UMONS ecra chair — from $CO_2$ to energy

POLYTECH MONS

S C T 2 — Smart $CO_2$ Transformation

**$CO_2$ Utilisation:** Catalyst for the European Industrial Renaissance

Square – Brussels Meeting Centre | 29 June 2016, 09:00-18:00

# ECRA ACADEMIC CHAIR "FROM $CO_2$ TO ENERGY" AT THE UNIVERSITY OF MONS: $CO_2$ CAPTURE & REUSE IN THE CEMENT INDUSTRY

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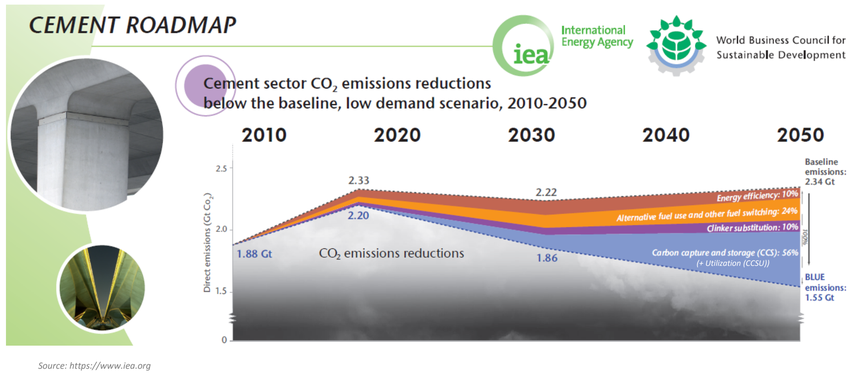
## CEMENT INDUSTRY CONTEXT

**Cement plants ≈ 30% of the industrial $CO_2$ emissions**




Source: https://www.iea.org

**$CO_2$ emissions reductions**

**44%** thanks to:
- Energy efficiency
- Alternative fuel
- Clinker substitution

**56%** thanks to:
**Carbon Capture Storage & Utilization (CCSU)**

The reduction of the $CO_2$ emissions from different industries (power plants, cement plants, etc.) at world scale requires the implementation of **Carbon Capture, Storage and Utilization (CCSU) processes**. The application of CCSU to power plants flue gases ($CO_2$ contents from 5% to 15%) has already been considered in many studies but there is still a lack of data concerning its specific application to the **cement industry** ($y_{CO2}$ > 15%).

Regarding the capture phase, two technologies are adapted to the cement industry, namely:
- the **post-combustion $CO_2$ capture** (currently tested at pilot scale in the cement industry), where the $CO_2$ in the pretreated flue gas (containing from 20% to 30% $CO_2$) is conventionally captured thanks to an absorption-regeneration process where it is absorbed in a solvent (such as monoethanolamine 30 wt.%) which is then regenerated requiring energy;
- the **oxy-fuel combustion $CO_2$ capture** (the selection of a cement plant for pilot tests is undergoing), where the combustion is performed with pure oxygen leading to flue gases highly concentrated in $CO_2$ (>80%) which need to be purified (de-$SO_x$, de-$NO_x$, etc.) prior to conversion into valuable products such as methanol.
Another option envisaged by the cement industry is the "**partial oxy-fuel combustion $CO_2$ capture**" which corresponds to an hybrid process which combines the combustion with $O_2$-enriched air ($CO_2$ contents in the flue gas between 40% and 60%) and post-combustion $CO_2$ capture by the absorption-regeneration process.

In this context, the **ECRA (European Cement Research Academy) Academic Chair** was established at UMONS in 2013, focusing on the $CO_2$ capture and reuse applied to the cement industry. Initially scheduled for a first period of 3 years, the ECRA Academic Chair has been recently prolonged until mid-2019!

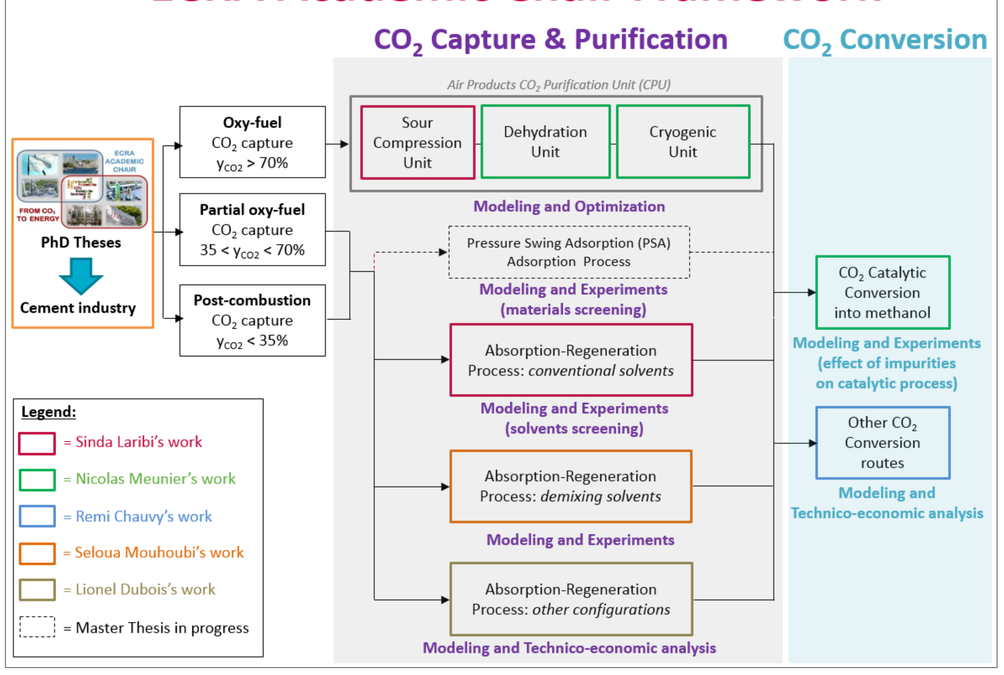
*April 2013: Important scientific agreement between ECRA (European Cement Research Academy) and UMONS (University of Mons)*

ECRA ACADEMIC CHAIR — FROM $CO_2$ TO ENERGY

*Centre of scientific expertise in the specific field of "carbon capture in cement production and its re-use"*

***Promotion of research and innovation through:***
→ PhD theses + Post-Doc
→ Projects for undergraduated students + ECRA Award
→ External communications
→ Technical/scientific Events
→ Visits of professors & experts

## ECRA Academic Chair Framework



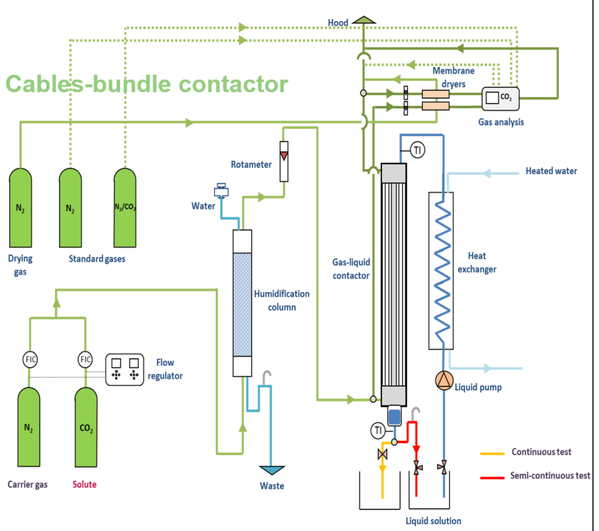

# $CO_2$ CAPTURE

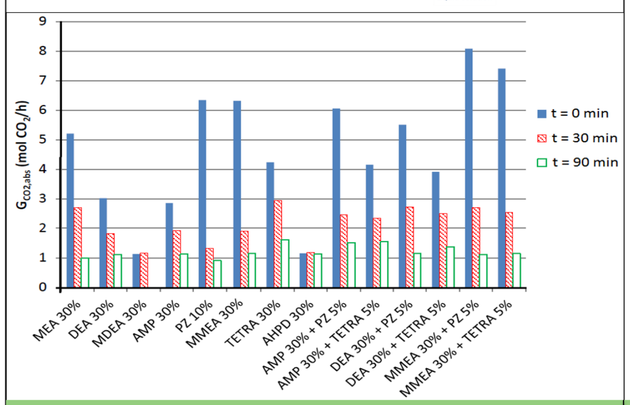
# $CO_2$ PURIFICATION

# $CO_2$ CONVERSION

## EXPERIMENTS

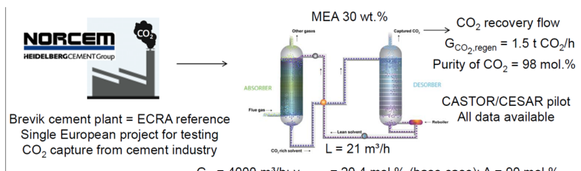
### Cables-bundle contactor




This graph shows that the ranking of the solvents based on their $G_{CO2,abs}$ is modified during the semi-continuous test due to the $CO_2$ loading.

## SIMULATIONS

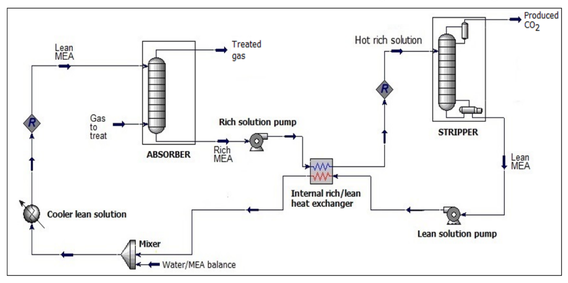



Brevik cement plant = ECRA reference
Single European project for testing $CO_2$ capture from cement industry

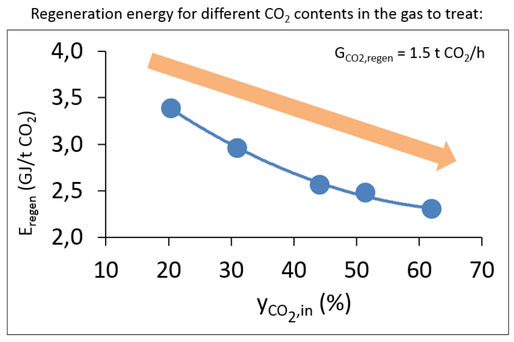
$G_{in}$ = 4000 m³/h; $y_{CO2,in}$ = 20.4 mol.% (base case); A = 90 mol.%

- Aspen Hysys V8.6
- Acid gas package
- Thermodynamic models: Peng-Robinson (gas) and e-NRTL (liquid)
- Reactions sets included in the package (validated with literature)

Aspen Hysys flow sheet of the classical absorption-regeneration configuration:

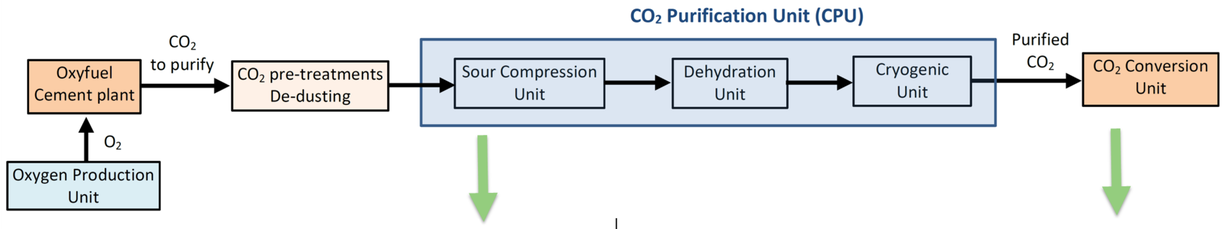



Regeneration energy for different $CO_2$ contents in the gas to treat:

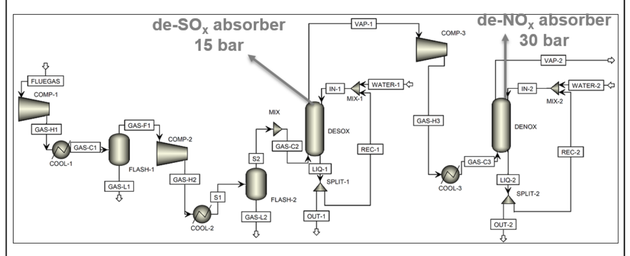



Increasing the $CO_2$ content into the gas to treat lead to a decrease of the regeneration energy of more than 30 % !

### $CO_2$ Purification Unit (CPU)




### SCU Process for de-$SO_x$ and de-$NO_x$ Simulation in Aspen Plus



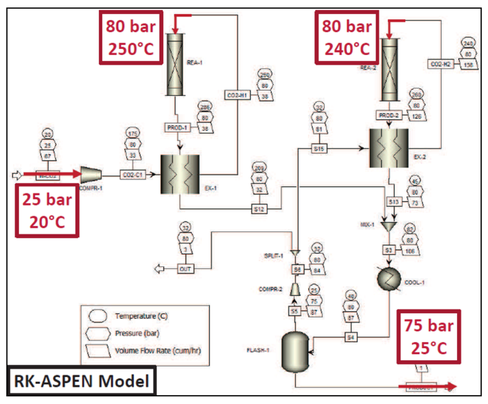

| Gas composition (%.mol) | Inlet de-$SO_x$ column | Outlet de-$SO_x$ column | Outlet de-$NO_x$ column |
|---|---|---|---|
| $CO_2$ | 83.13 | 83.82 | 83.89 |
| $N_2$ | 11.11 | 11.25 | 11.32 |
| $O_2$ | 3.27 | 3.21 | 3.23 |
| Ar | 1.34 | 1.36 | 1.37 |
| $H_2O$ | 1 | 0.35 | 0.19 |
| $NO_2$ | 96 ppm | 28 ppm | 3 ppm |
| NO | 861 ppm | Trace | Trace |
| $SO_2$ | 156 ppm | Trace | Trace |

Energy requirements

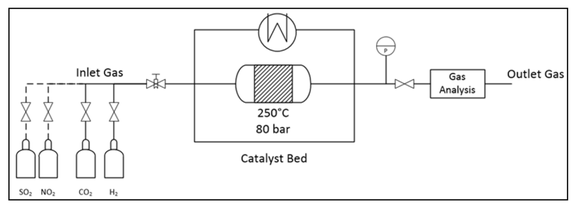
| Power type | Operation | Power (kW) | % |
|---|---|---|---|
| Electrical | 1 - 15 bar compression | 14.58 | 81 |
| | 15 - 30 bar compression | 3.42 | 19 |
| | Total | 18 | 100 |
| Thermal | 1 - 15 bar cooler (30°C) | - 16.47 | 80 |
| | 30 bar cooler (30°C) | - 4.19 | 20 |
| | Total | - 20.66 | 100 |

The SCU process is efficient for the de-$SO_x$ and de-$NO_x$ of flue gas coming from oxy-fuel combustion cement plant.

### $CO_2$ catalytic conversion into methanol Simulation in Aspen Plus




### Experimental device under development




The simulated results were successfully validated with literature. 15-25% of the $CO_2$ entering the process is converted in the first reactor and about 90% considering the whole process.

European Cement Research Academy (ECRA) and HeidelbergCement are acknowledged for the technical and financial supports accorded to the ECRA Academic Chair.

ECRA Academic Chair references:

*Meunier N., Laribi S., Dubois L., De Weireld G., Thomas D., $CO_2$ capture in cement production and re-use: first step for the optimization of the overall process, Energy Procedia 63, 6492, 2014.*

*Laribi S., Dubois L., Thomas D., Post-combustion $CO_2$ capture applied to cement plant flue gases: screening tests of innovative solvents for the absorption-regeneration process, 10th European Congress of Chemical Engineering (ECCE 10), Nice, France, 2015.*

*Meunier N., Laribi S., Dubois L., Thomas D., De Weireld G., $CO_2$ capture and re-use from oxyfuel cement kilns: Process simulation of the $CO_2$ purification and catalytic conversion into methanol, International Conference on Carbon Dioxide Utilization (ICCDU XIII), Singapore, 2015.*

*Dubois L., Laribi S., Meunier N., De Weireld G., Thomas D., Global optimization of the $CO_2$ capture and reuse applied in the cement industry, Brussels sustainable Development Summit 2015, Belgium, 2015.*

## 09-10th November 2016

## Save the date!

The European Cement Research Academy (ECRA) and the University of Mons (UMONS) are pleased to invite you to the Second Scientific Event of the ECRA Academic Chair:

**« $CO_2$ Capture & Reuse in the cement industry: from the lab to the plant »**

Workshop organized at Mons (Belgium) on the 09th November 2016
+ Visit of the Lixhe Cement plant on the 10th November 2016

ECRA Academic Chair website: http://hosting.umons.ac.be/html/ecrachair