EC Project :
iCap
Innovative CO_2 Capture

Project Overview

Overview

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

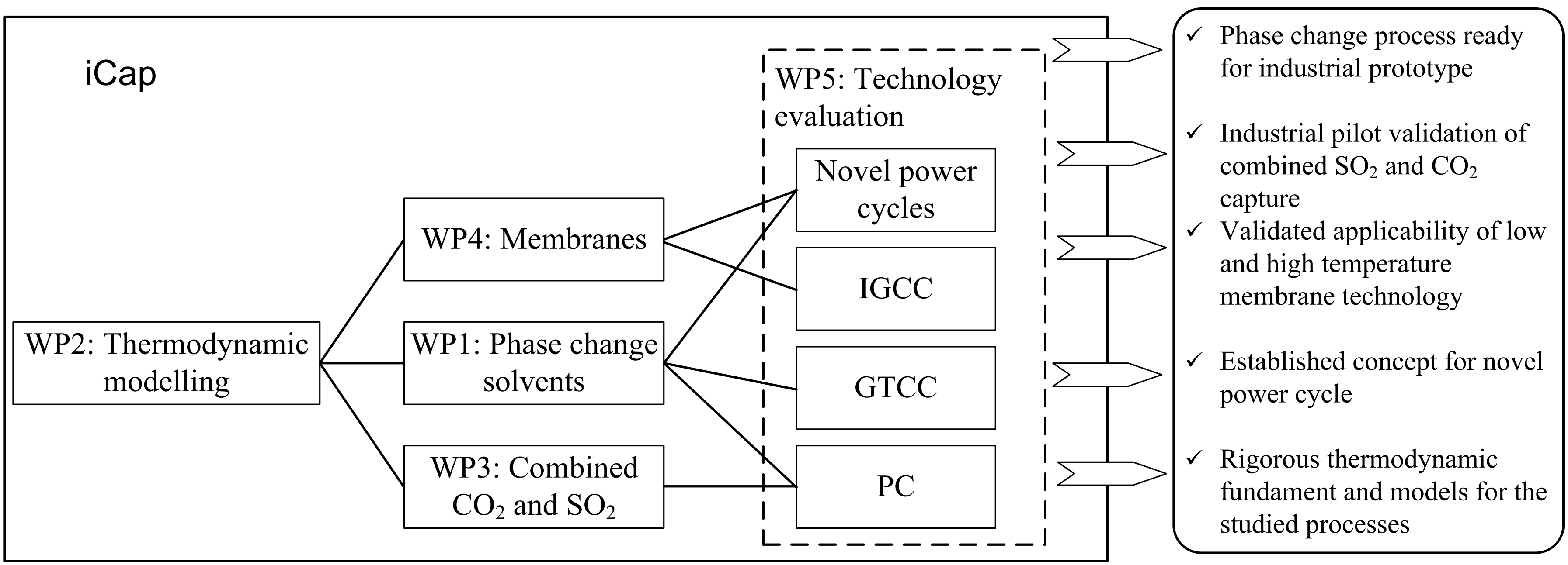
iCap CO_2

Project Overview

Objectives

- **iCap** seeks to remove the barriers for world wide 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 SO_2 and 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 CO_2 capture

Organization

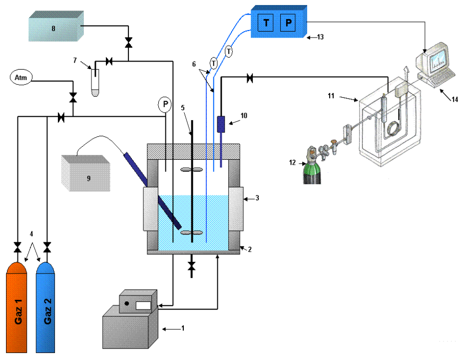


WP1 Phase change solvents

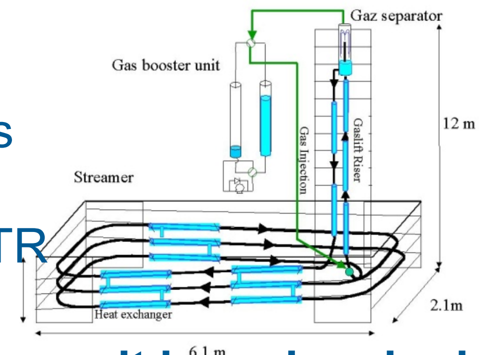
R&D area	State of the art	iCap advancements beyond the State of the Art
Novel post Combustion systems based on phase change solvents	Chilled ammonia process under development by Alstom. Carbonate and amino acid salt systems, both systems currently under development in the CESAR project. Hydrate formation at relatively high pressures (90bar) and low temperatures (0 - 10 C)	Systems forming two liquid phases, one lean in CO_2 and one rich in CO_2 phase, resulting in lower recycle, higher CO_2/H_2O 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.

CO_2 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

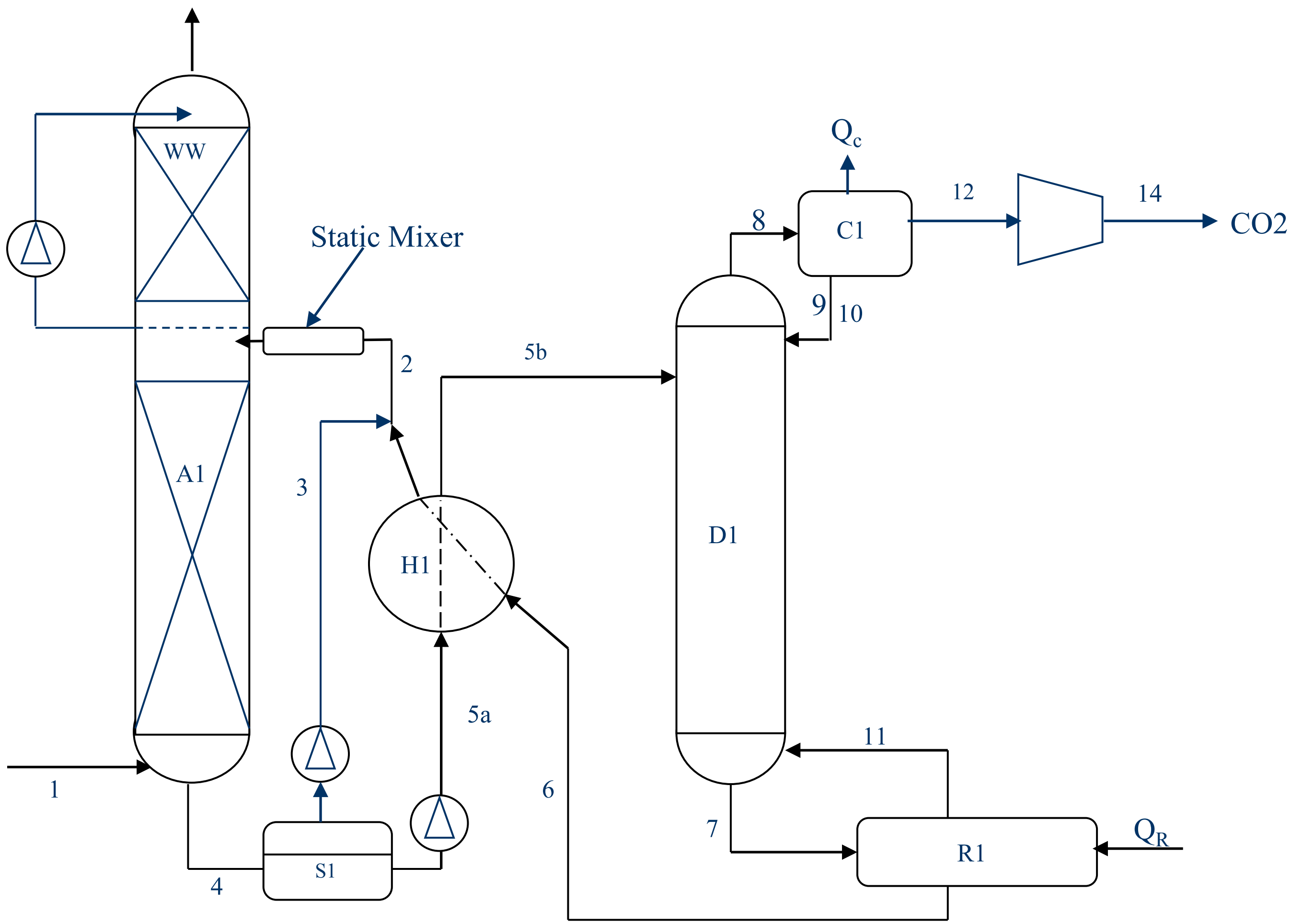
Scaling up

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

CO_2 capture by liquid/liquid formation

Example of liquid/liquid system



WP1 Thermodynamic modeling

R&D area	**State of the art**	**iCap advancements beyond the State of the Art**
Thermodynamic Modeling of absorption systems	Equations of state and activity coefficient thermodynamic and property packages for single phase mixtures. Column models for single phase absorption and desorption.	Gas/liquid/liquid/solid equilibrium calculations for low and high pressure mixed solvent mixtures. Property packages for complex multi phase high pressure system with both precipitation and two liquid phase formation. Column models for multi phase complex mixtures including slurries. Theoretical expansion for slurry absorbers and desorbers.

Models for phase change systems

Liquid/liquid

— Tools exist

— account for new solvents

— account for electrolytes

— incorporation into simulator tools (CO2SIM, gPROMS)

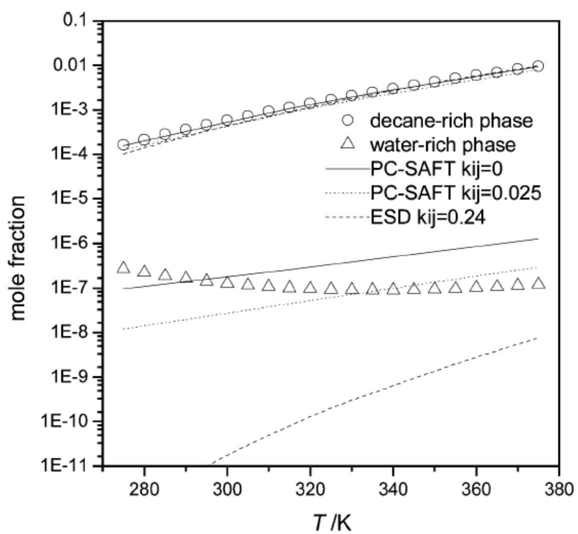
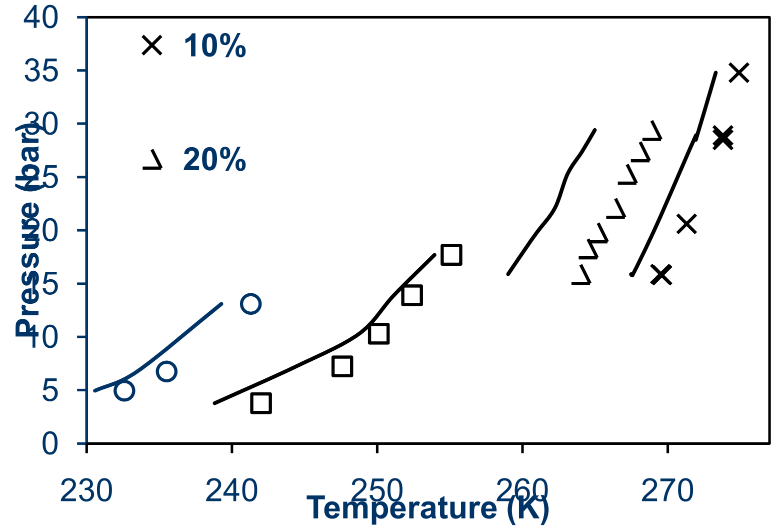


Figure 4. LLE in the system decane + water. The experimental values are those of Economou et al.[24] PC-SAFT prediction; k_{ij} fit to water-rich phase (both with water parameters of this work) and ESD fit to decane-rich phase.

CO_2 hydrate inhibition with methanol



Swaminathan and von Solms (2009)

— Tools exist

— account for promoters instead of inhibitors (e.g. THF)

— extension to more components (e.g. H_2S)

— Data from WP1

— Slurry absorber will incorporate thermodynamic model and data from WP1

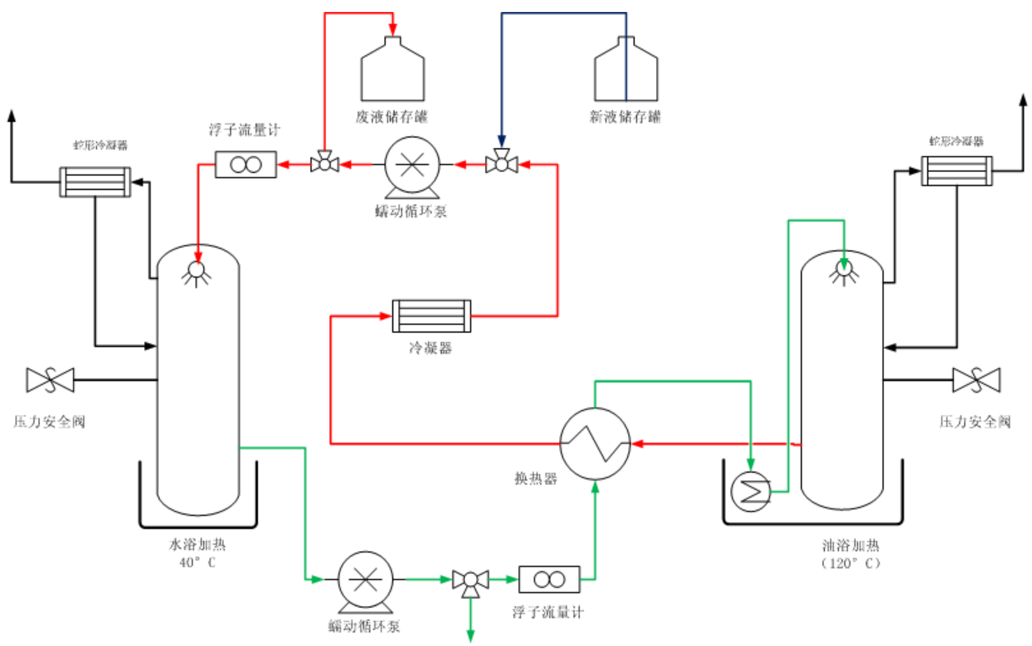
WP3:Combined CO_2 and SO_2 Removal

R&D area	State of the art	iCap advancements beyond the State of the Art
Combined SO_2 /CO_2 removal	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.	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.

Ammonia for combined SOx and CO_2 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

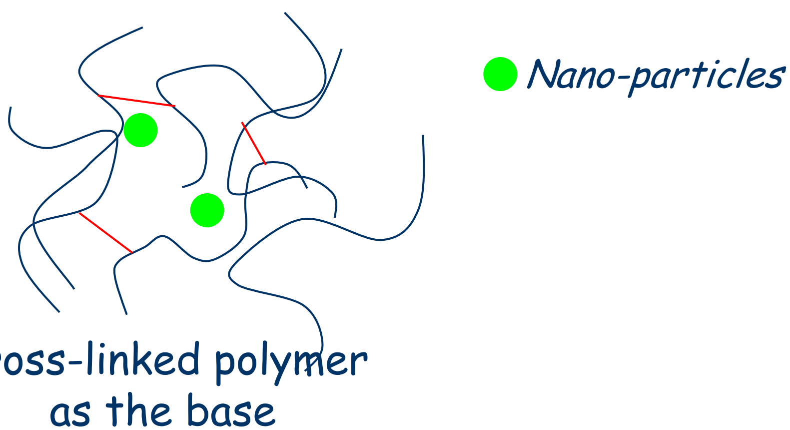
WP4: Membranes

R&D area	State of the art	iCap advancements beyond the State of the Art
Highly efficient and long term stable membranes for CO_2 capture	*Low temperature separation*: CO_2 selective polymeric membranes designed for low fluxes; not stable in flue gas environment and subject to plasticization *High temperature separation:* H_2 selective micro-porous membranes not stable in steam operation. H_2 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 CO_2 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.

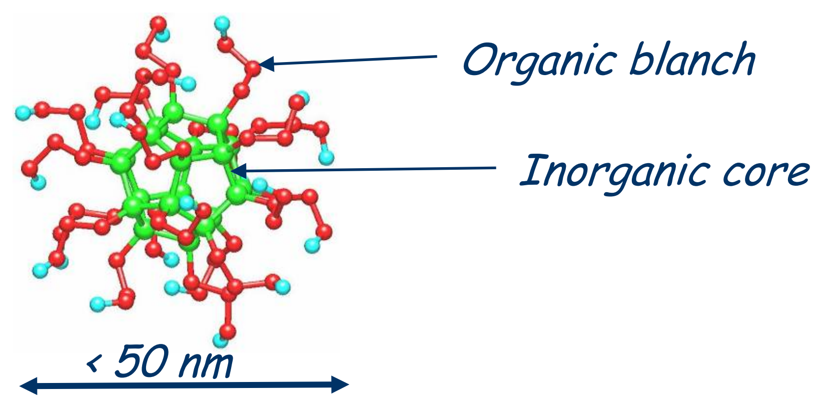
Polymer-based CO_2 selective membrane

- 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



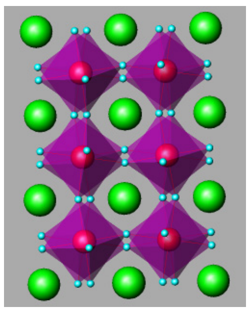
Inorganic particles, functionalized inorganic particles



H_2 extraction in High Temperature Steam Methane Reforming

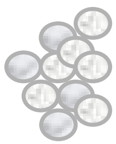
Phase 1: Development and screening of membrane material candidates

Phase 2: High flux and stability of best candidates



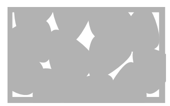
Perovskite based materials

Co-doping



Powder synthesis

Sol-gel, spray-pyrolysis



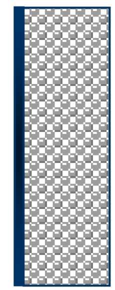
Symmetric membranes fabrication

Pressing-sintering

Testing

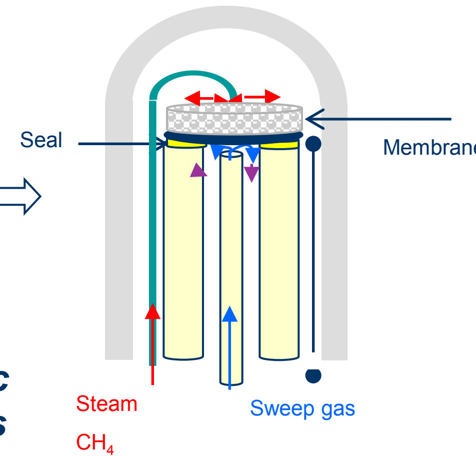
High Pressure high T

Transport mechanisms



Asymmetric membranes fabrication

Spray-coating, dip-coating



Testing

SMR

Flux and stability

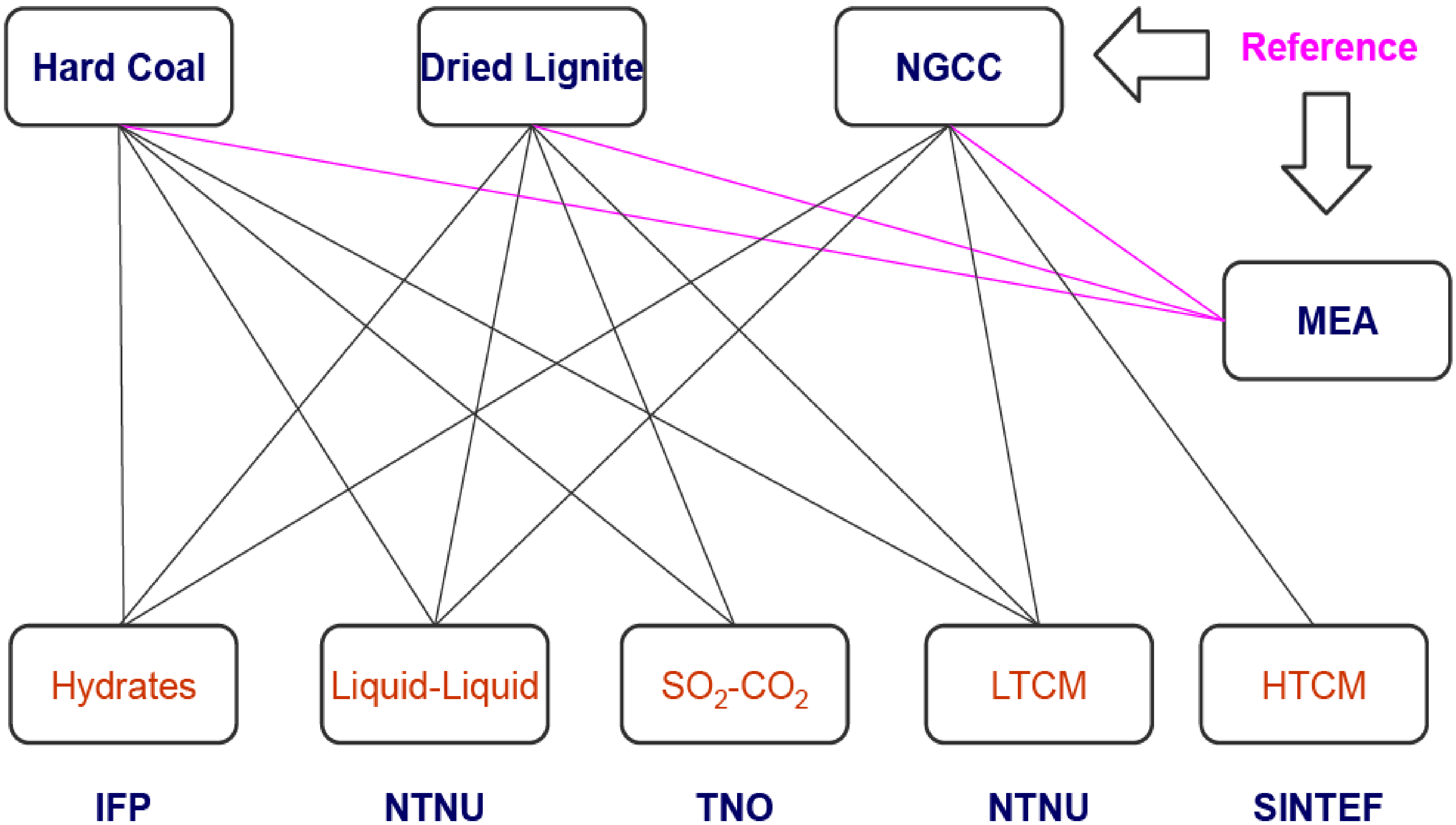
WP5: Technology evaluation

R&D area	State of the art	iCap advancements beyond the State of the Art
Technology evaluation and Novel Power Cycles	Gas turbines with very tight integration between compressor, combustor, and turbine. Low CO_2 partial pressure in the exhaust gas. Limits to fuel gas hydrogen fraction in pre-combustion concepts, because combustors are made for natural gas.	Power cycle with gas turbines designed to incorporate CO_2 capture at elevated pressure. High CO_2 partial cross-coupling or tandem coupling of two gas turbine cycles

Aim and Scope of WP 5

TUHH
Hamburg University of Technology
Institute of Energy Systems

- "Technology evaluation, cost and efficiency estimations, environmental impact, power cycles"



Potential Impact

- **Reduction of the efficiency penalty of CO_2 capture for power plants**
  - **phase change solvents (WP1)** with the ability to minimise energy requirement both in the capture plant and in the CO_2 recompression train
  - **combined SO_2 and CO_2 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

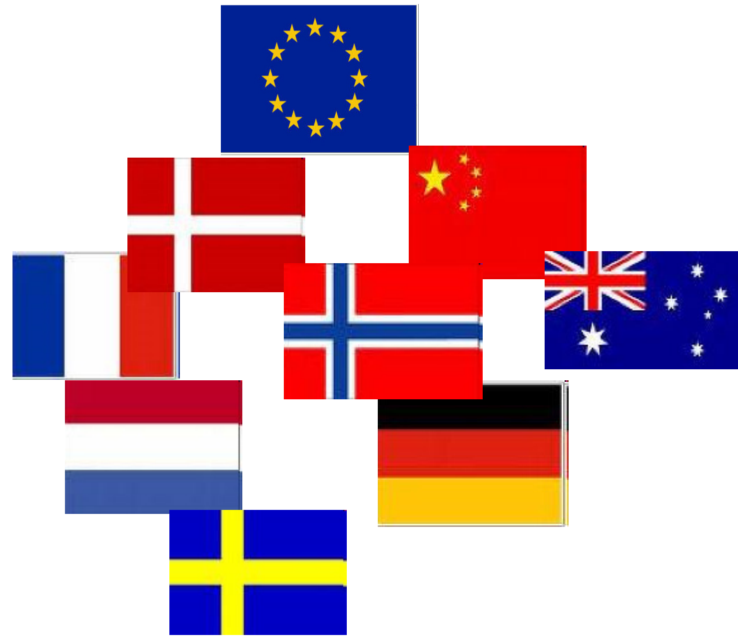
Consortium

RTD providers	CSLF partners	End-Users
NTNU TNO SINTEF IFP DTU TUHH ARMINES PROCEDÉ	CSIRO THU	DONG VTF AB VTF AS VTF R&D EnBW

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.

NTNU – Trondheim
Norwegian University of Science and Technology

Workshops Announcement and Invitation

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.

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 CO_2 capture
- Combined capture of CO_2 and SO_2
- High and low temperature membrane processes for CO_2 capture
- Fundamentals of CO_2 capture techniques
- Integration and techno-economic evaluations
- CO_2 transport challenges

Venue

The event is hosted by Tsinghua University and will take 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**, or send an email to **icap@nt.ntnu.no**

www.icapco2.org

Tentative Workshop Programme

Monday Sept 19, 2011 0900–1200 **SESSION 1: Workshop Opening and General Addresses** **SESSION 2: R&D Project outlines**	Monday Sept 19, 2011 1300–1700 **SESSION 3: Phase change solvents** **SESSION 4: Fundamentals** *DINNER*
Tuesday Sept 20, 2011 0800–1200 **SESSION 1: High & Low temperature membranes** **SESSION 2: CO_2 transport challenges**	Tuesday Sept 20, 2011 1300–1700 **SESSION 3: Integration and techno-economic** **SESSION 4: International Pilot and demo activities**

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