SINTEF

HiPerCap - High Performance Capture
FP7 Grant agreement n° 608555

HiPerCap

HiPerCap overview and major results

Hanne Kvamsdal, SINTEF Materials and Chemistry

Hanne.Kvamsdal@sintef.no

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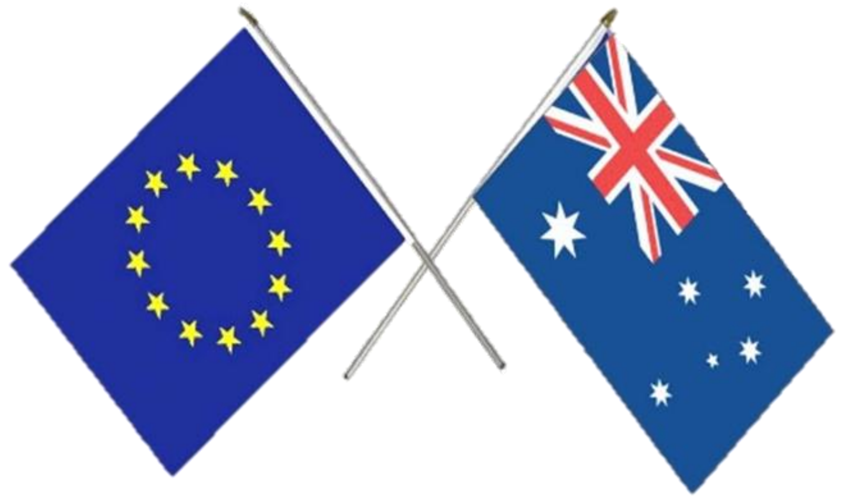
Outline

- ❑Project overview
- ❑Project objectives
- ❑Technology development in the project
- ❑Technology assessment and benchmarking
- ❑Major results
- ❑Remaining work

EU project HiPerCap



❑EU-Australia twinning project

- ✓ Call specifically important twinning with Australian partners and projects
- ✓ 5 other projects funded within the same call

❑Coordinator: SINTEF MC

- ✓(Dr. Hanne Kvamsdal)

❑Duration:

- ✓4 years, Jan 2014 - Dec 2017

❑Budget:

- ✓7.7 M€ (4.9 M€ from EU)

http://www.sintef.no/projectweb/hipercap/

Project partners:

Project objectives

- ❑Develop environmentally benign energy- and cost-efficient technologies for post-combustion capture
- ❑Develop a methodology for fair comparison and benchmarking of the technologies
- ❑Develop technology roadmap for the two most promising technologies

Key focus on potential of the capture technologies

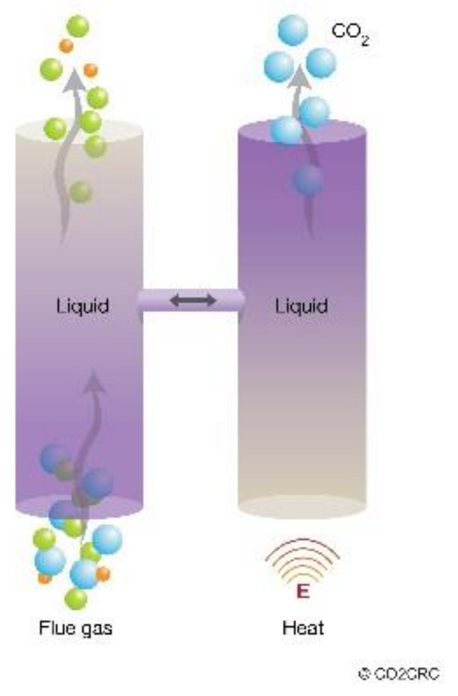
Specific objective:

- Reduction of 25% energy pentalty compared to the State-of-the-Art

Post-Combustion capture technologies in HiPerCap

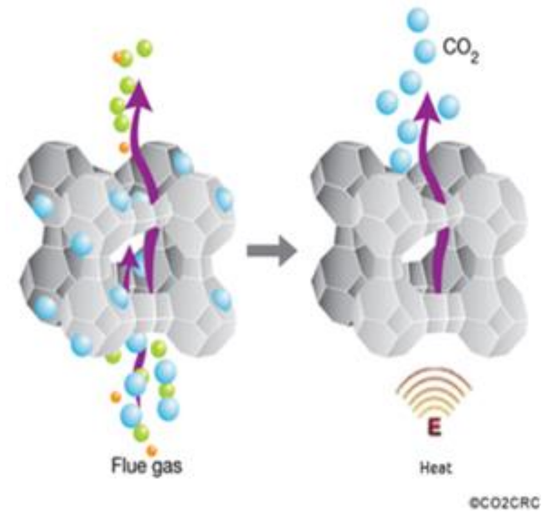
❑Absorption

- Proof-of-concept of 4 solvent concepts
- Feasibility study of bio-mimicking concept



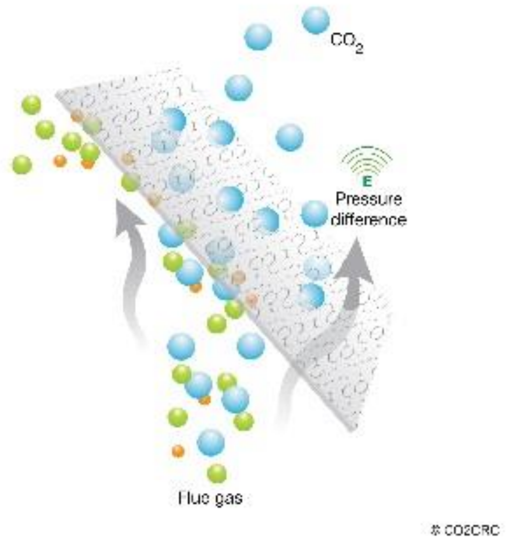
❑Adsorption

- Testing of various sorbents including "green" sorbents
- Studying two reactor systems (fixed-bed and moving-bed)



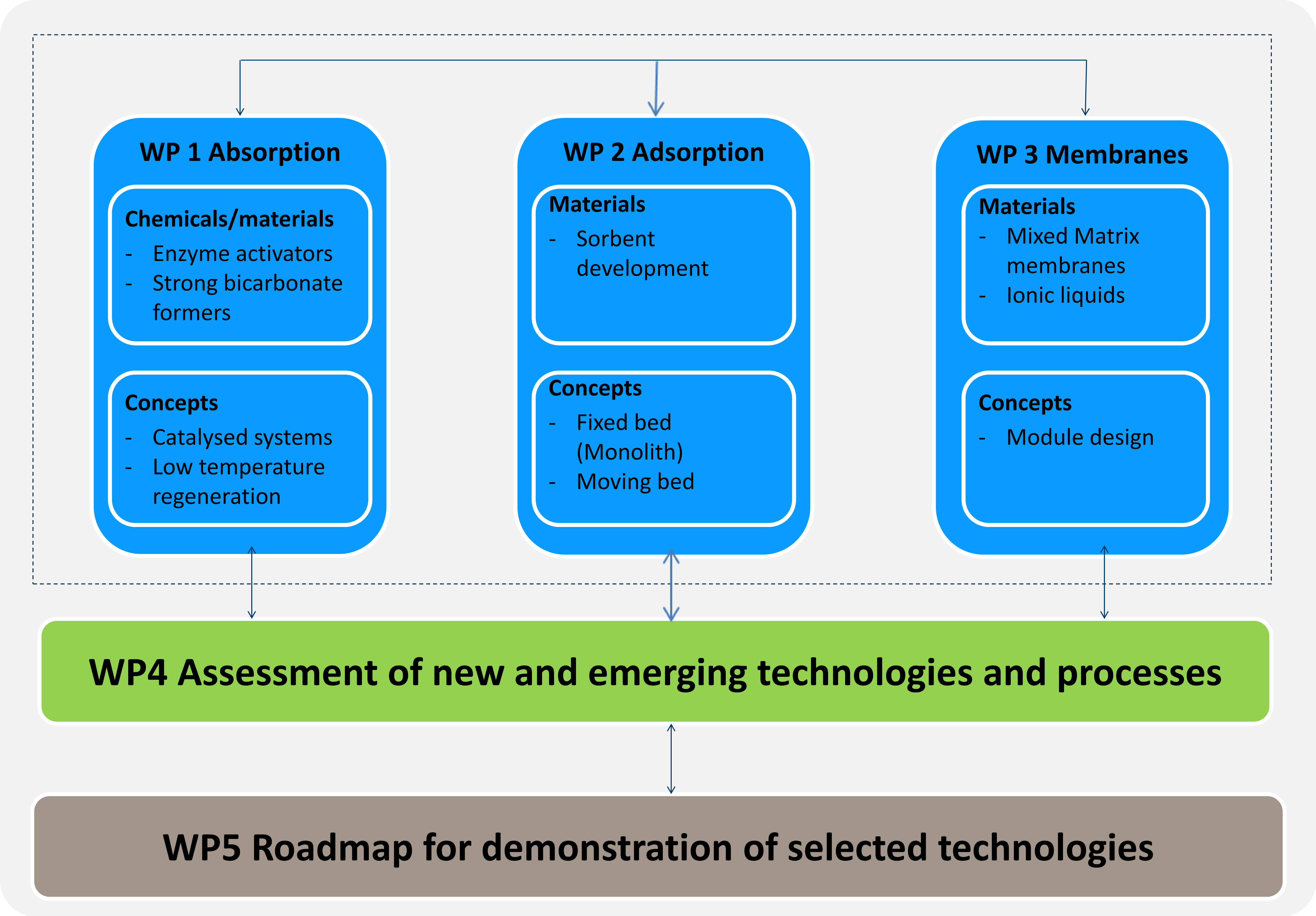
❑Membrane

- Hybrid (polymer + nanoparticles) membranes
- Supported ionic liquid membranes

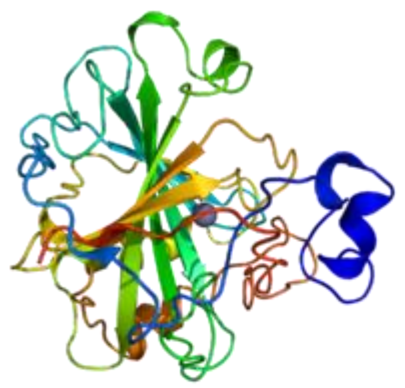


Images: www.co2crc.com.au

Project overview



WP1 ABSORPTION (LED BY TNO)



➢ Enzyme catalysis of CO_2 absorption (led by Procede)

Objective

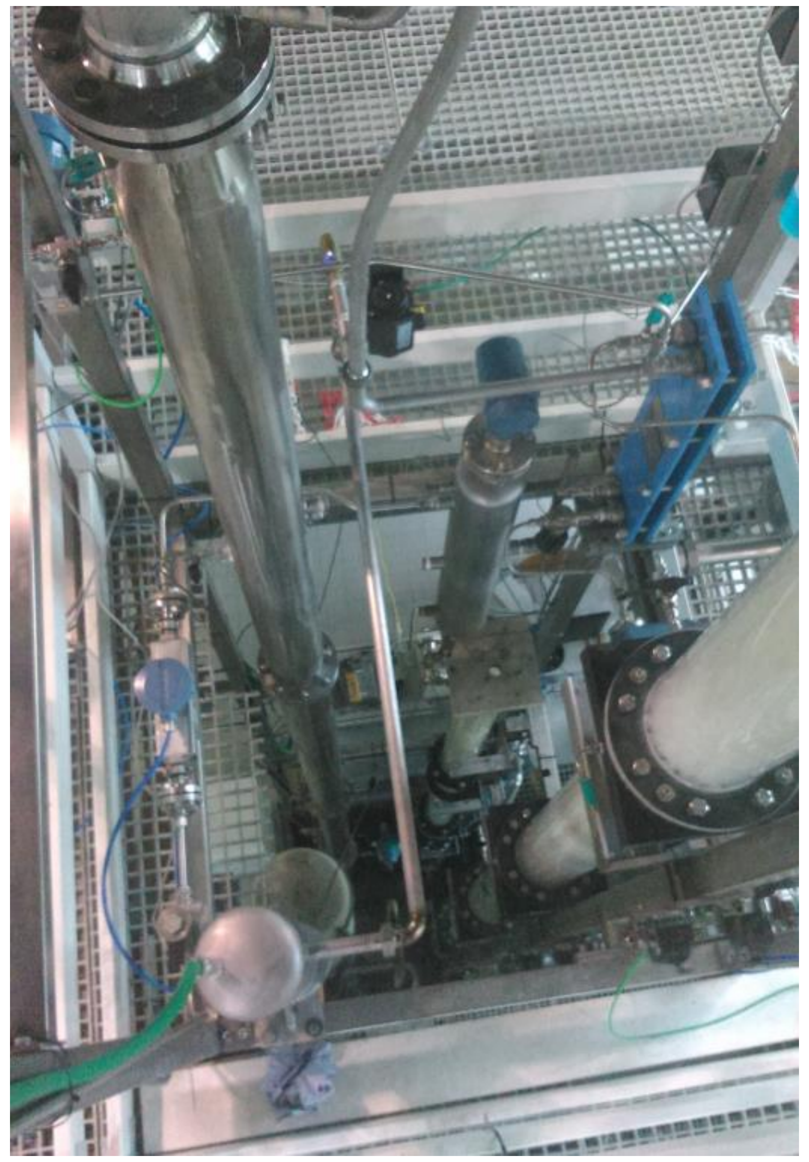
- An optimal enzyme-catalysed absorbent process where enzyme is not degraded by the stripper
- Show 10% improvement in energy performance over system without catalysis

Challenges

- Enzyme stability throughout the process
- Separation of the enzymes prior to desorption

Results

- Mass transfer with several amines promoted with the Carbonic Anhydrase (CA) studied. DMMEA gave the best result.
- Simulations show 15% SRD reduction with (DMMEA+CA) compared to the benchmark (CESAR 1), however, the height of packing in the absorber is 70 m
- Successful pilot demonstration of enzyme-enhanced CO_2 capture Membrane unit successfully kept enzymes from stripper



Procede Pilot set-up:
8.5m * 175mm Absorber
8.5m * 100mm Desorber

WP1 ABSORPTION (LED BY TNO)

➢ Precipitation solvent systems (led by TNO)

Objective

- Regeneration of only the CO_2 containing part of the solvent.
- Minimization of emission by the use of amino acids

Challenges

- Process control with solids present and the handling of large scale slurries.

Results

- Several packing materials tested. Open structured packing types (Montz B1) selected
- Thermodynamic model developed based on experimental data (VSLE, dHabs, etc.)
- Flowsheet calculations shows 15% improvements in thermal heat requirement, but integrated with power plant only 7 % improvement

TNO bench scale set-up:
1.2m * 65mm Absorber

WP1 ABSORPTION (LED BY TNO)

➢ Strong bicarbonate forming solvents (led by NTNU)

Objective

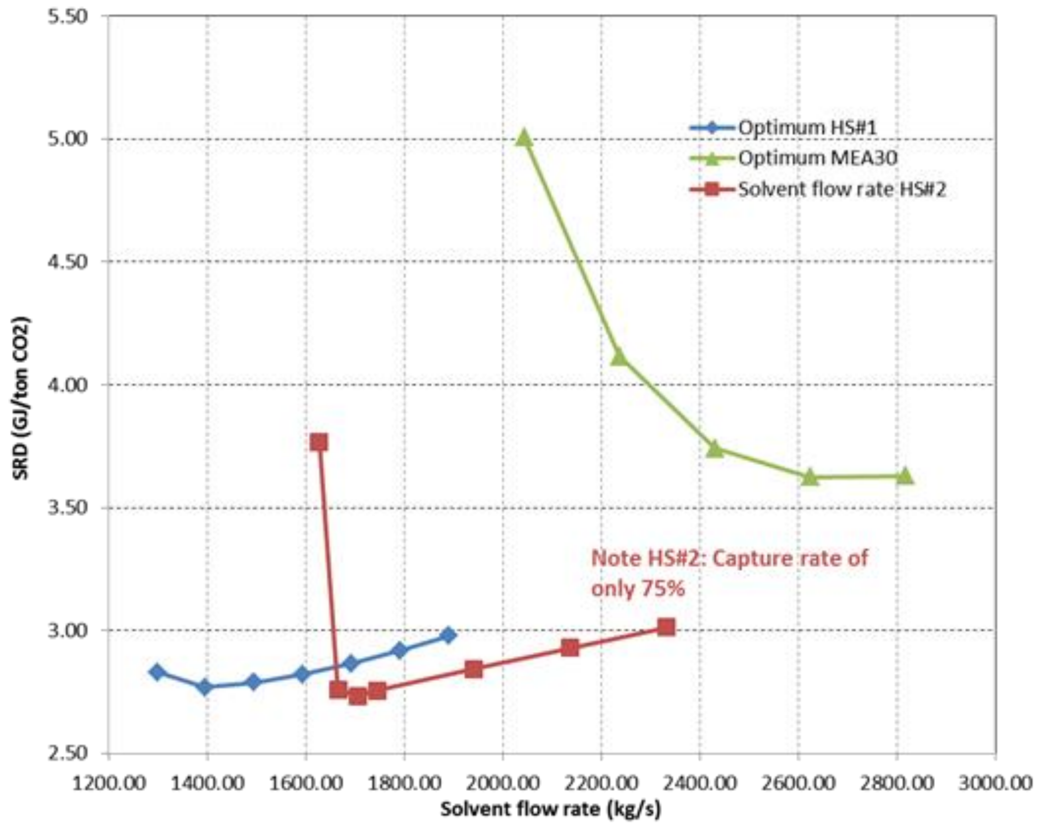
- Demonstrate 5% higher cyclic capacity than MEA and
- 15% reduction in efficiency penalty over state-of-the-art solvent (CESAR 1)

Challenges

- Limited understanding of "molecular structure – performance" relation
- Absorption rate can be slow

Results

- Two promising solvent candidates (HS#1 and HS#2) identified
- Several promoters tested and one selected for further study with HS#1 and HS#2
- Cyclic capacity is 8 and 10% higher, while SRD 10 and 4% higher compared to CESAR1 at 90% CO_2 removal
- Both solvents have better environmental properties than CESAR1, HS#2 the best
- Some tests with an activator is promising (tested further as part of WP5)



Process optimization in CO2SIM

WP1 ABSORPTION (LED BY TNO)

➢ Integration of CO_2 absorption with utilization (using algae) (led by TNO)

Objective

- Demonstrate algae production from a CO_2 rich solvent solution

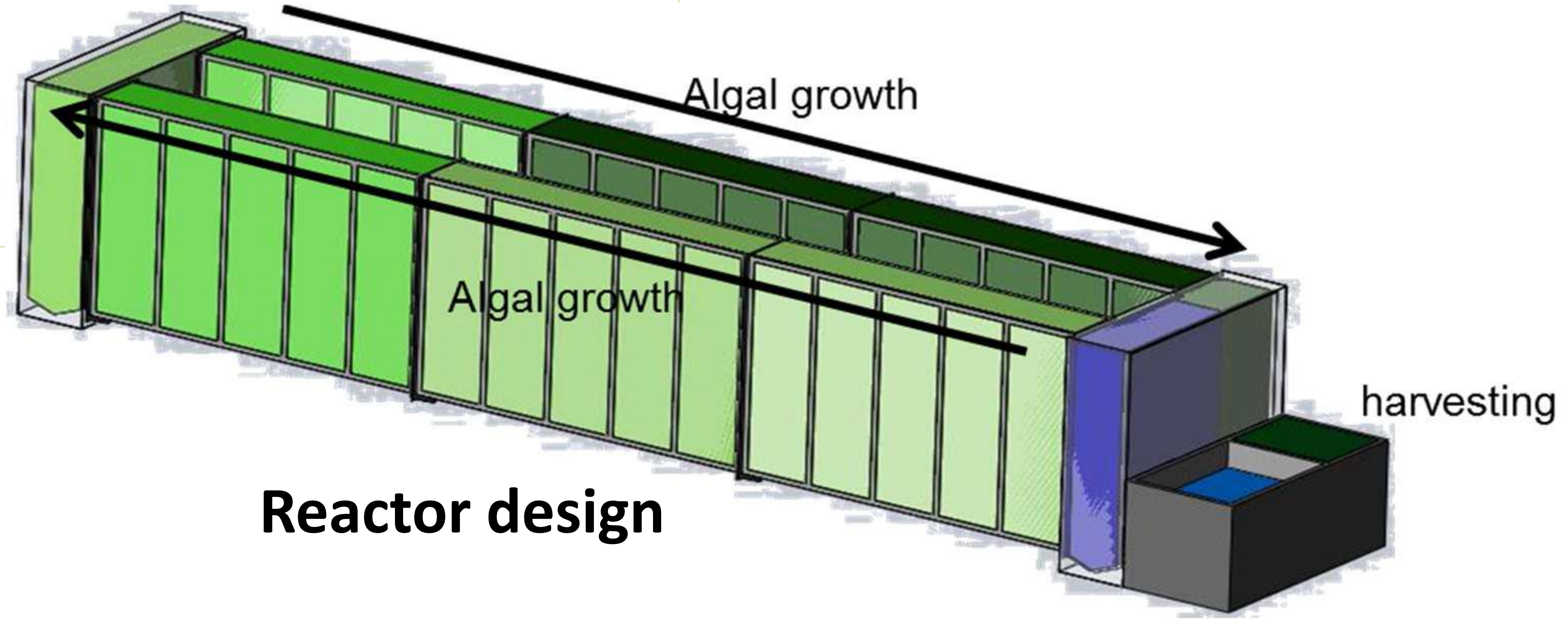
Challenges

- Solvent selection, optimize process conditions, resistance against impurities in flue gas.

Results

- Concept developed and experimentally proven
- Demonstration with real flue gas
- Process model is developed for scale-up studies

Algae growth test set-up:
Effect of pH, solvent and light intensity



Reactor design

WP1 ABSORPTION (LED BY TNO)

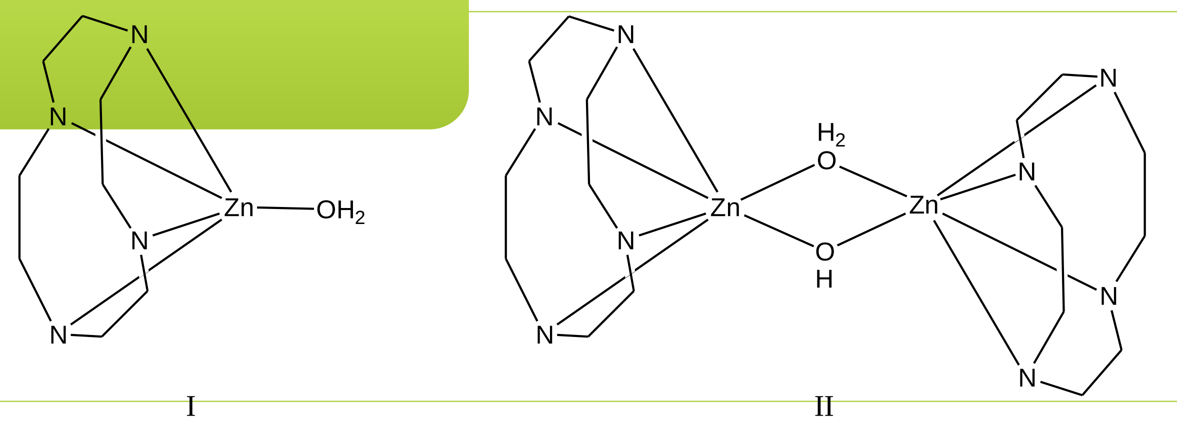
➢ Bio-mimicking study (led by SINTEF)

Objective

- Assessment of bio-mimicking as a concept for enhanced CO_2 absorption

Challenges

- Complicated synthesis with low yield
- Expensive catalyst



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Results

- 2 zinc complexes (bio-mimicking catalysts) synthesized and tested
- Increase in absorption rate compared to MDEA observed, however the effect is small compared to the carbonic anhydrase (biocatalyst)

Stirred cell reactor for mass transfer study

WP2 ADSORPTION (LED BY CSIC)

➢Sorbent development (Led by CSIC)

Objective

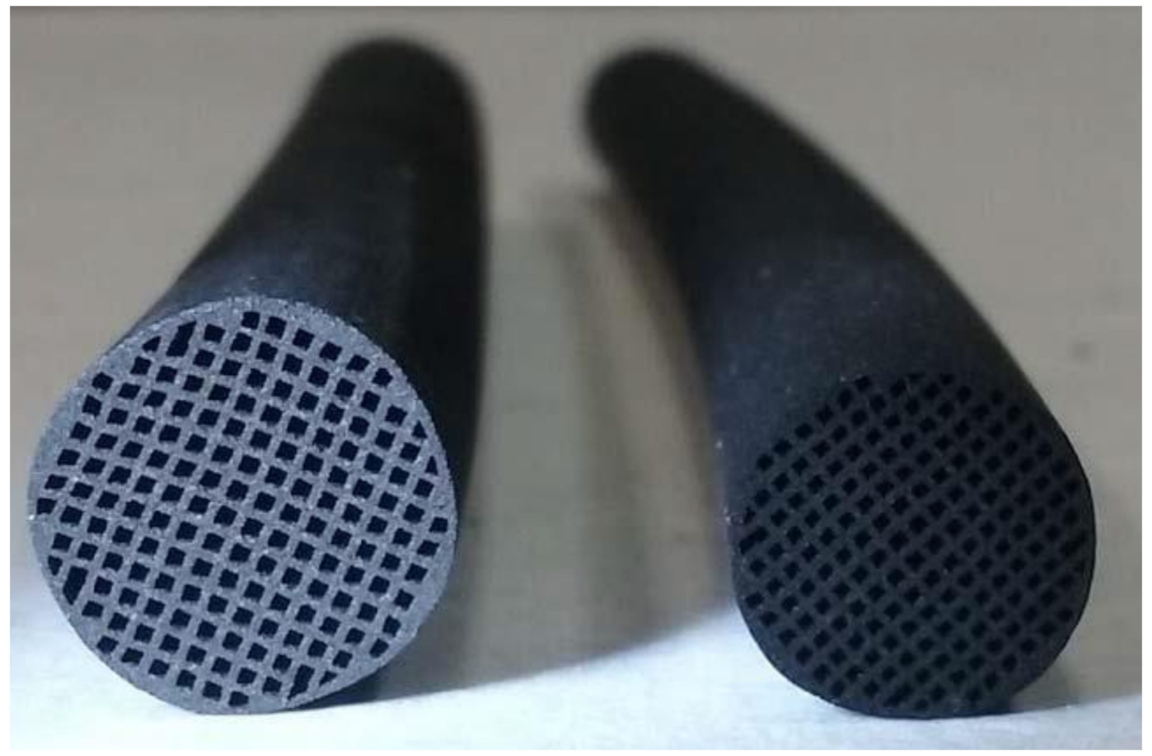
- Development of low temperature solid sorbents, low cost and with a high surface area

Challenges

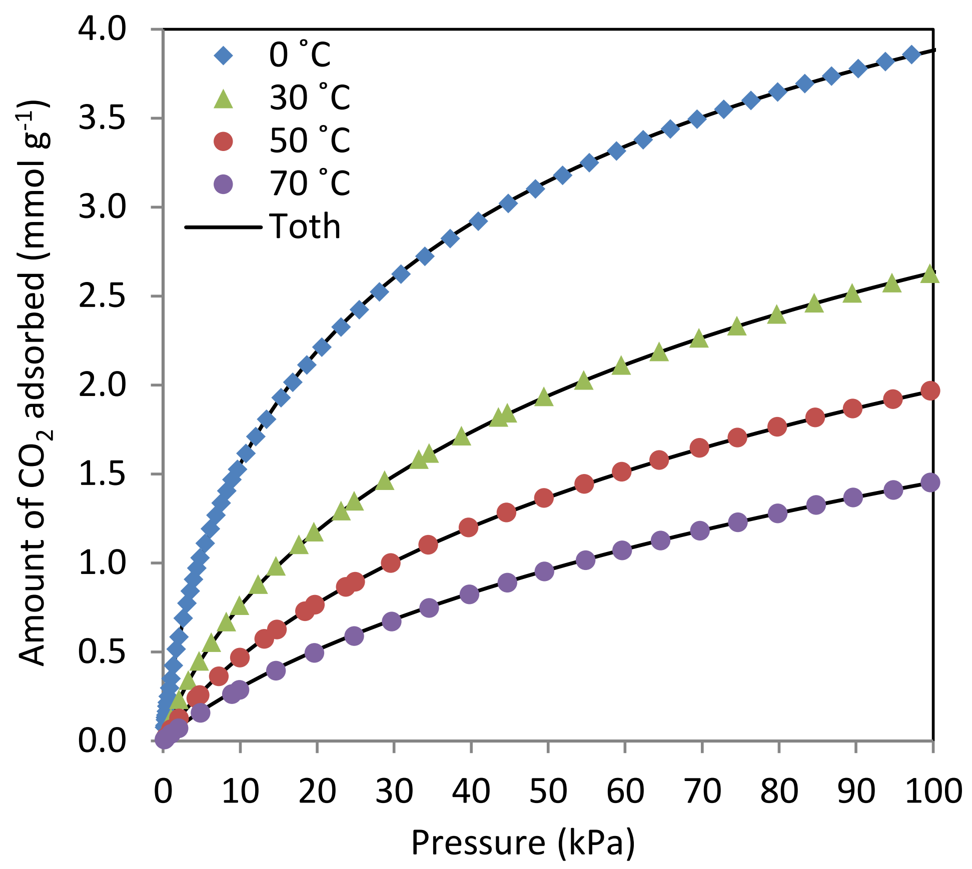
- Identification of materials suitable for the targeted process environment

Results

- Low-temperature carbon-based solid sorbents (both particulates and structured) developed, characterized and tested
- Targeted adsorption capacities reached, experimental facilities and materials have been set up, characterization tests completed
- Some promising monoliths tested with real flue gas from a coal power station (Maasvlakte)
- Exchange of two samples for cross-characterization between CSIRO (Australia) and CSIC (EU)



MAST Carbon monolith



CO_2 isotherms on MAST's monolith

WP2 ADSORPTION (LED BY CSIC)

➢Process development (Led by CSIC)

Objective

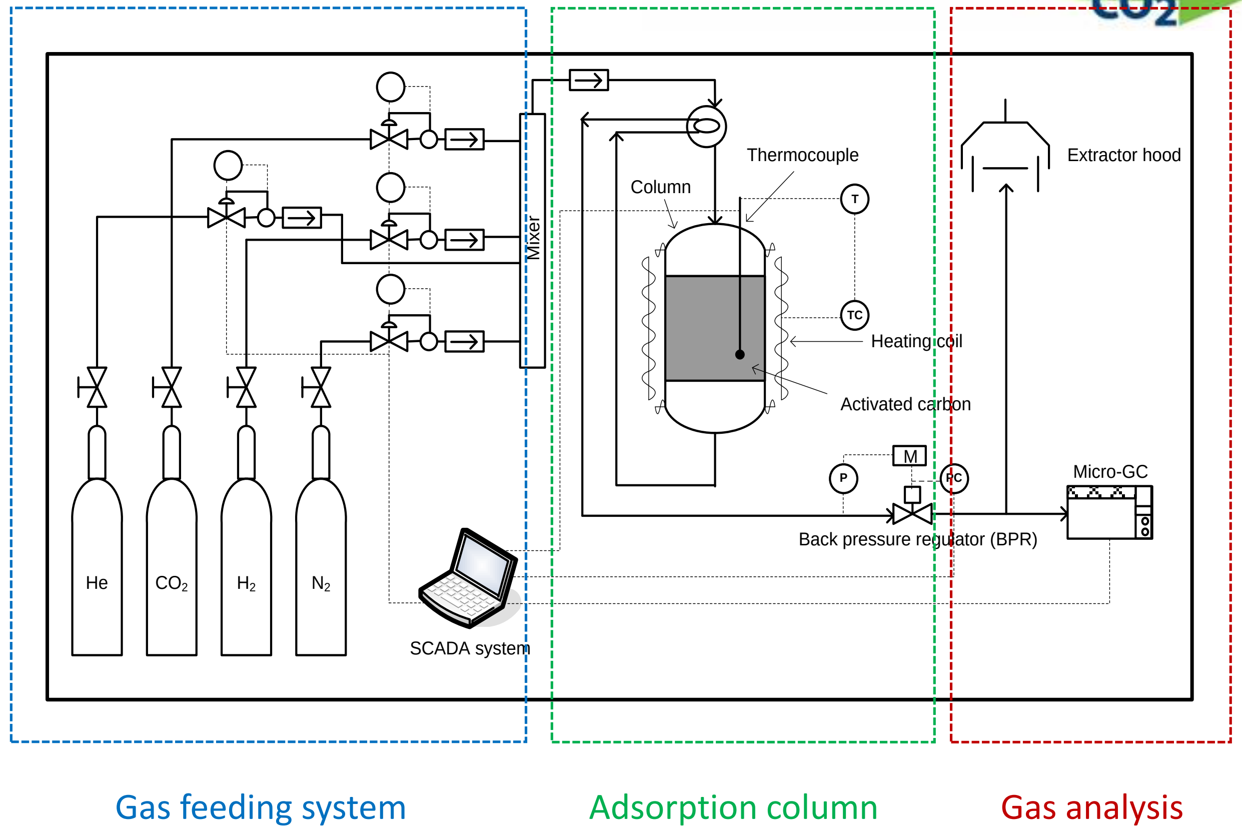
- Develop temperature swing adsorption process (fixed and moving bed concepts) for a full scale adsorption plant including the thermo-process integration with the power-plant

Challenges

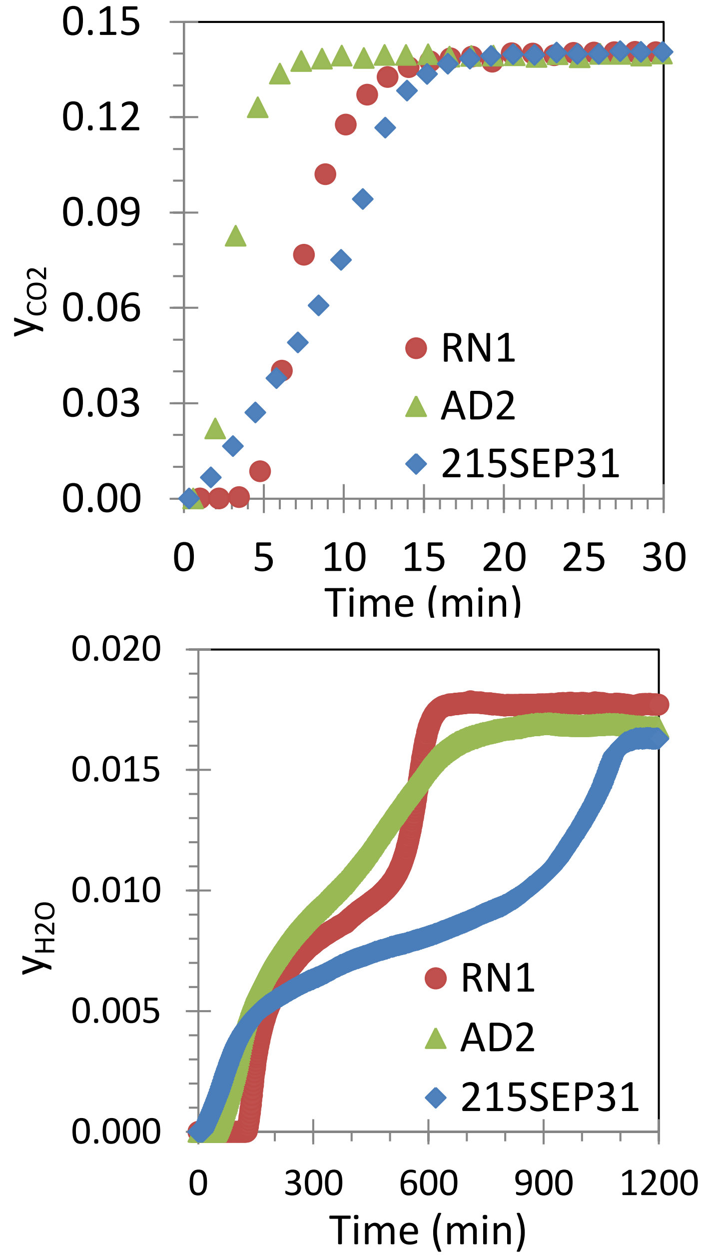
- Develop correlations describing kinetics and equilibrium relations for multi-component systems
- High uncertainty level in the models as data from relevant pilot plant are very limited
- The Aspen model does not allow condensation of steam (difficult to determine optimal operating conditions).

Results

- Breakthrough experiments performed in a lab-scale fixed bed unit with synthetic humid flue gas on carbon monoliths
- Process development for fixed-bed cyclic process using Aspen Adsorption model parameters based on data from lab experiments. A two-stage approach for the fixed-bed is established in order to meet the recovery (85%) and purity specifications (95% dry basis) for the CO_2
- Unit models for the different sections of the moving bed unit are being developed and implemented in gPROMS
- Both cases integrated with power-plant and energy numbers calculated



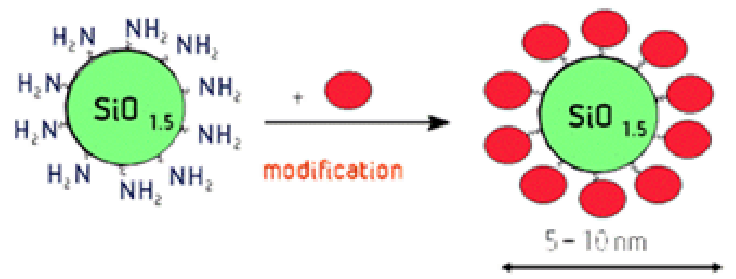
Fixed-bed experimental set-up



Breakthrough curves: RN1 (granular-biomass), AD2 (monolith-biomass) and 215sep31 (monolith-resin)

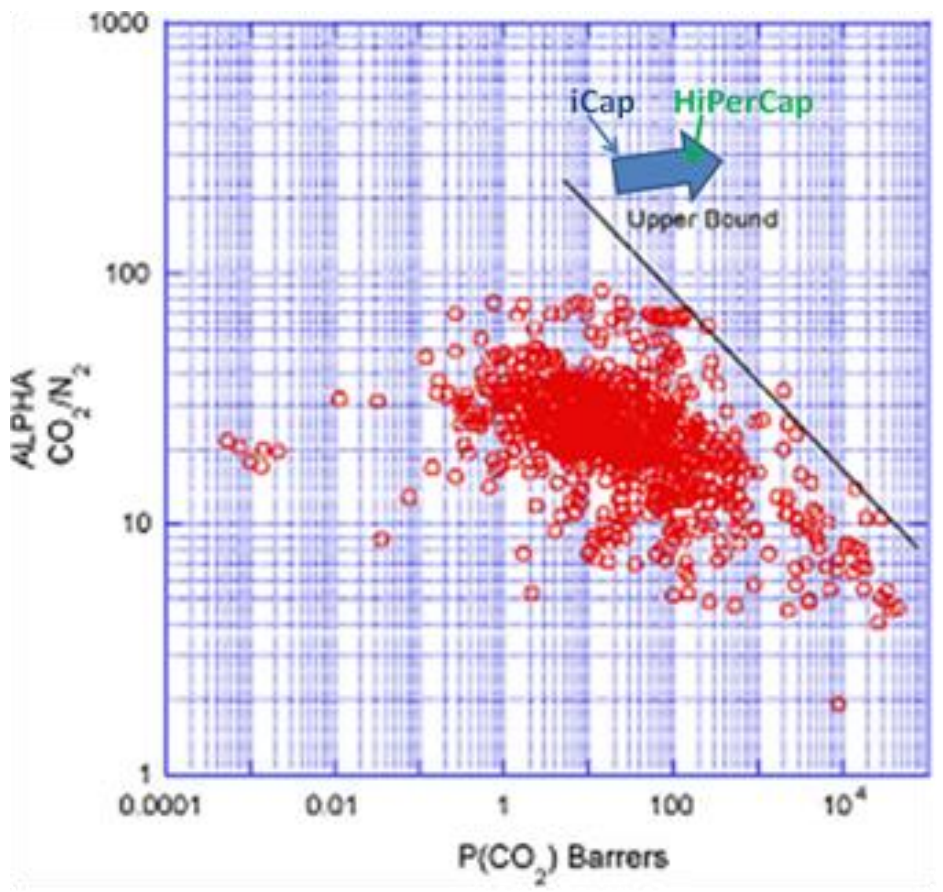
WP3 MEMBRANES (LED BY NTNU)

➢Hybrid and supported ionic liquid membrane development



Objective

- Develop:
  - high flux mixed matrix membrane with incorporated nanoparticles in a polymer
  - supported ionic liquid (IL) membranes
  - nanoporous polymer/ILs membranes

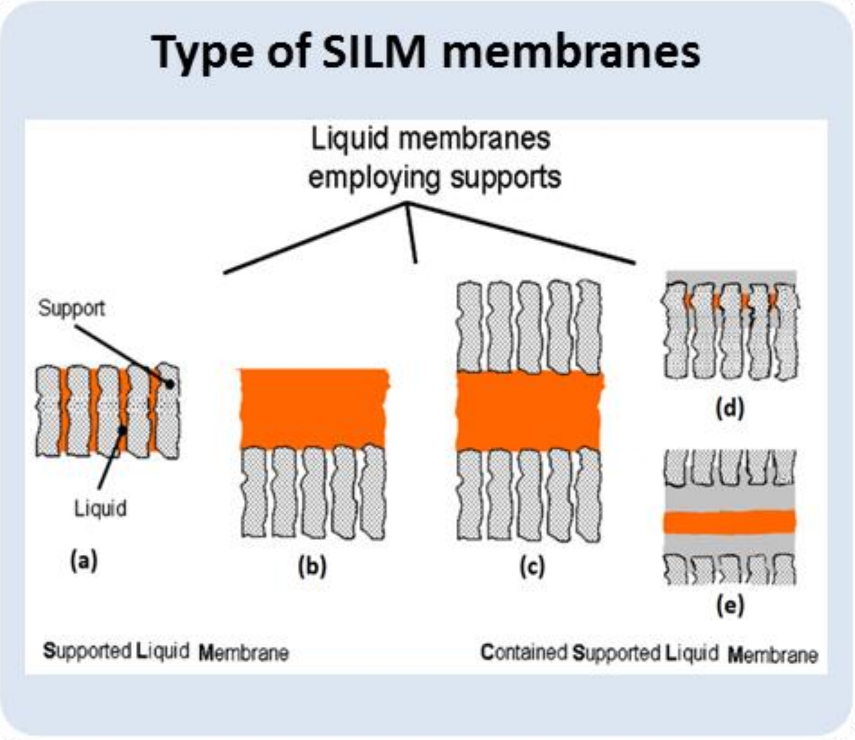


Challenges

- Membrane performance (permeance, selectivity)
- Large scale manufacturing and durability

Results

- Two types of hybrid membranes developed: excellent durability in tests with SO_2, but performance below the target (2.5 m^3/m^2h bar permeance; 100 selectivity CO2/N2)
- 3 ILs and 6 polymers selected for supported ILs membranes. Different membranes prepared and tested. High permeance (4 m^3/m^2h bar) achieved but selectivity is below the target (100)
- Nanoporous polymer/IL membranes prepared. Performance close to the targeted values (12-15 m^3/m^2h bar; 20-30 selectivity CO2/N2)
- Model developed for the hybrid membrane and a two stage process model is develop using Aspen Plus
- Four cases integrated with power-plant



WP4: ASSESSMENT AND BENCHMARKING IN HIPERCAP (LED BY DNV GL)

Develop and apply an assessment methodology for emerging technologies on different TRL-level

Idea

- Develop a KPI based methodology with a consistent way of scaling up to a representative scale of application.

Work in the project

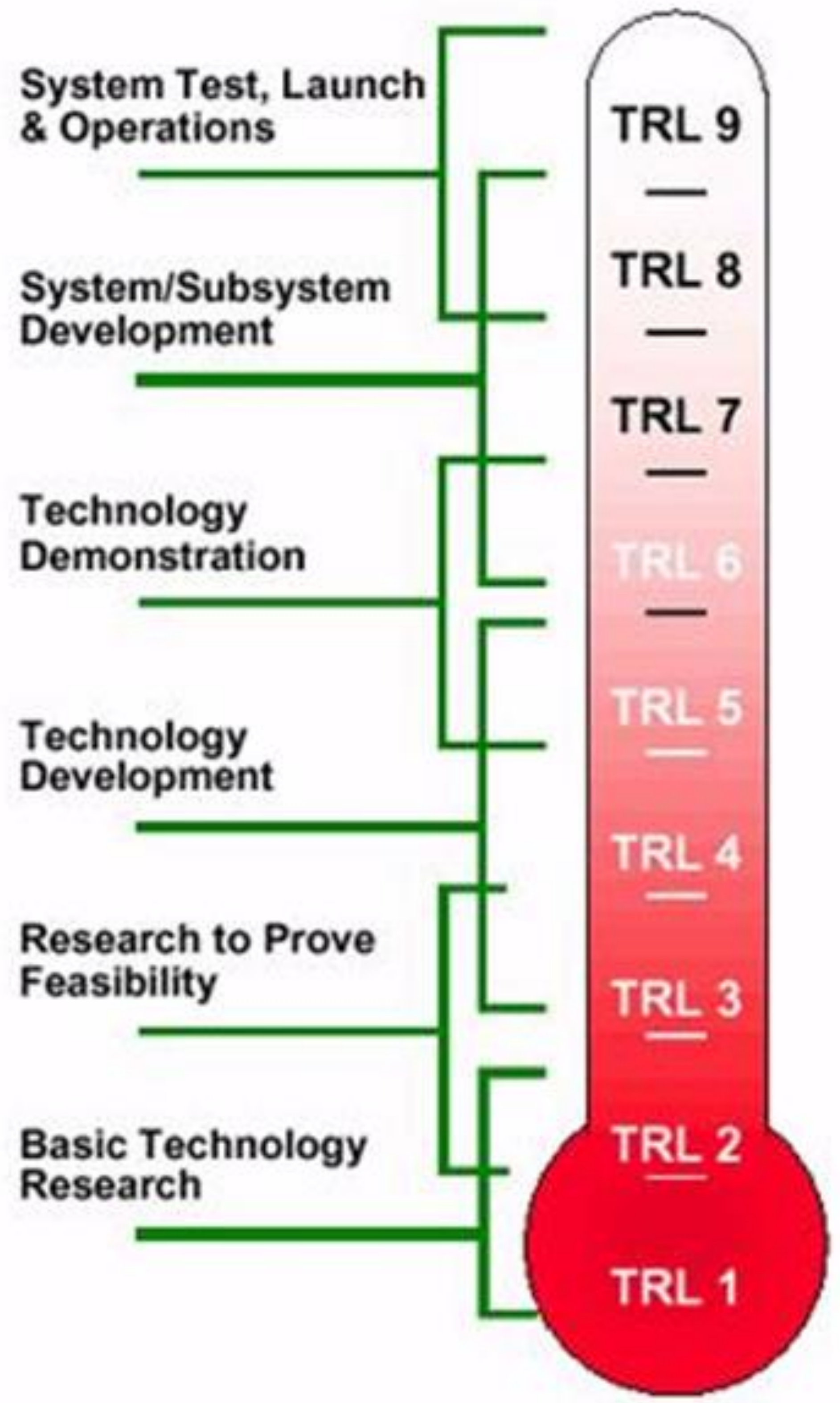
- Define a clear base case, use defined system boundaries, modeling approach and comparison criteria. Select the two most promising technologies for further studies.

Challenges

- Develop a fair methodology for comparison of immature technologies at different TRL levels.

Results so far

- Methodology developed based on two stage selection process
- Reference case established and the integrated process simulated
- Assessment finished for all chosen concepts and benchmarked to the reference
- Cost KPI method developed and assessment finished for all chosen conepts
- Two technologies with highest rank chosen for further studies



WP5: Technological roadmap for development of CO_2 capture technologies (led by Uniper)

›Develop a technological roadmap for the industrial demonstration of the two chosen technologies.

Idea

- Identify any gaps in knowledge required for implementing the technologies at industrial pilot units.

Work in the project

- Detailed studies of the two selected technologies. Identifying knowledge gaps concerning the technology and establish a plan for closing these gaps. Improvement of concepts and models for new benchmarking in WP4

Challenges

- Short time and limited budget for improvements

Results so far

- Knowledge gaps identified for both technologies
- Improvement of concepts and models are ongoing work

WHAT NEXT ?

- Finish work in WP5 to develop a technological roadmap for the industrial demonstration of two chosen technologies.
- Make a plan for demonstrating the technology at an industrial pilot plant.
- New benchmarking of the two technologies in WP4
- Public summary of major achievements

Thank you for the attention!