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Steps Toward Deployment

Advanced Capture

Optimum pressure and concentration of CO_2 in flue gases for CO_2 capture by antisublimation

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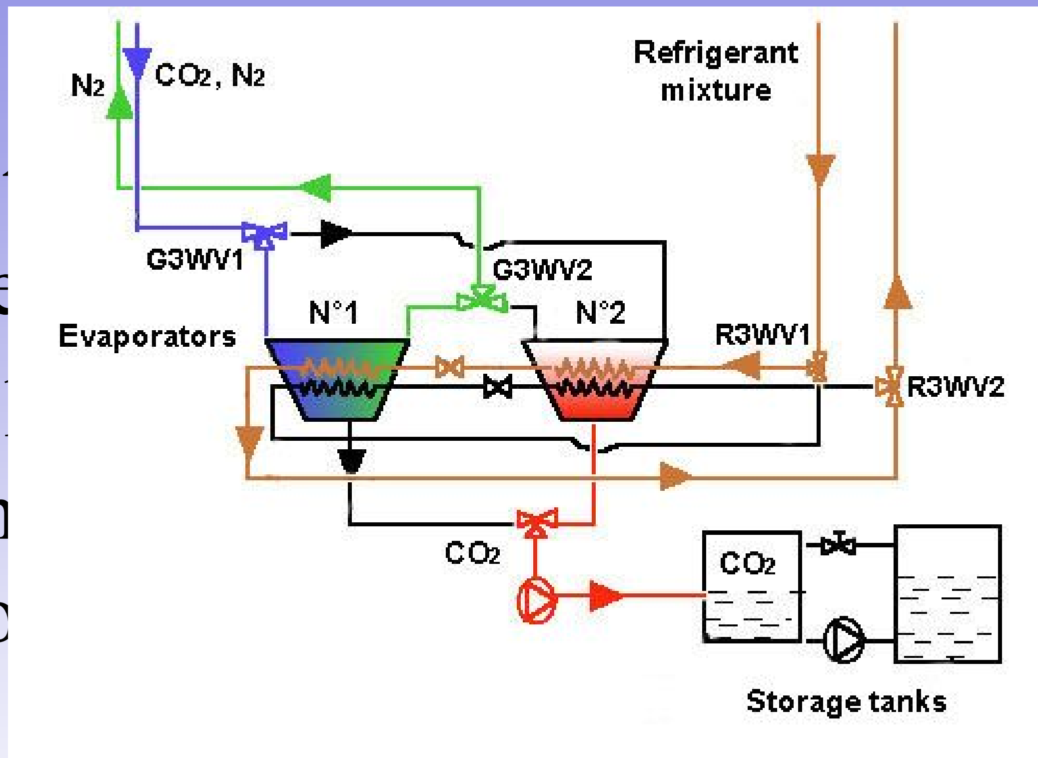
Outline

- Anti-sublimation CO_2 capture system
- Flue gases CO_2 concentration sensitivity analysis
- Flue gases pressure sensitivity analysis
- High Pressure Flue Gases
- Conclusions

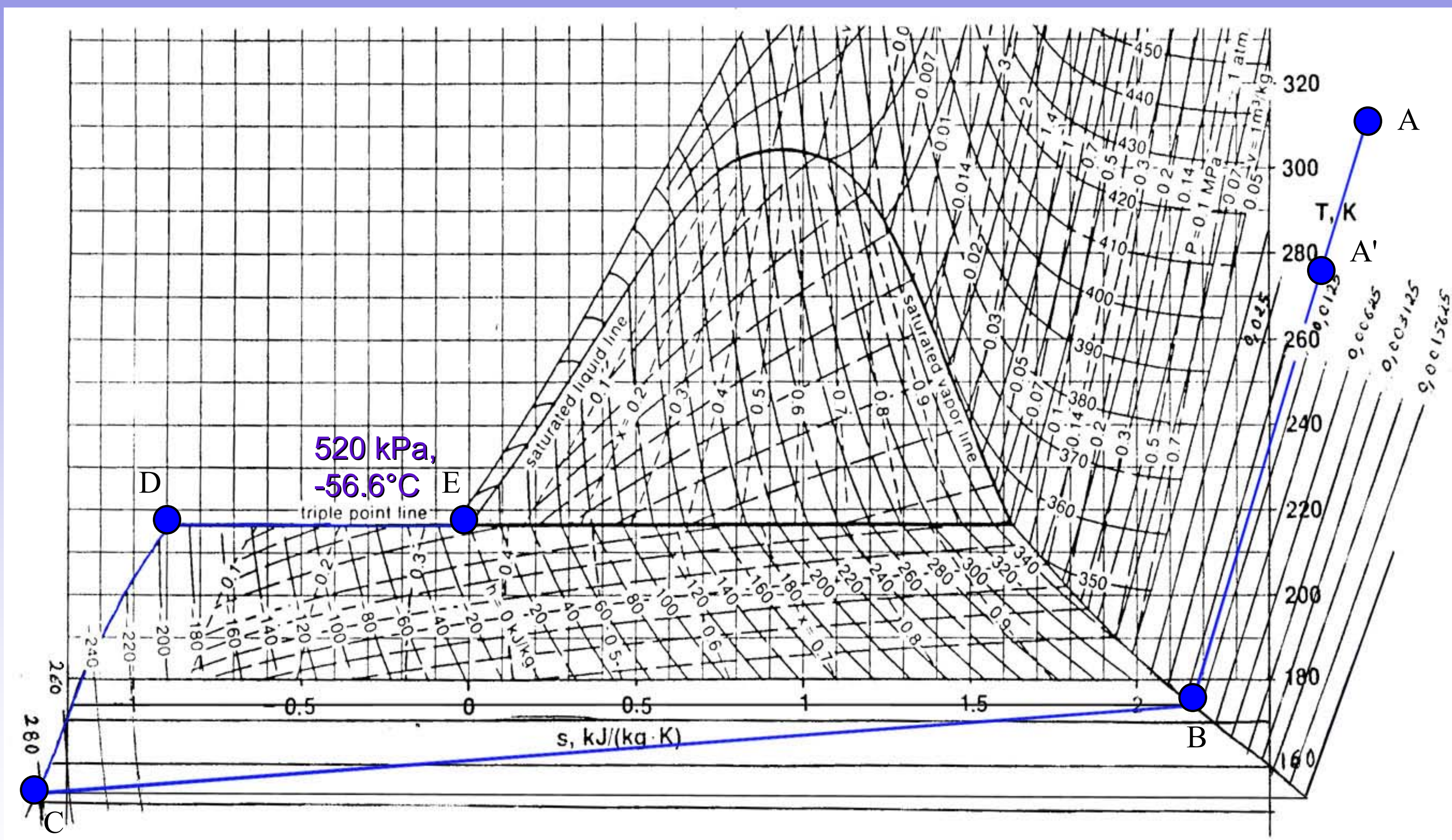
Anti-sublimation CO_2 capture system

- CO_2 cap… physical
  propertie…
- CO_2 trip… below
  these ten… either in
  gas or so…



- The CO_2 solid phase requires a defrosting process at a pressure higher then 520 kPa thus a swing process is necessary for continuous operation.

CO_2 capture system on the T-s diagram



AA': Cooling and water capture

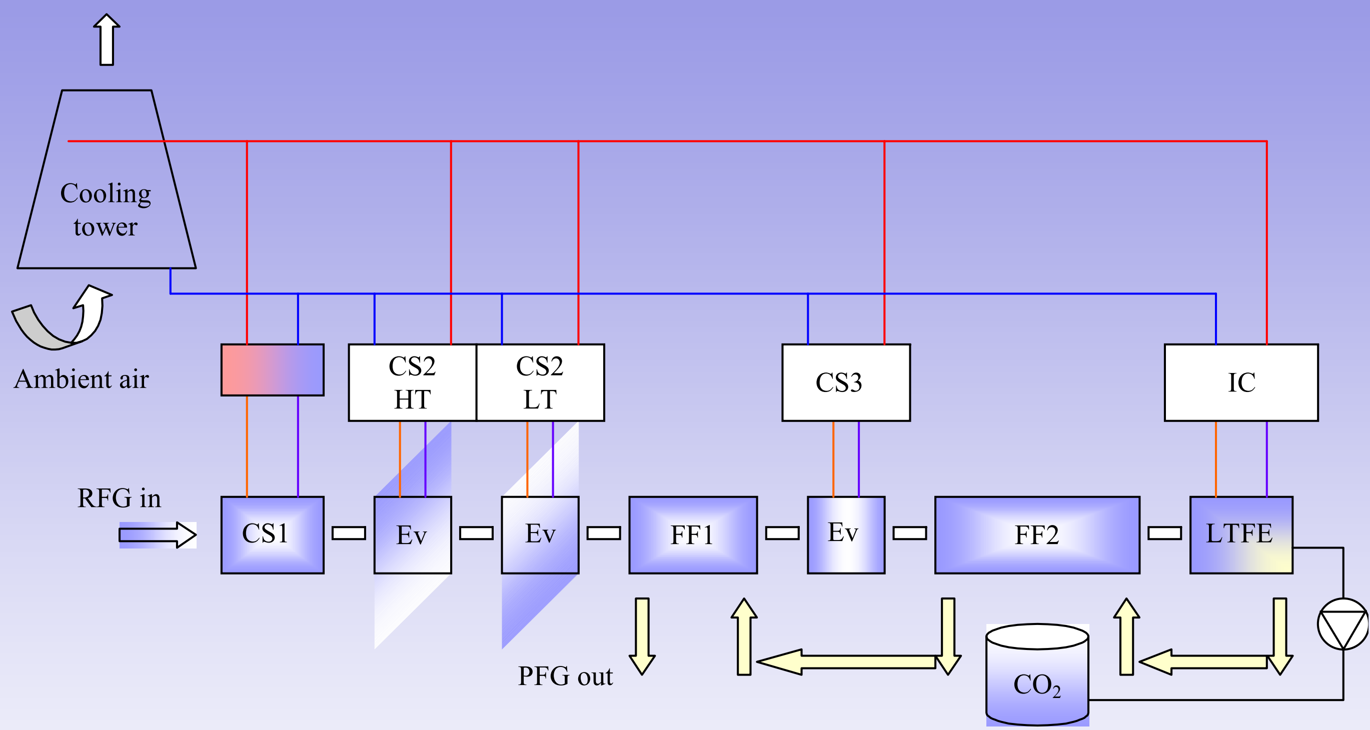
A'B: Cooling untill the CO_2 frosting temperature

BC: CO_2 frosting and capture

CD: Energy recovery from the CO_2 defrosting

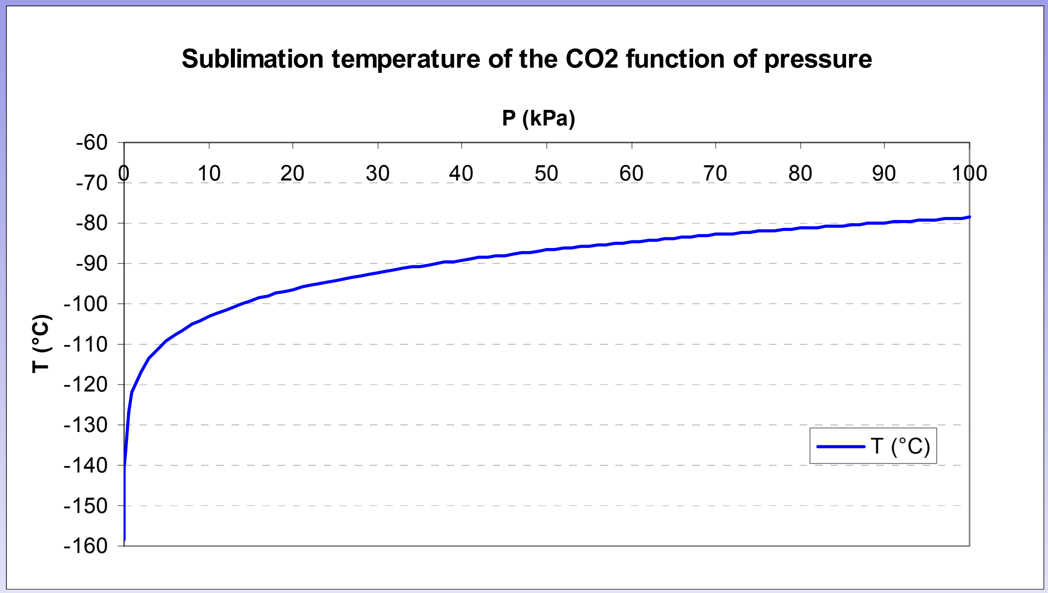
DE: Energy recovery of the CO_2 melting

CO_2 Operational scheme



- CS1: Cooling stage 1 down to ambiance
- CS2: Refrigeration system down to 0°C
- FF: Flue Gas/FG heat exchangers
- CS3: Refrigeration system down to –40°C
- IC: 4 stage Integrated Cascade down to the CO_2 sublimation temperature

CO_2 sublimation temperature



- The higher the CO_2 concentration, the higher is the CO_2 sublimation temperature and the higher is the Coefficient Of Performance (COP) of the IC to capture the CO_2

- It is more energy efficient to decrease the CO_2 concentration from 40 to 10% on a FG stream with a 75% capture efficiency than to capture 90% of a gas turbine FG for lowering the concentration from 4% to 0.4%

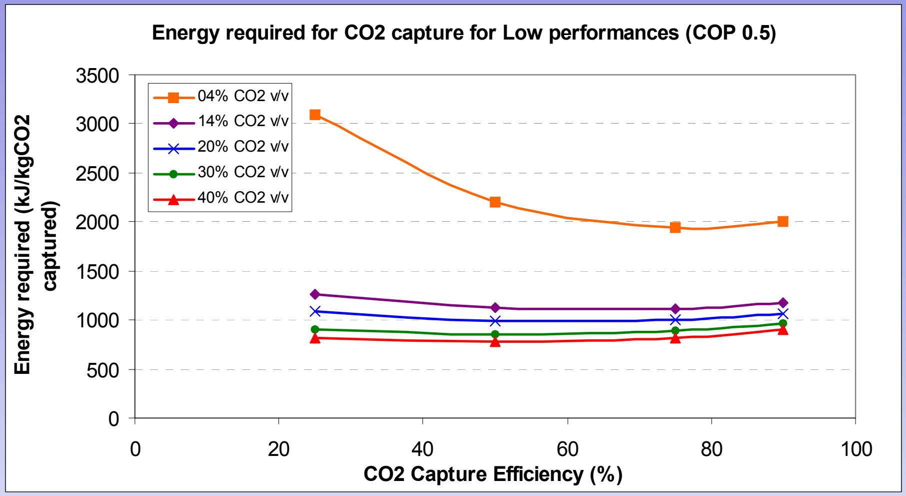
Flue gases CO_2 concentration sensitivity analysis

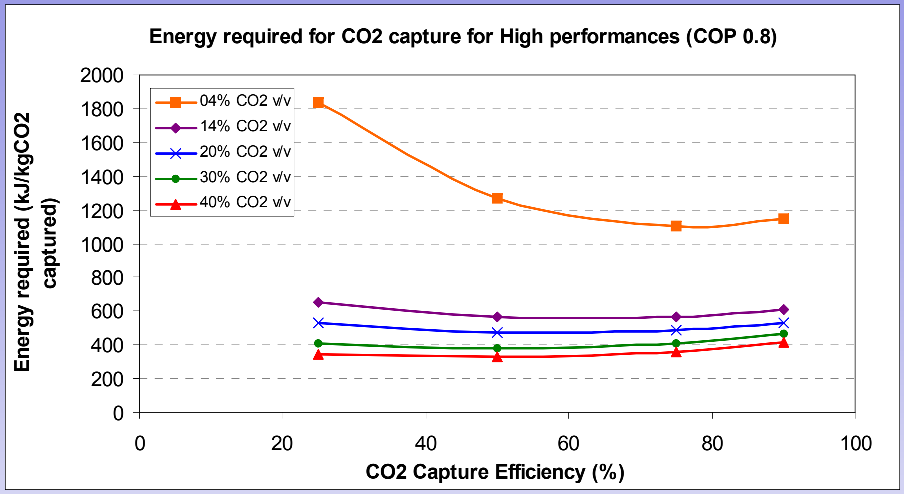
- The initial CO_2 concentration in the FG defines the high temperature threshold for CO_2 frosting
- The CO_2 capture efficiency defines the low temperature threshold for CO_2 frosting
- The performances of the CO_2 capture system vary according to the CO_2 concentration in the FG and to the CO_2 capture efficiency
- Calculations have performed for several CO2 concetrations in the flue gases and 2 CO_2 capture efficiencies

CO_2 (%)	N_2 (%)	O_2 (%)
4	80	16
14	80	6
20	77	3
30	67	3
40	57	3

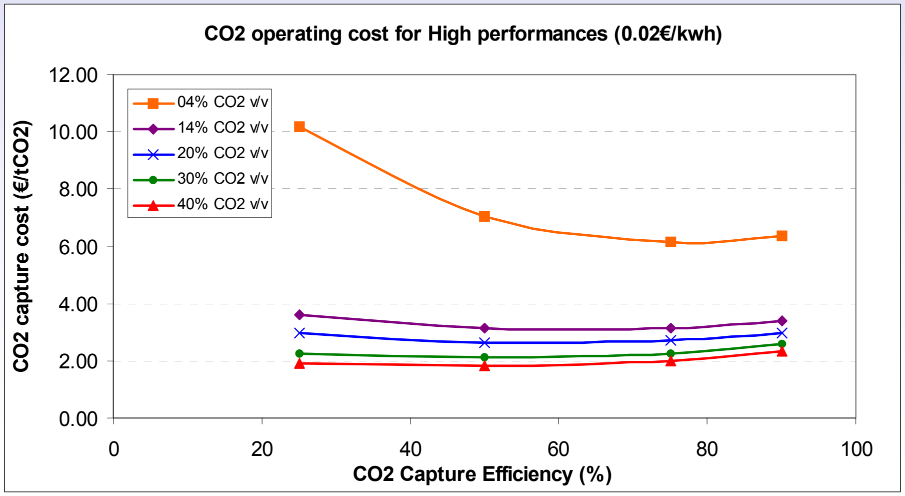
- Values are given for refrigeration cycle efficiencies of 80% and 50% referred to Carnot COP.

CO_2 capture energy requirements and costs





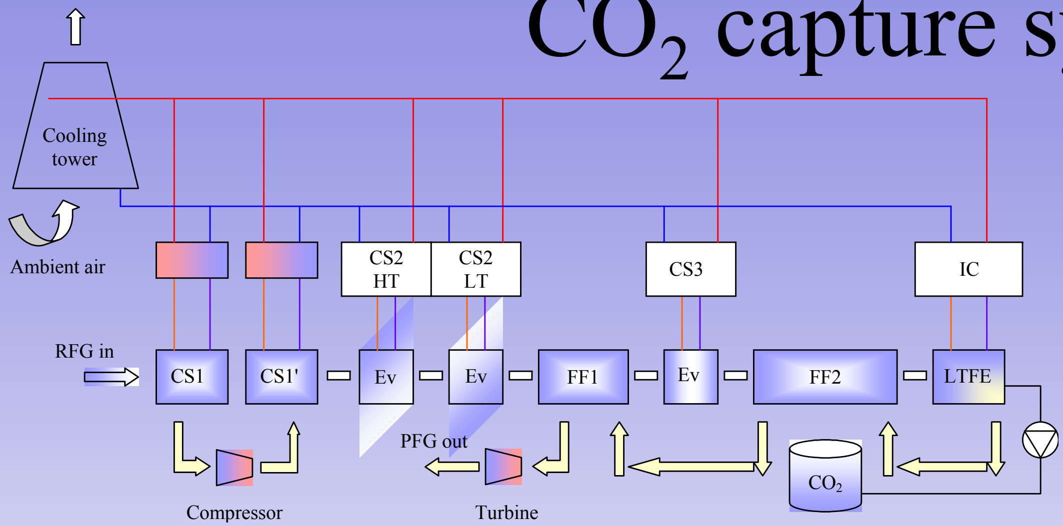
For each CO_2 concentration : energy / kg CO_2 and operating costs have been calculated

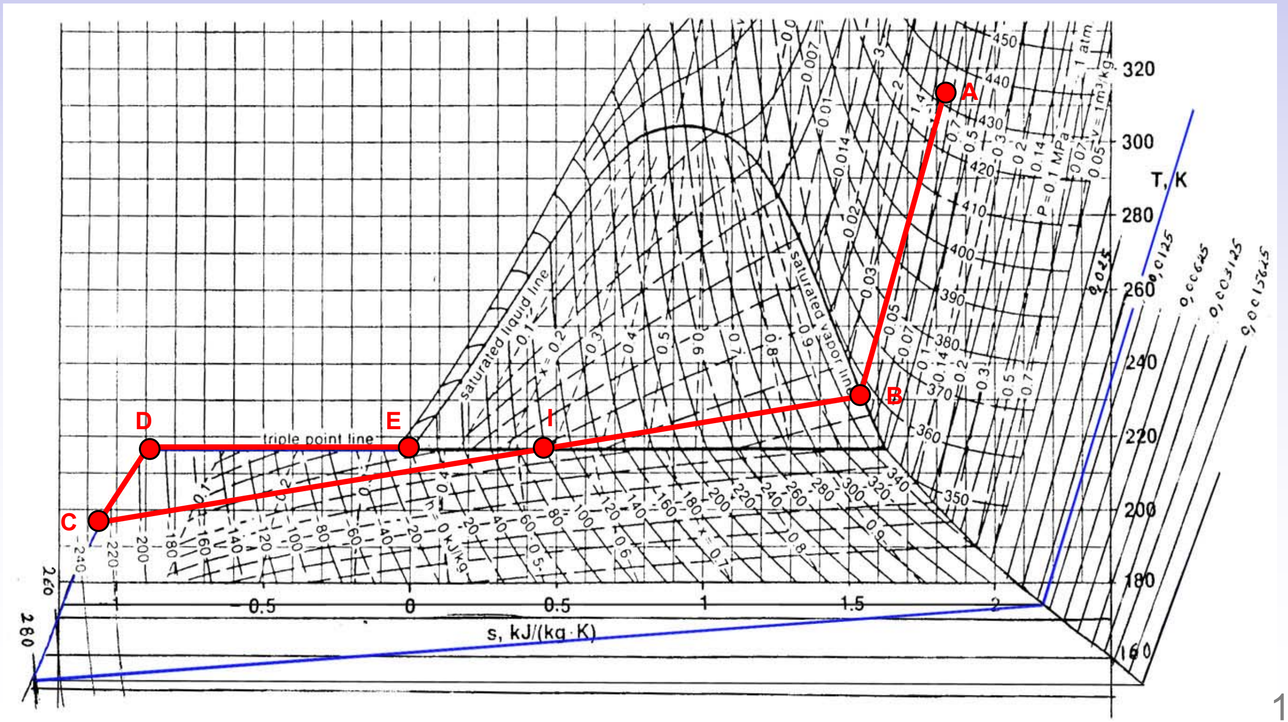


Raising the pressure of flue gases

- Some industrial processes have chosen to compress the gas streams in order to raise the CO_2 partial pressure above the triple point of CO_2 so as to condense it rather than to frost it.
- The FG are compressed, then expanded in order to recover part of the compression energy.
- The CO_2 partial pressure in the FG ranges from 4 to 40 kPa (i.e. 4 to 40% CO_2 v/v at ambient pressure) so the compression ratio ranges between 13 and 130 to reach a pressure superior to the triple point pressure.
- Hybrid capture in liquid and in solid phases can also be considered.

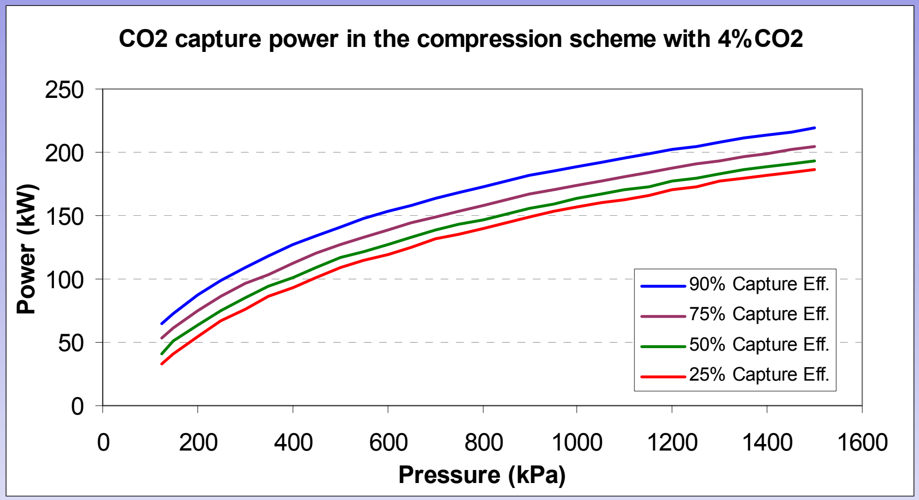
FG compression and expansion along the CO_2 capture system

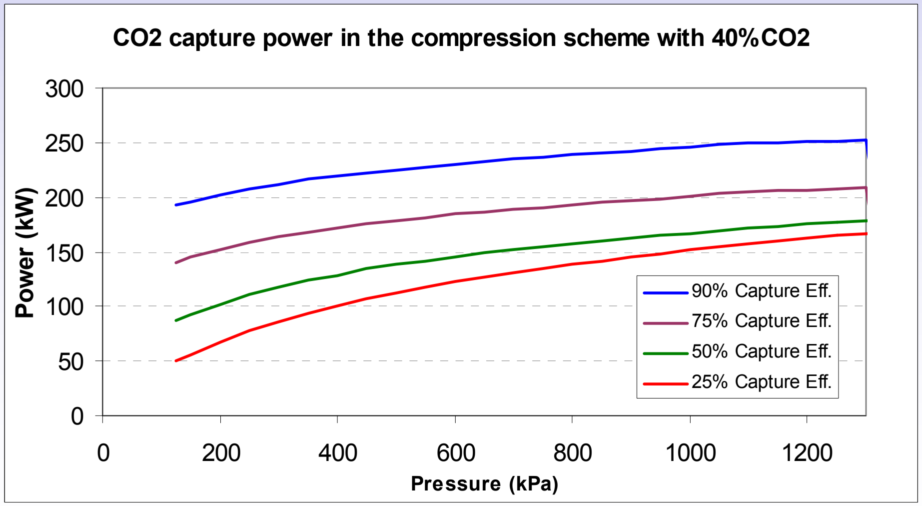




CO_2 capture power consumption in the compression scheme

- Calculations are done for 1 kg/s FG mass flow rate for the different CO_2 concentrations in the FG taking 80% efficiencies for the different systems.



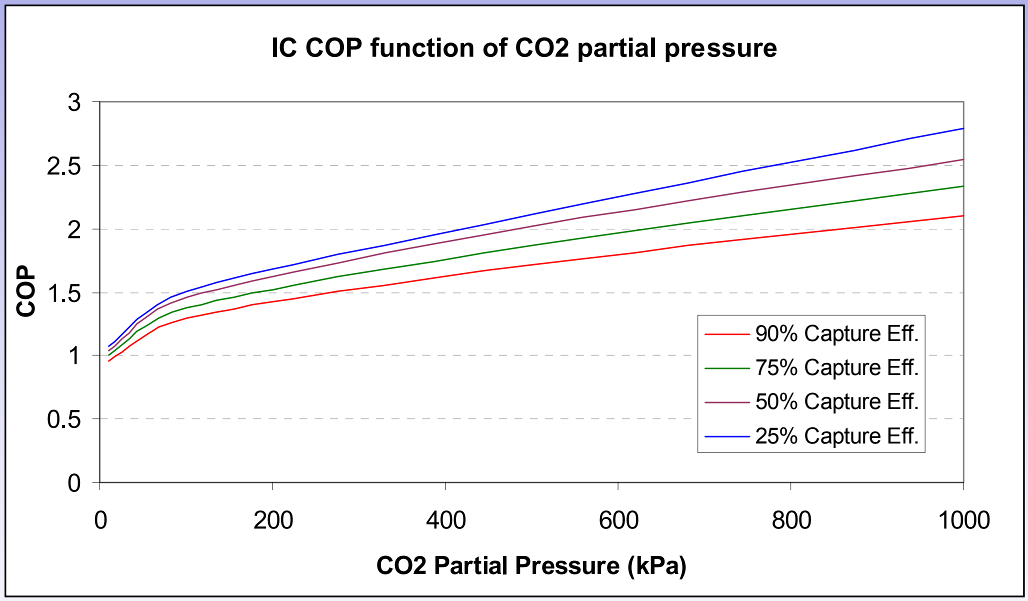


- Conclusion :

There is no energy savings associated with FG compression

High pressure Flue Gases

- In the case where the FG are delivered at high pressure (i.e:IGCC applications)



- The Integrated Cascade COP increases considerably with the CO_2 partial pressure

Conclusions (1)

- Energy consumptions for CO_2 capture at different pressures have been calculated.

- A sensitivity analysis has been carried out to analyze the impact of both the initial CO_2 concentration in the flue gases and the CO_2 capture efficiency.

- The study has shown that an energy penalty of about 25 to 40% exists between CO_2 capture for CO_2 initial concentration of 4% compared to higher initial concentrations varying from 14 to 40%.

- The operating costs of CO_2 capture have been calculated from 4 to 7 Euro / ton of CO_2 captured

Conclusions (2)

- The possible interest of pressurization of the FG has been analyzed, pressurization shows additional energy consumption compare to CO_2 capture at atmospheric pressure.
- If the FG are at delivered at high pressure, the refrigeration process for CO_2 capture is less energy intensive.
- The higher the partial pressure of CO_2, the lower the energy consumption. It is then possible to develop a refrigerating process where CO_2 is first condensed and then frosted for high pressure flue gases.