EC Project: iCap
Innovative CO$_2$ Capture
Project Overview
Overview

- Objectives
- Outline of work programme
- Snapshots from the activity
- Consortium
- Announcement
Objectives

■ **iCap** seeks to remove the barriers for world wide $\text{CO}_2$ capture deployment by developing new technologies with potential for:

- reducing the current energy penalty to 4-5% points in power plant efficiency by introducing a new breed of solvents based on phase change.
- to combine $\text{SO}_2$ and $\text{CO}_2$ removal, thereby introducing process intensification, reducing capital cost, and energy requirements
- make low temperature membranes feasible for post-combustion processes, thereby creating a solvent free alternative
- develop new power cycles that enable high pressure/high temperature post combustion membrane $\text{CO}_2$ capture
iCap Project Overview

Organization

iCap

WP2: Thermodynamic modelling

WP1: Phase change solvents

WP3: Combined CO₂ and SO₂

WP4: Membranes

WP5: Technology evaluation

Novel power cycles

IGCC

GTCC

PC

- Phase change process ready for industrial prototype
- Industrial pilot validation of combined SO₂ and CO₂ capture
- Validated applicability of low and high temperature membrane technology
- Established concept for novel power cycle
- Rigorous thermodynamic fundament and models for the studied processes
## WP1 Phase change solvents

<table>
<thead>
<tr>
<th>R&amp;D area</th>
<th>State of the art</th>
<th>iCap advancements beyond the State of the Art</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Novel post Combustion systems based on phase change solvents</strong></td>
<td>Chilled ammonia process under development by Alstom. Carbonate and amino acid salt systems, both systems currently under development in the CESAR project. Hydrate formation at relatively high pressures (90bar) and low temperatures (0 - 10 C)</td>
<td>Systems forming two liquid phases, one lean in CO₂ and one rich in CO₂ phase, resulting in lower recycle, higher CO₂/H₂O ratios. Thereby lower energy demand and creating possibility for pressurised desorption in smaller and less costly desorbers, thus lowering recompression cost. Hydrate process supported with thermodynamic promoters thus reducing needed pressure and increasing temperature range.</td>
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CO₂ capture by Hydrate formation

**Tools**
From lab to pilot to industrial scale

- P,V,T cells with gas, liquid and solid analyses
- 2 for gas/liquid/solid phase envelop characterization
- 1 (under construction) for gas/solid phase transition studies

**Thermodynamic experiments and crystallisation** (kinetic) experiments

Pilot flow loop for **rheological characterization** of gas hydrate slurries during crystallization under flow

- In line Cord Length Distribution, in line RAMAN and ATR

**Industrial air-conditioning unit based on hydrate circulation**
- highly concentrated slurry (40% vol.) rheological characterization
- slurry generator form cold scraped surfaces
- slurry generator (under constr.) from gas bubbling reactor

**Development of a prototype for CO2 capture**
CO₂ capture by liquid/liquid formation

Example of liquid/liquid system
## WP1 Thermodynamic modeling

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Models for phase change systems

Liquid/liquid

— Tools exist
— account for new solvents
— account for electrolytes
— incorporation into simulator tools (CO2SIM, gPROMS)

Figure 4. LLE in the system decane + water. The experimental values are those of Economou et al.24 PC-SAFT prediction: $k_0$ fit to water-rich phase (both with water parameters of this work) and ESD fit to decane-rich phase.

$\text{CO}_2$ hydrate inhibition with methanol

— Tools exist
— account for promoters instead of inhibitors (e.g. THF)
— extension to more components (e.g. H$_2$S)
— Data from WP1
— Slurry absorber will incorporate thermodynamic model and data from WP1

Swaminathan and von Solms (2009)
WP3: Combined CO$_2$ and SO$_2$ Removal

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<td>Combined SO$_2$/CO$_2$ removal</td>
<td>The benchmark process for SO$_2$ removal is limestone slurry spray towers producing gypsum. Only SO$_2$ is removed. Cansolv has developed a process for the removal of SO$_2$ and CO$_2$ in one absorption column. However, two different liquid loops are used and the process is very complicated.</td>
<td>iCap is aims to develop a process where in one gas/liquid contacting step both SO$_2$ and CO$_2$ are removed. Current available SO$_2$ scrubbing spray towers can be modified to capture both SO$_2$ and CO$_2$. By using step-wise regeneration, two different streams are obtained, one gypsum stream and one CO$_2$ stream. This CO$_2$ stream should contain no detectable SO$_2$.</td>
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</table>
Ammonia for combined SOx and CO₂ capture

Experimental facility

- A lab scale absorption/stripping facility has been built
- Gas flow and liquid flow system are OK
- Water wash system is needed for ammonia volatility
Loy Yang Power Station PCC Pilot Plant, Victoria, Australia

- ETIS support
- Lignite
- Amine based
- No FGD/DeNox
- Operational May 08
## WP4: Membranes

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</table>
| **Highly efficient and long term stable membranes for CO₂ capture**    | *Low temperature separation:*  
CO₂ selective polymeric membranes designed for low fluxes; not stable in flue gas environment and subject to plasticization  
*High temperature separation:*  
H₂ selective micro-porous membranes not stable in steam operation. H₂ selective Pd based membranes not stable at high temperature, sensitive to CO. Limited feedstock. Limited operation temperature window.  
Not stable in carbon and/or steam containing atmospheres. Manufacturing and scalability challenging for all high temperature membranes. | *Low temperature separation:*  
High performance ultra thin CO₂ membranes functionalized with nano-particles to increase the flux through the membrane by affecting the free volume of polymers.  
*High temperature separation:*  
Novel mixed conducting ceramic materials will be engineered as chemically and mechanically robuste membranes. Thin dense films on porous supports will be developed for reaching high fluxes. |
Polymer-based CO$_2$ selective membrane

- Commercially available CO$_2$ selective membranes are pure polymers
  - low cost 😊
  - Flexible and easy to scale up 😊
  - Plasticization at high CO$_2$ partial pressures 😞
  - Higher flux with sufficient selectivity 😞

High free volume polymer

Cross-linked polymer as the base

Inorganic particles, functionalized inorganic particles

Nano-particles

Organic branch

Inorganic core

< 50 nm
**H₂ extraction in High Temperature Steam Methane Reforming**

**Phase 1: Development and screening of membrane material candidates**

- Perovskite based materials
- Powder synthesis
- Symmetric membranes fabrication

**Phase 2: High flux and stability of best candidates**

- Co-doping
- Sol-gel, spray-pyrolysis
- Pressing-sintering

Testing

- High Pressure high T Transport mechanisms
- SMR
  - Flux and stability

Innovative CO₂ Capture, 7th FP, Cr. No 241391
## WP5: Technology evaluation

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<td><strong>Technology evaluation and Novel Power Cycles</strong></td>
<td>Gas turbines with very tight integration between compressor, combustor, and turbine. Low CO₂ partial pressure in the exhaust gas. Limits to fuel gas hydrogen fraction in pre-combustion concepts, because combustors are made for natural gas.</td>
<td>Power cycle with gas turbines designed to incorporate CO₂ capture at elevated pressure. High CO₂ partial cross-coupling or tandem coupling of two gas turbine cycles</td>
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Aim and Scope of WP 5

- “Technology evaluation, cost and **efficiency estimations**, environmental impact, power cycles”
Potential Impact

- **Reduction of the efficiency penalty of CO₂ capture for power plants**
  - phase change solvents (WP1) with the ability to minimise energy requirement both in the capture plant and in the CO₂ recompression train
  - combined SO₂ and CO₂ removal WP3 - process intensification and debottlenecking from performance limitations
  - polymeric and ceramic membranes (WP4) - inherently low efficiency penalty
  - Combined with and integrated into novel power cycles concepts (WP5) resulting in highly efficient configurations (energy penalty <4% points)

- **Substantial decrease in capture cost**
  - reduction in capital and operational costs thought simplified, more compact and intensified capture plants, and reduction in fuel cost through more efficient highly integrated processes
## Project Overview

### Consortium

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<th>CSLF partners</th>
<th>End-Users</th>
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<tr>
<td>NTNU</td>
<td>CSIRO</td>
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<td>TNO</td>
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iCap Project Overview

Summary
- 15 partners
- 8 nationalities
- Total Budget 6.3 M€
- EC Funding 4.3 M€
- About 90% Financed
- Duration 48 Months
- Starting Date 01.01.10
- Kick off 17-18 of February 2010
EU–China Workshop on Innovative CCS Technologies
Beijing, China, 19–20 September 2011

From Fundamental R&D to Large-Scale Demonstration and Technology Deployment

Under the auspices of the iCap project and other EU funded R&D projects, jointly organised by the Norwegian University of Science and Technology and Tsinghua University.

Scope and Objectives

EU–China Workshop on Innovative CCS Technologies
An EU–China Workshop on Innovative CCS Technologies will be held in Beijing hosted by Tsinghua University on Monday and Tuesday 19 and 20 of September 2011. The event is organised under the auspices of the Seventh Framework R&D programme funded by the European Commission.

The workshop aims to present recent advancements on carbon abatement technologies and disseminate results obtained from collaborative R&D activities between Europe and China within the EU funded projects iCap, CACHET II, CO2PipeHaz. The event will also bring together other on-going joint EU-Chinese CCS related initiatives, major Chinese R&D and demonstration projects and will form a unique knowledge sharing event for academia, R&D actors and industrial stakeholders active in the area of CCS. The conference is organised in conjunction with the CSLF Ministerial Meeting and will provide an excellent opportunity for promoting R&D results and interact with policy makers.

Workshops Announcement and Invitation

www.icapco2.org
The workshop will address critical areas of R&D currently being the focus of Sino-European collaborative activities such as:

- Phase change solvents and processes for post combustion CO₂ capture
- Combined capture of CO₂ and SO₂
- High and low temperature membrane processes for CO₂ capture
- Fundamentals of CO₂ capture techniques
- Integration and techno-economic evaluations
- CO₂ transport challenges

**Venue**
The event is hosted by Tsinghua University and will take place in Wenjin Hotel, Tsinghua Science Park, Beijing, China.

**Participation**
The event will be open for participation with a limited numbers of attendees up to 150–180. For more information please check out the project website for the upcoming announcements: [www.icapCO2.org](http://www.icapCO2.org), or send an email to icap@nt.ntnu.no

### Tentative Workshop Programme

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<th>Date</th>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>Monday Sept 19, 2011</td>
<td></td>
<td>SESSION 1: Workshop Opening and General Addresses</td>
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<tr>
<td></td>
<td>0900–1200</td>
<td>SESSION 3: Phase change solvents</td>
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<td></td>
<td>1300–1700</td>
<td>SESSION 4: Fundamentals</td>
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<tr>
<td>Tuesday Sept 20, 2011</td>
<td>0900–1200</td>
<td>SESSION 1: High &amp; Low temperature membranes</td>
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<td>1300–1700</td>
<td>SESSION 3: Integration and techno-economic</td>
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<td>SESSION 4: International Pilot and demo activities</td>
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[www.icapco2.org](http://www.icapco2.org)