# Electrochemical $CO_2$ Capture: Demonstration of new technology at industrial sites across Europe


## DTU Chemical Engineering

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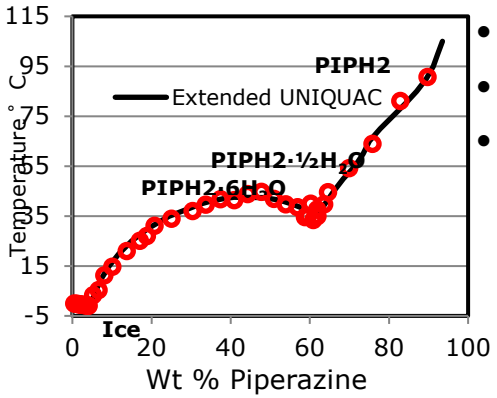
# DTU $CO_2$ Research

## Modelling (TRL 3)

- Energy consumption
- Heat of reaction
- Thermodynamics
- Kinetics

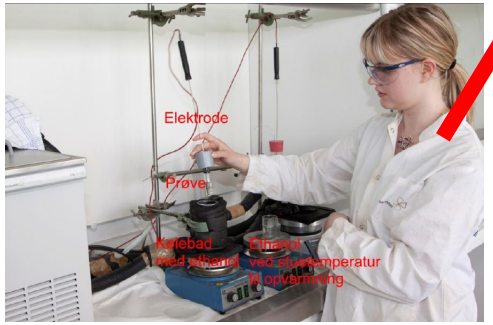


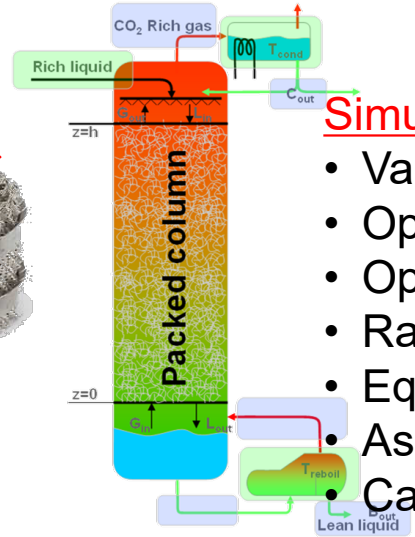

## Pilot tests (TRL 7)

- Real life tests
- Solvent study
- Packing testing
- Energy requirements
- Mass transfer

## Experimental (TRL 2)

- Physical Properties
- Equilibrium
- Kinetics




## Simulation (TRL 4)

- Variance analysis
- Optimization of energy use
- Optimization of packing
- Rate based approach
- Equilibrium approach
- Aspen Plus
- Cape-Open

CO-LaN

# Thermal $CO_2$ Capture

**Technologies**:
Advanced amines $CO_2$ capture, advanced configurations, LVC, Cold feed, MVR, heat implementation, etc.

Active projects: **CASPER**, **CORT**, **CO2MAN**, **POWLESS**
Recent projects: **BioCO2**, **ARC Net Zero**

DTU budget: 41 M DKK
Total budget: 139 M DKK

# $CO_2$ Utilization

**Technologies**:
Methanol production from biogas, catalytic reactor for syngas conversion.

Active projects: **VINGEGAARD, WURTZ, TOBIAS**
Recent projects: **Bio-ReFuel, Bio-ReFuel EFB**

DTU budget: 23 M DKK
Total budget: 69 M DKK

# Electro $CO_2$ Capture

**Technologies**:
Electrochemical carbon capture, pH-swing, PtX co-production of $H_2$, additives

Active projects: **ConsenCUS**, **ASGREEN**, **Innovandi**
Recent projects: **CCCH2**

DTU budget: 46 M DKK
Total budget: 151 M DKK

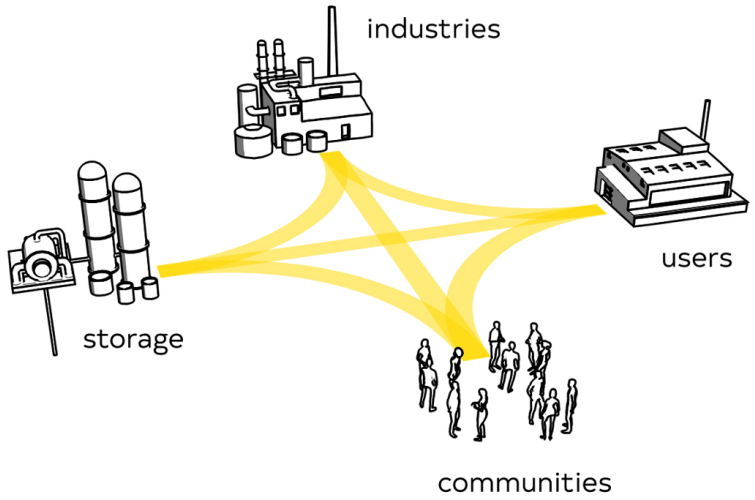

# Electro Gas Cleaning

**Technologies**:
Removal of impurities by oxidation, PtX co-production of $H_2$, purification of off-gasses

Active projects: **BE Clean, FRESH**
Recent projects: **Matchstick, HONORE, Waste-2-H2**

DTU budget: 16 M DKK
Total budget: 46 M DKK

# ConsenCUS at a glance




**Mission**

- To provide an industrial roadmap to a net-zero carbon future

**Timeline**

- 4 years, ends in the mid of 2025

**Budget**

- Approx 15 M€

**Activities**

- Demonstrating innovations in the three main components of CCUS in three industries where $CO_2$-emissions are hard to abate
- Life-cycle analysis and techno-economic evaluation for implementing these innovations
- Design of $CO_2$-clusters and carbon value chains
- Create narratives by researching social and environmental impact

# 19 Partners, 3 Continents

# Timeline

## Design phase

Design phase and start up of the research

**YEAR 1**

## Engineering phase

Engineering phase + initial research results

**YEAR 2**

## First demonstration

Building and first demonstration site

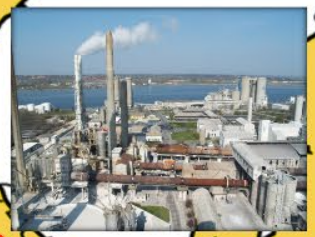
**YEAR 3**

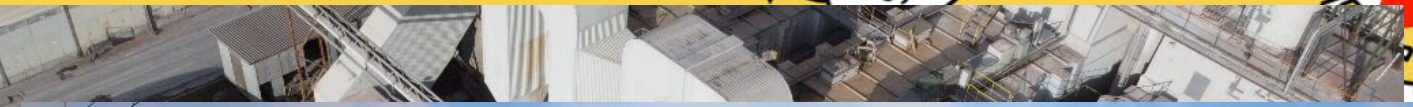
## Disseminiation

Demonstration & dissemination of all research results

**YEAR 4**

18-20 vol% $CO_2$

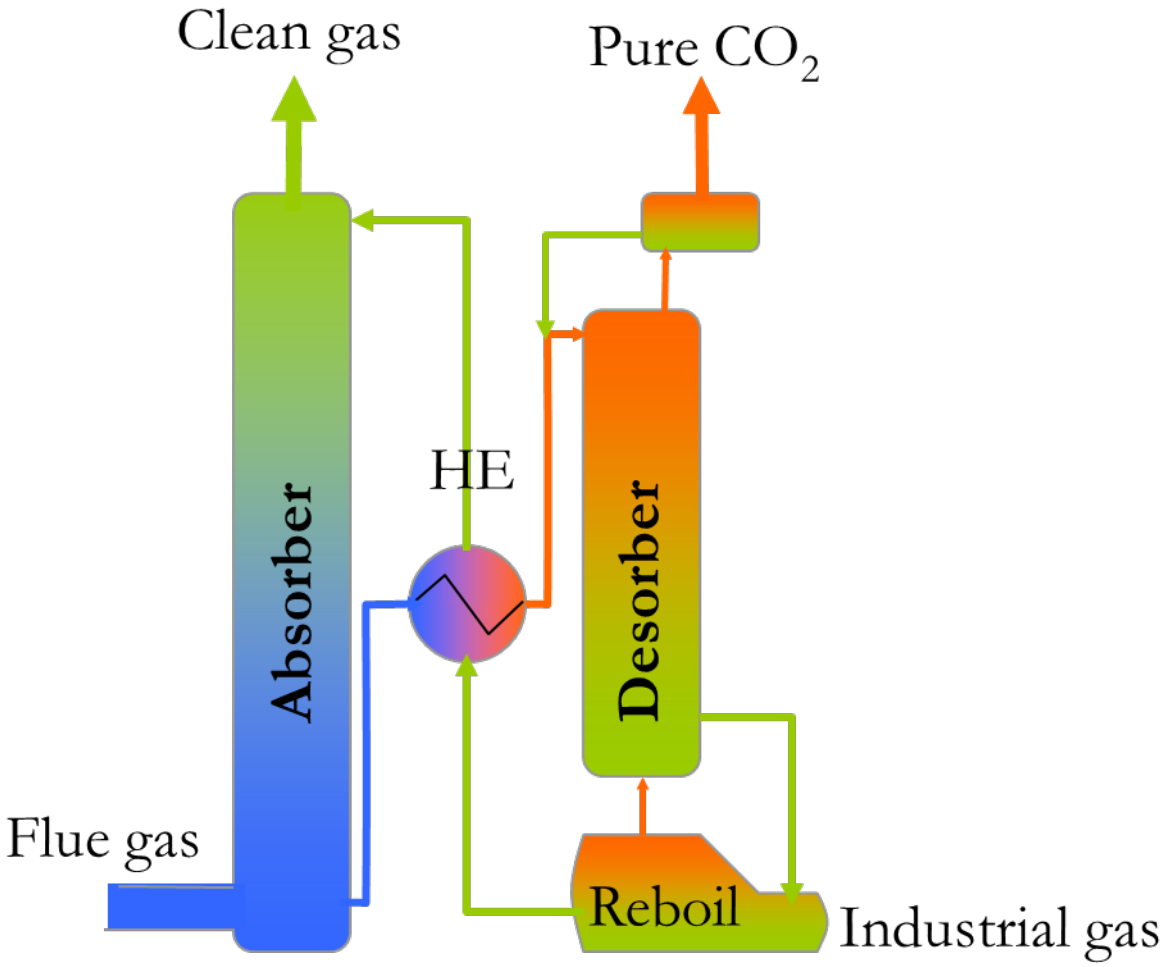


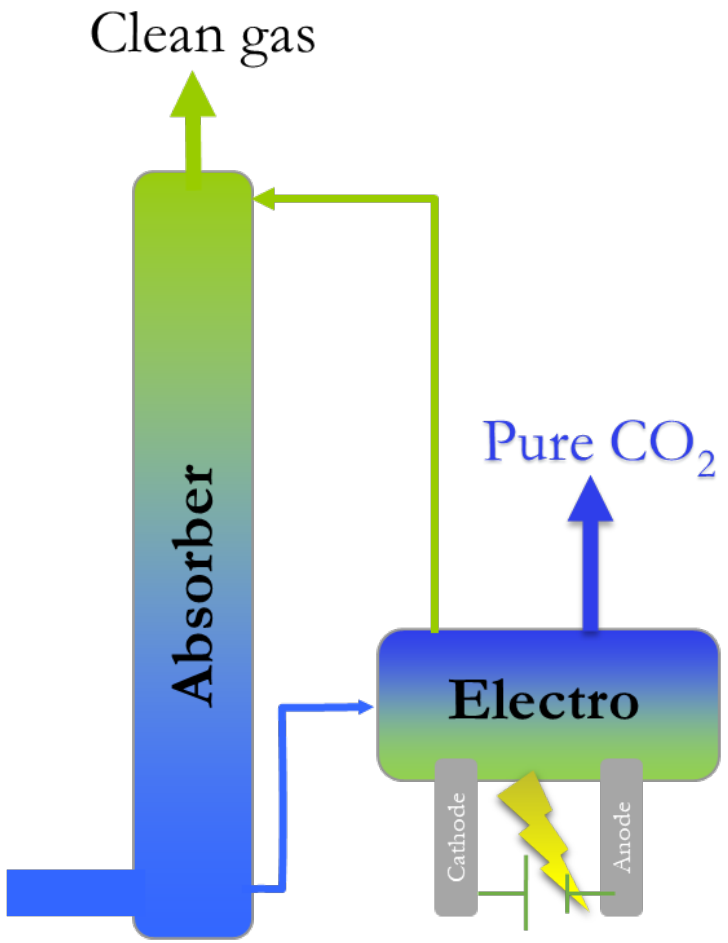


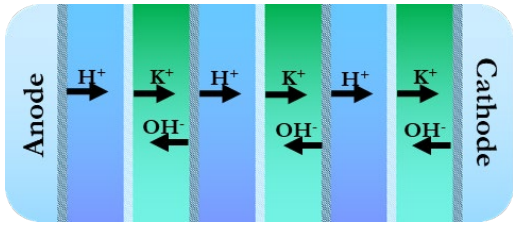
3-4 vol% $CO_2$

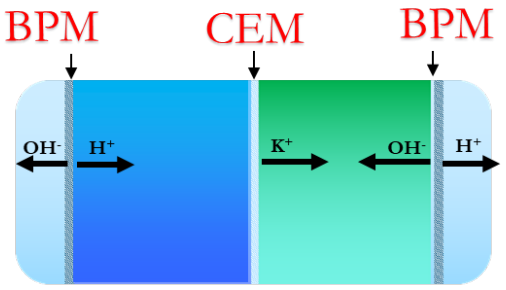
Opening the ConsenCUS pilot plant 27th of Nov 2023

# CO2 capture – thermal/electrochemical



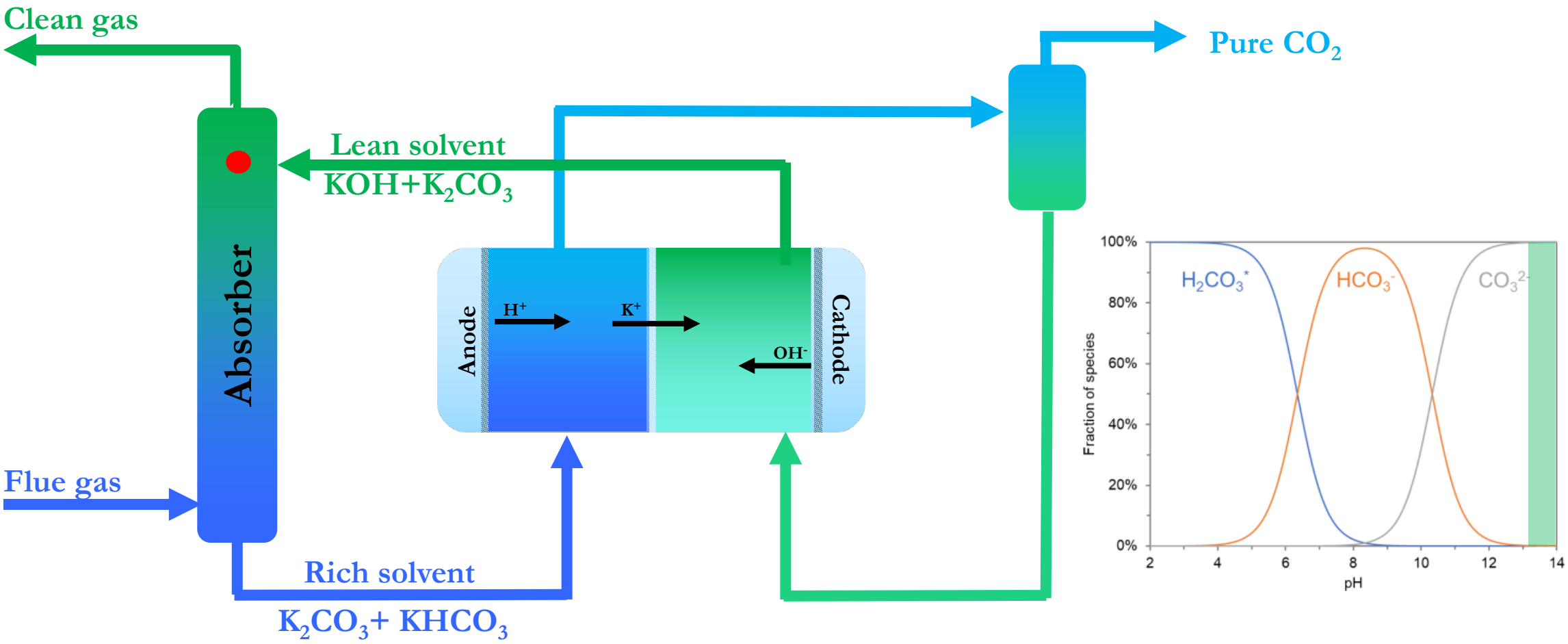



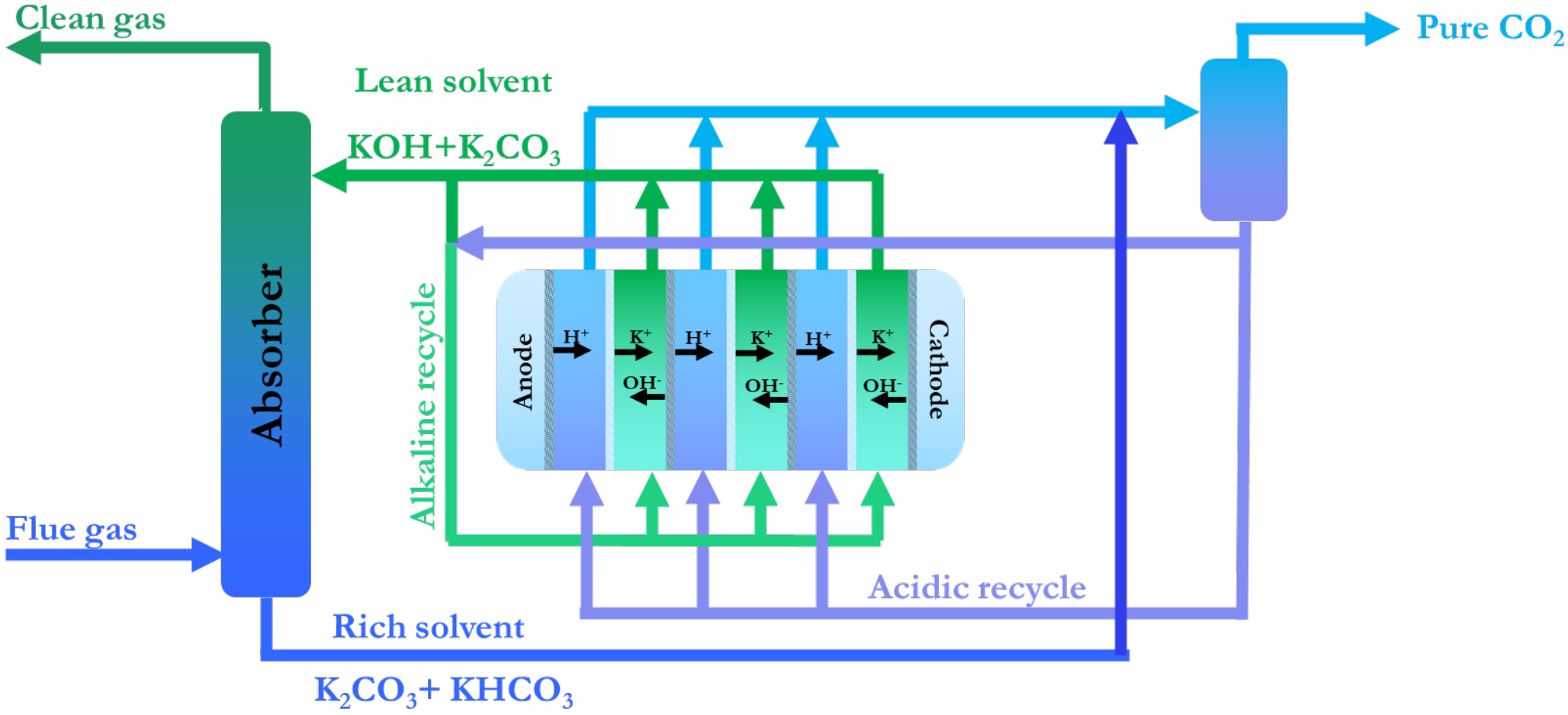




Potassium based solution

# Capture + Regeneration modules

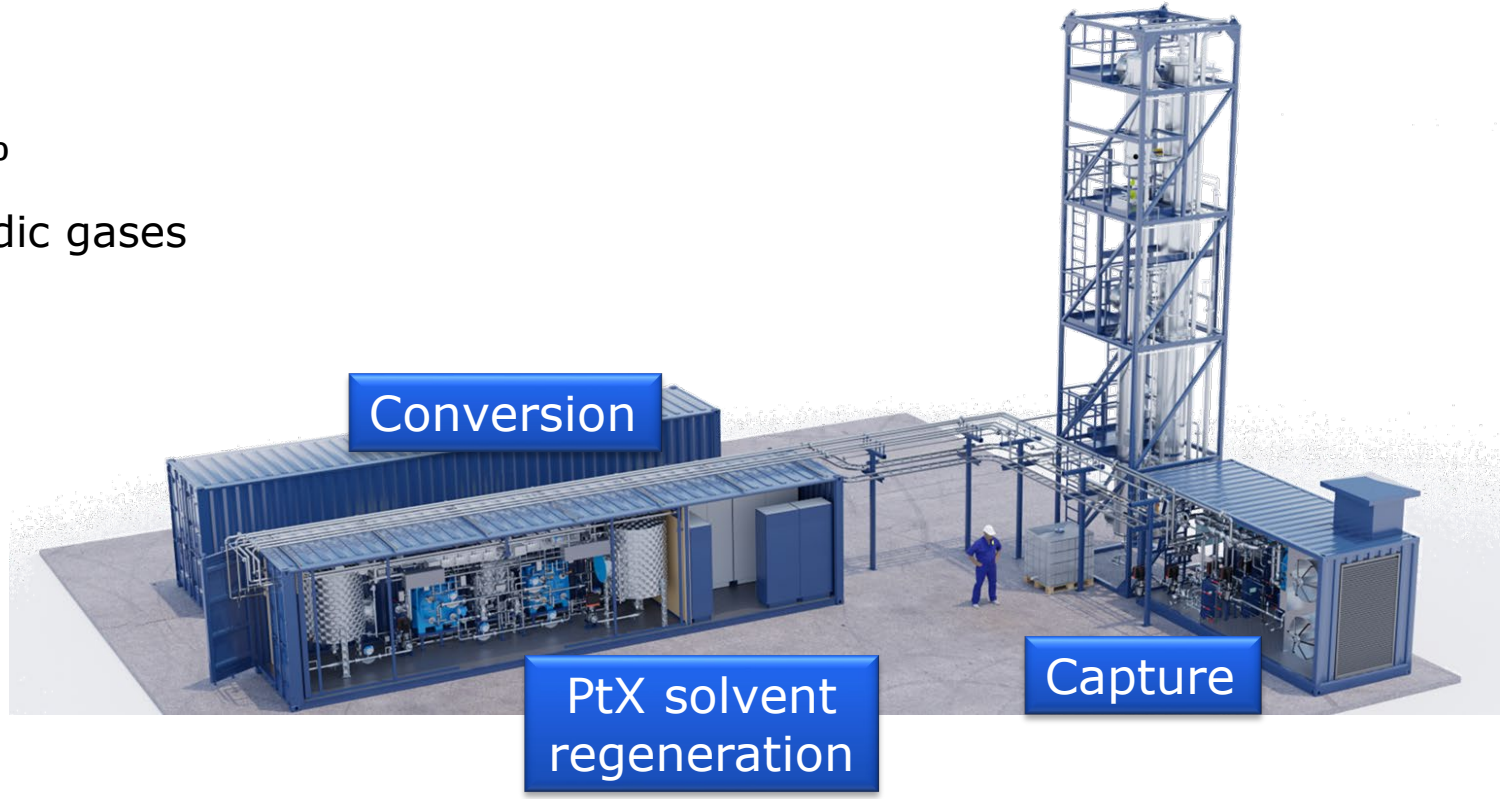


# The real plant: Capture + Regeneration + recycle



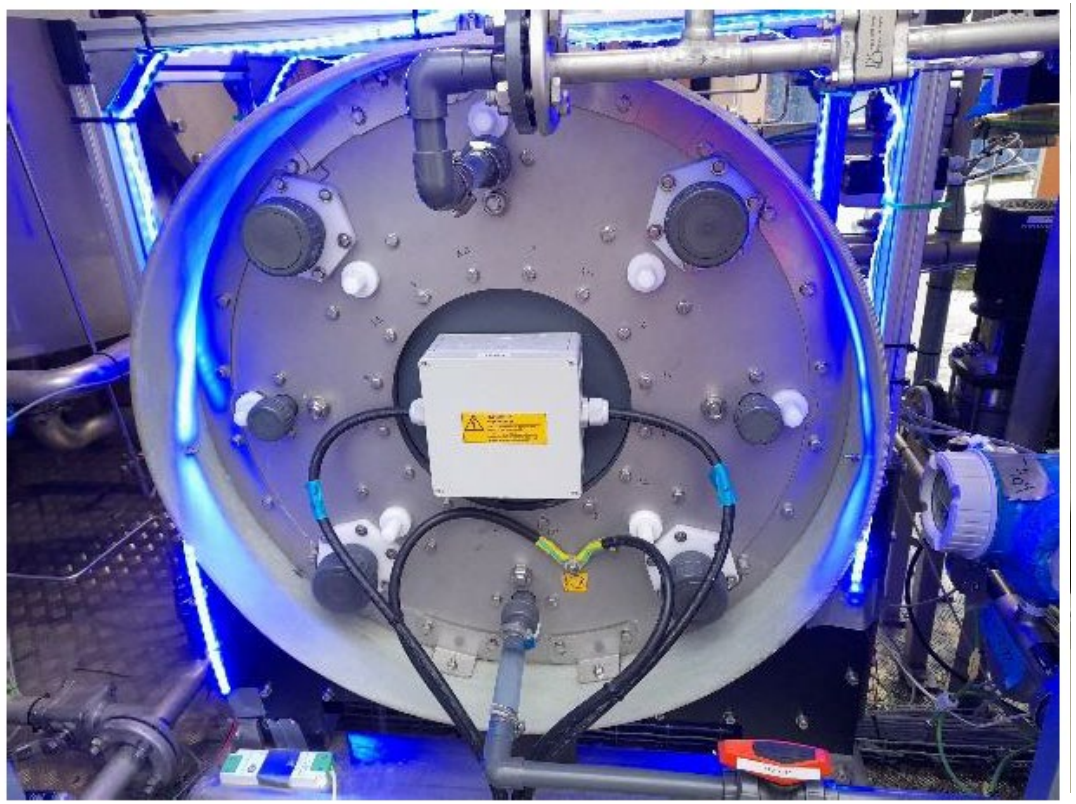
# The demonstration unit

- Pilot capacity: 100 kg $CO_2$/h
- $CO_2$ content in the flue gas: 3 to 20 vol%
- Flue gas impurities: SOx, NOx, other acidic gases
- Absorber packing: 10 m
- Two electrochemical stacks
- 126 cell pairs per stack
- Maximum current density: 1000 A/m2
- Possibility for advanced configurations
- Pre & post washing



# Key demonstration objectives

- Operation of the unit across three different industrial sites
- $CO_2$ capture efficiency (> 90%)
- $CO_2$ purity (>95%)
- Minimise energy consumption/energy requirements
- 1000 operating hours, across 3 different Industrial settings

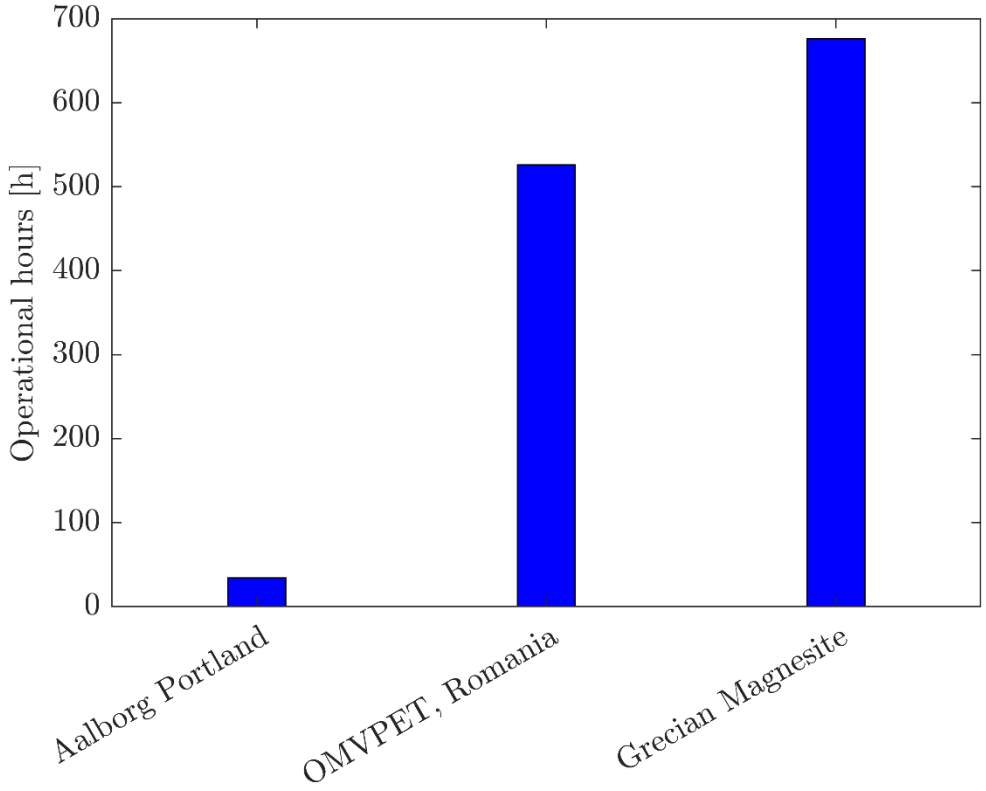


# Flexible design focus

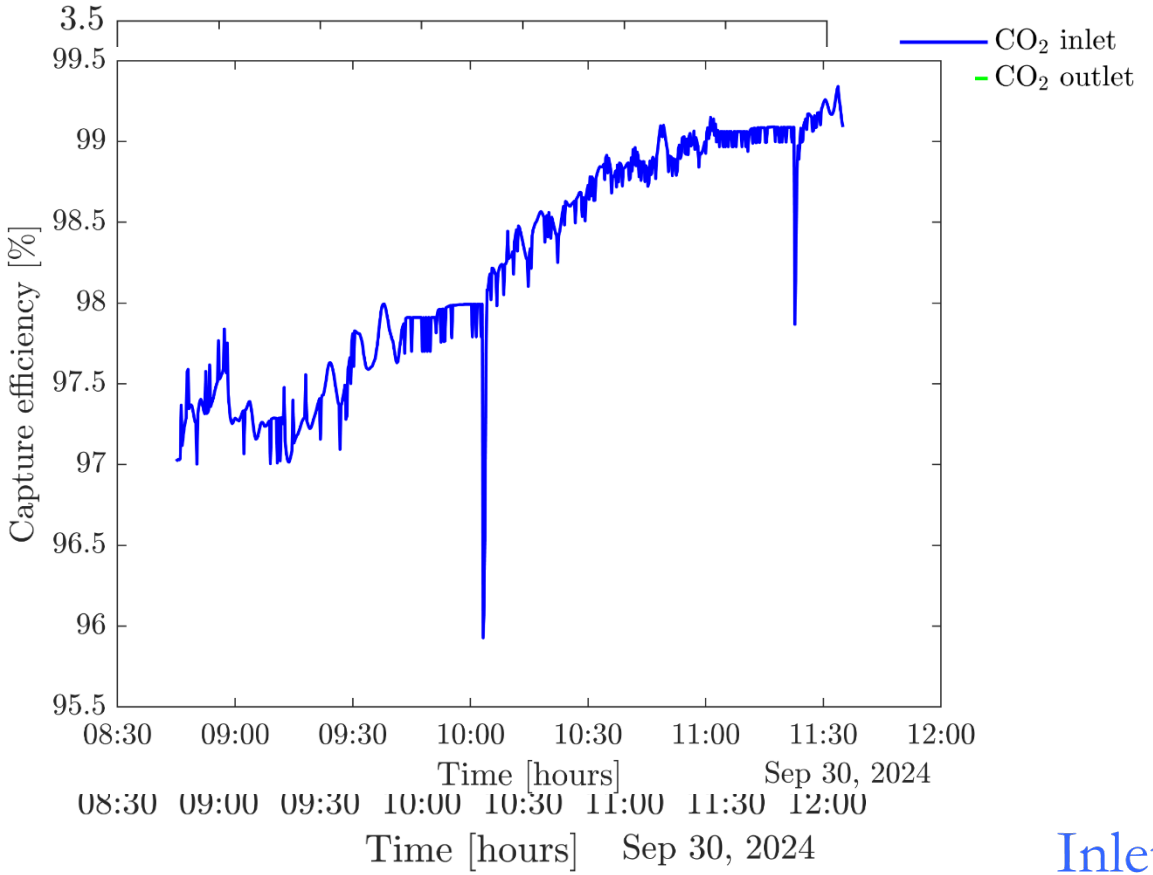
| | OMVPET | GM | AALPOR | Unit |
|---|---|---|---|---|
| **Temperature** | 170 | 150-200 | 122 | °C |
| **Pressure** | ? | 1000-1010 | 1004 | mbar |
| **CO2** | 3.5 | 15 | 20.9 | Vol% |
| **O2** | 14.5 | 7-15 | 6.9 | Vol% |
| **N2** | 76.5 | 65 | ? | Vol% |
| **H2O** | 6.5 | 6-13 | 35 | Vol% |
| **SO2** | 22 | 1500 | 0.29 | mg/Nm3 |
| **NOx** | 95 | 700 - 1500 | 253 | mg/Nm3 |
| **CO** | 19 | 1000 | 755 | mg/Nm3 |
| **Particles/dust** | 1.7 | ? | 11.2 | mg/Nm3 |
| **HCl** | ? | <10 | ? | mg/Nm3 |
| **HF** | ? | <1 | ? | mg/Nm3 |

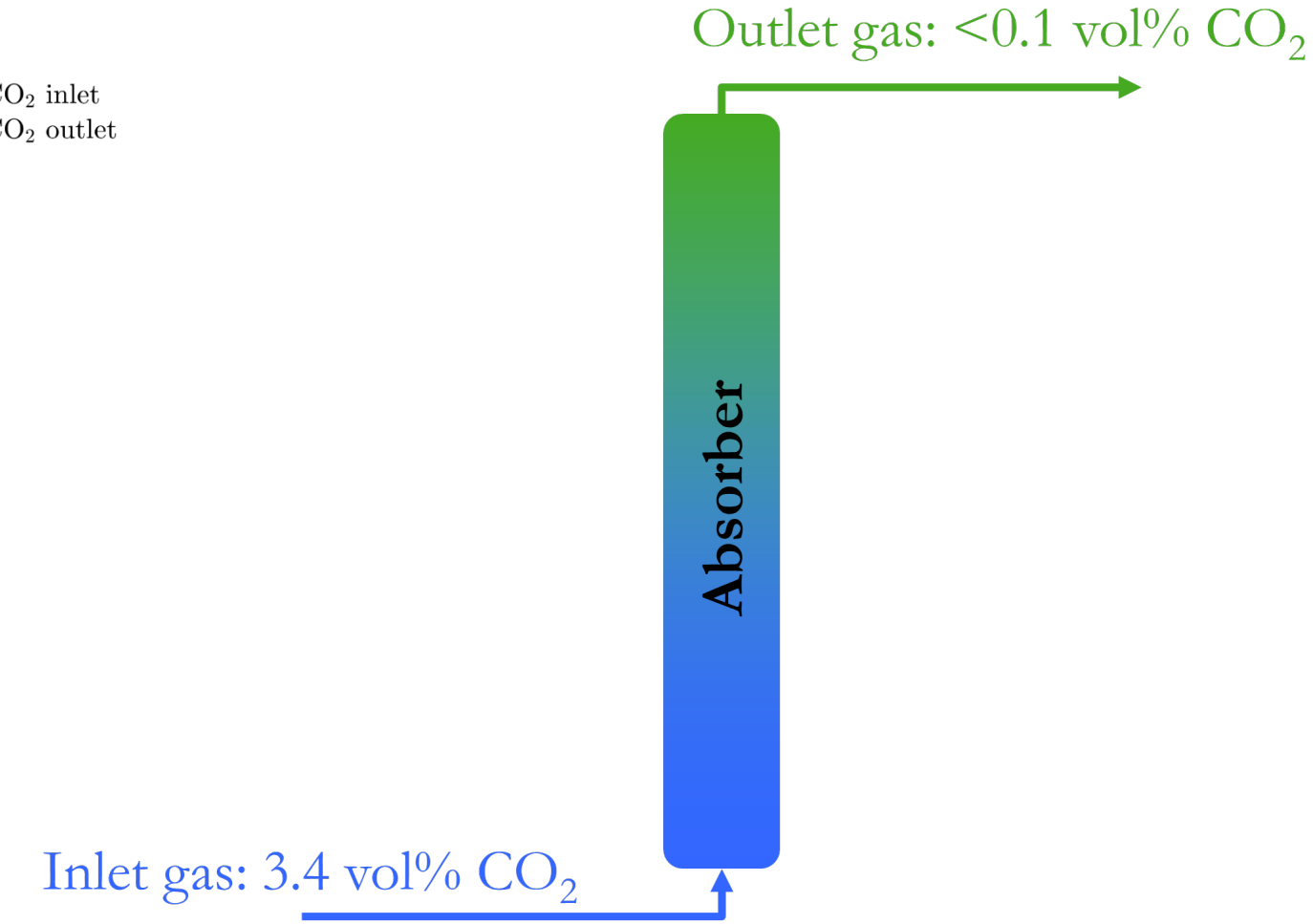
# Operational hours

- Total capture + regeneration operational hours > 1000
- Improvement in operation through time
- Aalborg and OMVPET – Single stack operation
- Grecian Magnesite – Single stack & Two stacks operation



# Capture efficiency > 90%



# $CO_2$ purity > 95%

- Capture module + regeneration module
- GC measurements of $CO_2$ stream by OMV

| Parameter | Lab | Result | Limit | UM | Conform | Auth. comment |
|---|---|---|---|---|---|---|
| Hidrogen. | P_G | <0.0500 | | %mol | √ | CONSENCUS_ proba din 24.07.2024 |
| Dioxid de carbon. | P_G | 75.0100 | | %mol | √ | |
| Oxigen. | P_G | 4.6700 | | %mol | √ | |
| Azot. | P_G | 20.3100 | | %mol | √ | |

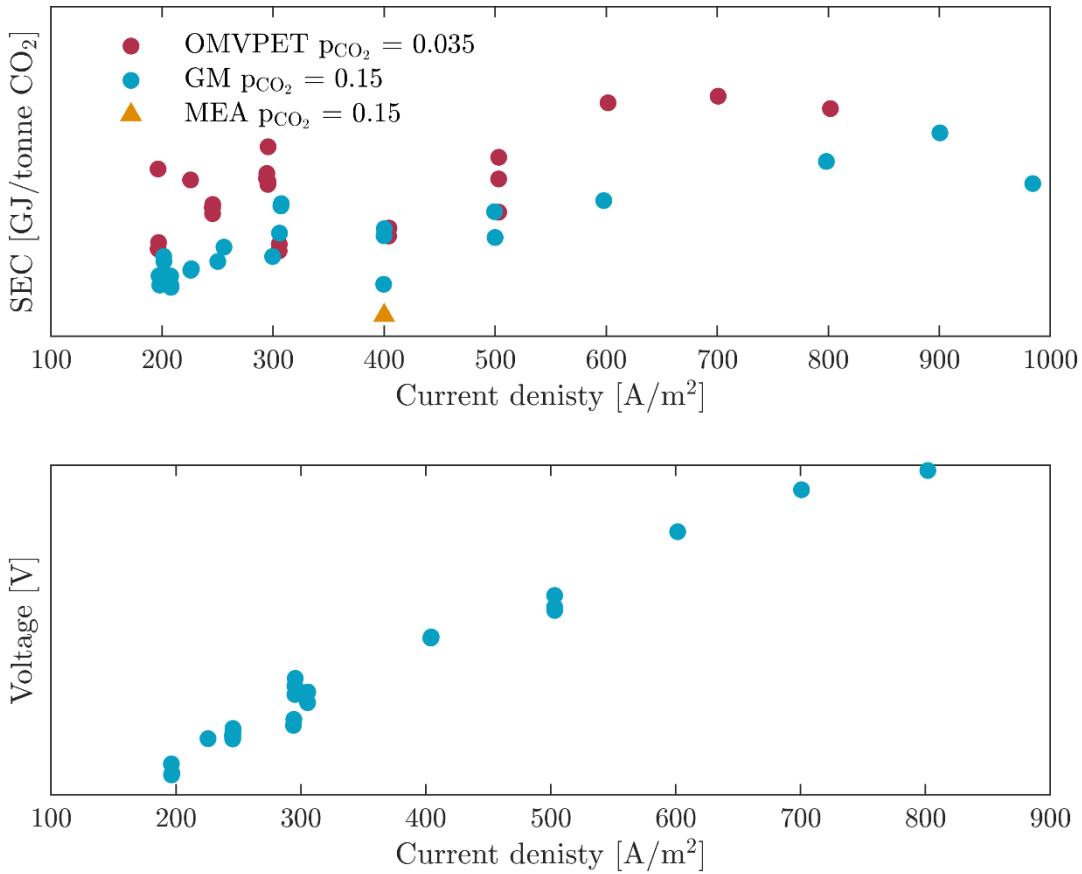
| Parameter | Lab | Result | Limit | UM | Conform | Auth. comment |
|---|---|---|---|---|---|---|
| Hidrogen. | P_G | <0.0500 | | %mol | √ | CONSENCUS_ proba din 25.07.2024 |
| Dioxid de carbon. | P_G | 98.5000 | | %mol | √ | |
| Oxigen. | P_G | 0.4000 | | %mol | √ | |
| Azot. | P_G | 1.0600 | | %mol | √ | |

| Parameter | Lab | Result | Limit | UM | Conform | Auth. comment |
|---|---|---|---|---|---|---|
| Hidrogen. | P_G | <0.0500 | | %mol | ✓ | CONSENCUS_ proba din 30.07.2024 |
| Dioxid de carbon. | P_G | 98.9300 | | %mol | ✓ | |
| Oxigen. | P_G | 0.3300 | | %mol | ✓ | |
| Azot. | P_G | 0.7200 | | %mol | ✓ | |

| Parameter | Lab | Result | Limit | UM | Conform | Auth. comment |
|---|---|---|---|---|---|---|
| Hidrogen. | P_G | <0.0500 | | %mol | ✓ | CONSENCUS_ proba din 31.07.2024 |
| Dioxid de carbon. | P_G | 99.2800 | | %mol | ✓ | |
| Oxigen. | P_G | 0.1900 | | %mol | ✓ | |
| Azot. | P_G | 0.5100 | | %mol | ✓ | |

# Specific Energy Consumption

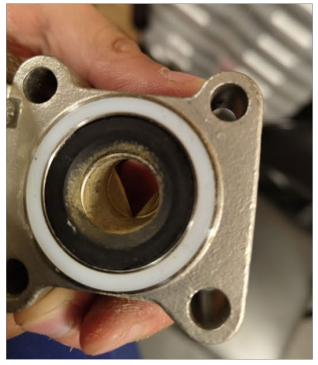
- SEC currently higher than thermal based capture
- SEC increases with current density
- SEC decreases with $Pco_2$ in the flue gas
- Voltage increases with current density contributing to higher SEC at higher current densities
- Laboratory setups have shown potential to reduce SEC up to 2 GJ/tonne $CO_2$

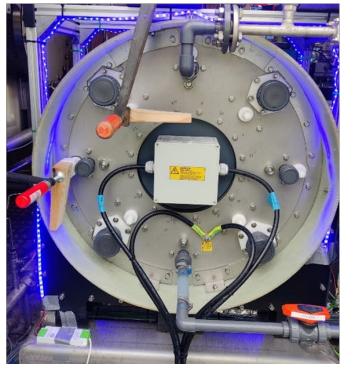


# Challenges and learnings

## Aalborg campaigns:

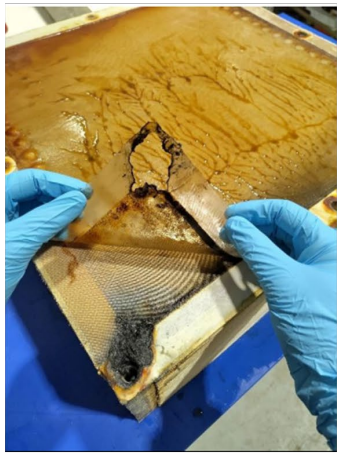
- Material of construction (broken rod)
- Corrosion





## OMVPET campaigns:

- Membrane damage
- High current densities damaged



## GM campaigns

- Deposits on the acidic side
- Decomposition of the electrode
- Pre-scrubber operation is vital
- Flue gas impurities play an important role
- Limited current density operation window

# Thank you for your attention

More information: Philip L. Fosbøl, plf@kt.dtu.dk