ECRA Chair@UMONS: *«From CO_2 to Energy: Carbon Capture in Cement Production and its Re-use»*

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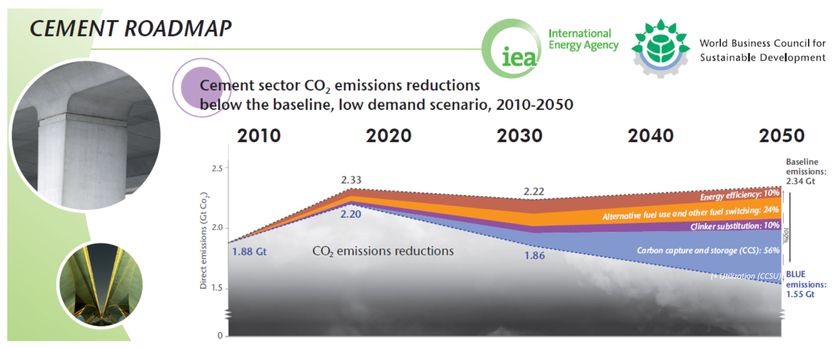
CEMENT INDUSTRY CONTEXT



CO_2 emissions reductions

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

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

Cement plants ≈ 30% of the industrial CO_2 emissions

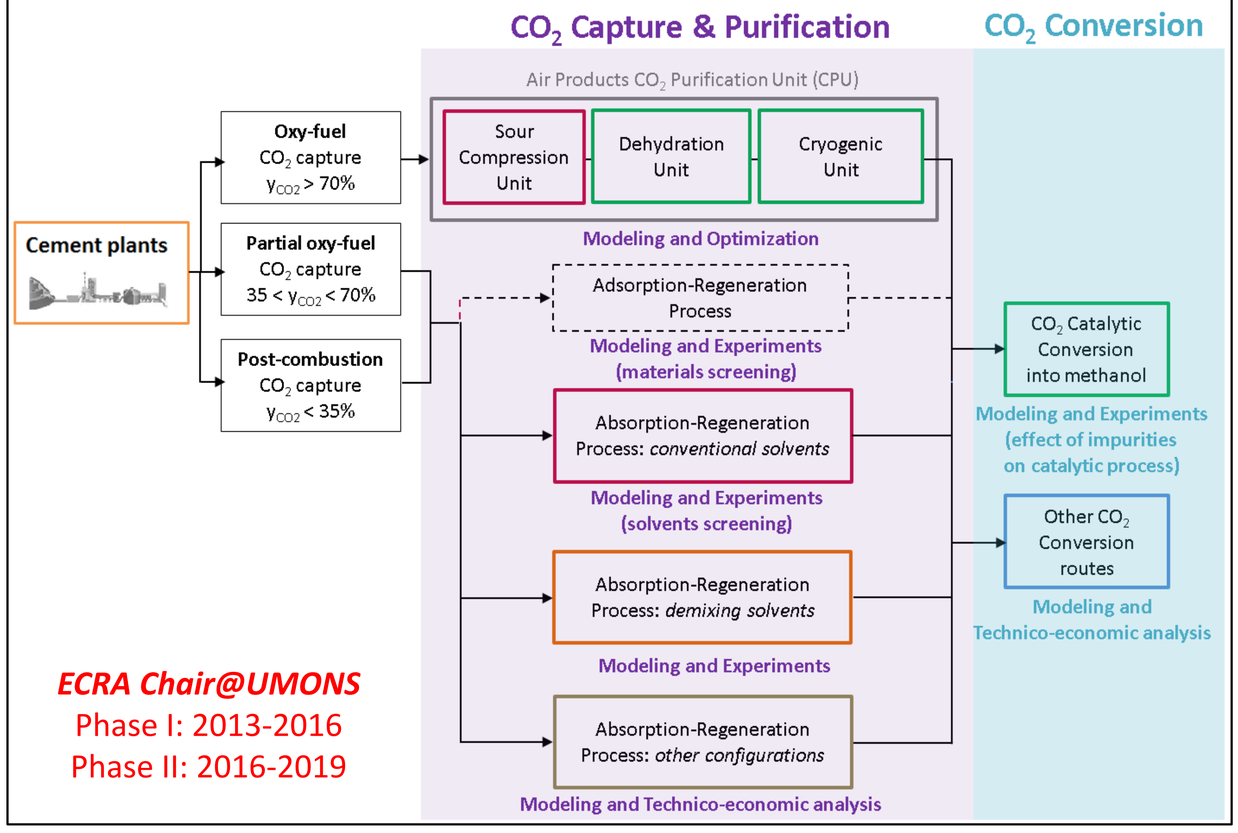
* **Reduction of CO_2 emissions** from different industries by **Carbon Capture, Storage and Utilization (CCSU) processes** but lack of data concerning its specific application to the **cement industry** (y_{CO2} > 15%).

* Two **capture technologies** adapted to the cement industry, namely:

- the **post-combustion CO_2 capture** *(currently tested at pilot scale in the cement industry)*:
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 MEA 30 wt.%) which is then regenerated requiring energy;
- the **oxy-fuel combustion CO_2 capture** *(undergoing selection of a cement plant for pilot tests)*: the combustion is performed with pure oxygen, leading to flue gases highly concentrated in CO_2 (>80%) needing to be purified (de-SO_x, de-NO_x, etc.) prior to conversion.

* Another **innovative option envisaged by the cement industry** = "**partial oxy-fuel combustion CO_2 capture**": hybrid process which combines the combustion with O_2-enriched air (CO_2 contents in the flue gas between 20% and 60%) and post-combustion CO_2 capture by the absorption-regeneration process.

ECRA Academic Chair Framework



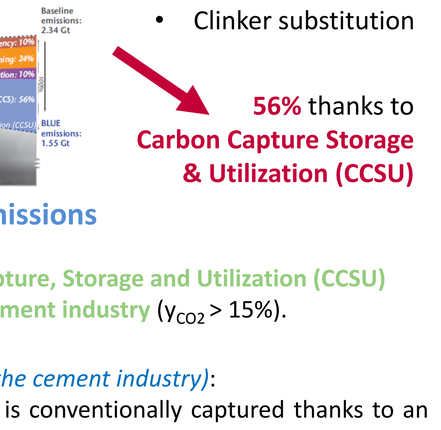
ECRA Chair@UMONS
Phase I: 2013-2016
Phase II: 2016-2019

A: CO_2 Capture and Purification Processes

Sinda LARIBI (01/2014 -> 01/2018)
" Capture and purification processes applied to CO_2 derived from cement industry for conversion into methanol "

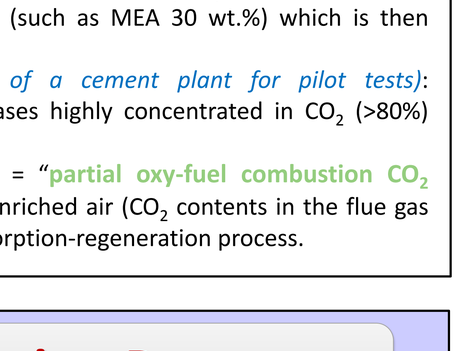
- **Post-combustion CO_2 capture by absorption-regeneration into amine solvents** applied to conventional and partial oxyfuel combustion cement flue gases (1):
  - *screening of solvents at laboratory scale*
  - *micro-pilot scale experimental tests*
  - *simulations of micro-pilot and industrial units*
  - *-> interest clearly demonstrated:*
    - *E_{regen} decreasing when y_{CO2} increased*
- Effect of SO_2 on CO_2 absorption performances into aqueous amine solutions:
  - *experimental study*

PID of the micro-pilot unit



- **Simulation of a Sour-Compression Unit for de-NOX and de-SOx:** CO_2 purification applied to full oxyfuel combustion flue gases (2):
  - *comprehensive modeling of the NOx-SOx chemical mechanisms*
  - *parametric study*
  - *-> optimization of the SCU process*

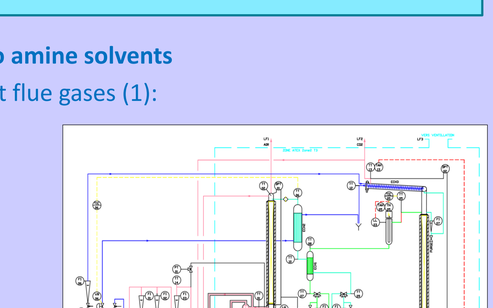
SCU process



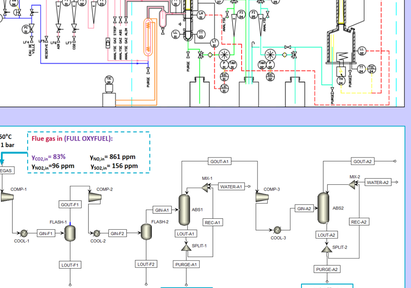
Seloua MOUHOUBI (02/2016 -> 01/2020)
" Development of a simulation model of the post-combustion CO_2 capture process by absorption-regeneration using demixing solvents: application to cement flue gases "

- Selection of the promising bipasic system:
  water
  + **DEEA** *(= 2-(diethanolamino)ethanol)*
  + **MAPA** *(= 3-(methylamino)propylamine)*

Flowsheet of a demixing process



- Identification of demixing and non-demixing conditions related to DEEA and MAPA concentrations, CO_2 loading and temperature
- Thermodynamic modeling of the system:
  extended UNIQUAC and e-NRTL to predict the LLV equilibrium
- Experimental determination of absorption performances and kinetic study : *reactive absorption modelling*



*-> **complete modeling** of the process using DEEA+MAPA aqueous demixing solvents and **assessment of the regeneration energy saving***

B: CO_2 Conversion Processes

Nicolas MEUNIER (09/2013 -> 09/2018)
" CO_2 capture in cement production and re-use: optimization of the overall process "

- Innovative modifications of the methanol process:
  Aspen modeling
  appropriate operating conditions
- Upgraded methanol process:
  technical description
  economic balance
- Building of a new micro-pilot installation for the determination of kinetic data relative to the simulation of the methanol catalytic process
  device's development
  experimental procedures tested
  calibration
  comparison of various catalysts (commercial and innovative)

-> optimization of the process

Flowsheet of a methanol process

Flowsheet of the experimental CO_2 conversion set up

Remi CHAUVY (09/2015 -> 08/2019)
" Study of the potential of different CO_2 conversion options for the application of Carbon Capture and Re-use to the cement industry: simulation and technico-economic analysis "

- Initial assessment: reduction of the panel
- Semi-quantitative analysis:
  - Criteria
  - Results -> *Ranking list of CO_2 conversion options and selection of routes studied**

CO_2-based compound	CO_2-conversion process	Weighted Score
*Methanol	Catalytic hydrogenation	20.5
Methane	Catalytic hydrogenation	16.9
Microalgae	Biological process	15.4
*Formic acid	Electrochemical reduction	15.1
*Calcium carbonates	Mineral carbonation	12.9
*Sodium carbonates	Mineral carbonation	11.3
Ethanol	Microbial process	11.1

Interest for the cement industry

- Two processes specifically and currently studied:
  - *CO_2 catalytic conversion (hydrogenation) into methanol*
  - *CO_2 conversion into formic acid (electrochemical reduction)*

*-> Aspen Plus and LCA modelisations for **comparison of performances***

KEY WORDS

Exp (• absorption • catalysis • demixtion) → Simu (• equilibria • flowsheeting • LCA) → Compa-risons → Optimization of the processes → **From CO_2 to energy**

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