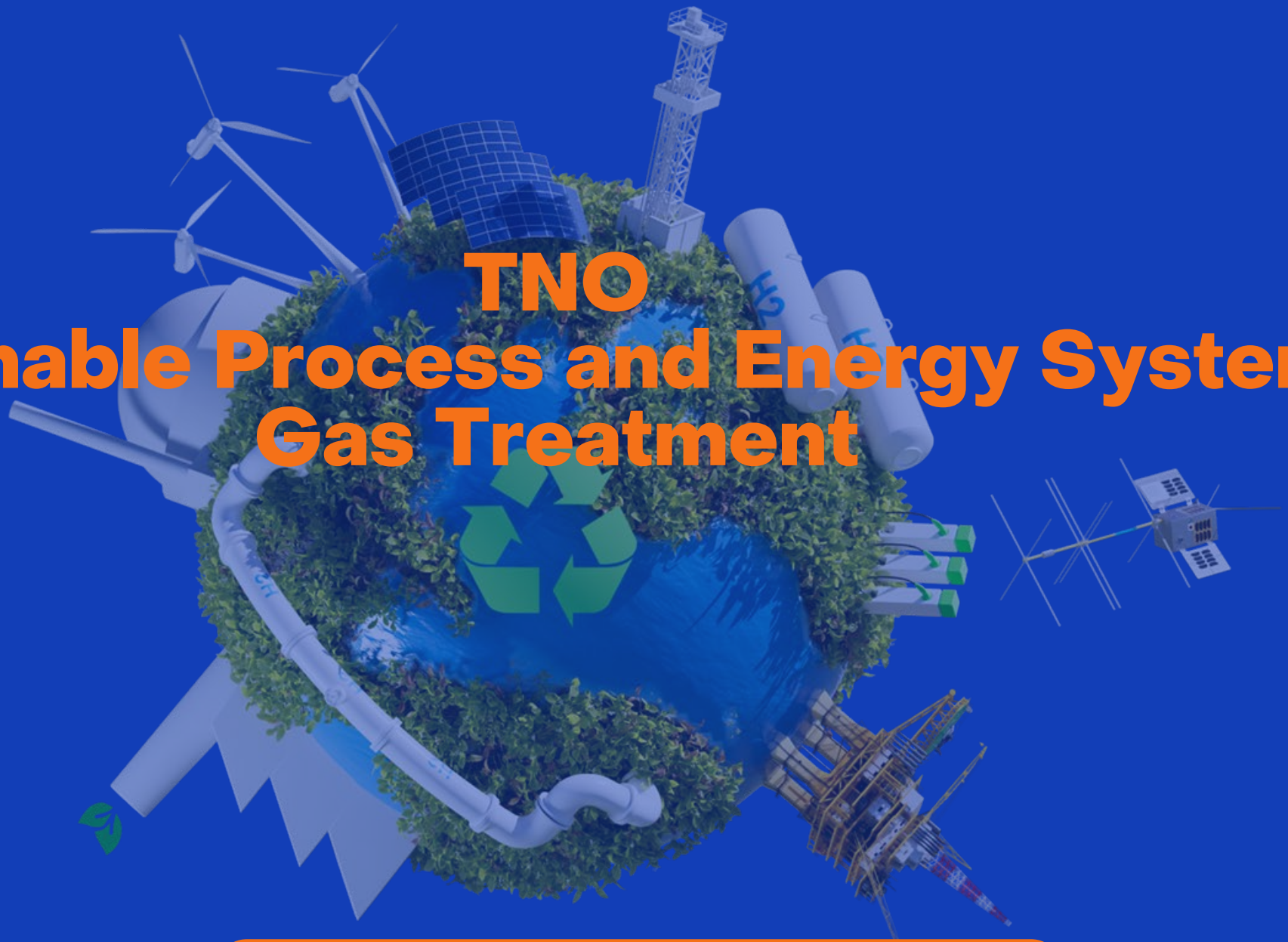
TNO
Sustainable Process and Energy Systems
Gas Treatment



Soledad van Eijk | CATO Event December 11th 2025

TNO innovation for life

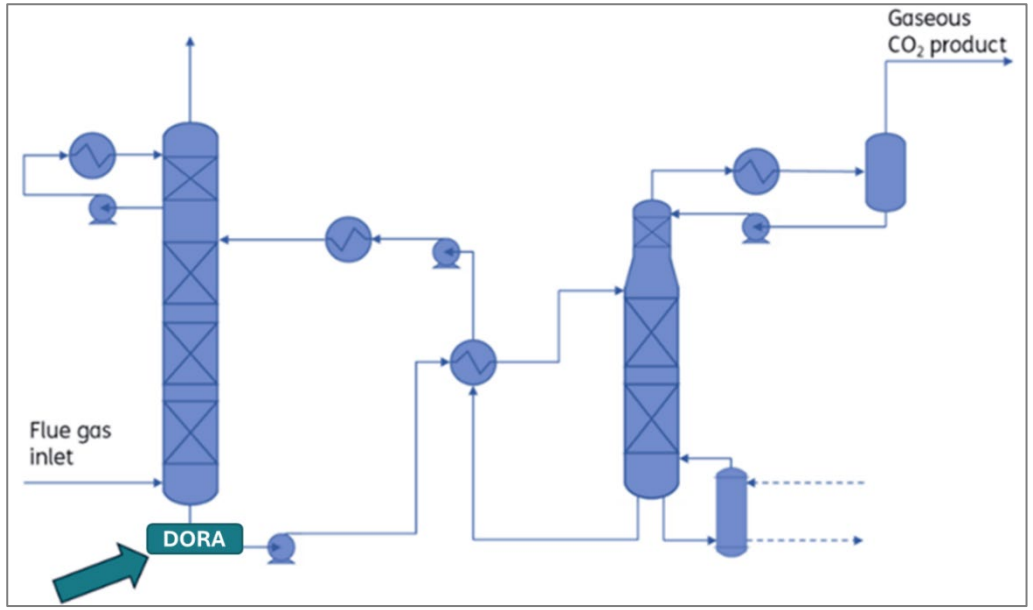
MeDORA
Oxygen Removal System

MeDORA: Membrane-assisted Dissolved Oxygen Removal from Amine solutions for CO_2 capture.

SINTEF TNO hvc. RWE NTNU slb Capturi

MeDORA
Oxygen Removal System

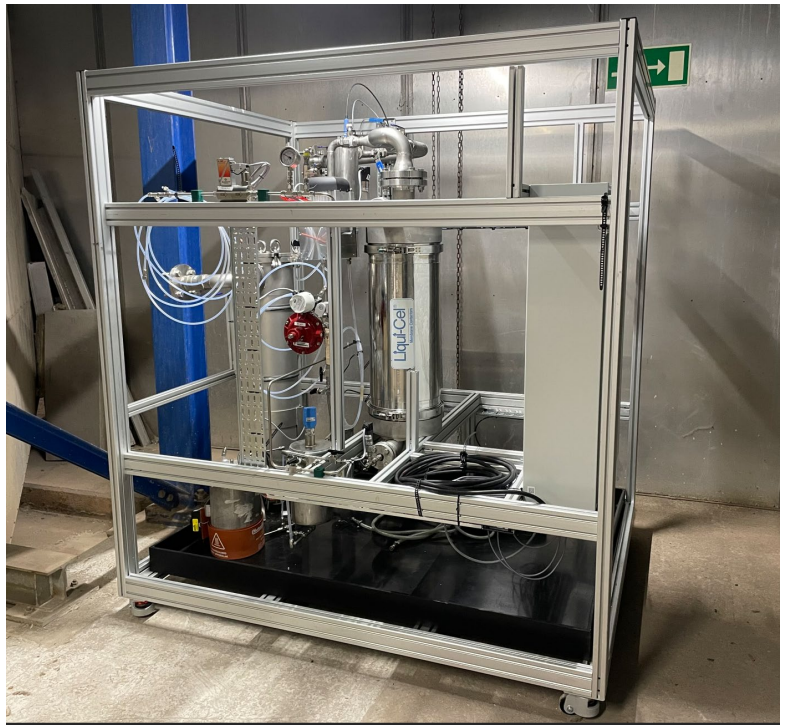
- **Objective**
  - Making amine-based carbon capture cheaper and more sustainable by implementing **DORA technology**
- **Specific goals**
  - Demonstrate 90% dissolved **O_2 removal** from amine absorbents, leading to up to 70% reduction in OPEX of the plant associated with solvent management
  - Demonstrate the achievement of less than 10 ppm O_2 content in the CO_2 product



Placement of DORA in an amine-based post combustion carbon capture process

Main activities

- Lab-scale activities to identify an alternative asymmetric membrane, de-risk the campaigns and provide data for model development
- 3 long-term campaigns to validate DORA technology in real environments and optimize the lifetime of the technology
- Development models, perform TEA and LCA, and benchmark against other alternative technologies for oxygen removal



The DORA skid as deployed in a previous campaign at HVC in 2022

Testing campaigns at industrial sites

- HVC campaign (NL)
  - Demonstrate long-term operation, including regeneration cycles to overcome the challenge of pore wetting and clogging

- RWE campaign (DE)
  - Compare non-porous asymmetric membranes with porous membranes during long-term operation, as a potential solution to avoid membrane wetting

→ Longer campaigns ongoing

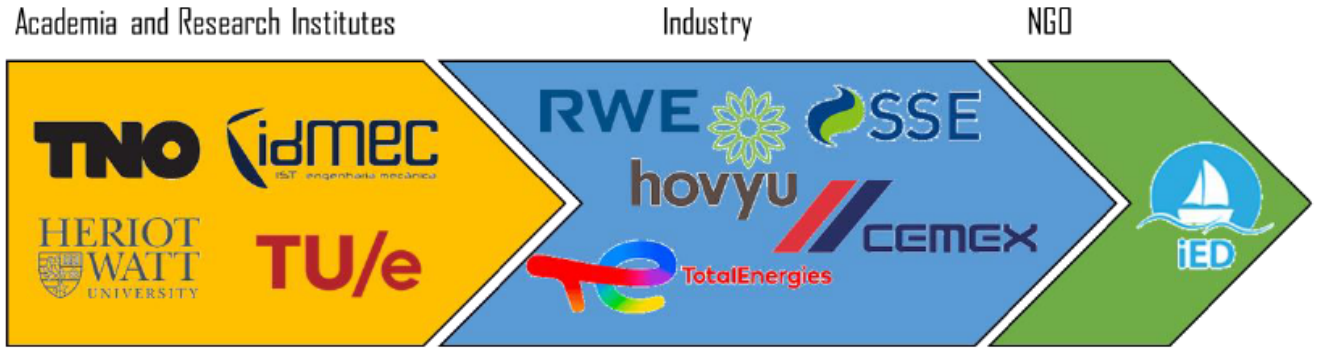
- Tiller campaign (NO)
  - Test effect of dissolved O_2 removal on the quality of CO_2 produced

→ Shorter campaign planned to start in March 2026

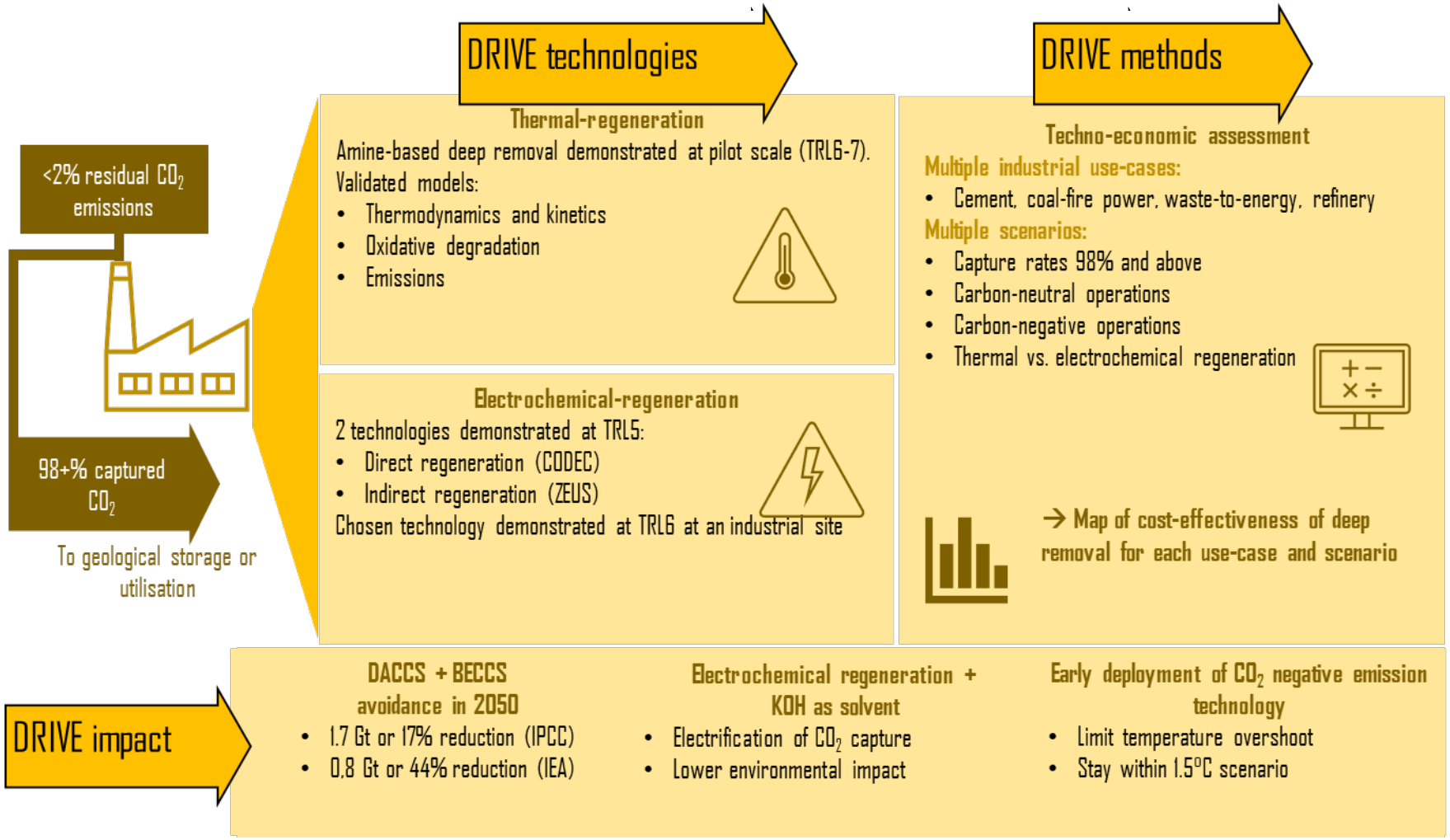
D2IVE

Deep Removal of CO2 &
InnoVative Electrification concepts

CO_2 Capture electrification and deep removal



Graphical project summary

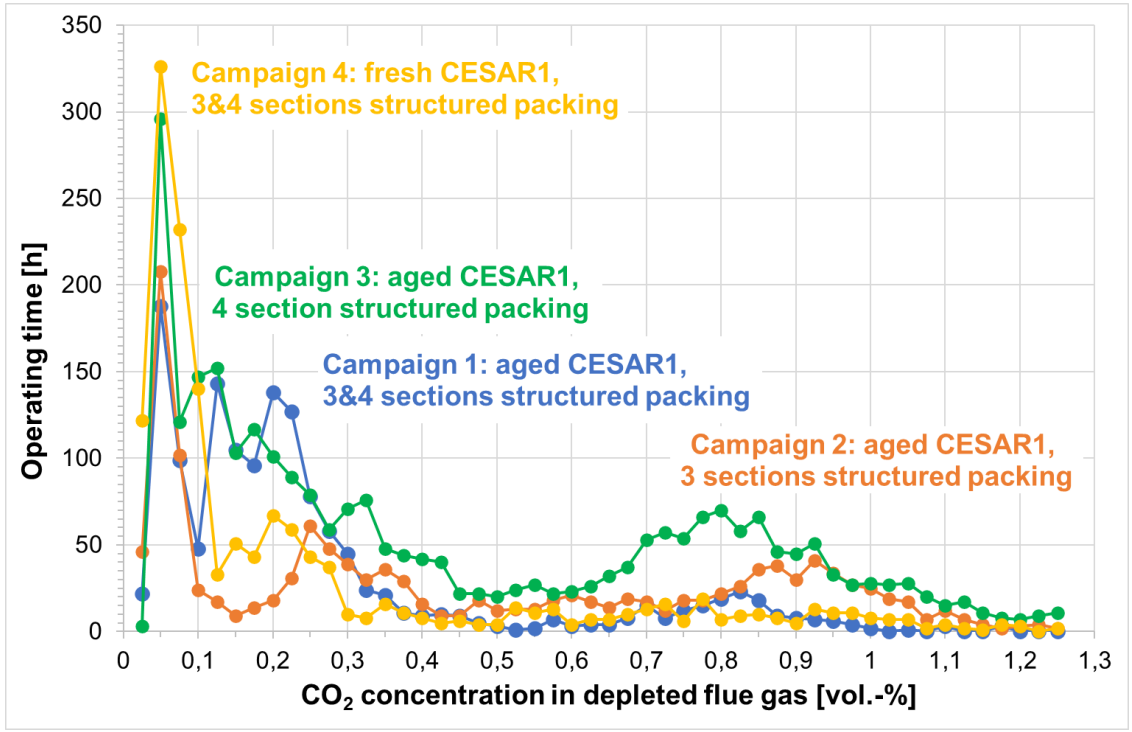


Results electrochemical regeneration

- Electrically driven CO_2 regeneration
  - Two technologies ZEUS (Hovyu/TUE) and CODEC (TNO)
  - Demonstrate (better) alternative to thermal regeneration
  - Operate with inorganic salts
  - Compare with SoTA technologies (target 3 GJ/ton CO_2)
- Both systems are under construction and soon ready for operation at TNO
- Both systems will be:
  - Integrated and tested with the TNO Mini Plant in the lab with synthetic flue gas for various sectors to determine the performance.
  - One of them will be selected for an onsite experimental campaign at CEMEX in Czech Republic.

Results thermal deep removal

Longer, non-interrupted testing periods with capture efficiencies >99%



- More than 2,100 operating hours during the four campaigns with residual CO_2 concentration in the depleted flue gas <1,000 ppm
- Highest capture efficiencies have been achieved in non-interrupted longer test periods:
  - **Campaign 2**: at 130.5°C regeneration temperature **193 hours: 99.69%, 436 ppm**
  - **Campaign 4**: at 129.1°C regeneration temperature **292 hours: 99.70%, 539 ppm**
  - **Campaign 4**: at 119.5°C regeneration temperature **100 hours: 99.75%, 514 ppm**

18.09.2025 Effect of Solvent Aging on the Performance of CESAR1 at Highest Capture Rates of 98.0-99.9%, Moser et al., PCCC-8, Marseille, France

ACERT

ACERT – Advanced CO2 capture and Energy Re-covery Technology

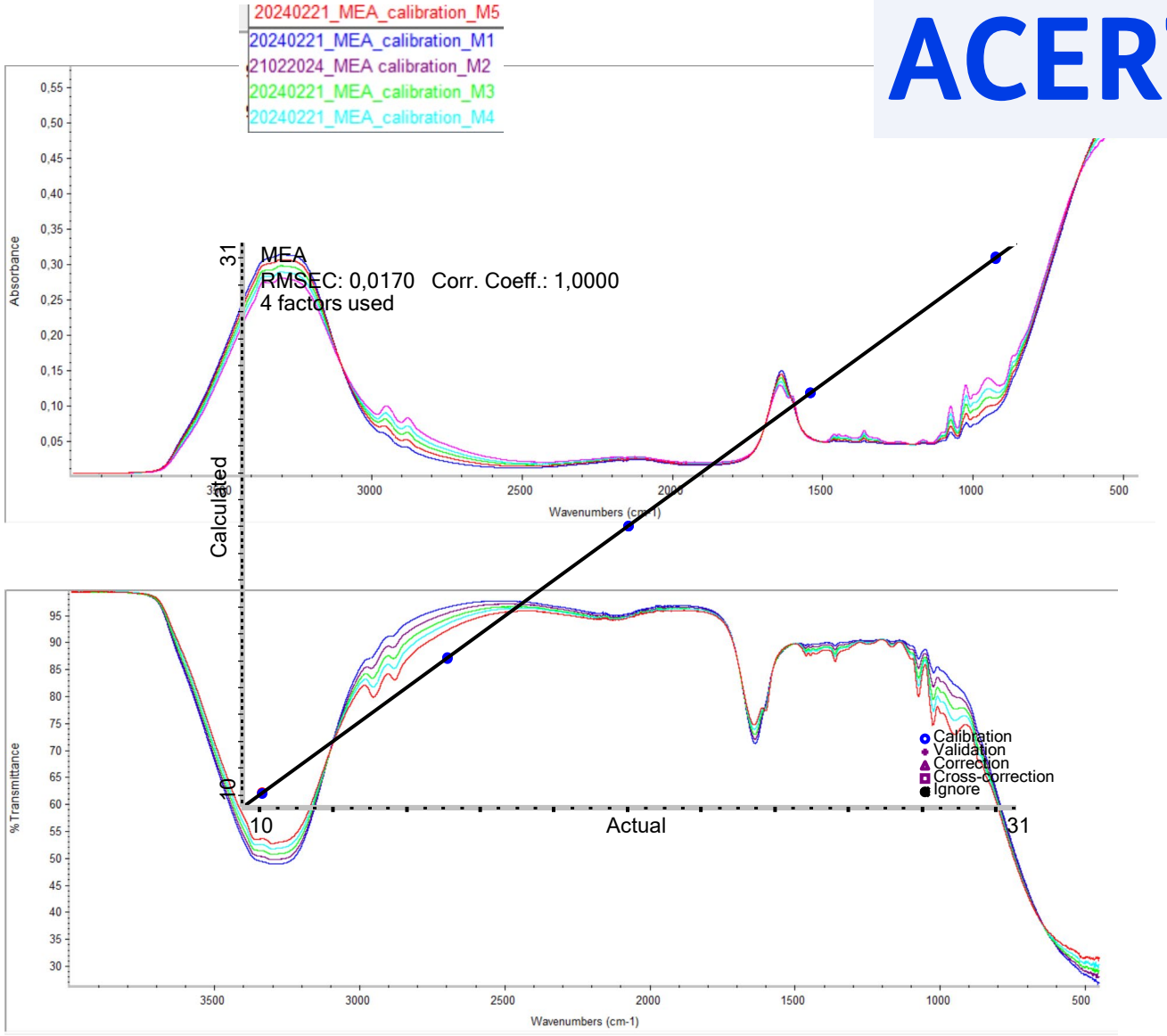
Objectives

ACERT

- Demonstrate novel CO_2 capture technology Hyperion at a CC pilot
- Develop and assess the integration potential of heat
- Develop and demonstrate TNO's online solvent monitoring system
- Identify cost reduction potential (and increase energy recovery efficiency) at an incineration plant

The hardware

The Mini ATR which is the heart of the online monitoring system

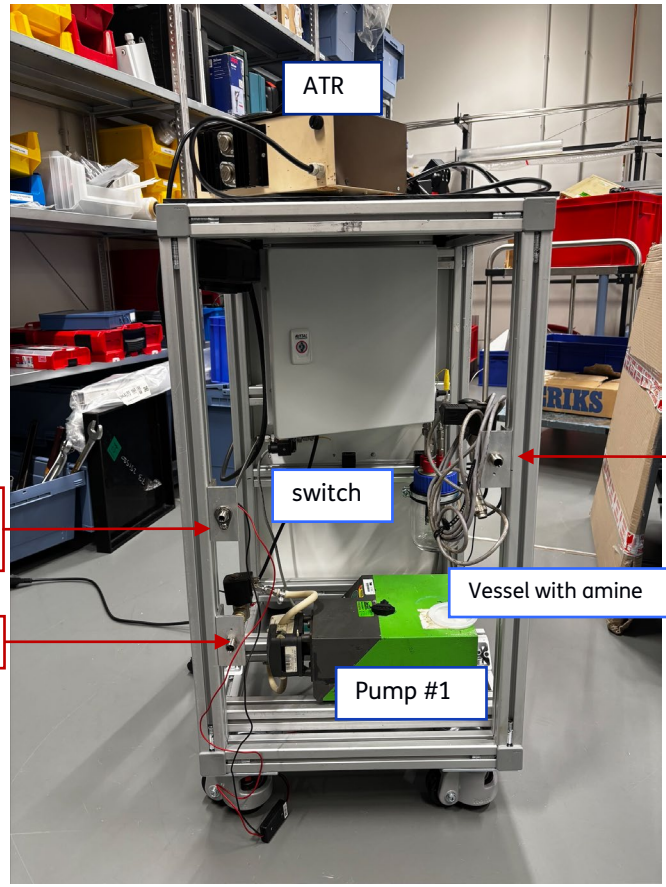


ACERT

ACERT

Online monitoring initial design

The Mini ATR has a continuous flow cell and is build into an automated system for online sampling and analysis



SolveMORE

Solvent Management Optimisation for Reducing Environmental footprint of the CO_2 capture process

SINTEF

CARBON CENTRIC

CARBON CIRCLE

LIÈGE université

RWE

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES ROUEN NORMANDIE

CUURIOS

ENTRAIN Engineering

NTNU

TNO

Objectives

SolveMORE

Solvent Management Optimisation for Reducing Environmental footprint of the CO_2 capture process

- Improve solvent management for CO_2 capture by reducing solvent degradation.
- Focus on CESAR1, a 2nd-generation benchmark solvent for post-combustion capture.
- Builds on insights from previous projects (ALIGN-CCUS, LAUNCH, SCOPE, AURORA).
- Focus on improving solvent management:
  - Lowering costs
  - Reducing emissions
  - Improving operational safety

Activities

SolveMORE
Solvent Management Optimisation for Reducing Environmental footprint of the CO_2 capture process

- Research & Development:
  - Pilot plant campaigns at RWE's site in Niederaussem.
  - Laboratory and bench-scale experiments and detailed analysis.
  - Computational modelling of degradation mechanisms.

- Key Deliverables:
  - Technical solutions to reduce solvent loss, emissions, and waste by 50%.
  - Recommendations for optimal solvent management strategies.
  - Development of COMPASS tool for online solvent quality monitoring.
    - TNO and the Dutch company Cuurios will extent the online monitoring tool build in ACERT with AI Machine Learning algoritms.

- Target TRL for solvent management: TRL 3–4 → TRL 6.

Acknowledgements

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Thank you for your attention