HiPerCap - High Performance Capture
FP7 Grant agreement n° 608555

Overview of HiPerCap results so far

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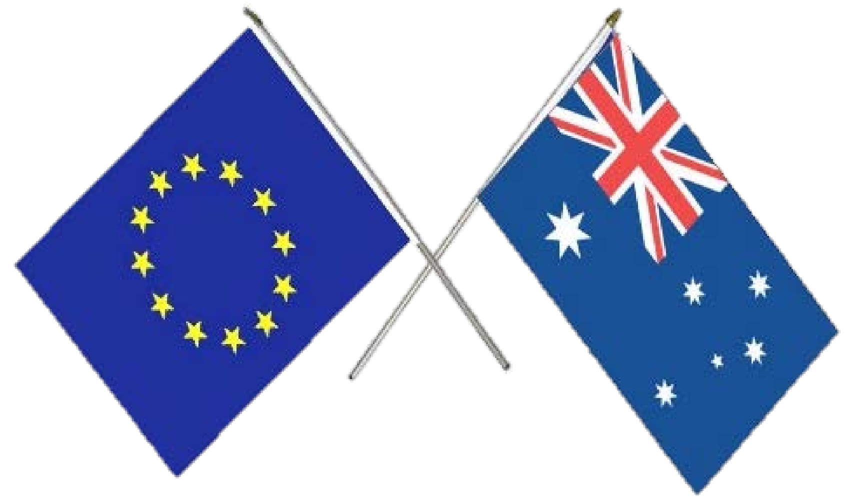
Outline

- ❑Project overview
- ❑Project objectives
- ❑Technology development in the project
- ❑Technology assessment and benchmarking

SEVENTH FRAMEWORK PROGRAMME

EU project HiPerCap

- EU-Australia twinning project
- Coordinator: SINTEF MC (Dr. Hanne Kvamsdal)
- Partners:
  - 13 EU partners
  - 1 from Australia
  - 1 from Russia
- Duration:
  - 4 years, Jan 2014 - Dec 2017
- Budget:
  - 7.7 M€ (4.9 M€ from EU)



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

PROJECT PARTNERS

EDF

PROCEDE

CSIRO

gasNatural fenosa

SINTEF

ANDRITZ

TIPS RAS

e·on

CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

MAST

NTNU

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

CSIC

INSTITUTO NACIONAL DEL CARBÓN

TNO innovation for life

DNV·GL

Algae-Tech™

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 objectives

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

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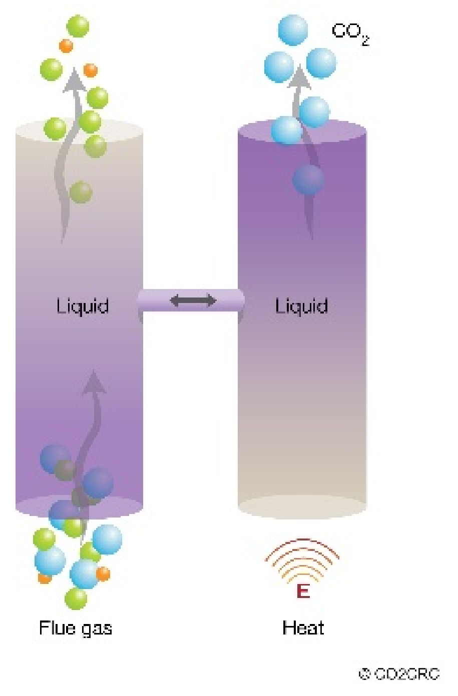
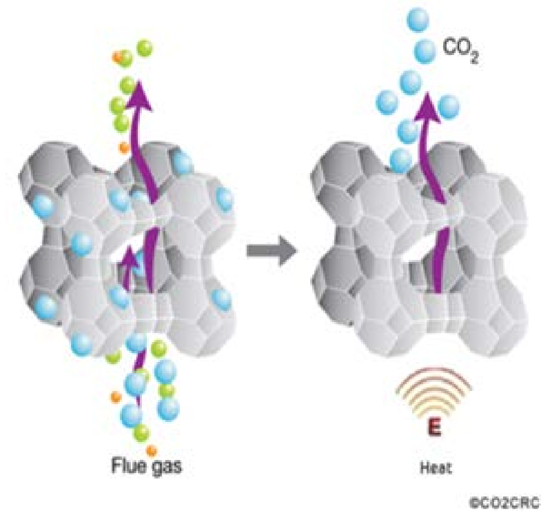
Post-Combustion capture technologies in HiPerCap

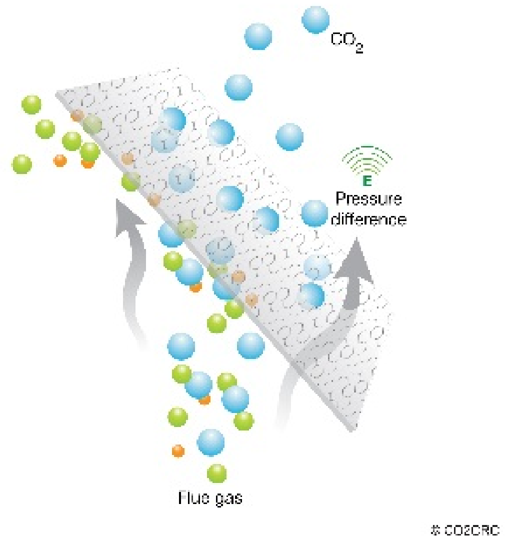
- Absorption
  - Proof-of-concept of 4 solvent concepts
  - Feasibility study of bio-mimicking concept



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

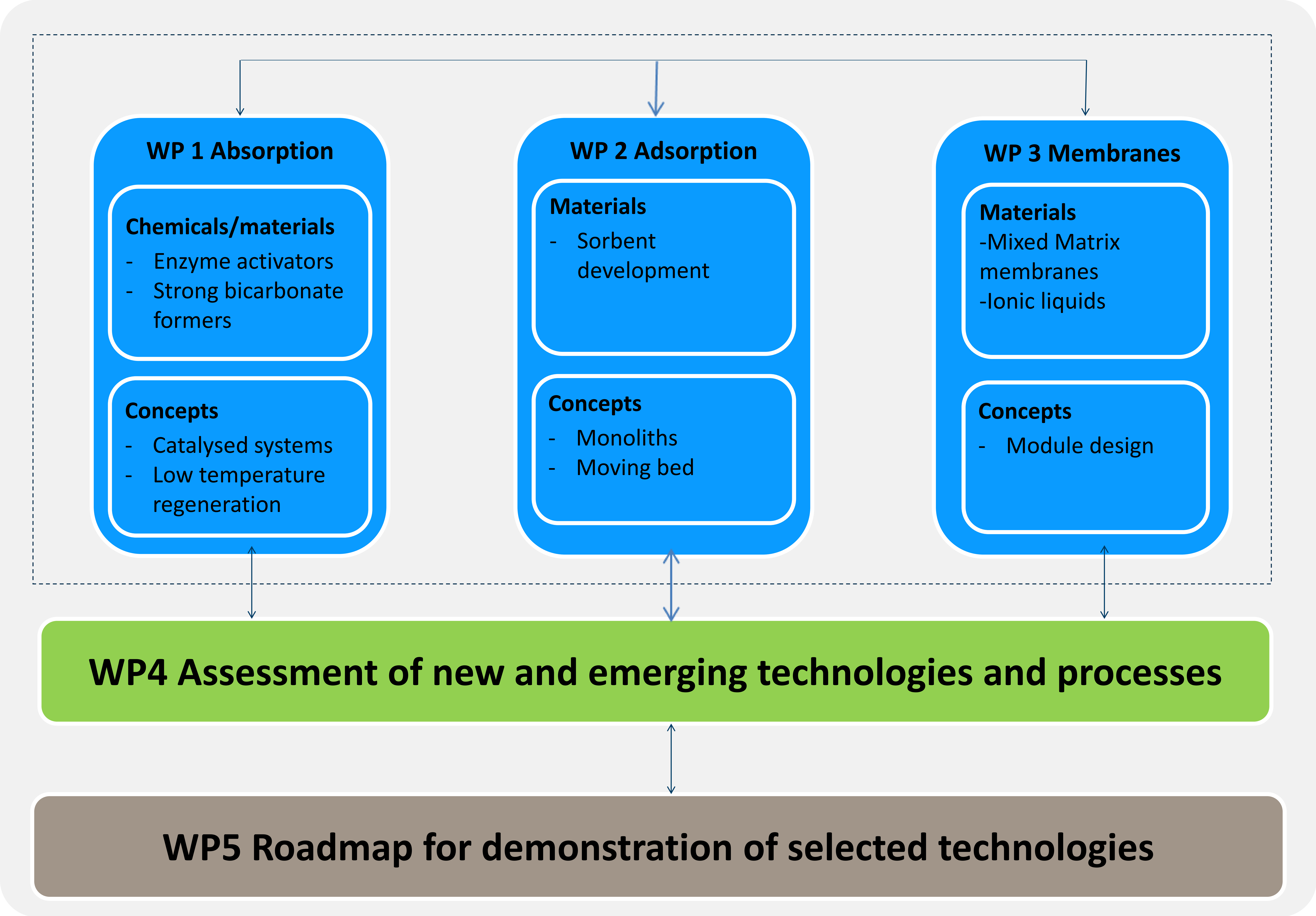


- Membrane
  - Hybrid (polymer + nanoparticles) membranes
  - Supported ionic liquid membranes



Images: www.co2crc.com.au

Project overview



WP1 ABSORPTION (LED BY TNO)

Enzyme catalysis of CO2 absorption (led by Procede)

Idea

- Enzymes in solvents can drastically accelerate the capture of CO_2. It’s an environmentally friendly promotor.

Work in the project

- Testing of carbonic anhydrase and develop and test an optimized process in a pilot plant

Challenges for this technology

- Enzyme stability throughout the process and separation of the enzymes prior to desorption due to the high temperature

Results so far

- 40 wt% DMMEA + enzymes best results so far, challenges with column heights to achieve 90% capture and some safety issues with DMMEA for testing

WP1 ABSORPTION

› Precipitation solvent systems (led by TNO)

Idea

- Regeneration of only the CO2 containing part of the solvent. Minimization of emission by the use of amino acids.

Work in the project

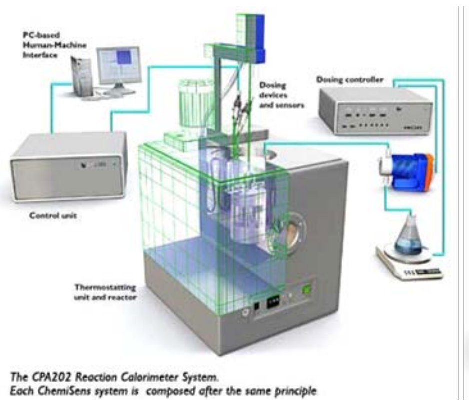
- Develop an process with the focus optimization of the absorber packing.

Challenges for this technology

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

Results so far

- Models for vapour-liquid-solid equilibria and several other thermodynamic properties developed based on experiments
- Preliminary flowsheet calculations shows thermal heat requirement of 2.4-2.5 GJ/ton CO2 (benchmark solvent is 2.8-2.9), 15% improvement



WP1 ABSORPTION

›Strong bicarbonate forming solvents (Led by NTNU)

Idea

- Bicarbonate forming solvents with high pKa will accelerate reaction kinetics and allow for lower regeneration temperature.

Work in the project

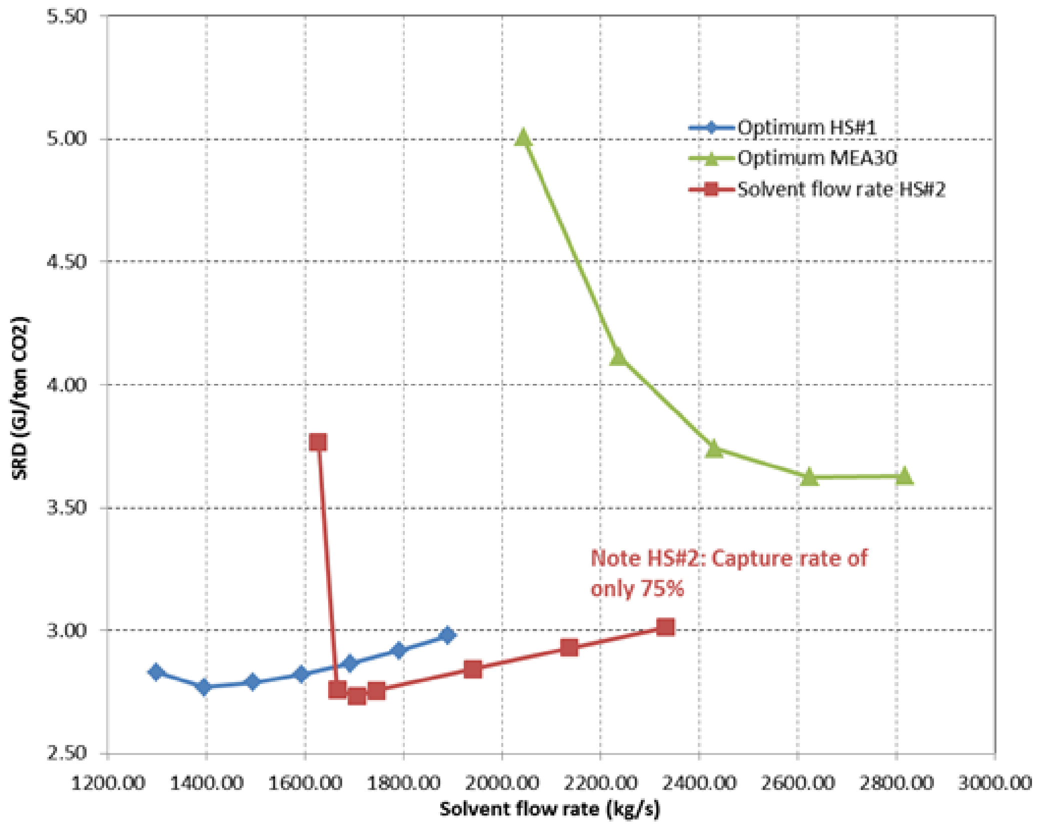
- Screening activity to find promising candidates for detailed studies.

Challenges for this technology

- There are many candidates. Low absorption rates might require a promotor (investigate connection with the enzyme task)

Results so far

- Two solvents identified, extra tests with a promoter shows promising results energetically
- The best one has some stability and environmental issues



WP1 ABSORPTION

›Integration of CO2 absorption with utilization (by algae) (Led by TNO)

Idea

- Use algae to “eat” the CO2 from the solvent loaded by the flue gas. Create biomass as a product.

Work in the project

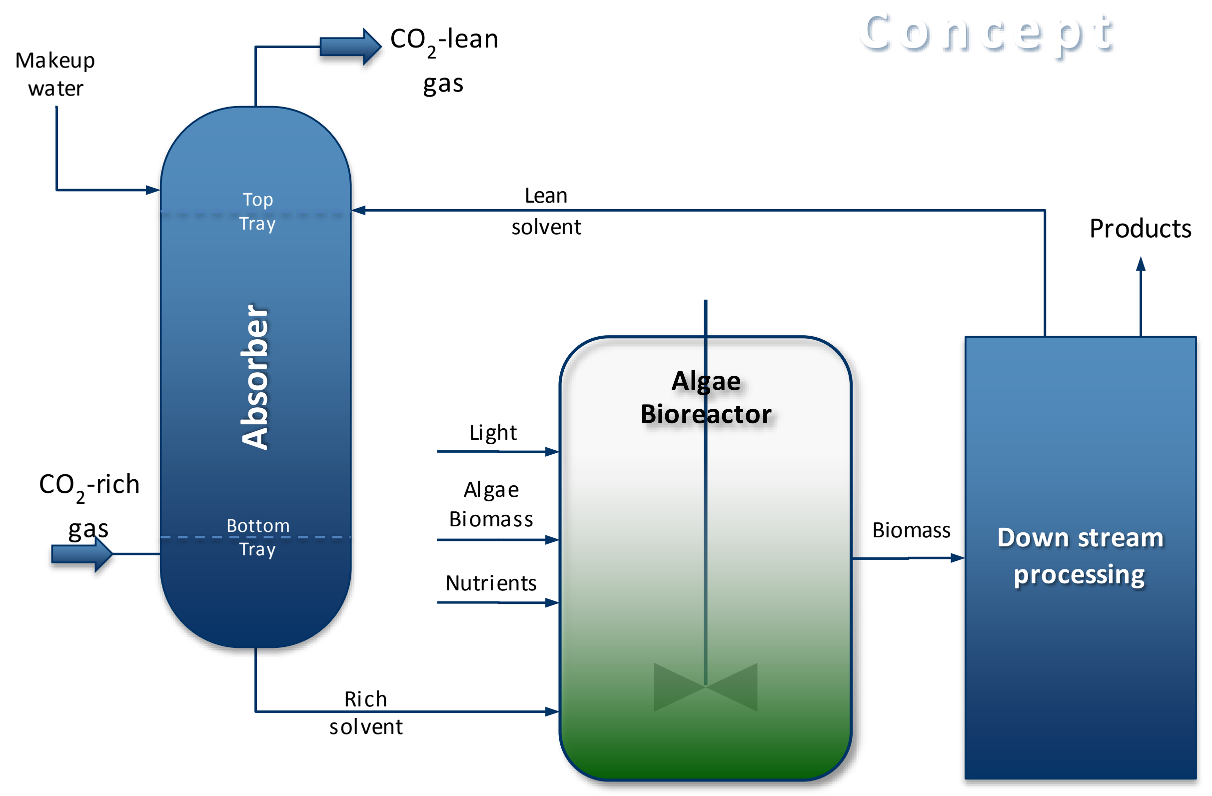
- Process development (algae strain, solvent, operation conditions). Test proof of concept with real flue gas.

Challenges for this technology

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

Results so far

- Concept developed and experimentally proven
- Process model is developed for scale-up studies



WP1 ABSORPTION

Study of bio-mimicking systems (Led by SINTEF)

Idea

- Perform a fundamental study of CO2 binding mechanism in nature an determine processes for the utilization industry.

Work in the project

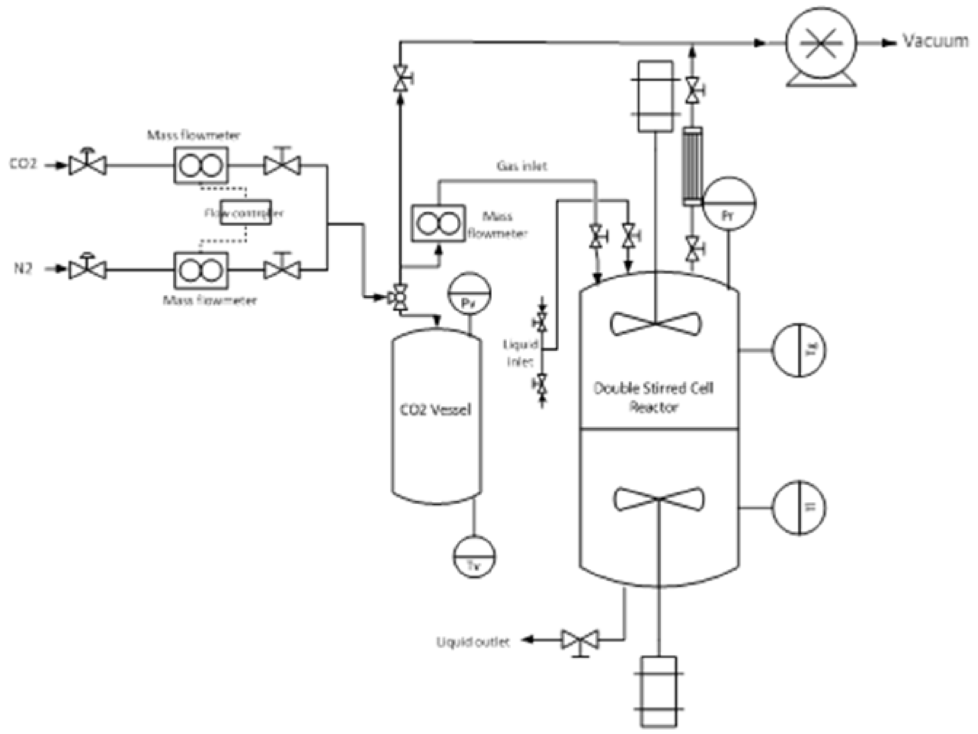
- Review and assessment of potential candidates. Perform screening experiments.

Goal

- Define some possible systems.

Results so far

- 2 zinc complexes (bio-mimicking catalysts) synthesized and tested
- Increase in absorption rate (MDEA reference), but small compared to carbonic anhydrase (biocatalyst)



WP2 ADSORPTION (LED BY CSIC)

›Sorbent development (Led by CSIC)

Idea

- Development of low temperature solid sorbents, low cost and with a high surface area. Integrate them in a process.

Work in the project

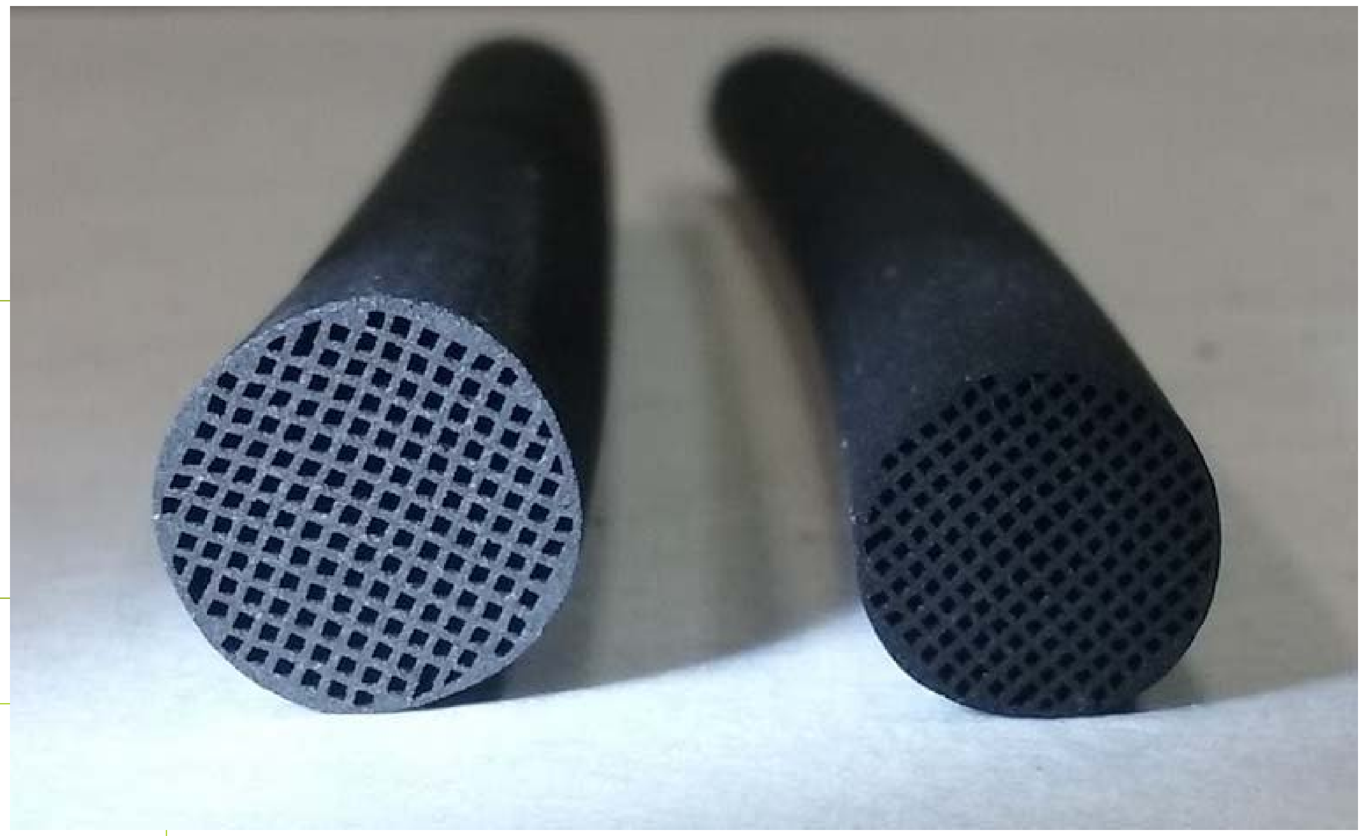
- Production and characterization of possible candidates.

Challenges

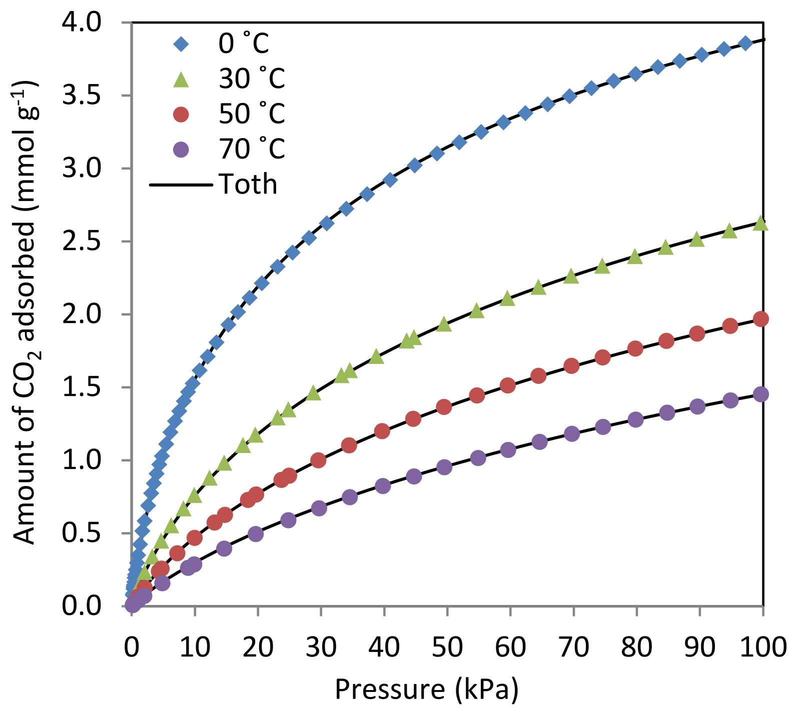
- Identification of materials suitable for the targeted process environment.

Results so far

- 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
- Exchange of two samples between CSIRO and CSIC



MAST Carbon monolith



CO_2 isotherms on MAST's monolith

WP2 ADSORPTION (LED BY CSIC)

Process development (Led by CSIC)

Idea

- Develop temperature swing adsorption processes by means of fixed and circulating moving beds

Work in the project

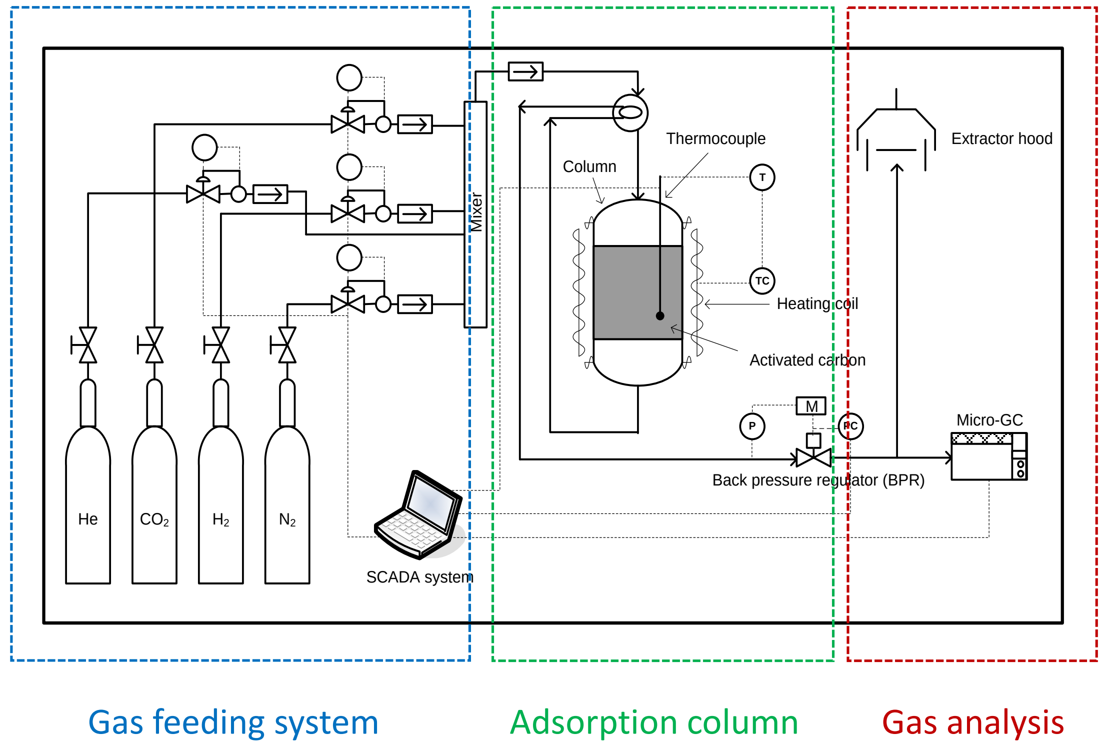
- Tests in labs relevant for fixed bed and circulating bed conditions, but with real flue gas conditions at coal and NG fired power stations
- Tests in pilots with real flue gas from coal power station (TNO Maasvlakte pilot)

Challenges

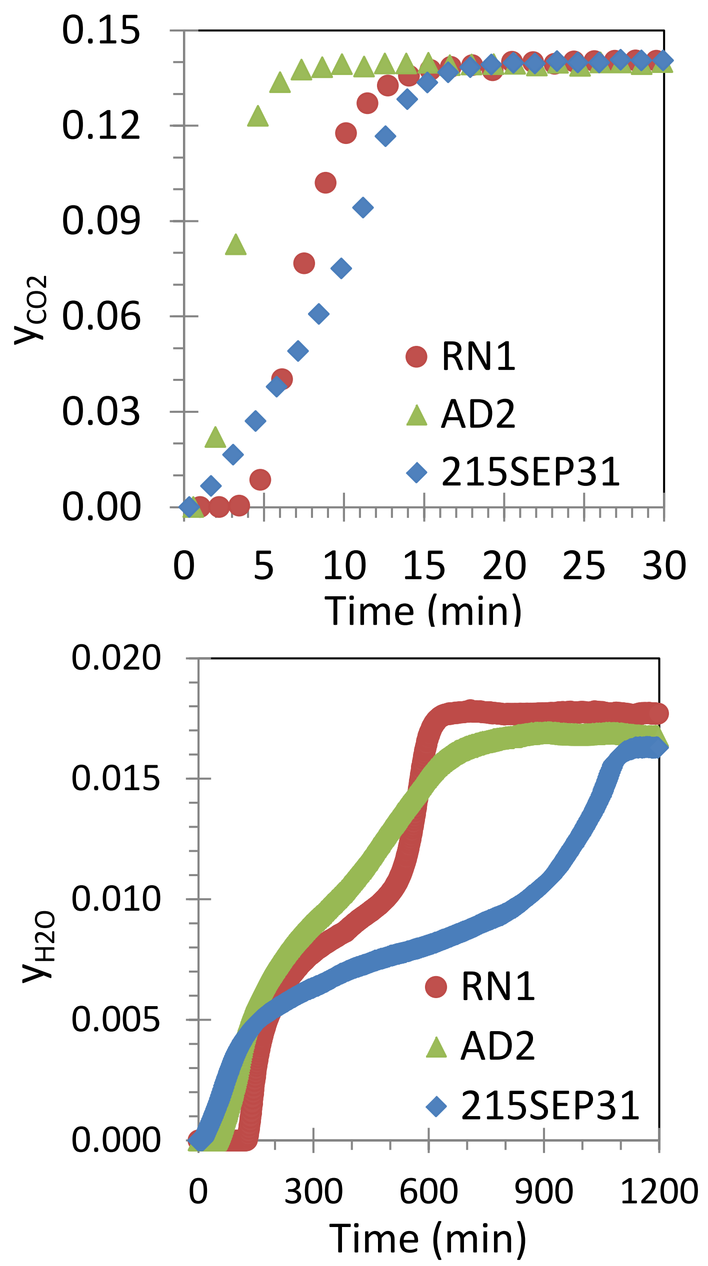
- Develop correlations describing kinetics and equilibrium relations for multi-component systems.

Results so far

- Breakthrough experiments in a lab-scale fixed bed unit with synthetic humid flue gas on carbon monoliths
- Process development based on simulation of fixed-bed cyclic process using Aspen Adsorption model parameters based on lab experiments
- Unit models for the different sections of the moving bed unit are being developed and implemented in gPROMS



Fixed-bed experimental set-up



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

WP2 ADSORPTION (LED BY CSIC)

Process modeling (Led by SINTEF)

Idea

- Develop process concepts for a full scale adsorption plant including the thermo-process integration with the power-plant

Work in the project

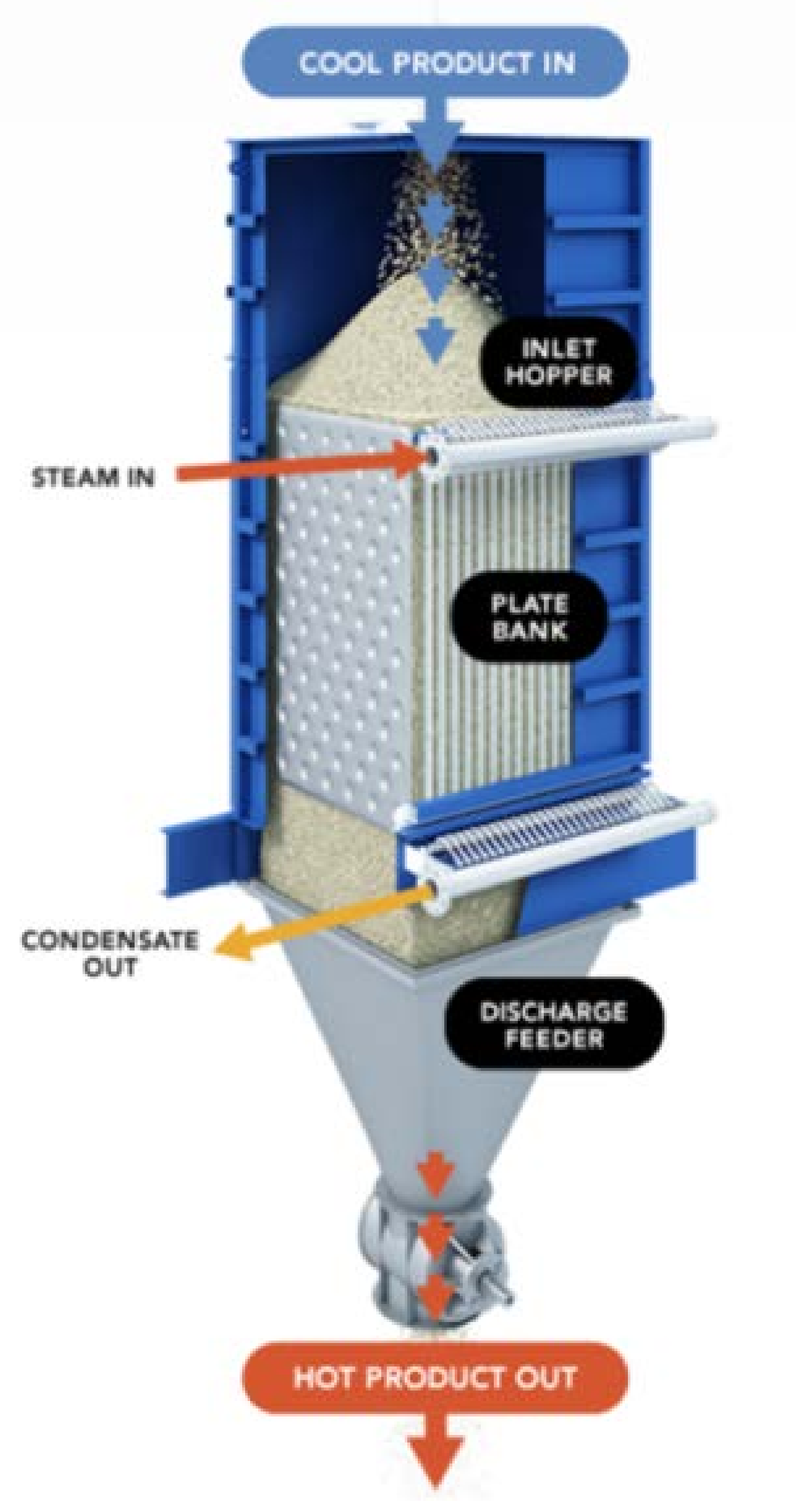
- Simulations to determine optimal design for integration with the power-plant

Challenges

- High uncertainty level in the models as data from relevant pilot plant are very limited .

Results so far

- 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



MBTSA process

WP3 MEMBRANES (LED BY NTNU)

›Hybrid and supported ionic liquid membrane development

Idea

- Investigate high flux mixed matrix membrane with incorporated nanoparticles in a polymer.
- Develop supported ionic liquid membranes

Work in the project

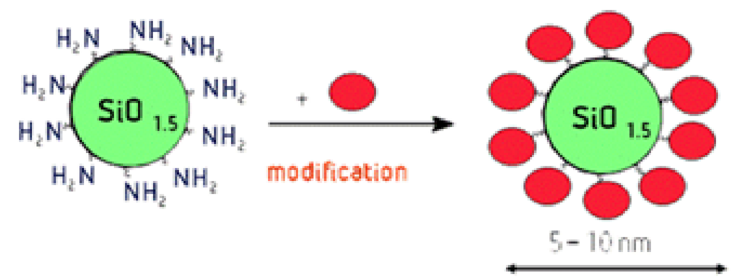
- For the hybrid membranes: realization of the membranes and study the transport phenomena. For the ionic liquid membranes: development, preparation and performance testing. Perform modeling work.

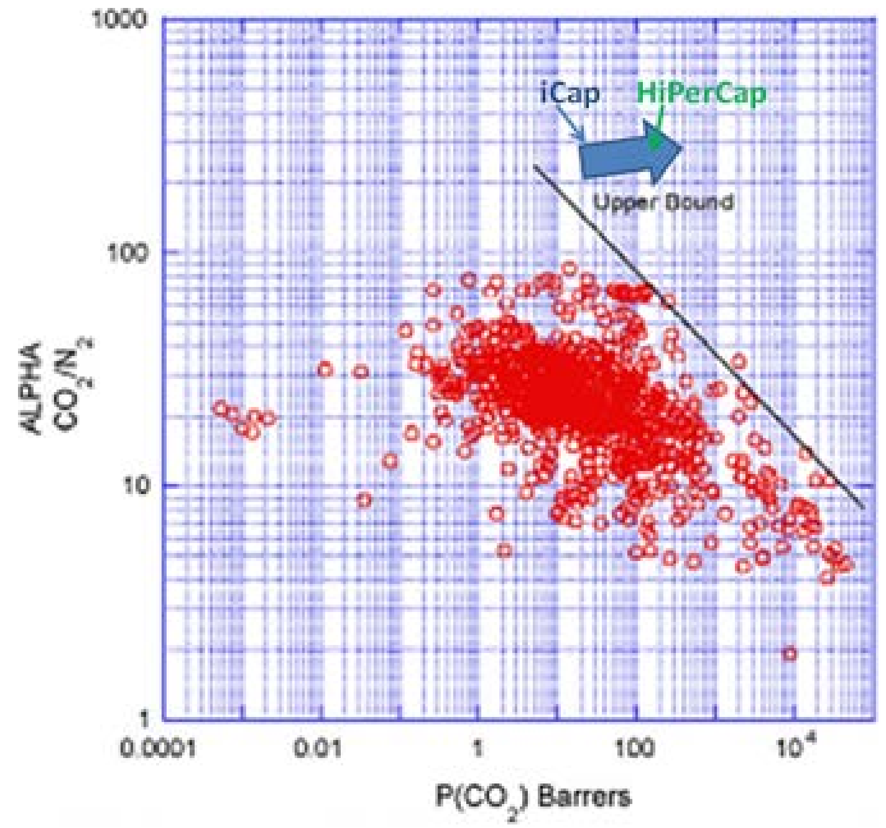
Challenges

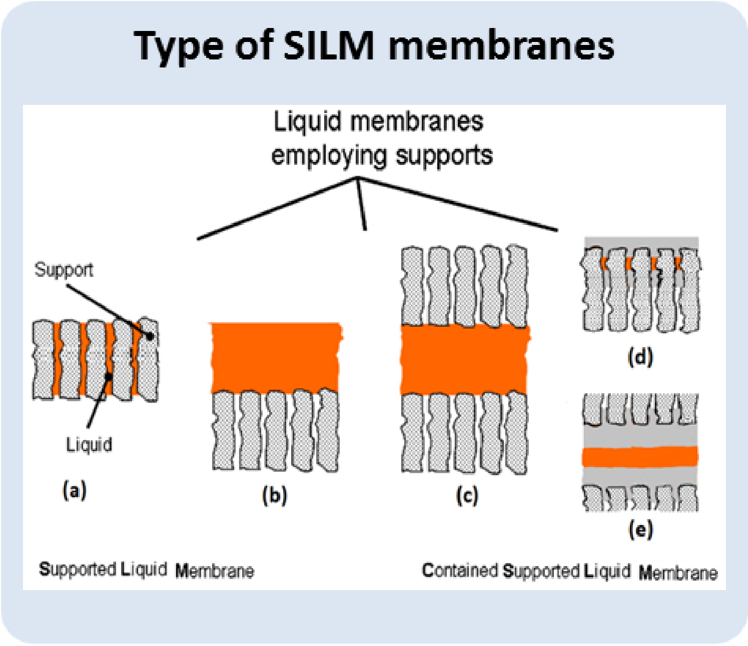
- Performance. Large scale manufacturing and durability

Results so far

- Hybrid membranes: Two types prepared, but targeted performance was not reached. SO2 tests promising regarding durability.
- Ionic Liquids NTNU: 3 ionic-liquids + polymer chosen, so far high permeance, but low selectivity. Will test and optimize with a new polymer
- Ionic Liquids TIPS: Improved performance by inclusion of a selective layer support, targeted values almost reached for the performance, will optimize further
- Model developed for the hybrid membrane and a two stage process model is develop using Aspen Plus







WP4 BENCHMARKING (LED BY DNVGL)

›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

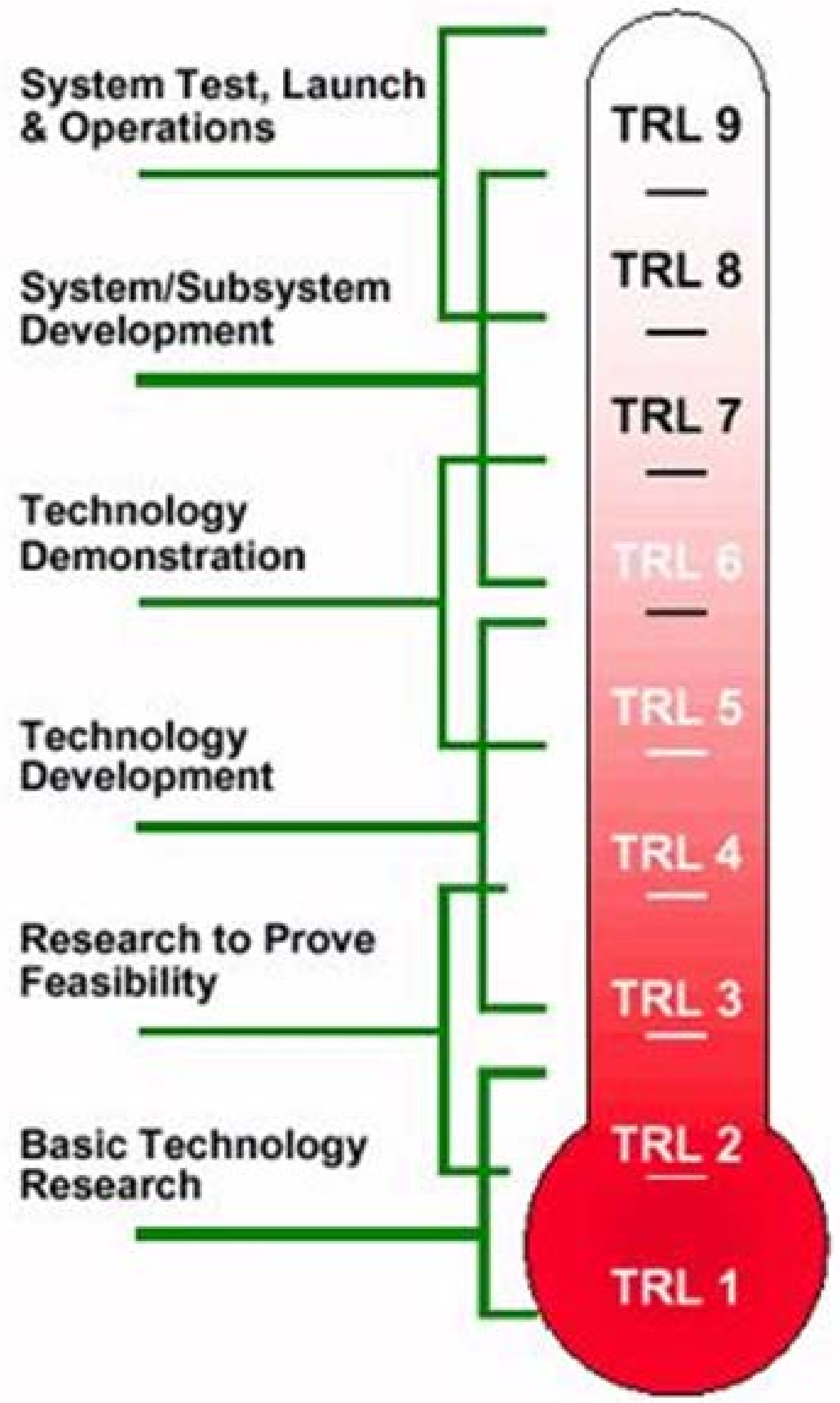
- Define a clear base case, use defined system boundaries, modeling approach and comparison criteria. Select the two most promising technologies.

Challenges

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

Results so far

- Methodology developed based on two stage selection process
- Reference case established and the integrated process simulated
- Starting collecting available data especially from WP1



HiPerCap CO_2

WP5 ROADMAP DEVELOPMENT (LED BY UNIPER, FORMER E.ON)

- **Develop a technological roadmap for the industrial demonstration of two chosen technologies. Furthermore, we also aim to identify any gaps in knowledge required for implementing the technologies at industrial pilot units.**
- **A plan will be made for demonstrating the technology at an industrial pilot plant.**
- **Depending on the specific technology to be further studied, additional activities such as experimental lab activities for improved models and further process optimization are foreseen in order to reduce the uncertainty in the performance data prior to the final benchmarking.**

SINTEF

ACKNOWLEDGEMENTS

Thanks to co-authors:

Inna Kim[1], Peter van Os[2], Covadonga Pevida[3], May-Britt Hägg[4], Jock Brown[5], Robin Irons[6], and Paul Feron[7]

1. **SINTEF Materials and Chemistry, Norway**
2. **TNO, Netherlands**
3. **CSIC, Spain**
4. **NTNU, Norway**
5. **DNVGL Oil and Gas, Norway**
6. **UNIPER, U.K.**
7. **CSIRO, Australia**

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Thank you for the attention!