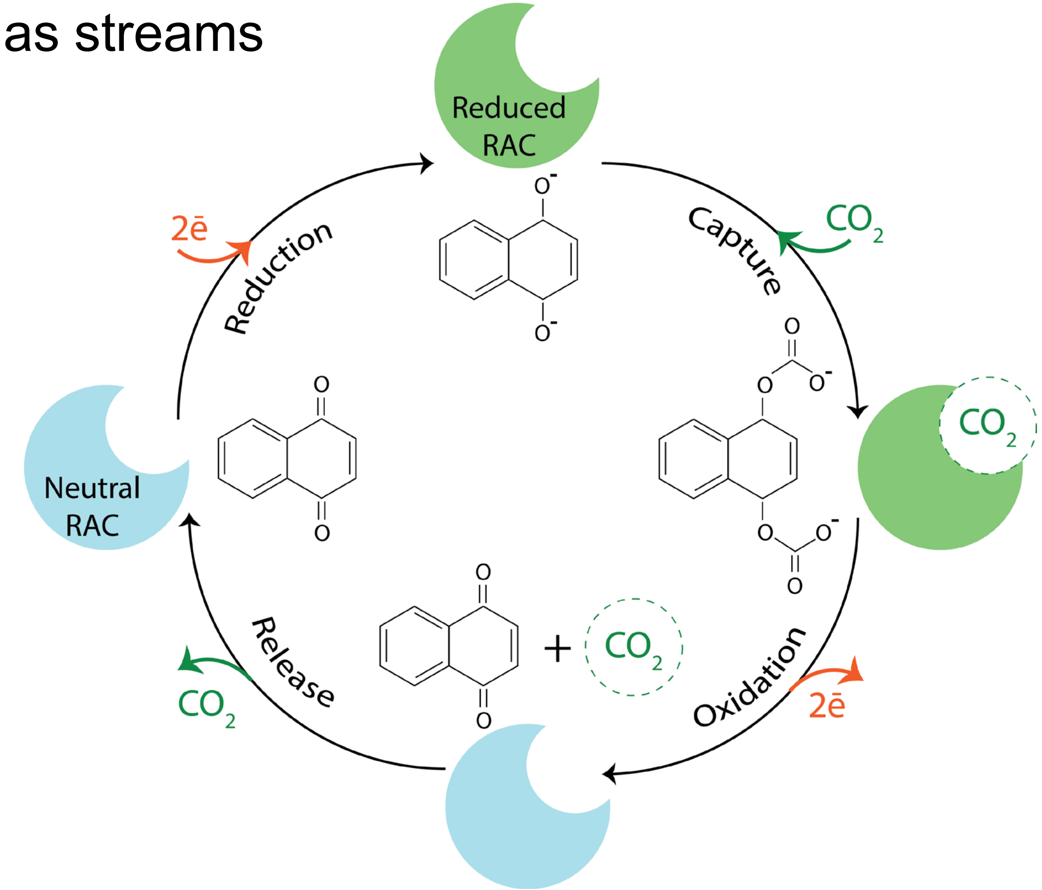
Electrochemical carbon capture (e-CC)

- Using redox-active carriers (RACs)
- Carbon capture capacity >8 mmol/g$_{RAC}$
- For dilute gas streams



Further reading: https://doi.org/10.1002/cssc.202202345

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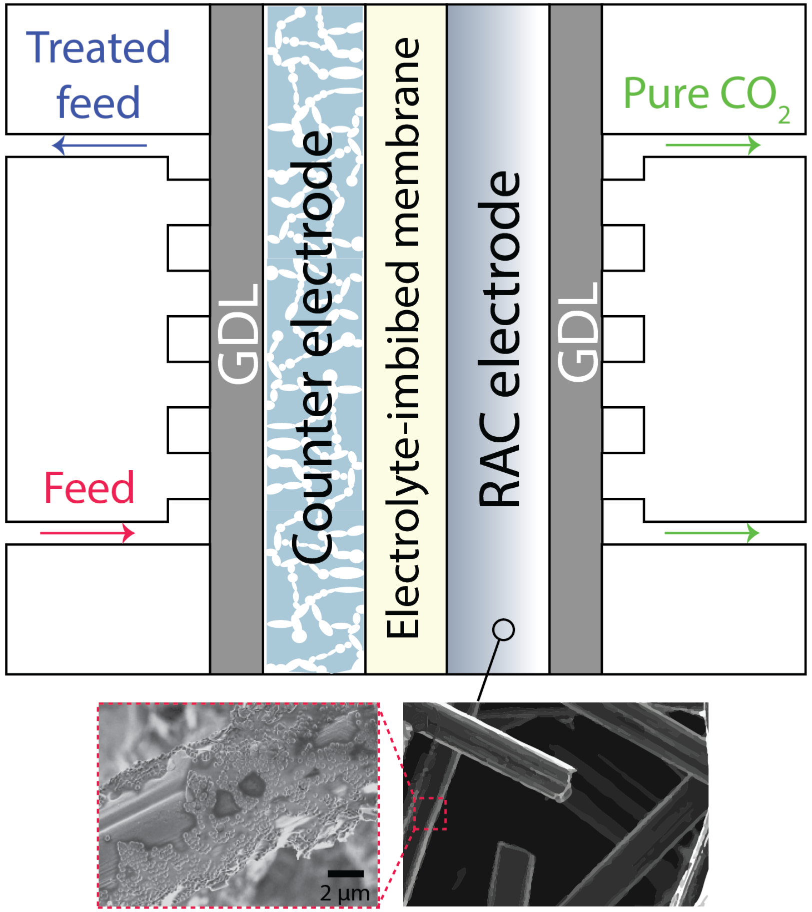
Electrochemical carbon capture (e-CC)

- Immobilised RACs on electrodes
- Energy consumption <100 kJ_e/mol
- >97 vol.% pure CO_2
- Low energy consumption



Redox-active electrodes

Further reading: https://doi.org/10.1039/C9EE02412C

Porous framework materials for CO_2 capture

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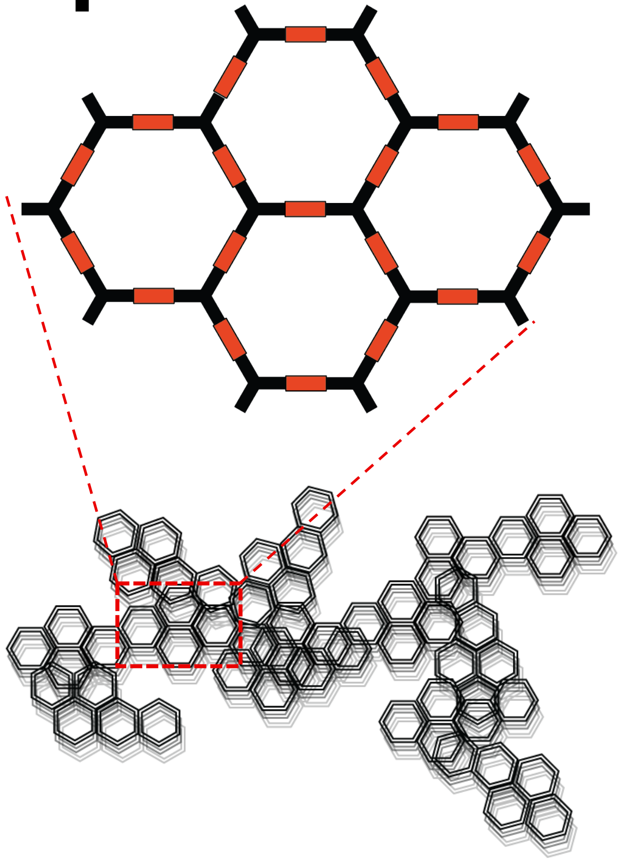

Further reading: 10.1021/acsami.3c04561

Porous framework materials for CO_2 capture

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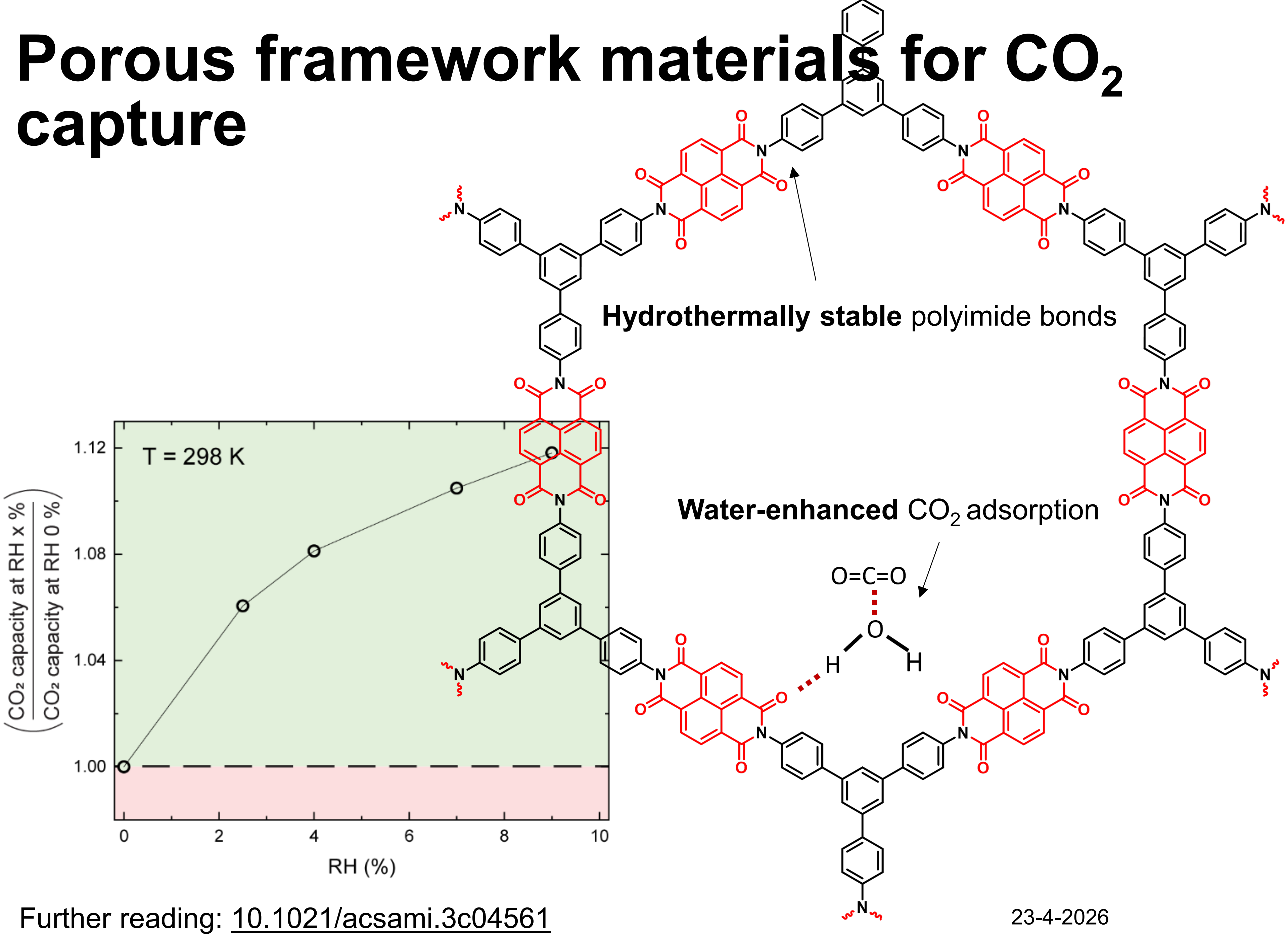

Further reading: 10.1021/acsami.3c04561

Atomic layer deposition for stable catalysts to convert CO_2 to methanol

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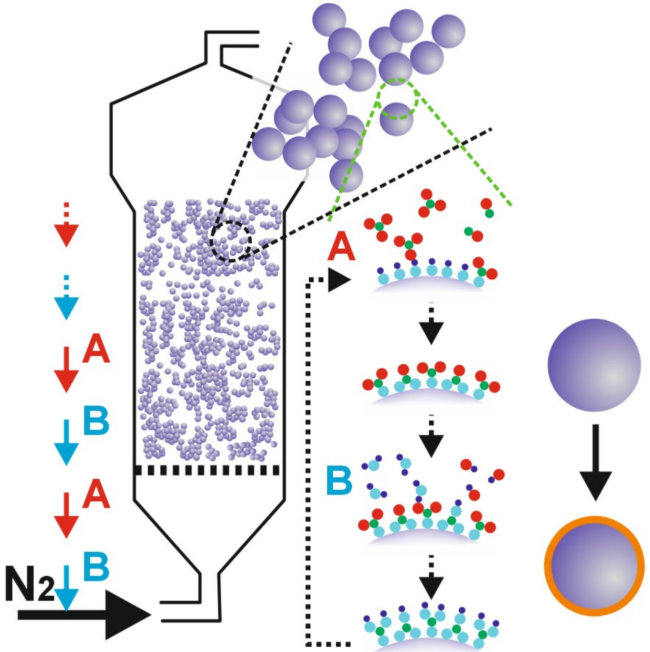
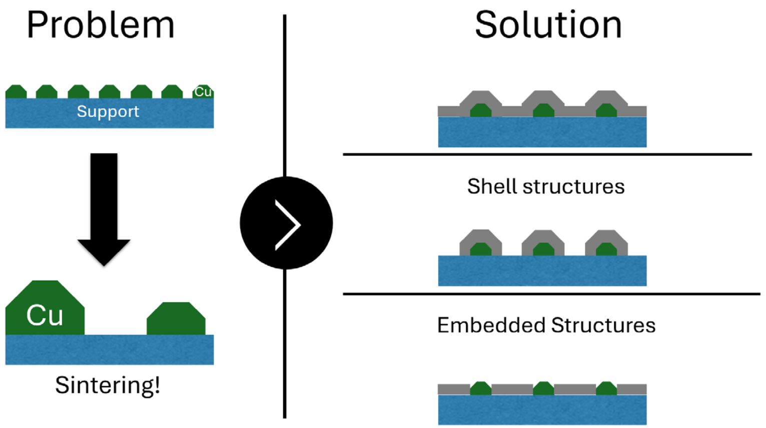


Our group is specialized in scalable nanostructuring of particles by atomic layer deposition (ALD).

Methanol production is a great use of CO_2 but hard with today's commercial catalysts.

$$CO_2 + 3\ H_2 \longleftrightarrow CH_3OH + H_2O$$

With ALD, we make structures that protect the catalyst.



Further reading: pubs.acs.org/doi/full/10.1021/acs.chemmater.5c01919

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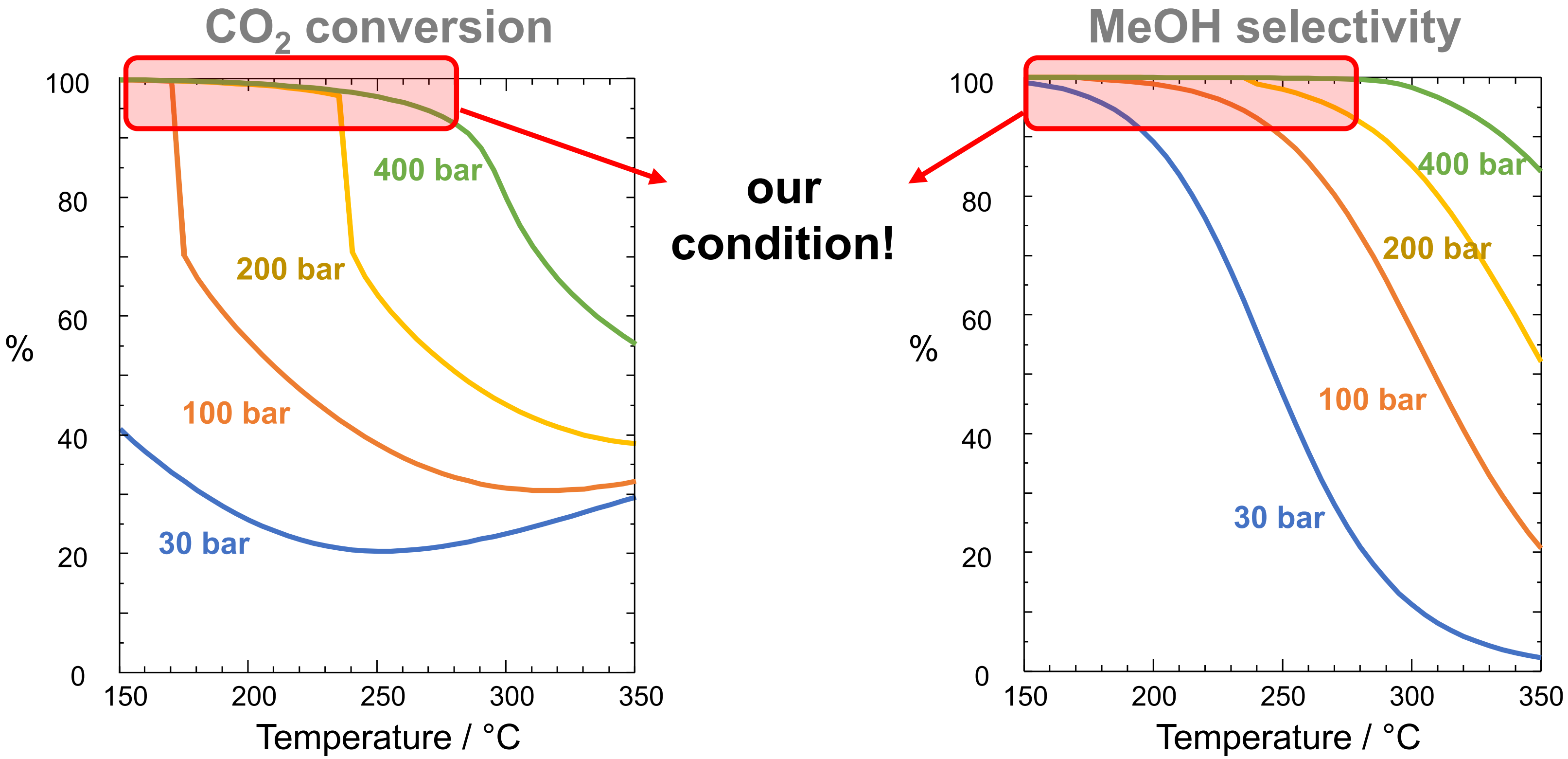
Boosting activity and selectivity in CO_2 to methanol (and more)

- **High-pressure approach** (e.g. 100-400 bar) to create thermodynamically and kinetically favourable reaction environment.
- **>95% one-pass conversion** and **>98% methanol selectivity**



Further reading: 10.1021/acs.chemrev.6b00816, 10.1016/j.jcat.2013.09.005

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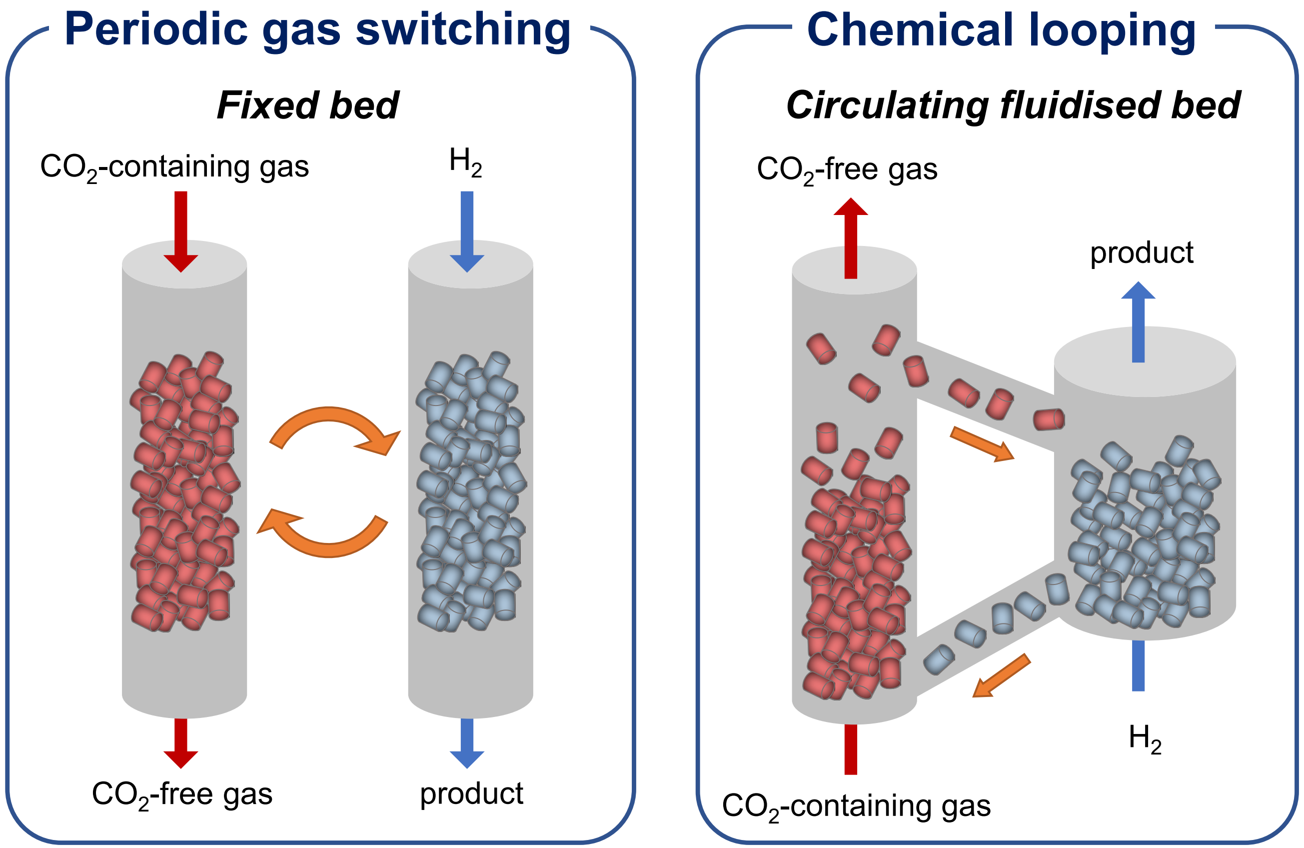
Integrated CO_2 capture-reduction

- **Two processes (CO_2 capture and conversion) in one** to obtain CO, methane and other molecules – without thermodynamic limitation
- Two modes of operation with excellent capture/conversion efficiency



Further reading: 10.1016/j.jcou.2016.04.003, 10.1016/j.cej.2022.138055

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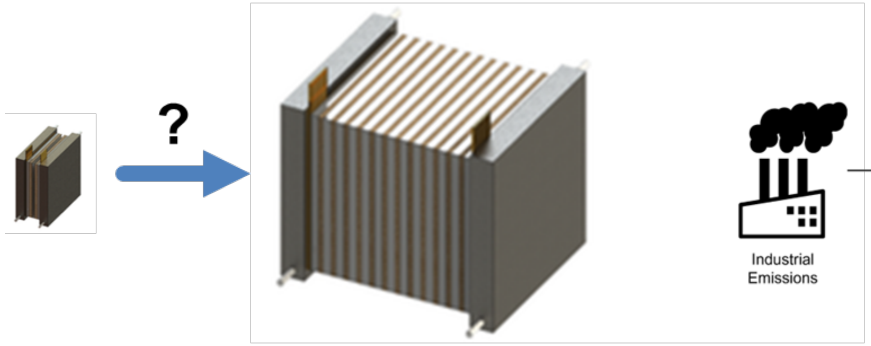
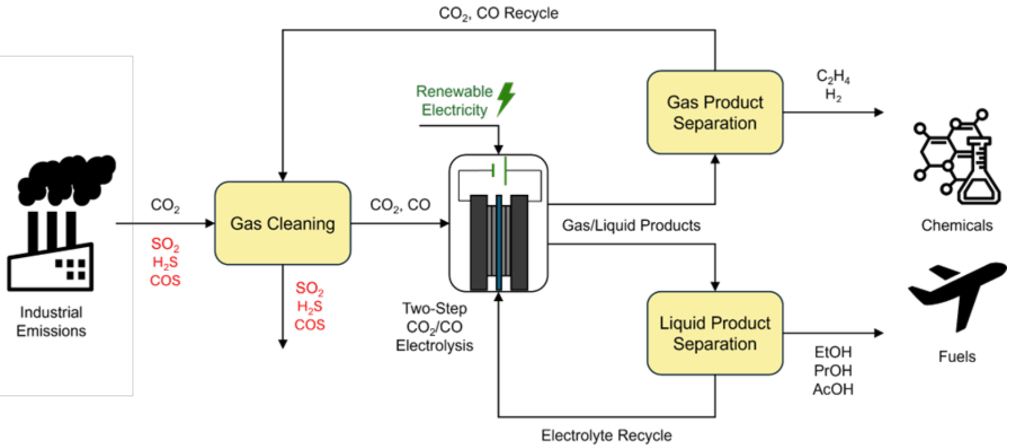
CO_2 electrolysis to valuable products





- Our group targets outstanding questions regarding upscaling of CO_2 electrolysis and implementing it into a process:
  - *Limited understanding of stability issues; how to increase overall lifetime?*
  - *How to upscale and manufacture CO_2 electrolyzers and components?*
  - *How to separate (low concentration) products coming from the electrolyzer?*
  - *What are the effects of using industrial emissions as feedstocks?*

Further reading: 10.1021/jacs.5c11790; 10.1021/acsenergylett.5c02368

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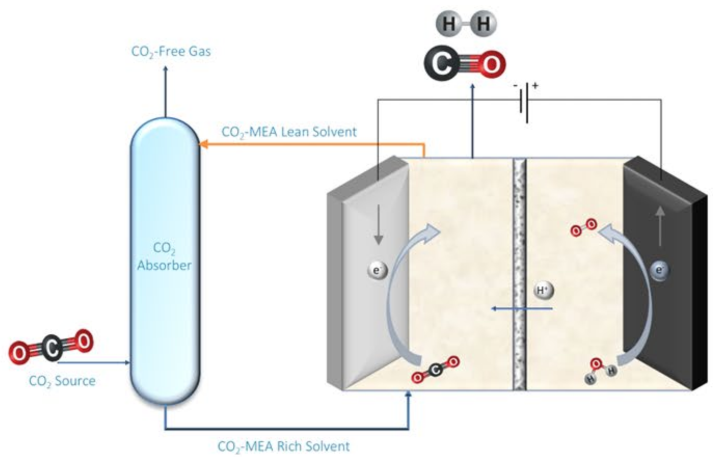
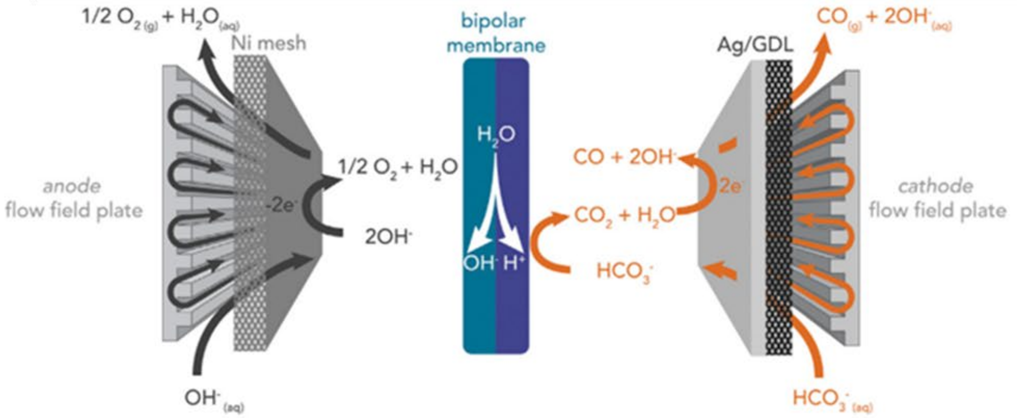
Integrating CO_2 electrolysis & capture

Non-aqueous CO_2 capture & electrolysis



Bicarbonate Electrolysis



- We study two different technologies to integrate CO_2 capture with CO_2 electrolysis:
  - Capture of CO_2 in (amine-containing) non-aqueous solvents that can simultaneously serve as electrolyte.
  - Bicarbonate electrolysis where carbonates from captured CO_2 are converted to valuable products

Further reading: 10.1002/cssc.202401631; 10.1021/acselectrochem.5c00197

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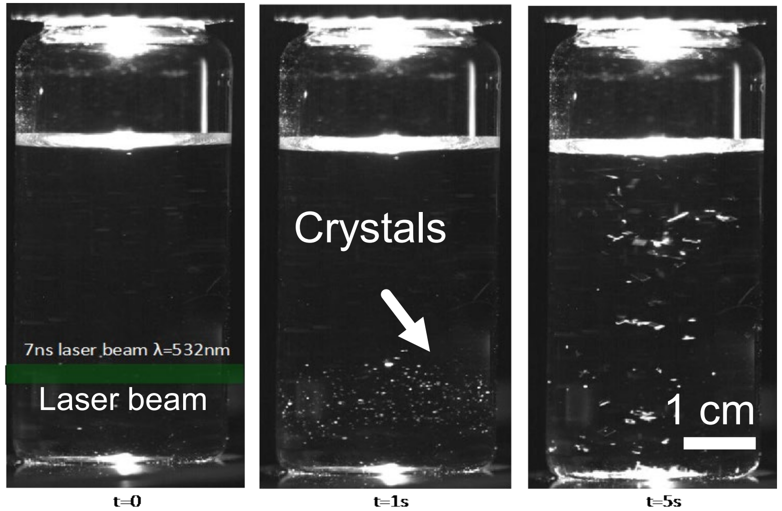
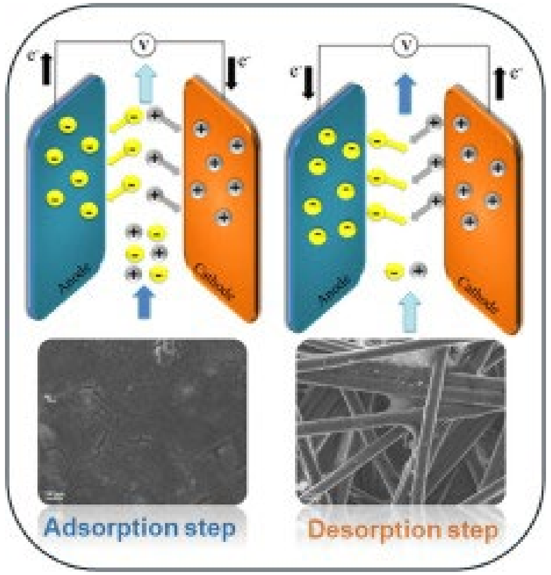
Scale up of reactive crystallization/mineralization for carbon capture from flue gas



- Industrial challenge:
  - Scale up of reactive crystallization is challenging due to lack of verified thermodynamic and kinetics models, scaling and slurry handling prone to clogging.
- At resource recovery group @ TUDelft
  - We develop out-of-the-box solutions to address these industrial challenge such as **laser induced nucleation** and **“molecular recognition” based low driving force separations.**



Further reading: 10.1103/PhysRevLett.131.124001, 10.1016/j.seppur.2023.124554

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Solubility of Acids in CO_2 at Transport Conditions

- NO_x and SO_x can cause acid formation in CO_2 transport pipelines. The solubility of these acids in high pressure/liquid/supercritical CO_2 are important for their drop-out, accumulation, and corrosion behavior.

We have a high-pressure sapphire VLE cell to measure acid solubilities in CO_2

- P-range: 1 to 250 bar
- T-range: -50 to 150 ^oC
- Acid resistant alloys
- Sampling gas and liquid phases to determine partitioning of impurities

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TU Delft ENCASE

Molecular Simulations & Equation of State Modeling for CO_2 transportation streams

- Impure CO_2 Streams
- Transient operations
- Phase stability
- Limited Data

Monte Carlo Simulations[1]

Phase equilibria (VLE) of pure & multi-component CO_2 mixtures.

Thermodynamic properties: Speed of sound, density, compressibility, heat capacities, Joule-Thomson coefficient.

Molecular Dynamics Simulations[2]

Transport properties: viscosity & thermal conductivity.

Interfacial properties of CO_2 mixtures.

Density profiles of vapor-liquid interfaces.

EoS Modeling and Machine Learning[2]

PC-SAFT EoS with classical Density Functional Theory for interfacial properties.

Metastable limits via Classical Nucleation theory

Machine learning models for phase equilibria and interfacial properties

Further reading: 1. 10.1021/acs.jced.4c00268 2. 10.1021/acs.iecr.5c04932

Flow behavior of CO_2 with impurities

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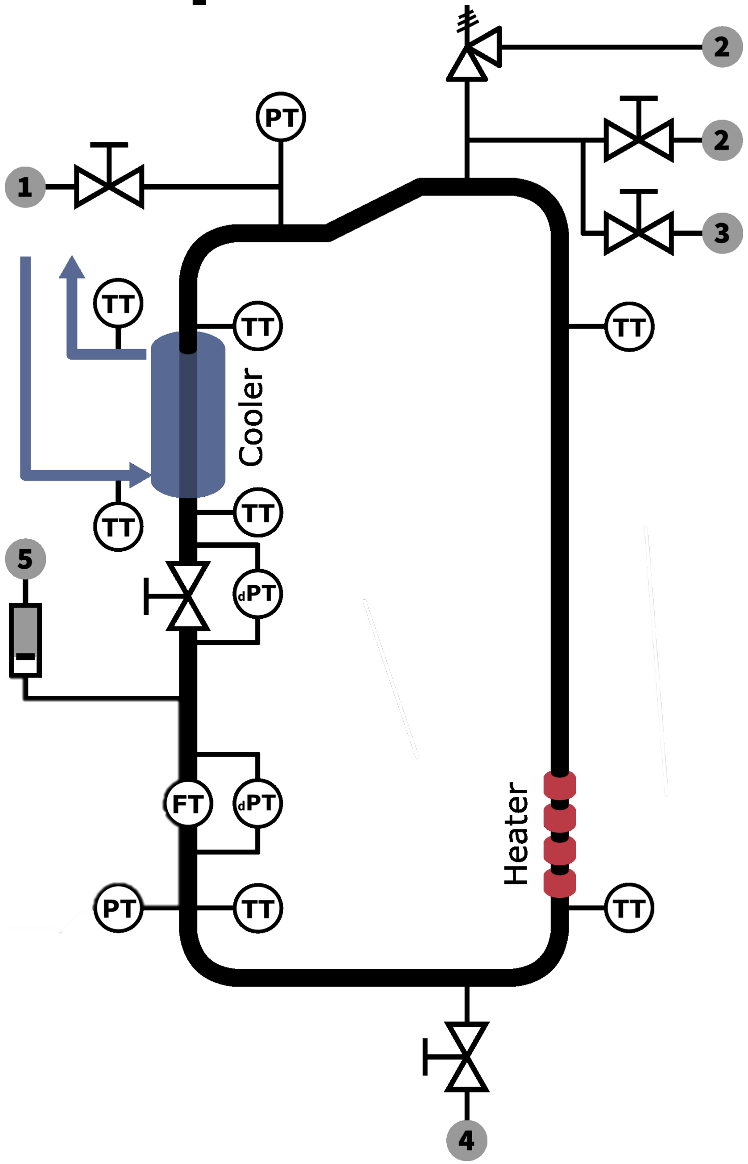
- Understanding the flow behavior of CO_2 with impurities is relevant for a safe design and operation of transportation pipelines.

We have a high-pressure natural convection-based flow loop to study CO_2 mixtures under different conditions

- P-range: 1 to 140 bar
- T-range: subzero to elevated temperatures
- Diameter: 1 inch



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TUDelft

Thermo- and hydrodynamics of carbon capture

- Direct Air Capture, (intensified) point source capture, and integrated capture+conversion
- Numerical simulations and targeted experiments
- Bridging material, device and process scales (10^{-4} – 10^{1} m)

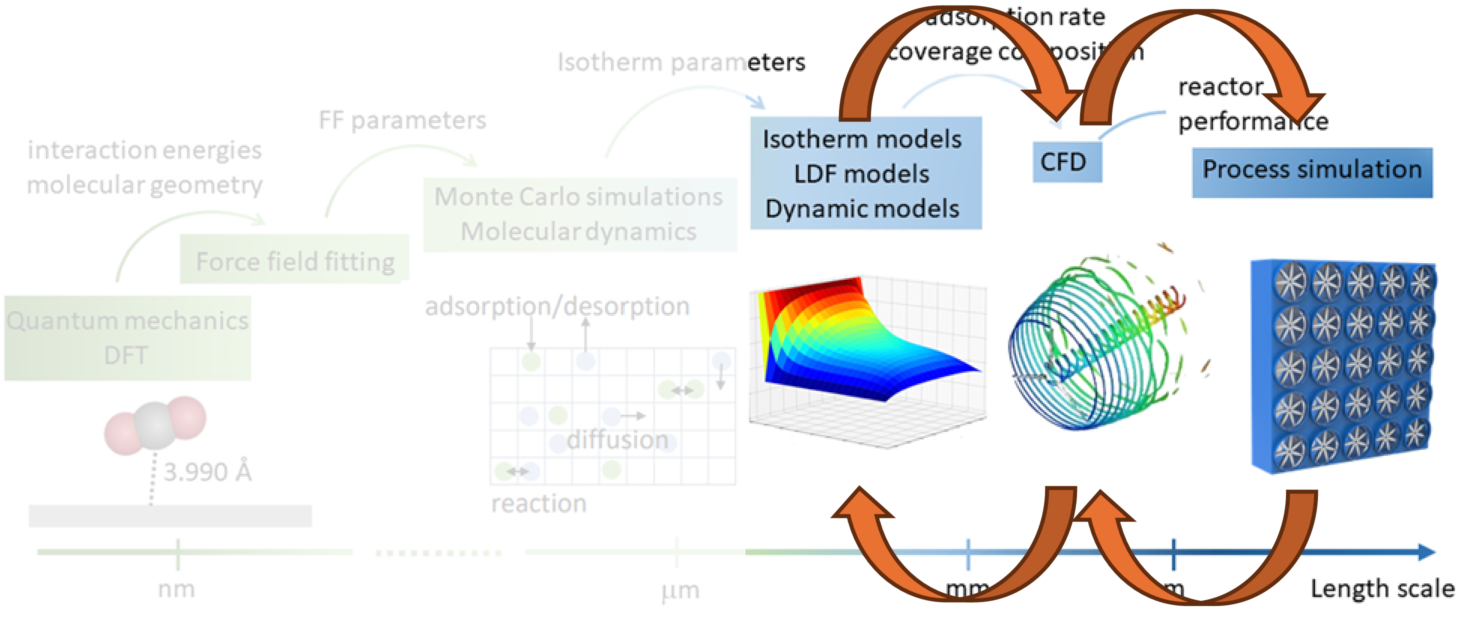

Fig. 1. Schematic representation of simulation methods at different length scales potentially used in a multiscale model and their outputs.

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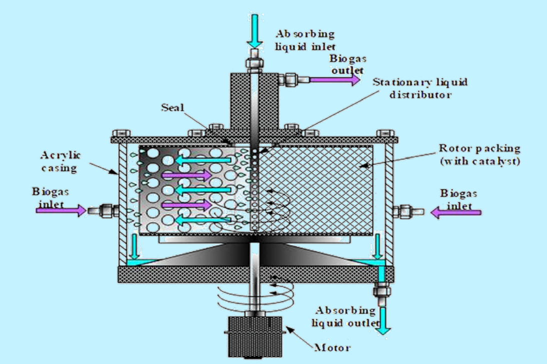
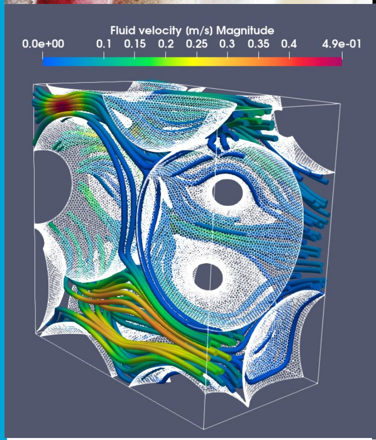
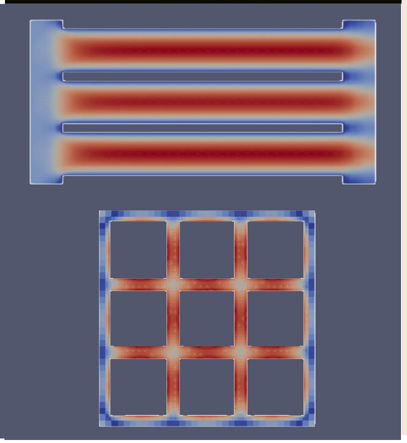
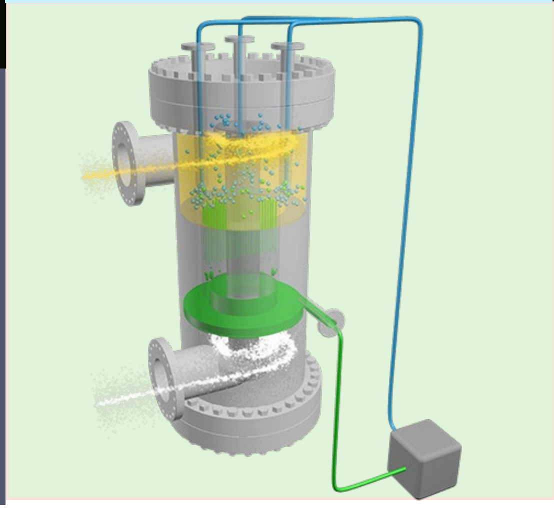
Thermo- and hydrodynamics of carbon capture









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skytree

SDS SEPARATION

NWO

CCUS-related education at TU Delft

- BSc Molecular Science and Technology
  - Separation Technology
- MSc Chemical Engineering
  - Electrochemistry for Renewable Energy
- BSc Werktuigbouwkunde
  - Process Engineering & Thermodynamica, Integrated Mechanical Systems
- MSc Mechanical Engineering
  - Track Energy, Flow and Process Technology
- Minor Engineering for Large-Scale Energy Conversion and Storage
- BSc Technische Bestuurskunde
  - Introductie in energie- en industriesystemen
- MSc Industrial Ecology
  - Integrated Project: Industrial and Urban Systems
- MSc Sustainable Energy Technology
  - Economics and Regulation of Sustainable Energy Systems
- BSs Civiele Techniek
  - Mitigation of Climate Change
- MSc Civil Engineering / Environmental Engineering / Applied Earth Sciences
  - Subsurface Storage for Energy, Water and Climate Applications

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23-4-2026