From MEA to demixing solvents and future steps, a roadmap for lowering the cost of post-combustion carbon capture

Ludovic Raynal, Pierre-Antoine Bouillon, Adrien Gomez and Paul Broutin
+ IFP colleagues

Outlook

- IFP & CCS
- 1st generation PCC
- Needs for new processes
- DMX™ and future processes
- Conclusion
# IFP

## IFP at a glance

- 1,710 people*, including 1,166 researchers (engineers and technicians), based in Rueil-Malmaison and Lyon
- 200 doctoral and post-doctoral researchers
- More than 50 professions represented: from geological engineers to powertrain engineers
- A very high-quality technical environment (testing resources, equipment)

- Status: State-owned industrial and commercial establishment (EPIC)
- Funding: State budget and resources provided by private French and foreign partners
- Budget for 2008: €286.2 million, including €238.2 million for R&D

* mean workforce, full-time equivalent

## CCS @ IFP

- **PS1 strategic priority**
- **intensive work on PCC**
  - 1st & 2nd generation processes
  - future processes
  - involve many research fields

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PCC reference = MEA

- Reference process : MEA 30 wt.%
  - proven via Castor pilot test campaigns
  - Cost evaluated around 50 to 65 €/t CO₂ avoided
  - Energetic penalty for the power plant : - 10.5 pts
  - High sensibility to O₂ : degradation

- IFP solution : HiCapt+™
  - increase in MEA concentration + use of additives
  - keep reliability and robustness of the reference process
  - increase performances
HiCapt™ process – results 1/2

- **HiCapt™** (40 wt.% MEA + additives)
- Screening and tests of inhibitors
  - More than 130 products evaluated
  - Very good results obtained

HiCapt™ process – results 2/2

**ENEL Site:**
Coal power plant in Brindisi (4 x 660 MWe)

**Pilot Main Data:**
- Flue gas: 10,000 Nm3/h
- CO2 captured: 2.25 t/h
- Start-up: 2010

**ENEL/IFP collaboration:**
Classical MEA process
HiCapt™ process
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Targets for a new PCC process

Too high CO₂ costs : 50 €/t - 65 €/t

- purified gas: -90 % CO₂
- CO₂ @ 110 bars: y > 95 %

Objective:

- develop "low-cost" CO₂ capture processes
  (with clearly given boundary conditions)

<table>
<thead>
<tr>
<th>Flue gas flowrate</th>
<th>78 480 kmole/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flue gas temperature</td>
<td>45 °C</td>
</tr>
<tr>
<td>Flue gas pressure</td>
<td>1 bar abs.</td>
</tr>
<tr>
<td>Flue gas composition</td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>13% vol.</td>
</tr>
<tr>
<td>N₂</td>
<td>75% vol.</td>
</tr>
<tr>
<td>O₂</td>
<td>5% vol.</td>
</tr>
<tr>
<td>H₂O</td>
<td>7% vol.</td>
</tr>
</tbody>
</table>
Scientific & Technical information

- VLE data + adapted thermodynamic model
- Degradation / Corrosion
- Operational issues
- Kinetics & Mass transfer performances
- Process simulations / cost evaluations

Case of the MEA 30wt.% process

- Reference case
- Enough data for complete design
- Main focus on reboiler duty
  => 3.7 GJ / t\_CO₂
- reboiler duty = only cost ?

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
New process : main targets 1/3

Opex (2/3) + Capex (1/3)

compressors = 30 - 40 %

columns + packings = 30 – 50 %

regeneration heat = 50 – 60 %

1 : high capacity solvent with low heat regeneration requirements

New process : main targets 2/3

Opex (2/3) + Capex (1/3)

compressors = 30 - 40 %

columns + packings = 30 – 50 %

regeneration heat = 50 – 60 %

1 : high capacity solvent with low heat regeneration requirements

2 : high capacity solvent with good kinetics
   + adapted mass transfer technology
New process : main targets

Opex (2/3) + Capex (1/3)

- 30% - 40% compressors
- 25% - 30% compressor
- 30% - 50% columns + packings
- 90% CO₂ capture
- 13.5% CO₂ flue gas
- HP CO₂ (110 bars)
- Regeneration heat = 50% - 60%

1: high capacity solvent with low heat regeneration requirements

2: high capacity solvent with good kinetics + adapted mass transfer technology

3: solvent with low temperature degradation (Reg in pressure)

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Demixing solvents concepts

amine + H₂O + CO₂ ↔ ammonium salts

1) high capacity solvents
2) low reaction heat
3) regeneration of a fraction of the solvent only
4) CO₂ rich phase has an "abnormally" high loading

=> important energy savings

DMX™ solvents
Thermodynamics
DMX™ solvents
L/L Decantation

- NB Oil & Gas reference case:
  - high separation quality is not needed
  - densities and viscosities less in favor
- Step 1:
  - stirred cell tests
- Step 2:
  - lab-scale decanter test
  - CFD

DMX™ solvents
Degradation

- Very low thermal degradation, little influence of CO₂ or/and O₂ concentration (DMX-1 vs 17 molecules) => possibility to increase temperature at stripper and therefore possibility to increase pressure at stripper + low solvent consumption
DMX™ Process
Process evaluation

DMX™ Process
Mini-pilot tests

- Tests in a laboratory test rig
  - complete loop
  - comparison of solvents (qualitative)
  - degradation/corrosion tests

- 30% MEA
  - 110°C
    \[ V_{corr} = 4.5 \text{ mm/year} \]

- DMX-1 solvent
  - 105°C (mini-Pilot)
    \[ V_{corr} < 2 \mu\text{m/year} \]
  - 180°C, 20 bar CO₂ (CSTR)
    \[ V_{corr} = 10 \mu\text{m/year} \]

important decrease in reboiler duty
=> a more complex cost repartition...
=> more work needed on all items for further cost reduction!
Chilled Ammonia Process 1/2

- a process with very low reboiler duty
- -64% electrical energy

1.2-2.4 GJ/ton CO₂ (-35-68%)

Chilled Ammonia Process 2/2

- a process with very low reboiler duty
- BUT with pre/post conditionning
- -64% electrical energy

additional CAPEX + OPEX !! for appropriate boundary conditions

1.2-2.4 GJ/ton CO₂ (-35-68%)
Hydrates process 1/2

- a process with no OPEX at reboiler!

0 GJ/ton CO₂ !!!

Hydrates process 2/2

- a process with no OPEX at reboiler!
- BUT with pre-conditioning

0 GJ/ton CO₂ !!!
Technologies 1/2

- absorber
- stripper
- purified gas
- CO₂
- flue gas
- lean amine
- rich amine
- HP CO₂
- compressor = 25 – 30 %
- regeneration heat = 50 – 60 %
- columns + packings = 30 – 50 %
- compressors = 30 - 40 %
- blower = 5 – 10 %

Opex (2/3)
- column design:
  - optimum packing / distribution
  - minimum pressure drop
  - maximum mass transfer characteristics

Capex (1/3)
- column design:
  - optimum packing / distribution
  - minimum pressure drop
  - maximum mass transfer characteristics

Technologies 2/2

- random / structured packings
- original G/L contactors
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- 1st generation PCC
  - MEA 30wt.% ready for demos and more but high CO₂ cost
  - HiCapt+™
  - cost repartition => drivers
- 2nd generation PCC
  - lots of required data / steps
  - clear boundary conditions for smart comparison
  - DMX™
- Technologies
- Long term studies
  - hydrates, membranes, ionic liquids, sorbents...
Thank you!

Innovating for energy

www.ifp.fr

Ludovic.Raynal@ifp.fr