Laboratory for Analysis
and Synthesis of
Chemical Systems

Université
de Liège

Cape Forum Aachen, March 2010

Modeling post-combustion CO_2 capture with amine solvents

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Global warming context

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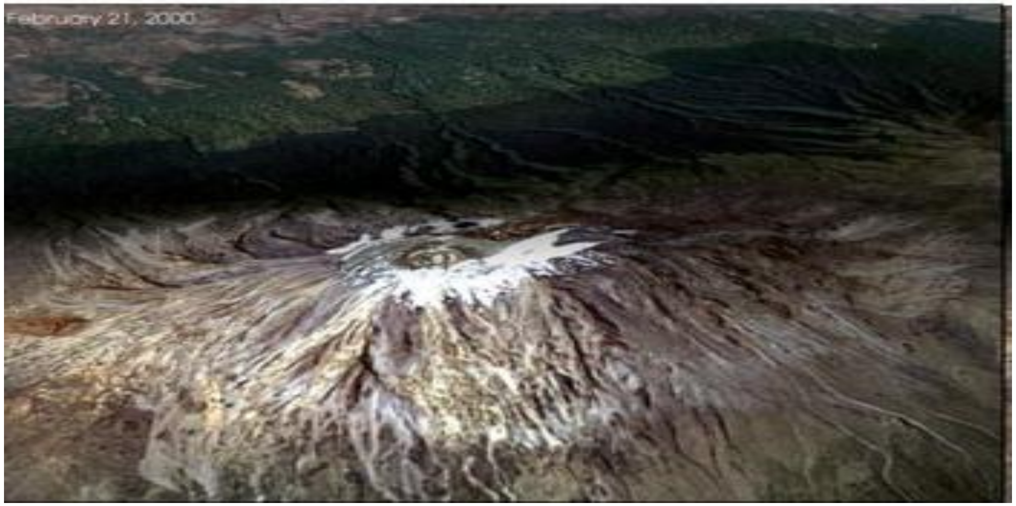
February 1993

February 2000



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1. Introduction

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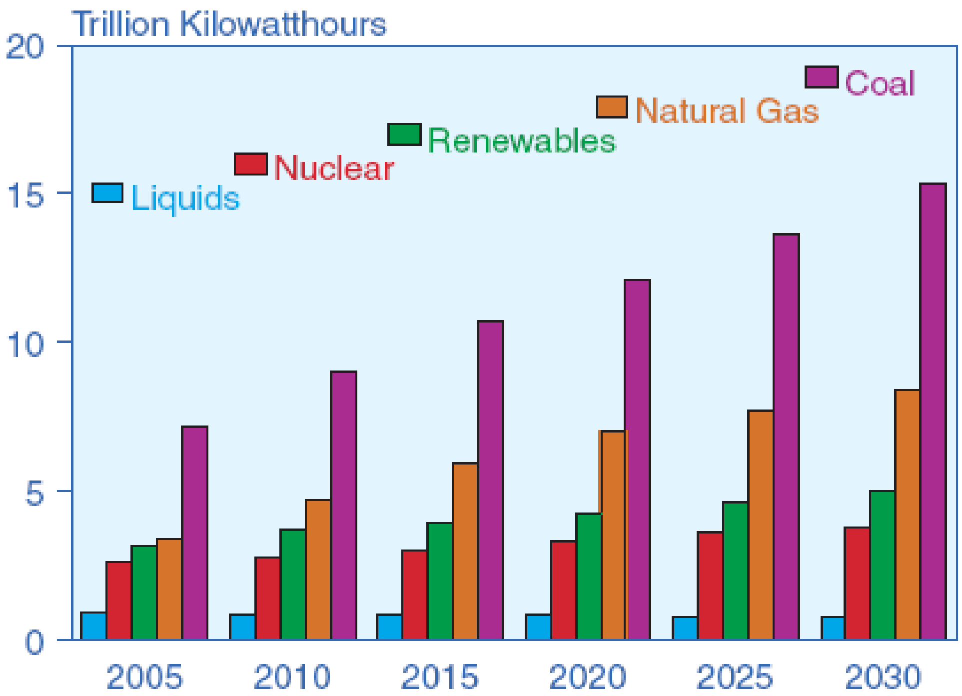
- Importance of coal for electricity generation in the near-future

- Environmental concerns

=> Energy efficiency
=> biomass
=> Carbon Capture and Storage (CCS)

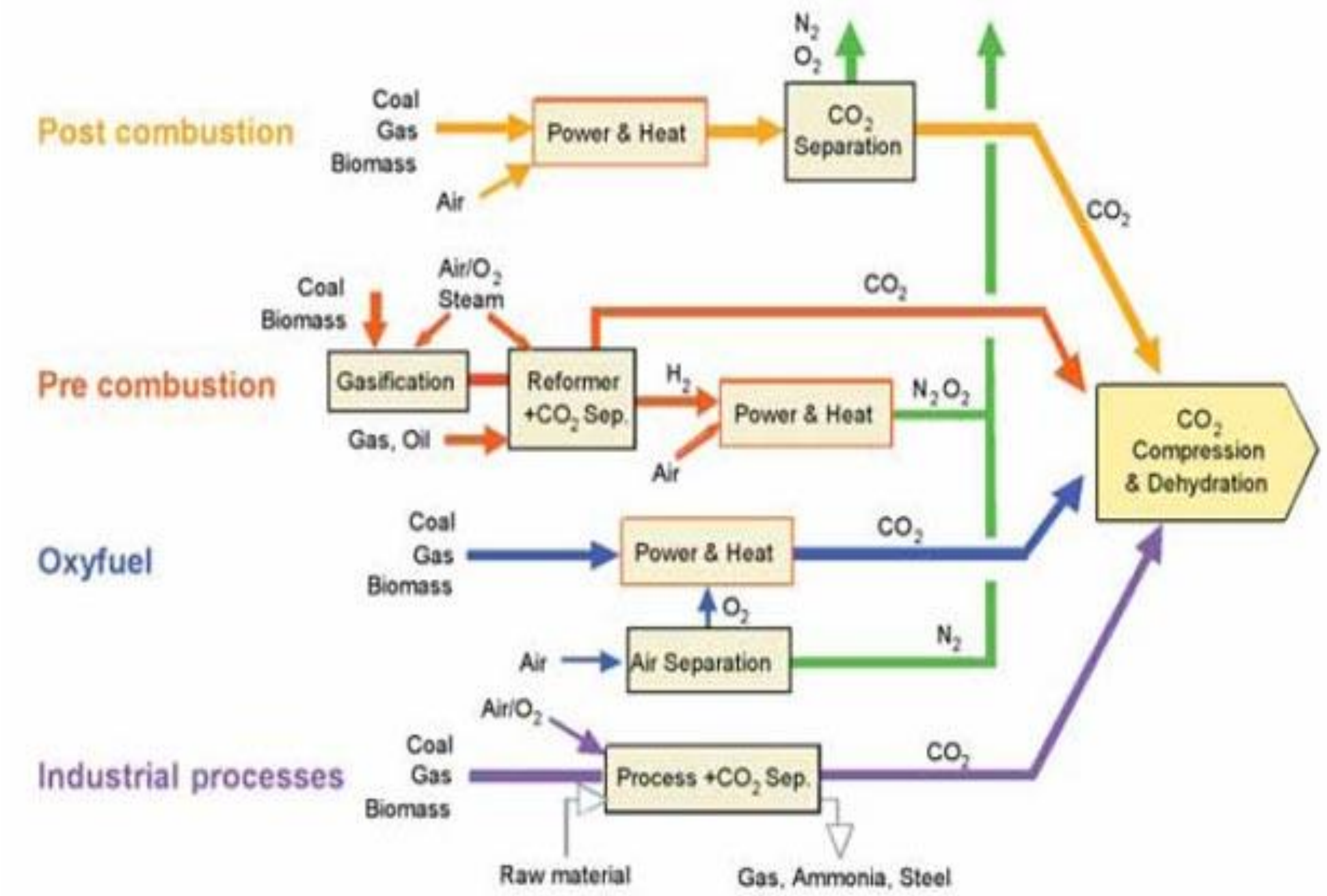
World Electricity Generation by Fuel, 2005-2030



International Energy Outlook 2008

1. Introduction

CO_2-Capture methods



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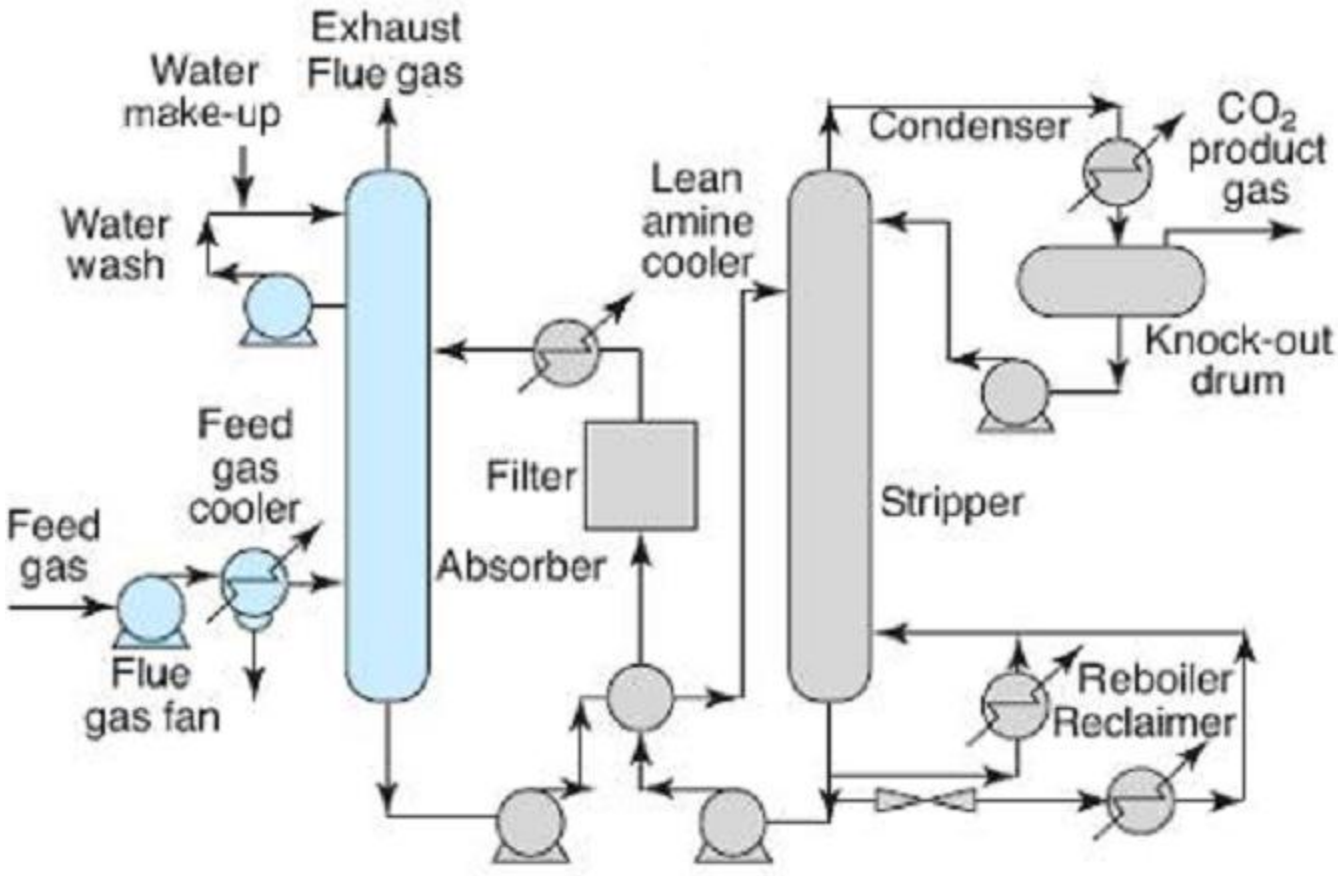
Post-combustion capture



2. Objectives

2. Objectives

Objectives:

- Development of a simulation model for a pilot capture installation (5000 Nm^3 flue gas per hour / 1 ton CO_2 per hour)
- Identification of clue parameters
- Optimization of the developed model
- Simulation of process improvements

3. Model description

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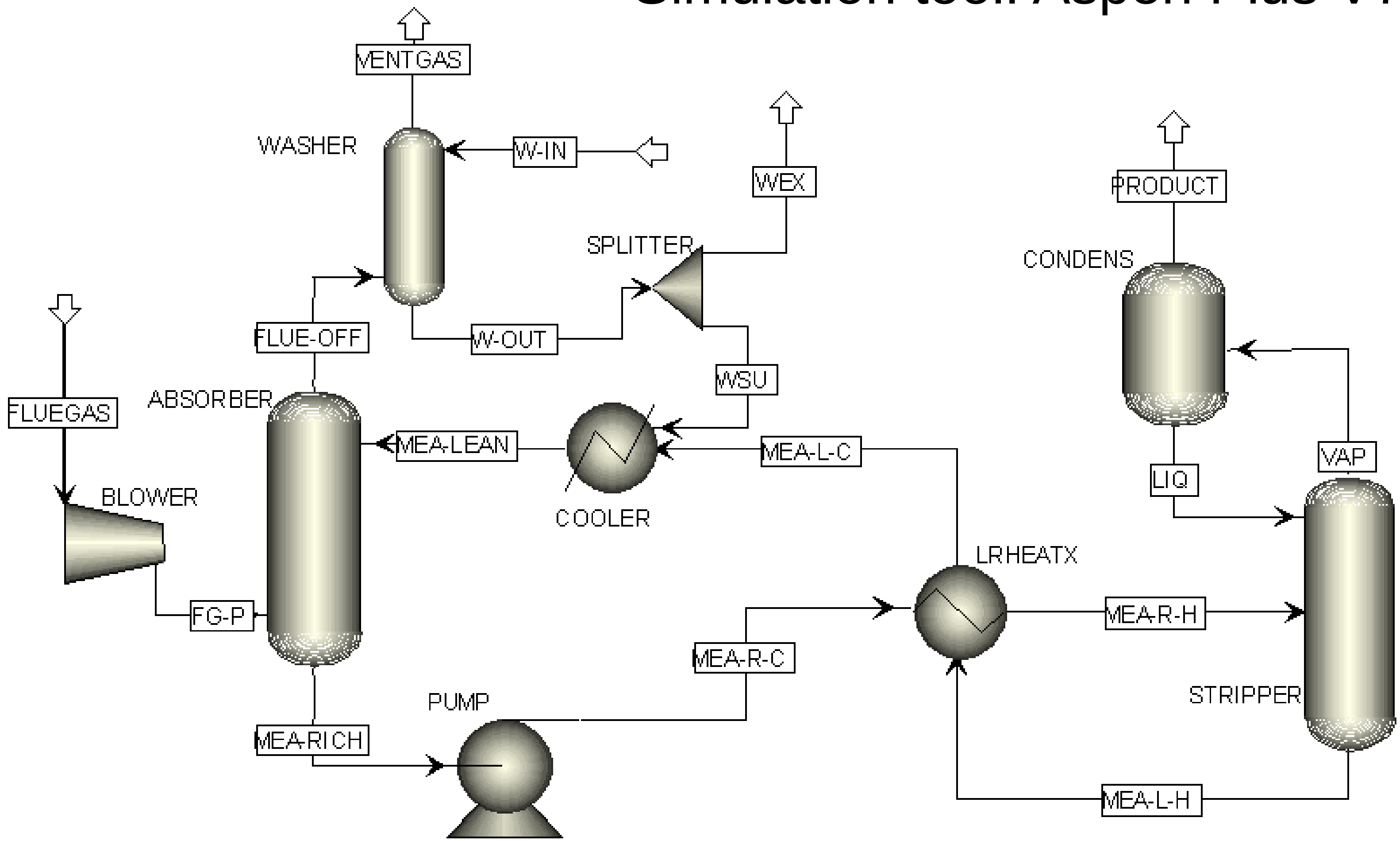
Simulation tool: Aspen Plus V7.0



3. Model description

Model main characteristics

- Flue gas flow: 2500 Nm^3/h
- 90% CO_2-recovery rate
- captured CO_2: 566 kg/h
- MEA solvent, concentration = 30 wt-%

3. Model description

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Thermodynamical equilibrium model for the columns

=> No mass transfer limitations

=> No reaction kinetics limitations

However, global results are still in good agreement with the experimental results[1].

⇒ Not a problem as long as internal column profiles are not studied in details![2]

[1]:J. Knudsen, P. Vilhelmsen, J. Jensen, O. Biede, First year operation experience with a 1t/h CO_2 absorption pilot plant at Esbjerg coal-fired power plant, 2008

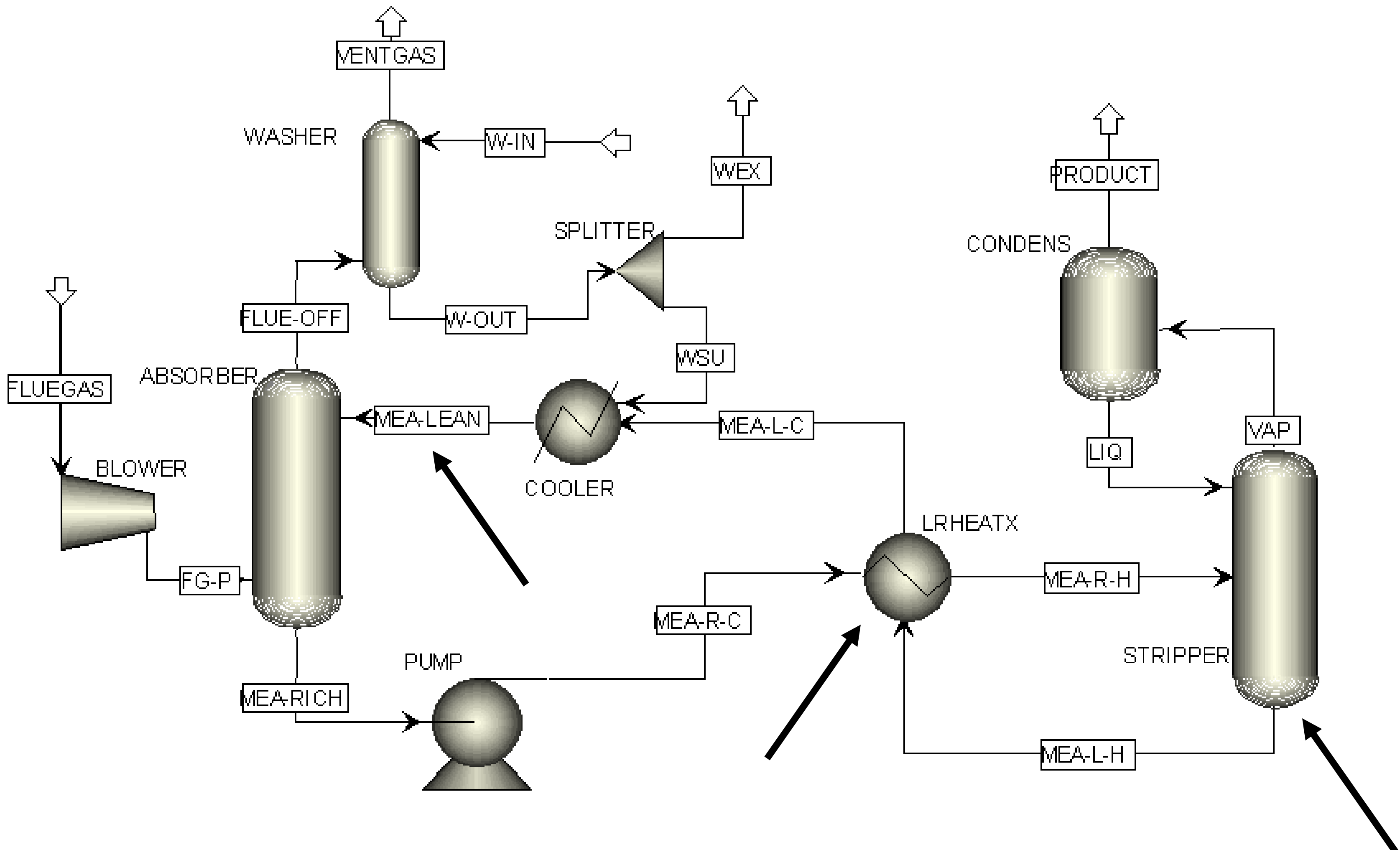
[2]: Abu Zahra M., 2009. Carbon dioxide capture from flue gas, PhD Thesis, TU Delft

4. Simulation results

Optimization of the base case

- 4.1 Lean solvent flow
- 4.2 Lean solvent concentration
- 4.3 Lean solvent inlet temperature in the absorber
- 4.4 Stripper pressure
- 4.5 Temperature approach at the lean-rich heat exchanger

4. Simulation results



4. Simulation results

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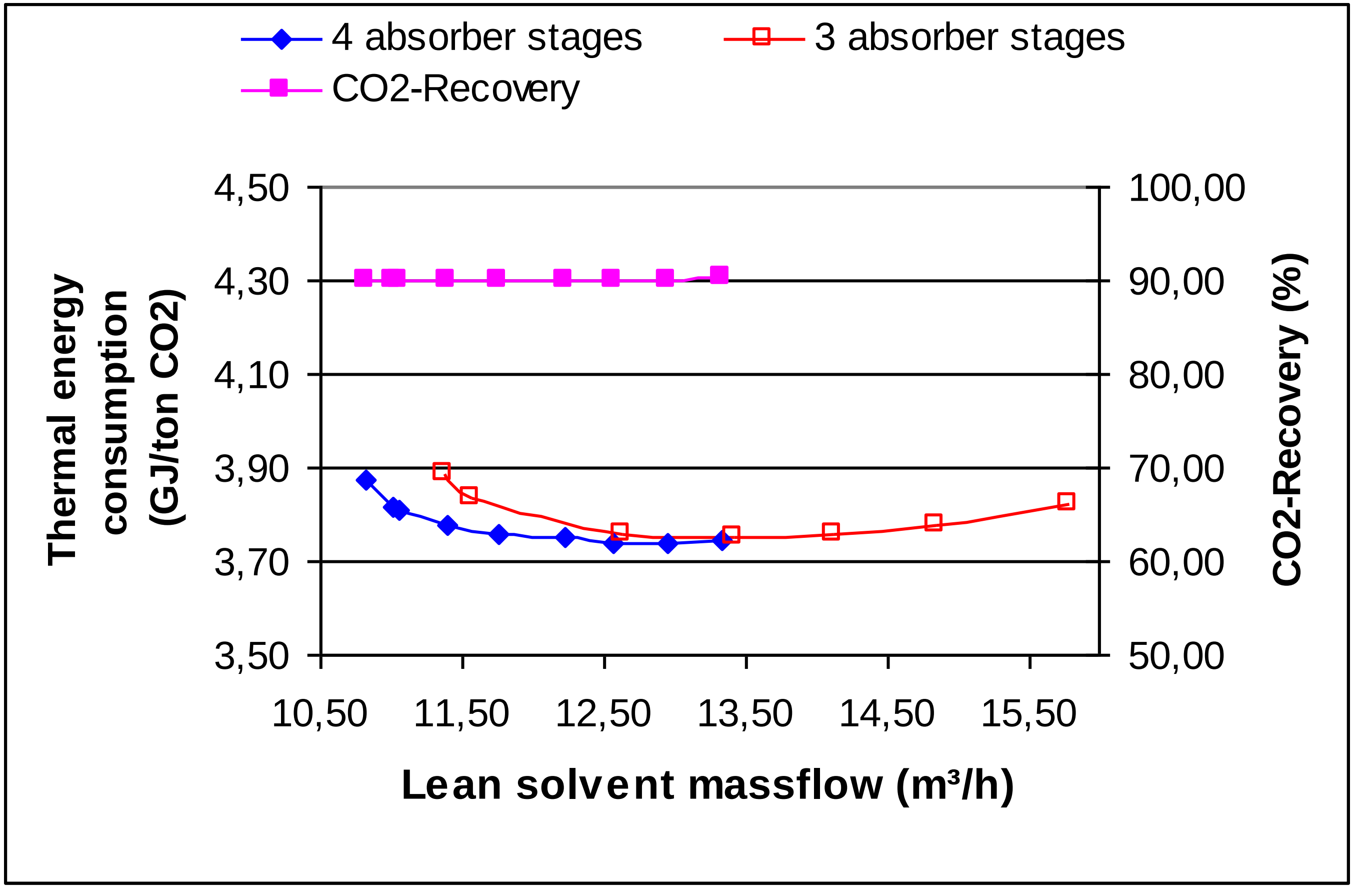
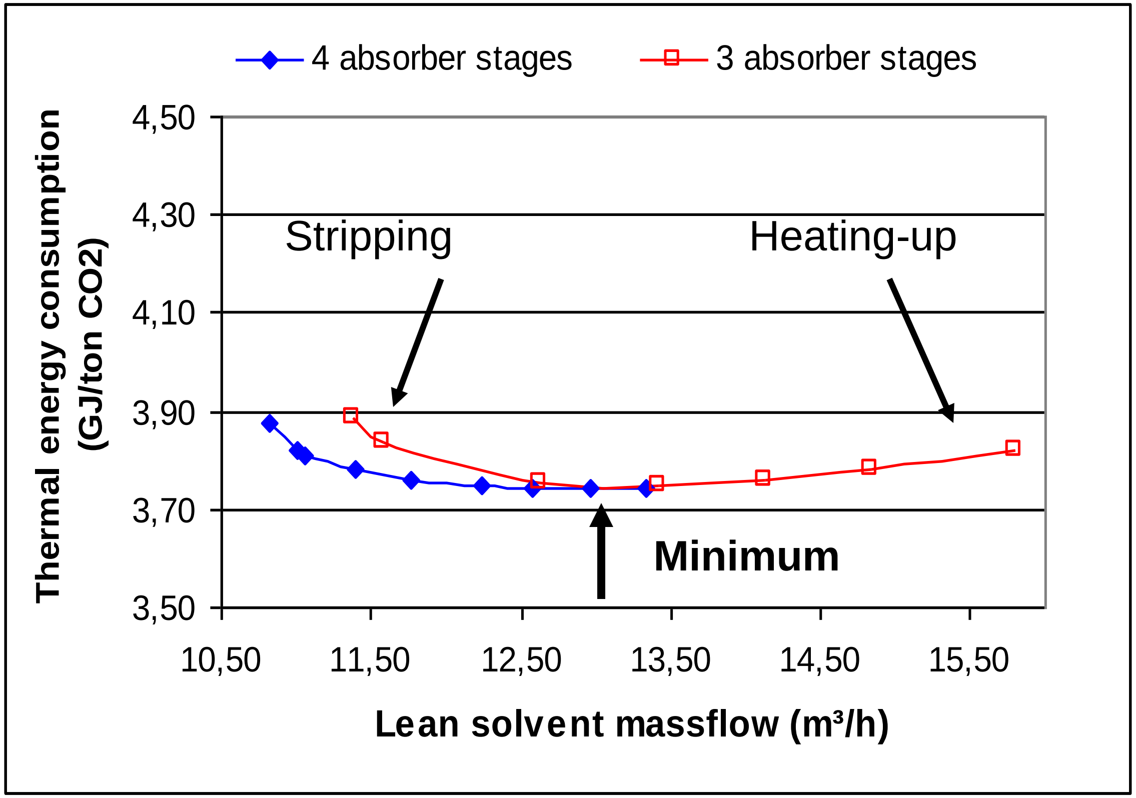
4.1 Optimization of the lean solvent flow



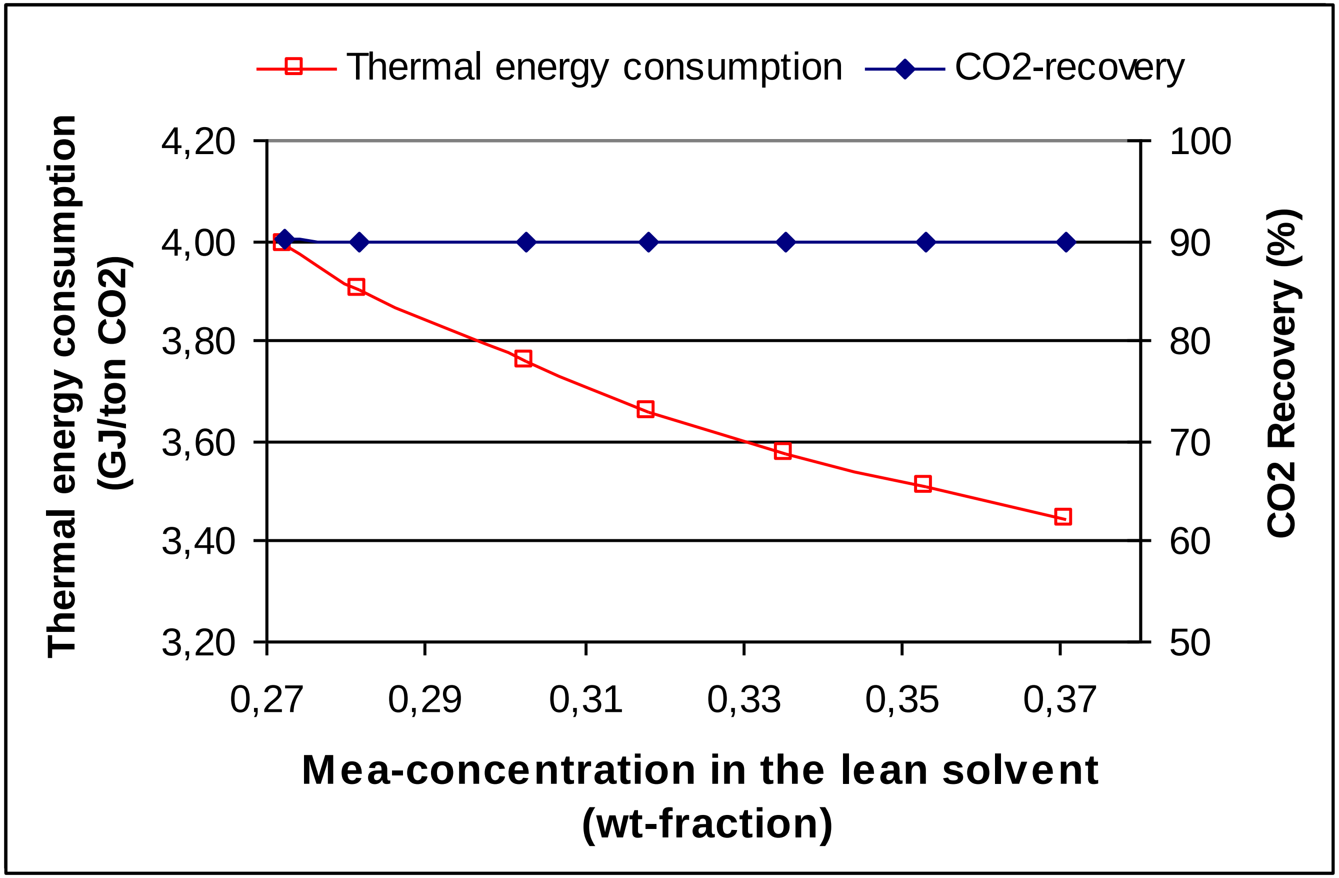
4. Simulation results

3 contributions to the thermal energy consumption :

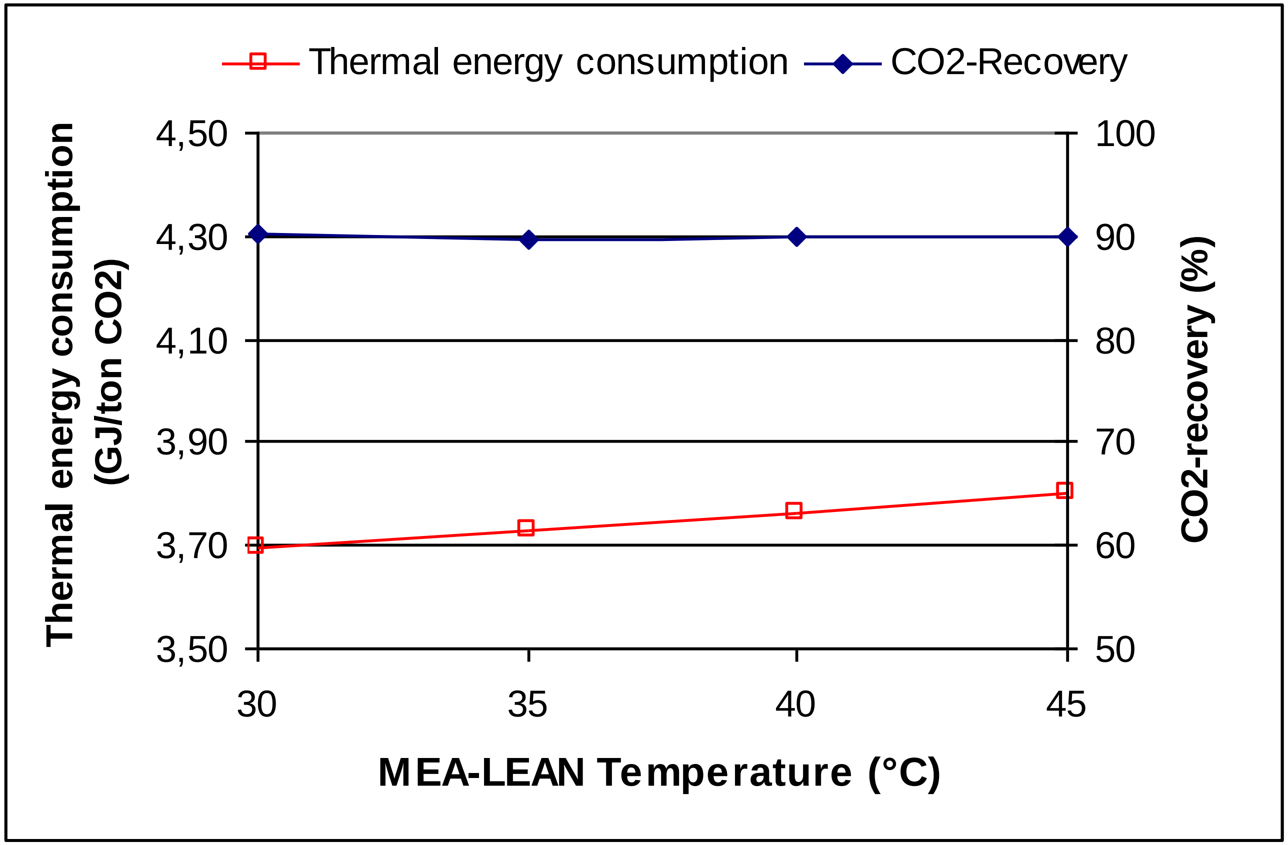
- Solvent heating-up
- Desorption enthalpy
- Stripping steam



4.2 Optimization of the lean solvent concentration



4.3 Optimization of the lean-solvent inlet temperature in the absorber



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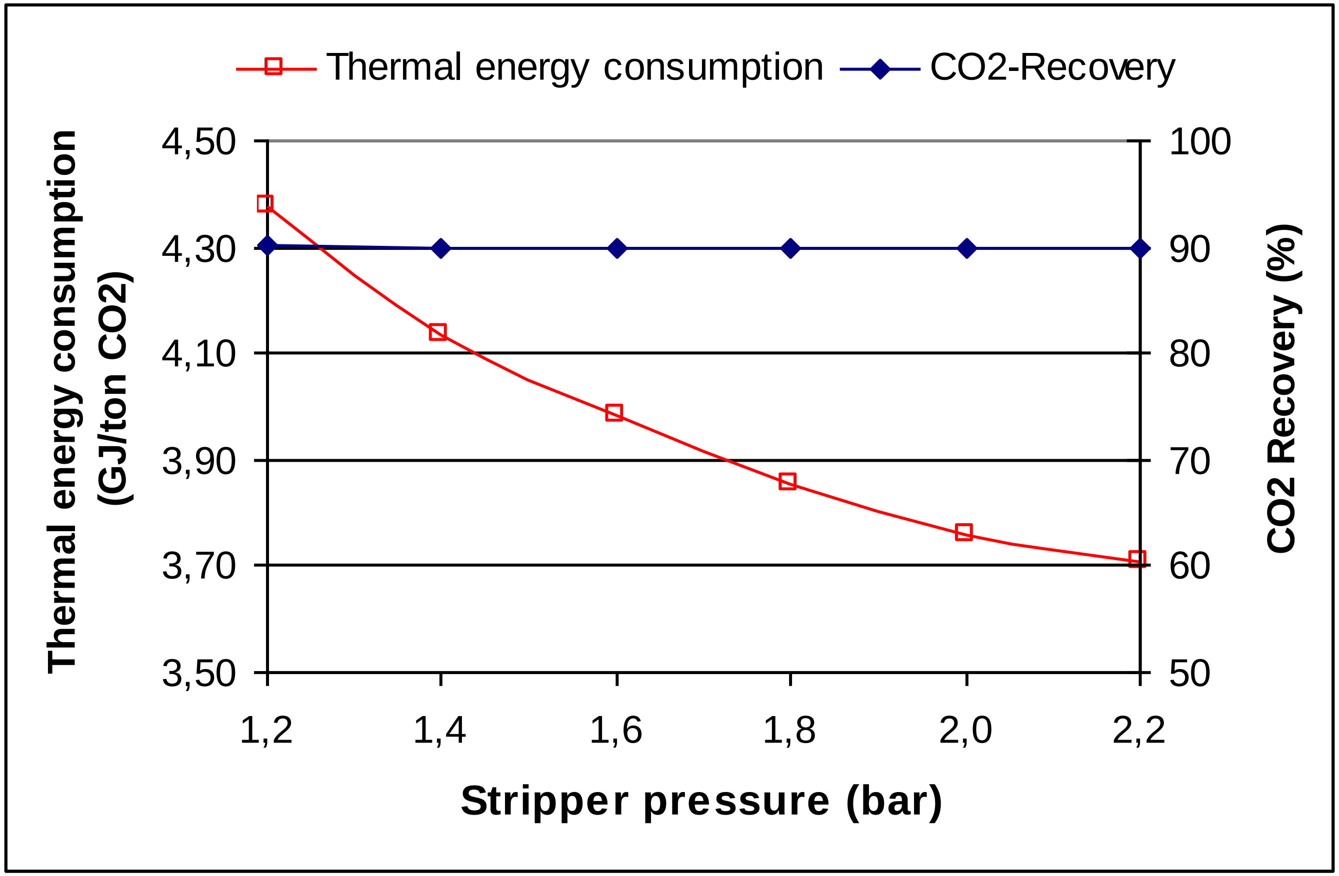
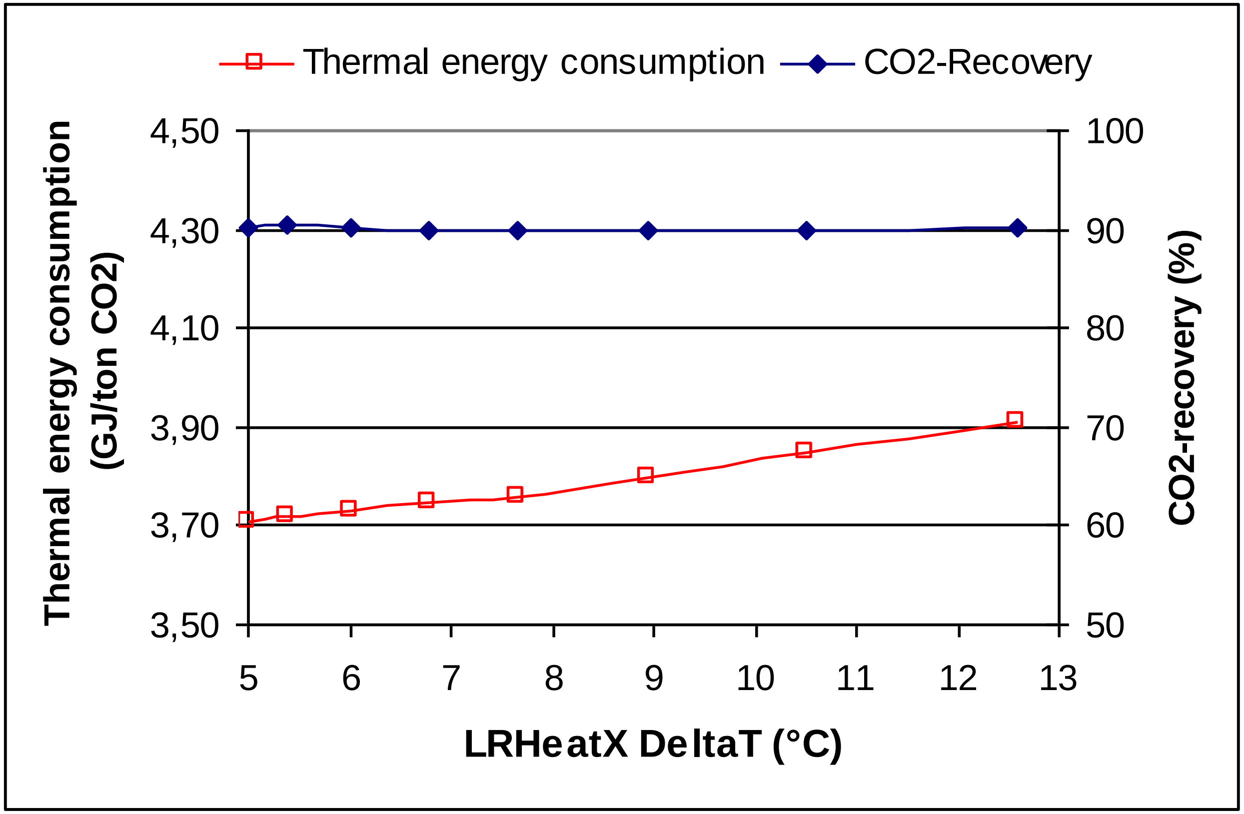
4.4 Optimization of the stripper pressure



4.5 Optimization of the temperature approach at the lean-rich heat exchanger



4. Simulation results

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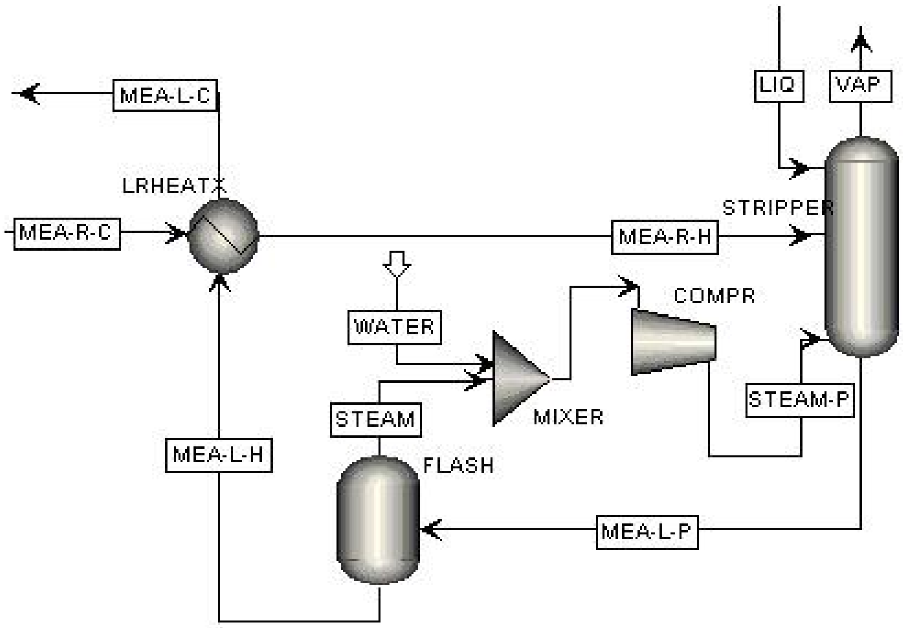
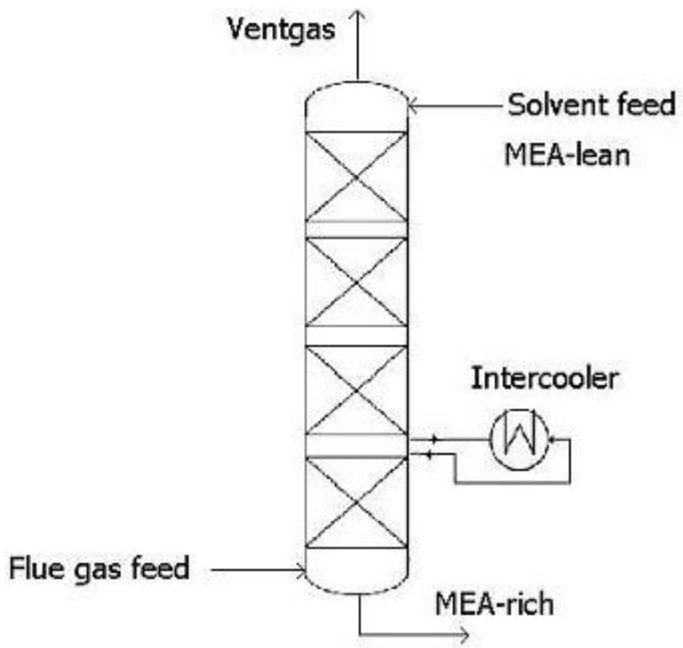
Parameter	Best-case value	Reduction of the thermal energy consumption	Disadvantage
MEA inlet flow	11,725 m^3/h	- 3%	not experimentally confirmed yet
MEA inlet concentration	40 wt-%	- 12,5%	Corrosive behavior
MEA inlet temperature	30 °C	-2,5%	Increase of the cooling water requirement
Stripper pressure	2,2 bar	- 16%	Possibility of solvent degradation
Temp. approach at the L-R heat exchanger	5 °K	- 5%	Increase of the equipment costs

5. Process modifications

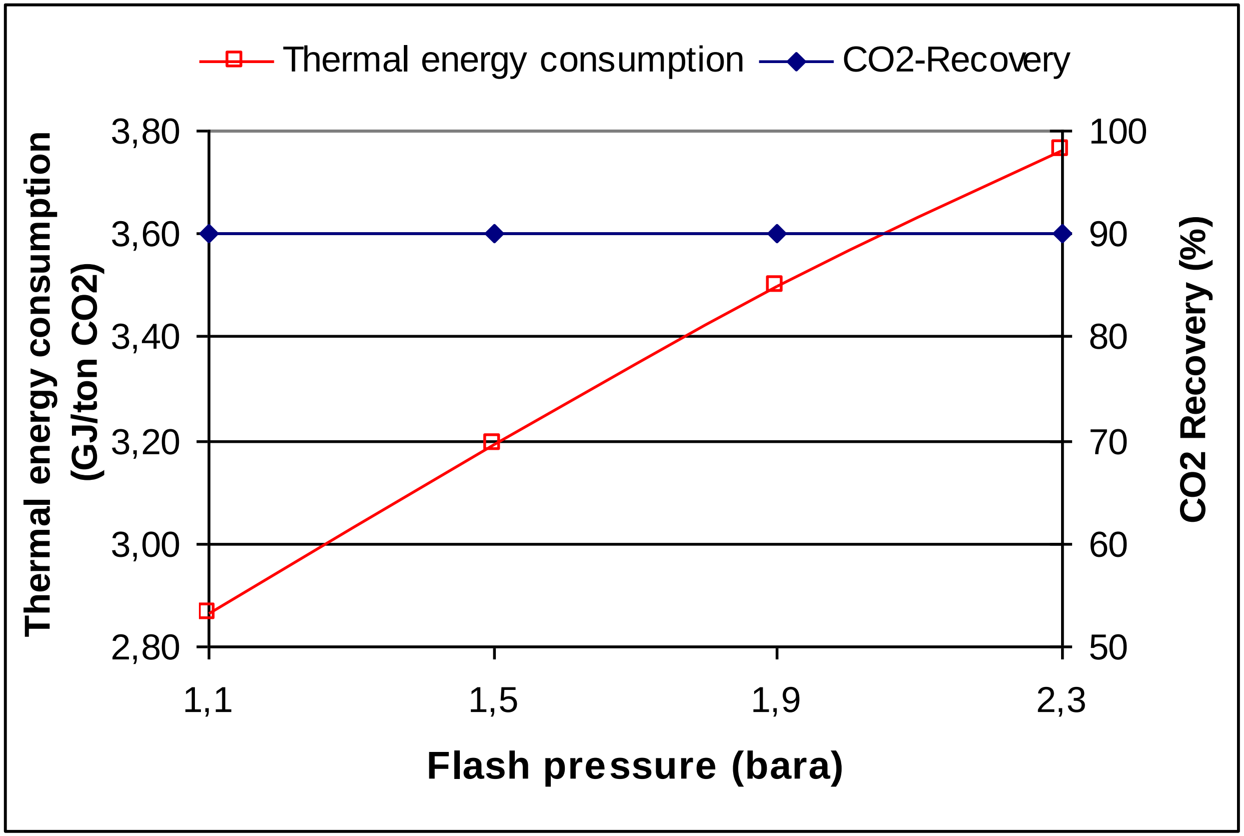
5. Process modifications

- **5.1 Lean vapor compression**
- **5.2 Absorber intercooling**





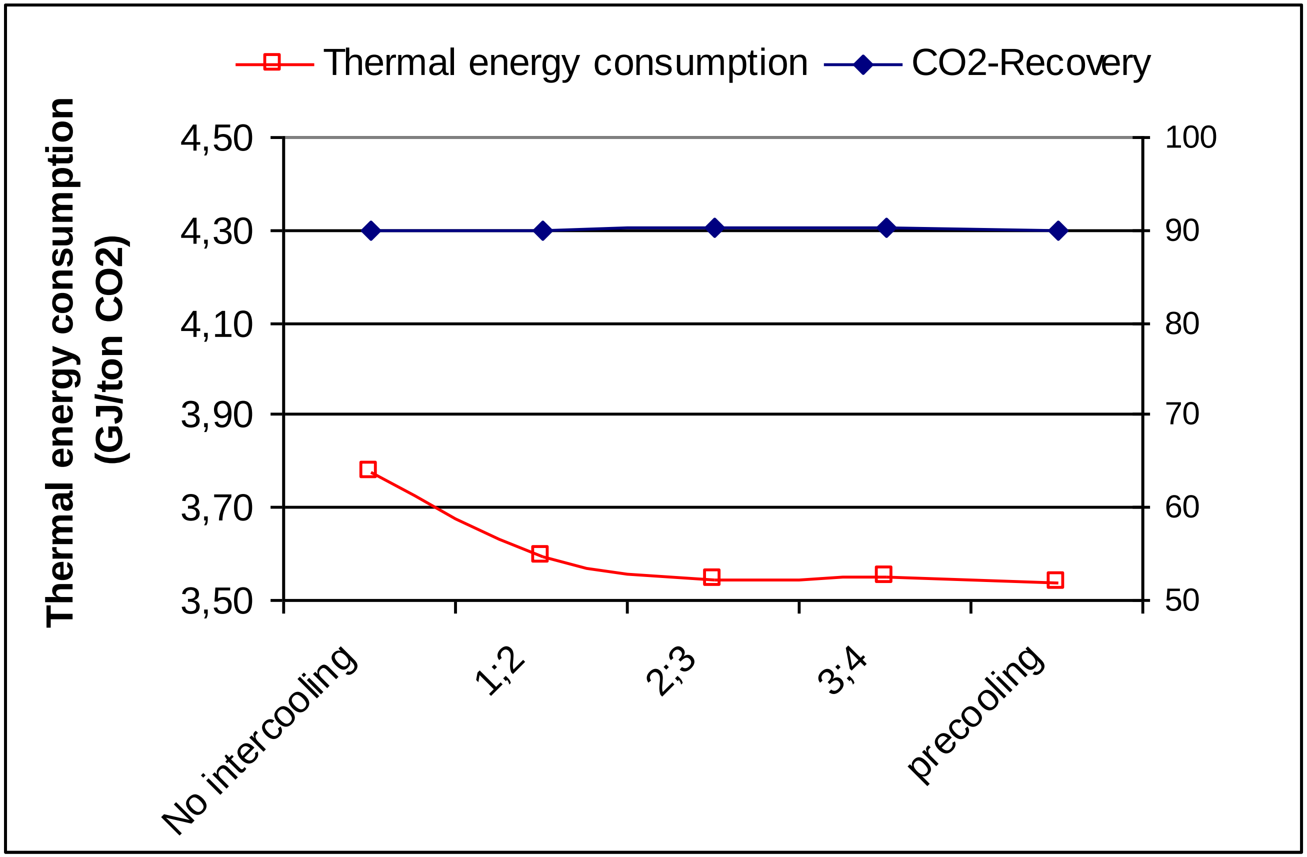
5.1 Influence of the flash pressure by the LVC



- 25 % Thermal energy consumption

- 18 % Exergy consumption

5.2 Influence of intercooler position



- 6 % Thermal energy consumption

6. Conclusion and perspectives

6. Conclusion and perspectives

- Simulation model => coherent results in comparison with the experiments on the Esbjerg pilot plant
- Reduction of the thermal energy consumption by 29% achievable (IC + LVC)
- Reduction of the process exergy consumption reaches 19,5%
- Still some limitations to overcome

Consequences of degradation on:

- Process operating costs:

  - Solvent make-up (4,78 M€/year for a 600MWe bitumous coal-fired power plant[1])

  - Removal and disposal of toxic degradation products

  - 4-10% of the total operating costs!

- Process performance

  - Solvent loading capacity decreases

  - Viscosity increases

- Capital costs

  - Corrosion

[1]: Abu Zahra M., 2009. Carbon dioxide capture from flue gas, PhD Thesis, TU Delft

6. Conclusion and perspectives

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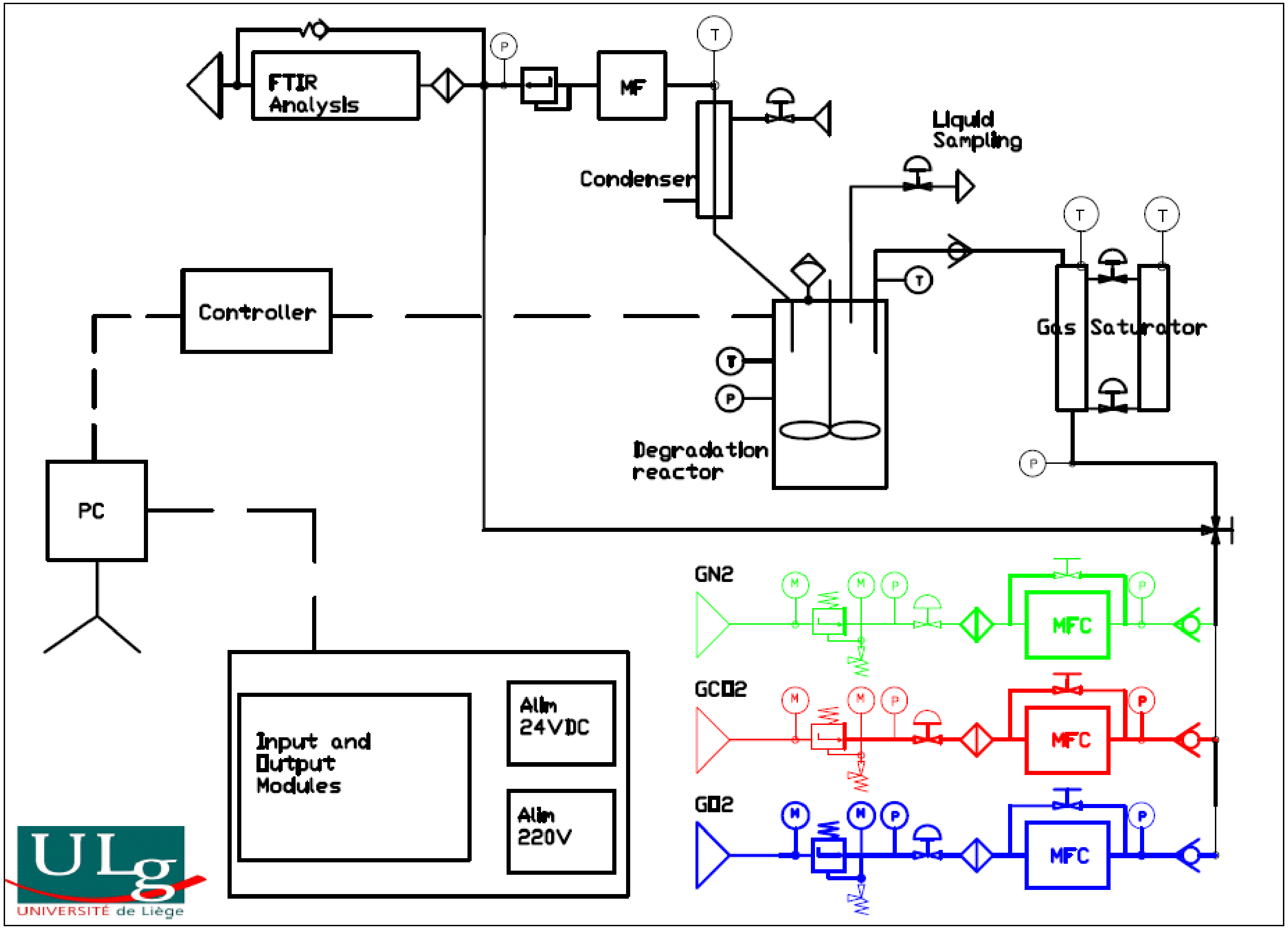
Degradation studies:

- Construction of a test installation for the study of solvent degradation phenomena
- Study of classical solvents
- Study of newly developed solvents and of degradation inhibitors
- Optimal conditions in order to minimize degradation

6. Conclusion and perspectives



6. Conclusion and perspectives

- Results of degradation studies will be used for process simulation purpose.
- Multi-objective analysis will focus on the conciliation of economical and environmental considerations
- Final objective is to propose optimal operating conditions for the CO_2 capture process

Acknowledgements

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LABORELEC

F.R.I.A. – F.N.R.S

Thank you for your attention !