ASCENT - Advanced Solids Cycles with Efficient Novel Technologies

Matesa Day
16th June 2016

Project Overview

Paul Cobden

www.ascentproject.eu

ASCENT project and its consortium

FP7- THEME: ENERGY.2013.5.1.2 – topic: New generation high-efficiency capture processes

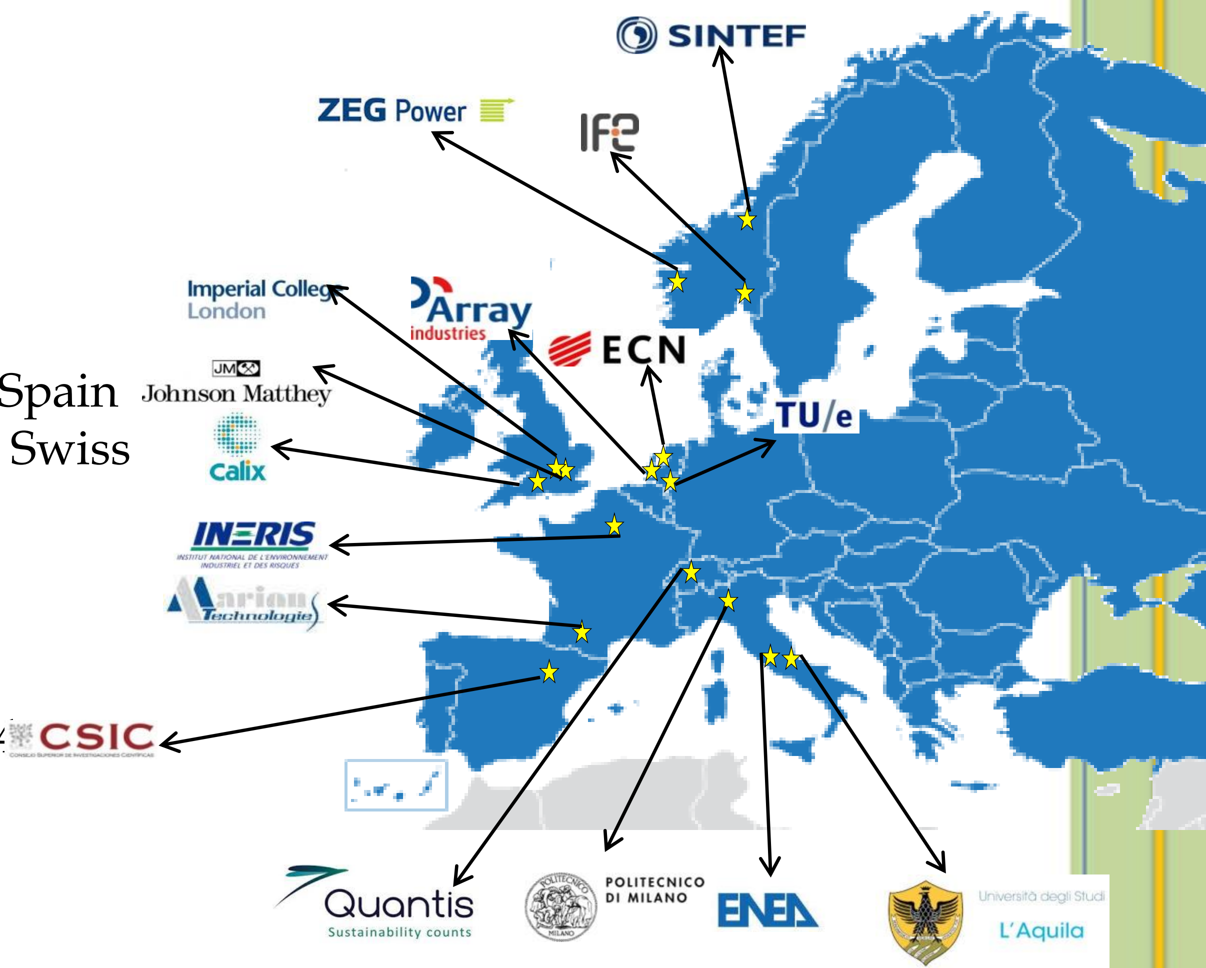
16 European Partners:

7 Countries:

5 Member States:
Netherlands, UK, Italy, France, Spain
2 Associate Countries: Norway, Swiss

+ 1 Twinned country: Australia

4 years duration:
Starting date: on March 1st, 2014



Budget size: 9.2M €:

7.0M € EC grant
2.2M € own Partners funding

Overall goal of ASCENT project

Provide a proof of concept of three thematically-related and sustainable technologies using industrially relevant materials under industrially relevant conditions for power and H_2 production

Material

- Industrially relevant materials can be manufactured at the scale needed for real implementation

Process

- Industrially relevant conditions are those to be expected in an actually operational environment

Proof of concept

- The Proof-of-concepts will help to increase the Technology Readiness Level of the investigated technologies

Expertise of the ASCENT consortium

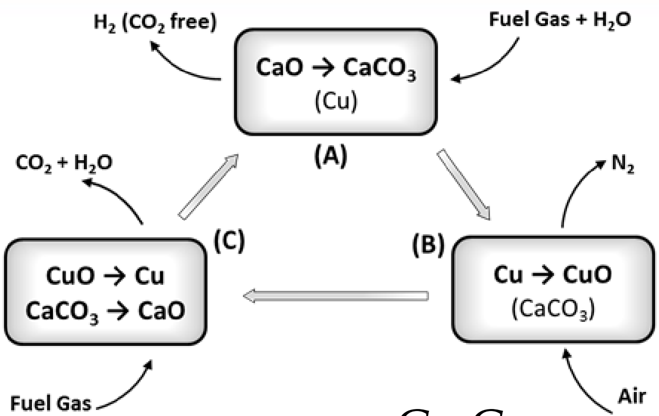
Each process is backed by an SME seeking to take their technological knowledge to a robust proof of concept

Each process is championed by a EERA affiliated research institute translating the needs of industry into relevant questions to be solved at the research level

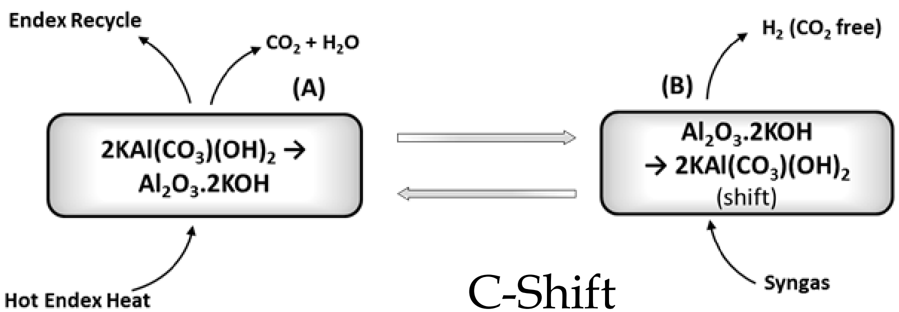
Each process is examined by academic research labs, combining their abilities in chemistry and chemical engineering to address the technological challenges in a robust manner

Each process is sponsored by an European material supplier looking to expand their product portfolios related to sustainable processes.

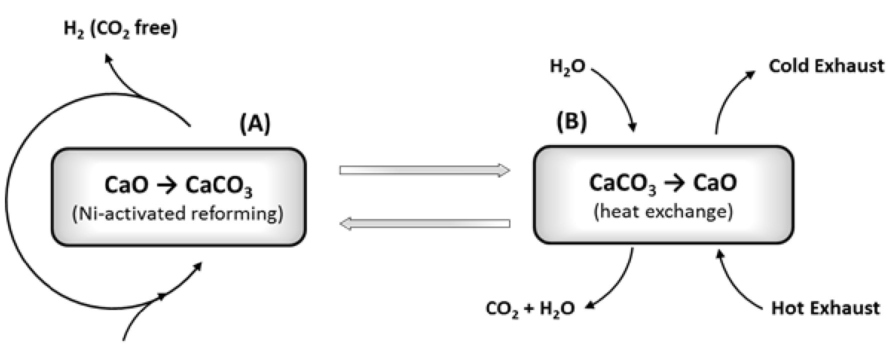
ASCENT: an experimental framework of solid-based technologies for H_2 and power production



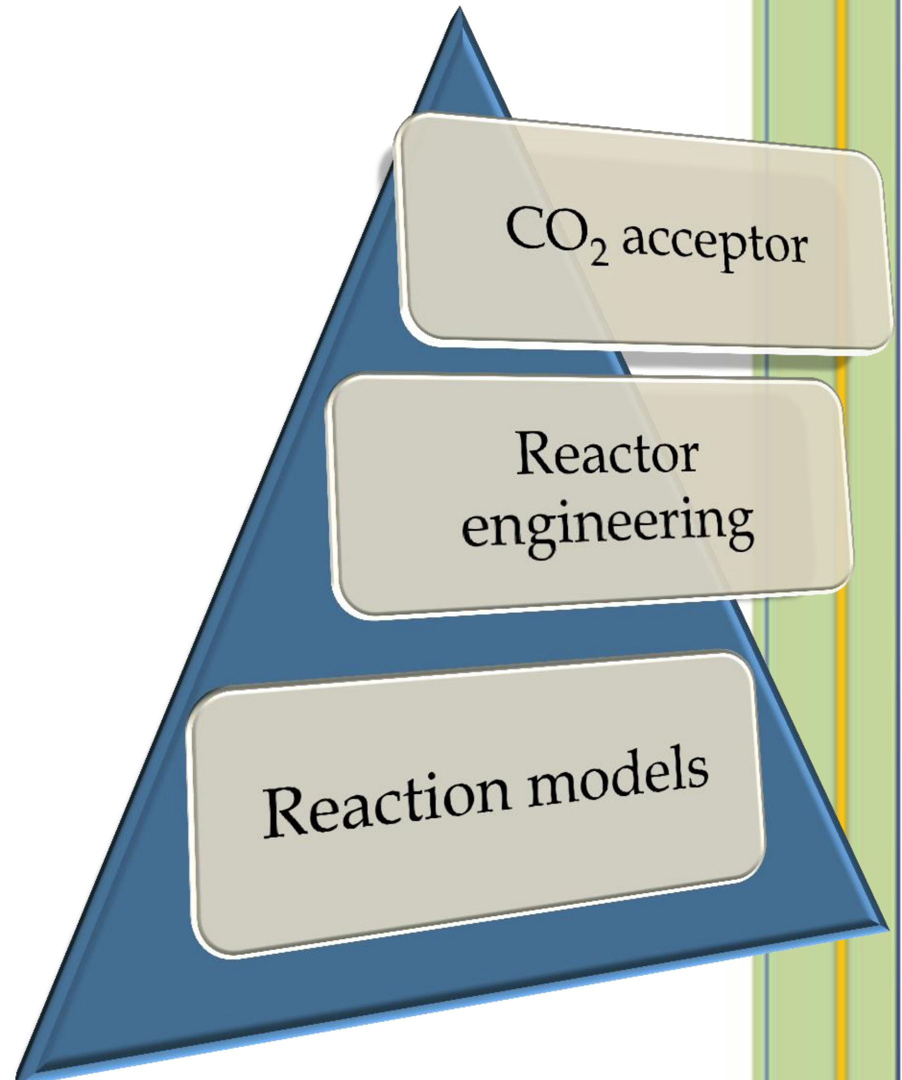
Ca-Cu



C-Shift



SER



Three Technologies, Many Synergies

Feature	Ca-Cu	CSHIFT	SER	Advantage
Simultaneous Reaction & Sorption	⊗	⊗	⊗	Higher conversions and process intensification, reduction in number of pieces of equipment
High temperature CO_2 capture	⊗	⊗	⊗	Increased efficiency, reduced steam knock-out
Highly engineered CO_2 capture materials	⊗	⊗	⊗	Economics, through cheap production methods, increased capacity and lifetime
Integrated CaO-$CaCO_3$ looping cycle	⊗		⊗	In situ heat production through matched chemical reactivity
Pressure Swing driven regeneration	⊗	⊗		Decreased demand for regeneration energy
Capture of CO_2 at high pressure	⊗	⊗		Increased fuel utility due to pressurized hydrogen, facilitated integration with CC
Integrated heat exchange within reactor concept	⊗	⊗	⊗	Process intensification
Fluidized bed technology		⊗	⊗	Allows active control in solid handling, efficient heat transfer, continuous operations
Hot Hydrogen Production	⊗	⊗	⊗	Highly aligned to power generating technology
Common Framework for techno-economic assessment	⊗	⊗	⊗	Direct Comparison Available

Synergies between the ASCENT technologies

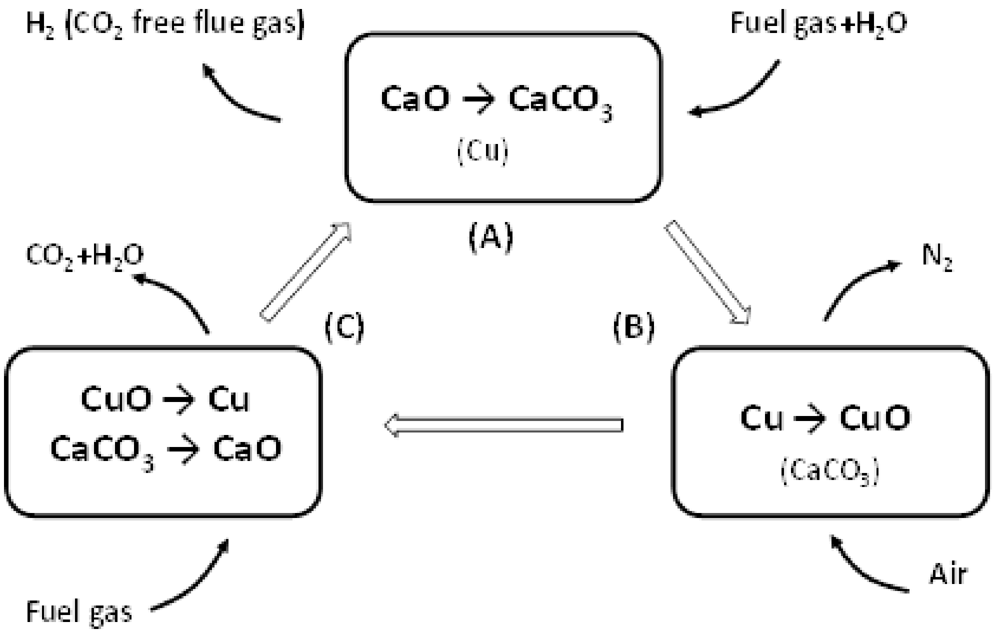
CaCu process

CSHIFT process

SER process

Task 1. Selection of performance criteria of material and process conditions
Task 2. Synthesis of the functional materials for solids looping processes
Task 3. Detailed experimental investigation at particle scale
Task 4. Development of multi-scale modelling: particle and reactor models
Task 5. Proof of concept and validation of the material performances and of the developed models

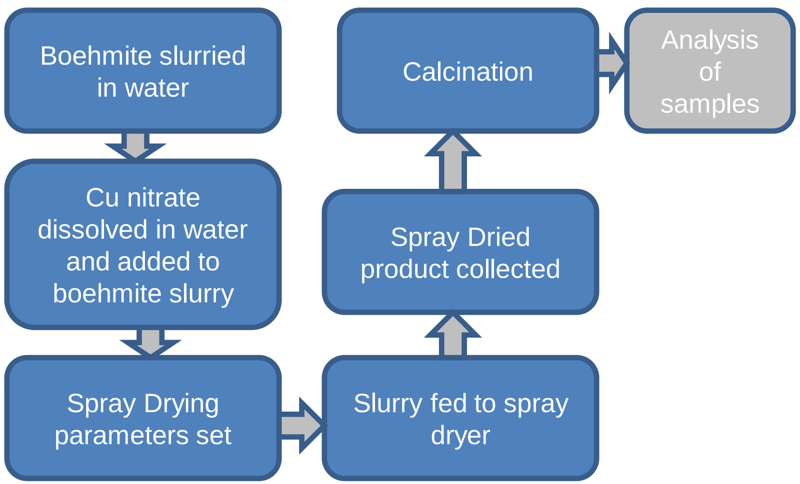
WP2 Combined Ca-Cu Chemical Loop: process development



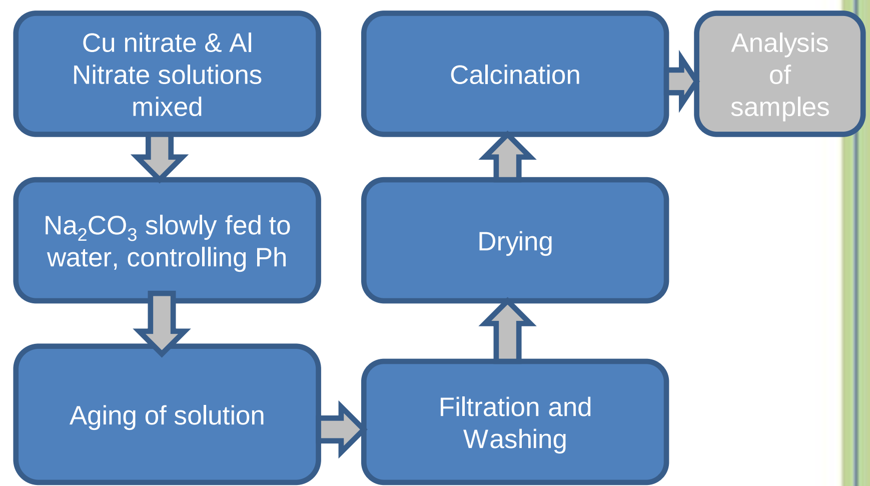
During the first reporting period, the development of the **conceptual design of the Cu-Ca process** was carried out and delivered (D2.1). **Several synthesis routes** were explored for the **CO_2 sorbents**, for the **Cu-based** materials and for the **combined CaO-CuO** materials, and the solids produced have been extensively tested in the TGA apparatus available by the partners from the WP

WP2: synthesis procedures

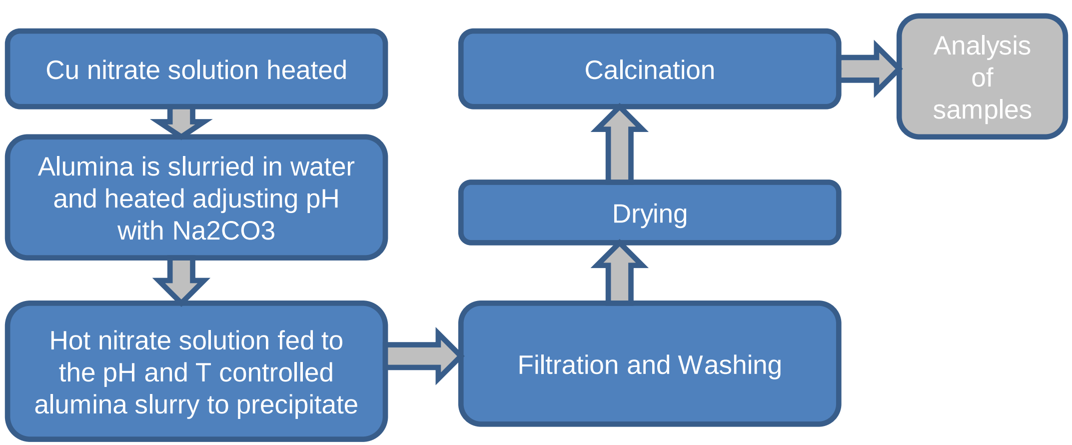
SPRAY DRYING



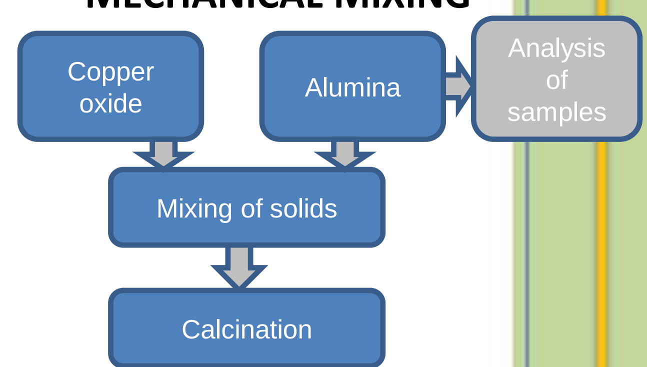
CO-PRECIPITATION



DEPOSITION-PRECIPITATION



MECHANICAL MIXING



WP2 Characterisation and testing of materials

- **CHEMICAL AND MECHANICAL STABILITY**

  TESTS IN THERMO GRAVIMETRIC ANALYZER (**TGA**)

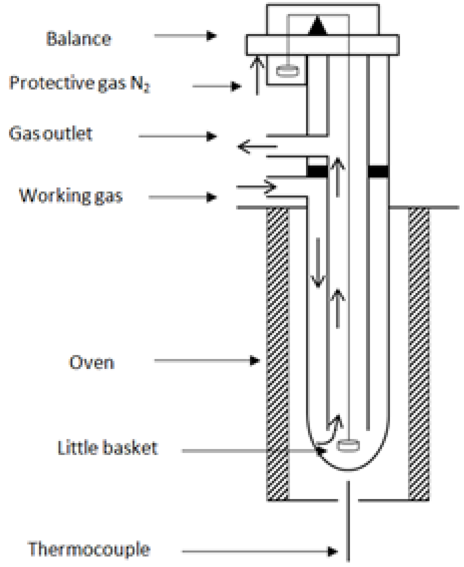
  - Powder : TGA tests via **100** red/ox cycles at 870ºC.
  - Pellets: TGA tests via **200** red/ox cycles at 870ºC.

  TESTS:

  Reduction: **20% H_2 in N_2 at 870ºC**

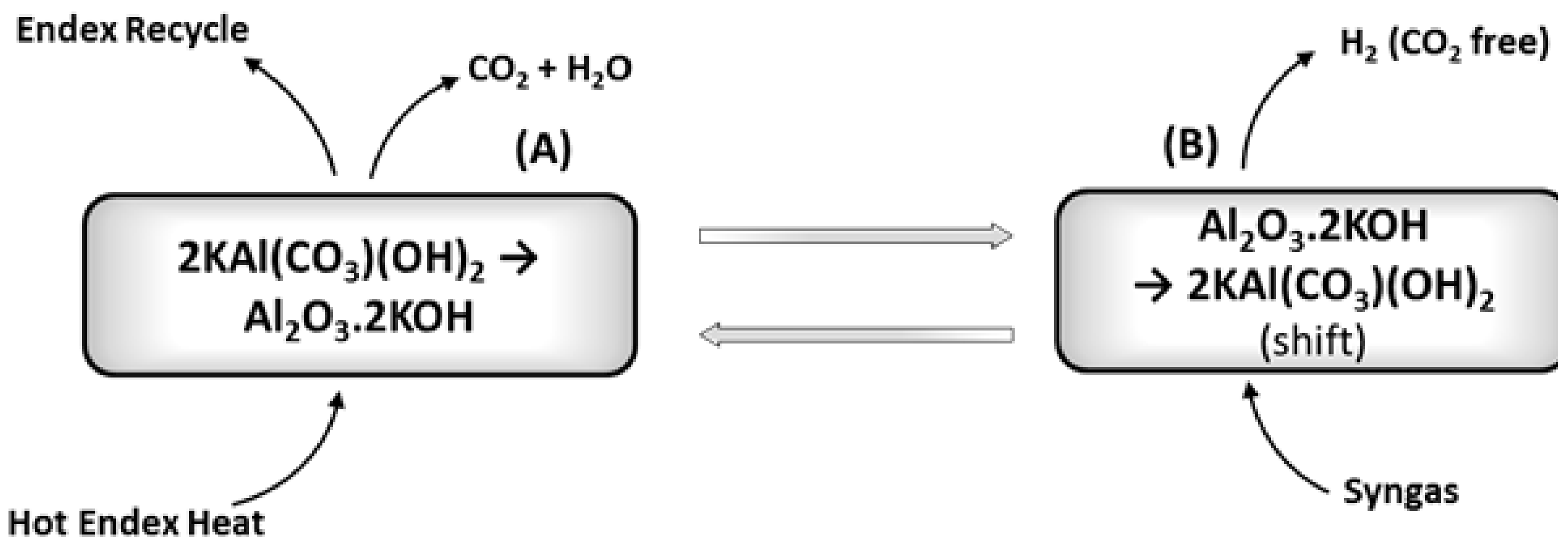
  Oxidation: **20% O_2 in N_2 at 870 ºC**

  1 min purge in N2 between stages



- **CHARACTERIZATION**
  - X-Ray Diffractometry Analysis (**XRD**)→ to identify crystalline species
  - Temperature-programmed reduction test (**TPR**) → to determine reducible species
  - **He picnometry** → to calculate solid density
  - Physorption (**BET method**) → to calculate specific surface area

WP3 Fast Sorbent mediated water-gas shift (CSHIFT)

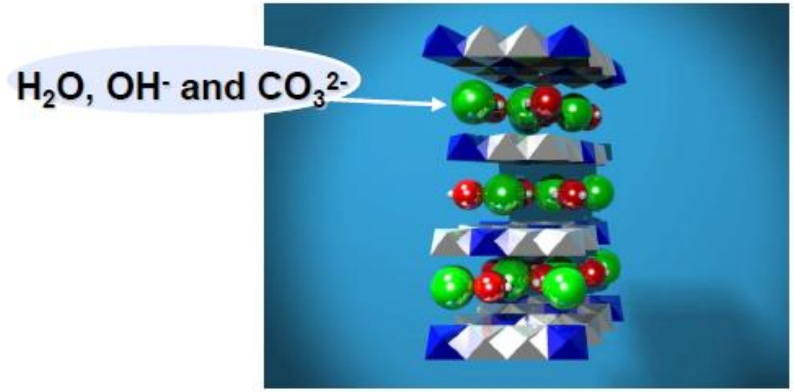


Work has been performed on pelletisation for pressurized fluidized bed reactors. In-situ DRIFTS and XRD studies have been performed on as received and CO_2/steam loaded samples in order to obtain insight into bonding modes of CO_2 and structure. Fixed bed tests to assess CO_2 capacity at elevated pressure, and also in the presence of H_2S, have been initiated. Initial modelling developments have been carried out.

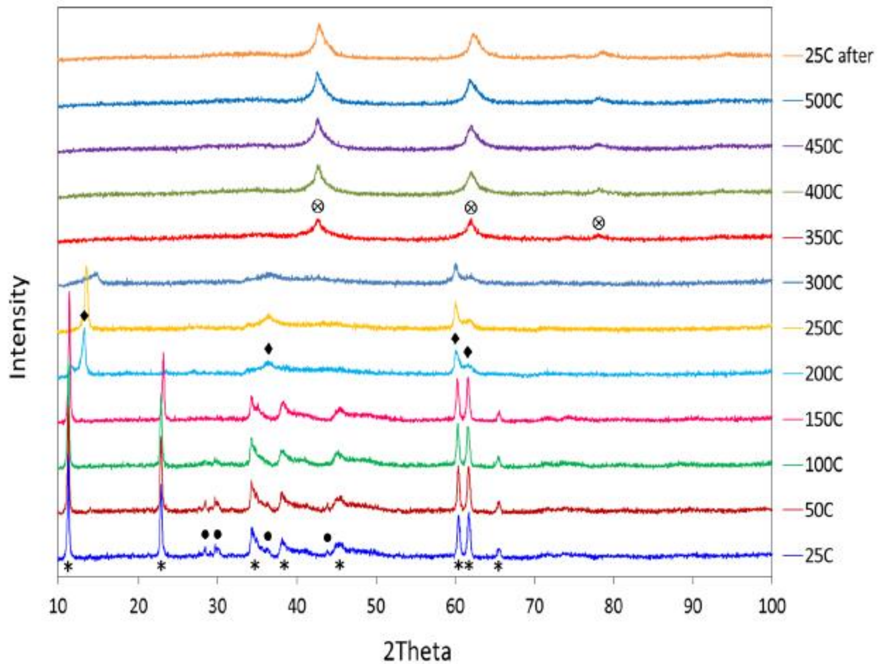
WP3: Materials optimisation studies

Sorbent characteristics:

- Effect of Steam/CO_2
- Effect of T
- Effect of pressure
- WGS reactivity
- H_2S tolerance
- Cyclic stability



Hydrotalcites are layered solid inorganic materials with the general formula $Mg_{1-x}Al_x(OH)_2(CO_3^{2-})_{(x/2)} \cdot nH_2O$.

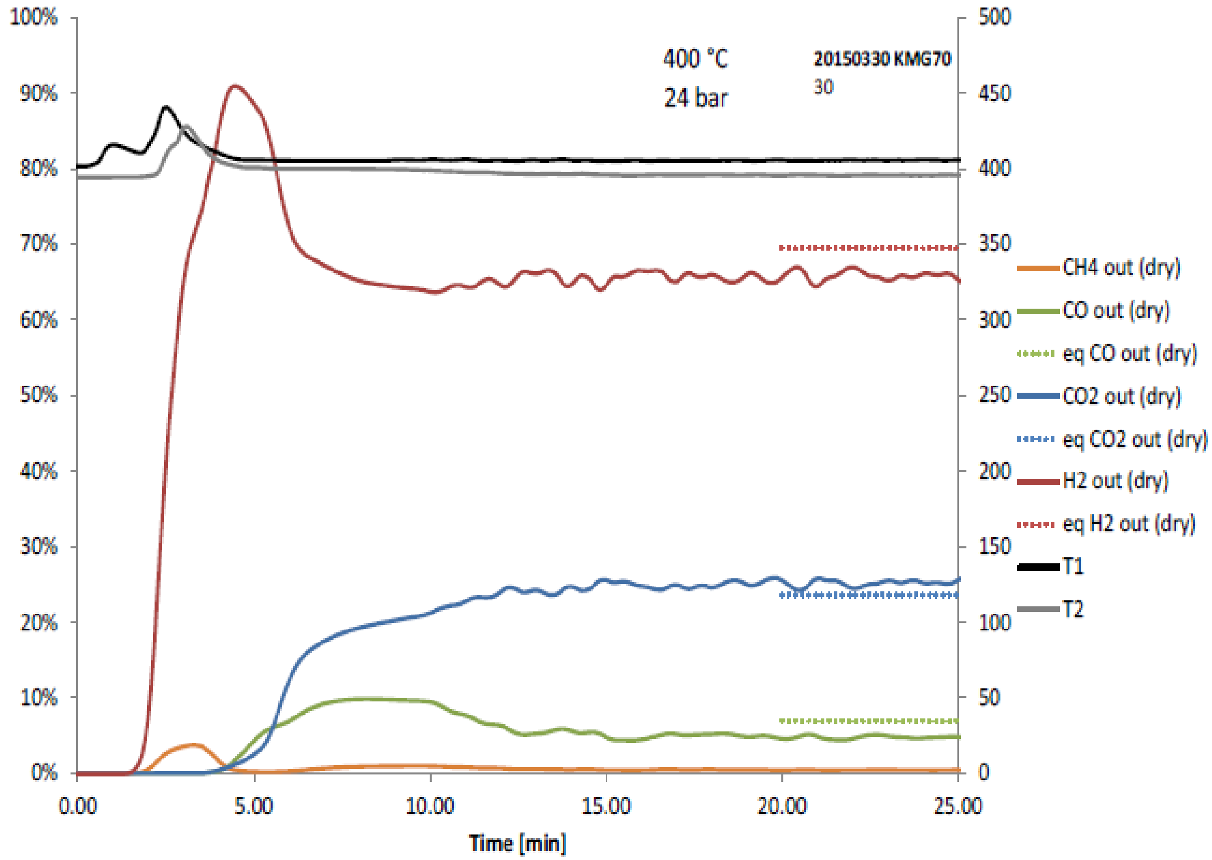


WP3: Water Gas Shift reactivity

WGS reactivity

Status :

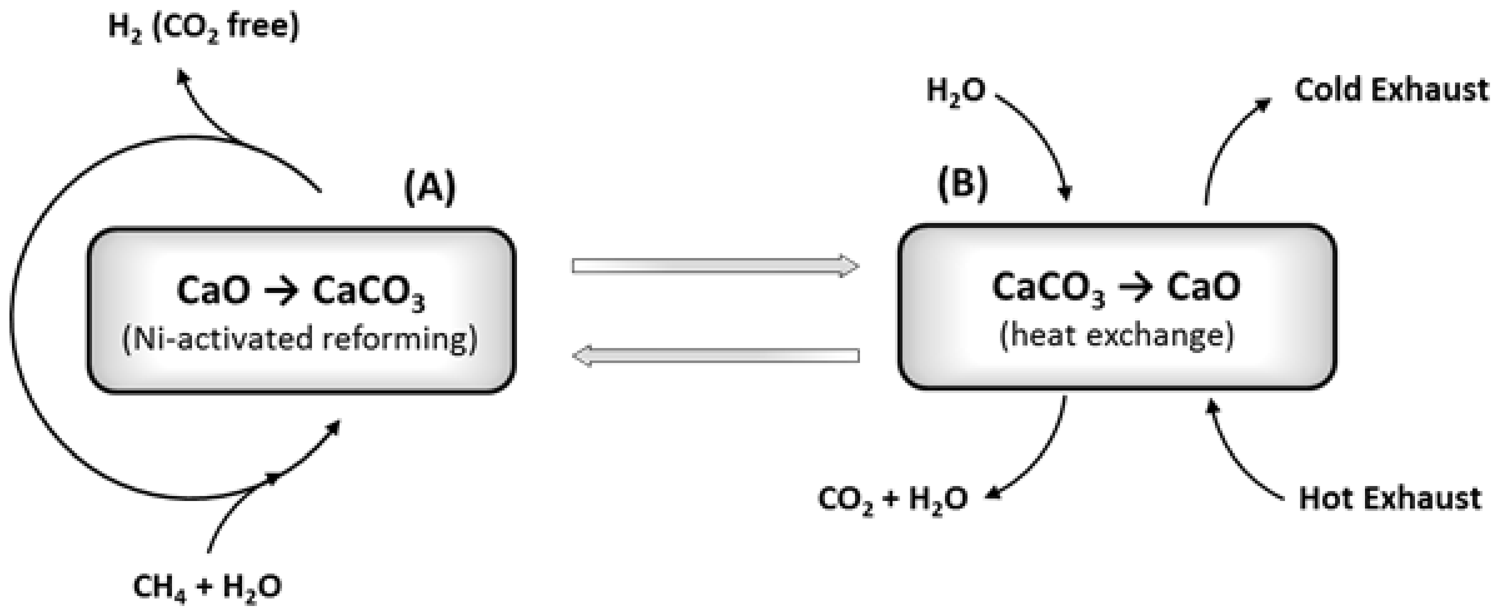
- H_2S tolerance: ok



Other sorbents: Dawsonite derived sorbents (alkali aluminium carbonate hydroxide)

- by product aluminium industry

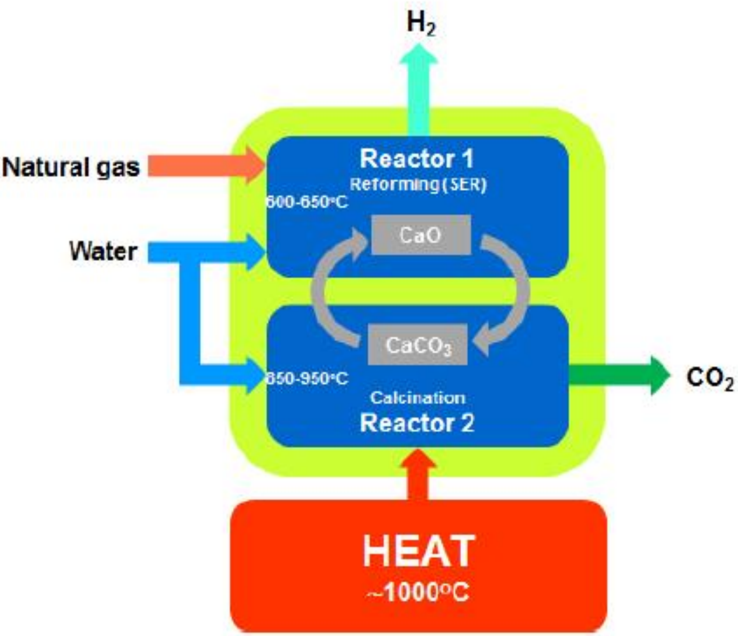
WP4 SER looping cycle



The work performed has been focused on the four following topics:

1. Determination of material performance criteria and operating process conditions
2. Development of CaO-based sorbent, reforming catalysts and combined materials (CSCM)
3. Measurement of attrition index of selected materials
4. Modelling of the SER looping process

WP4: SER looping cycle (Sorption Enhanced Reforming)



Reforming

$CH_4\,(g) + H_2O\,(g) \rightarrow CO\,(g) + 3H_2\,(g)$

Water gas shift

$CO\,(g) + H_2O\,(g) \rightarrow CO_2\,(g) + H_2\,(g)$

Carbonation

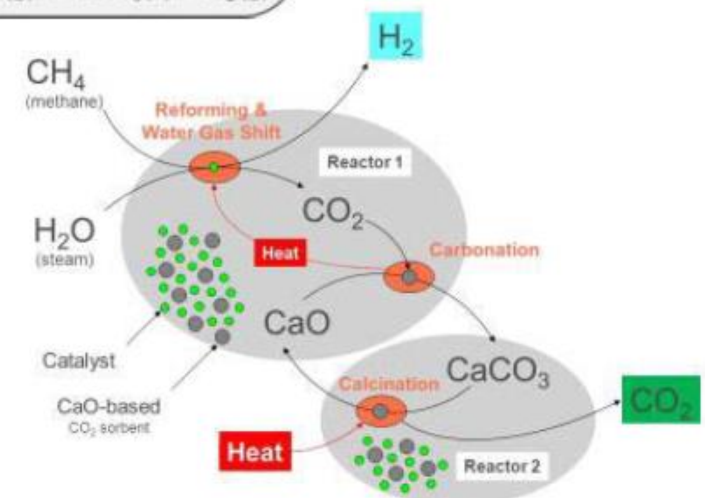
$CaO\,(s) + CO_2\,(g) \rightarrow CaCO_3\,(s)$

Total reaction (SER)

$CaO\,(s) + CH_4\,(g) + 2H_2O\,(g) \rightarrow CaCO_3\,(s) + 4H_2\,(g)$

Combination of :

- Reforming
- Water gas shift
- Carbonation



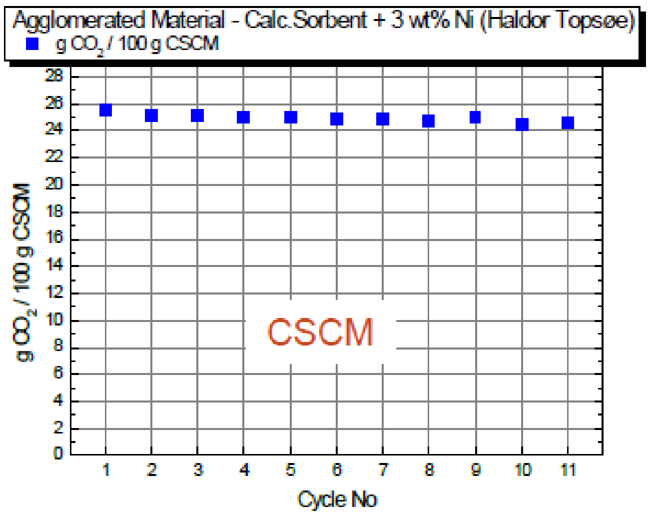
- Higher H_2-yields (95 vol% +) than in conventional SMR, in one single step, and at lower temperature (600-650°C)
- No need for shift reactors and catalysts
- Production of relatively pure CO_2
- Simplified process layout and process intensification
- **Potential for ~20% energy savings and lower costs**

Calcination (regeneration)

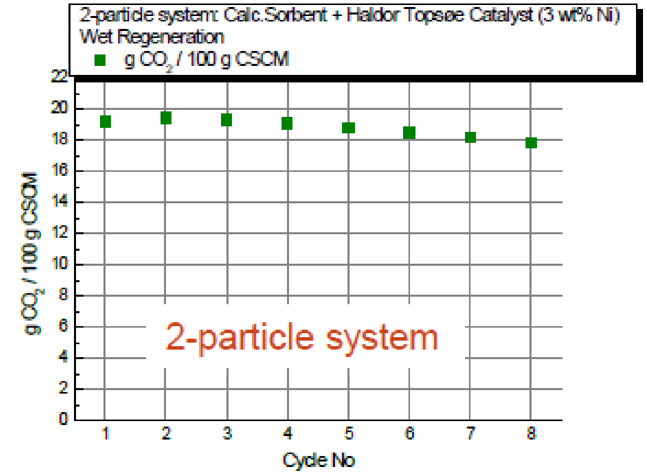
$CaCO_3(s) \rightarrow CaO(s) + CO_2\,(g)$

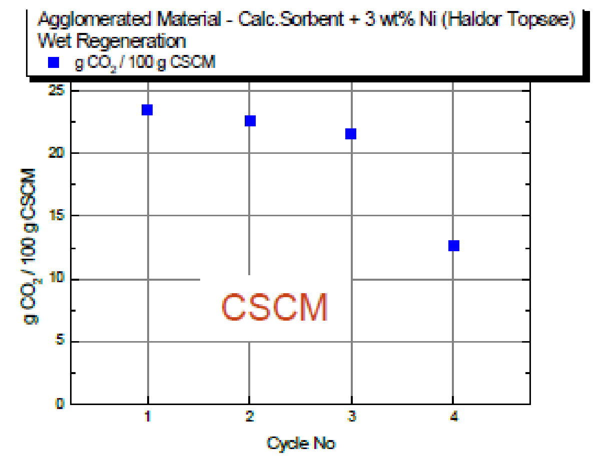
WP4: TGA tests on Combined Sorbent Catayst Materials (CSCMs)

Dry regeneration



Wet regeneration

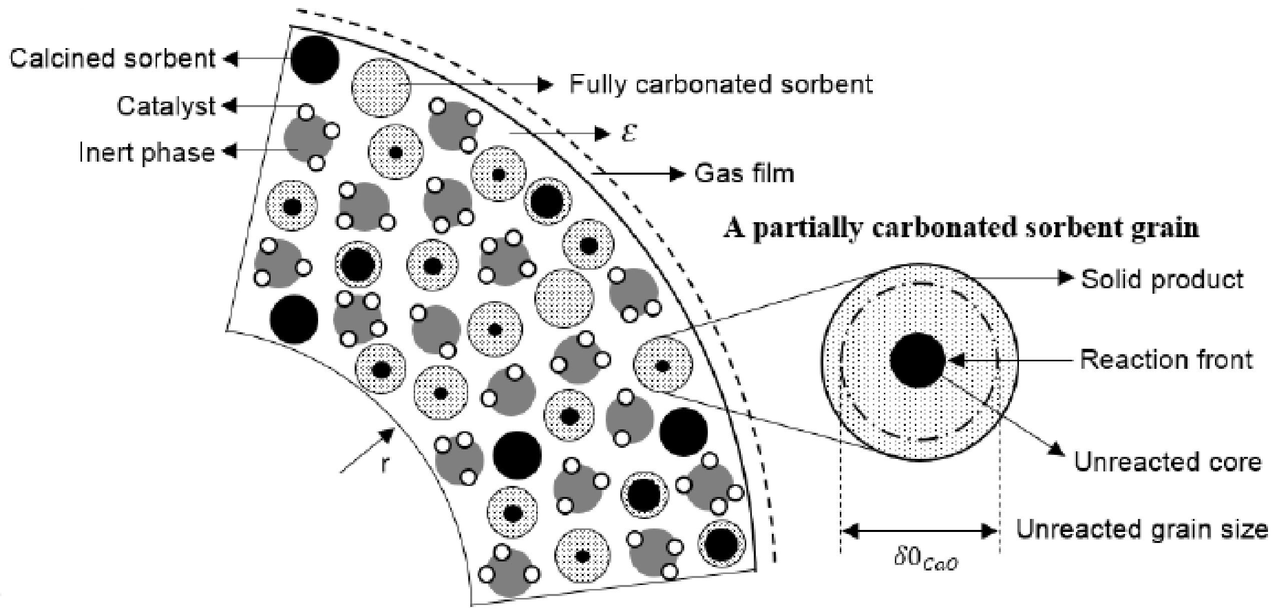




- 2-particle system and CSCM stable in dry regeneration condition
- CSCM not stable in wet regeneration condition

WP4: modelling of CSCM

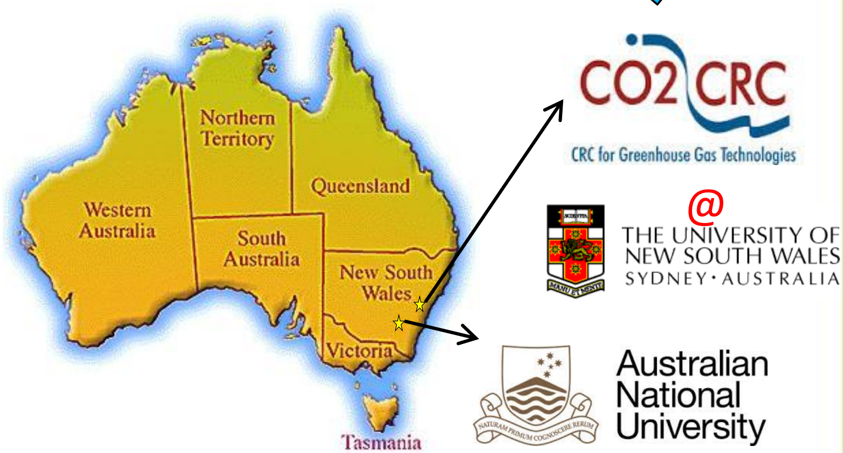
- The particle model has been derived from a previously developed sorbent grain model [1] by implementing the SMR and WGS reactions together with the carbonation heterogeneous reaction



[1] S. Stendardo, P.U. Foscolo, Carbon dioxide capture with dolomite: a model for gas-solid reaction wthin the grains of a particulate sorbent, Chem. Eng. Science, 64 (2009), 2343-2352.

Cooperation with the twinned Australian projects

Selection of performance criteria and synthesis and characterisation of the material



Thermodynamic optimisation: Australian National University

Economic optimisation: CO2CRC

Acknowledgement

The research leading to these results has received funding from the European Union's Seventh Framework Programme under grant agreement n° 608512.

SEVENTH FRAMEWORK PROGRAMME

www.ascentproject.eu