SEVENTH FRAMEWORK PROGRAMME

OCTAVIUS

OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

Methodology for benchmarking in the OCTAVIUS project

(Sören Ehlers, TUHH)

Project Background

- **Different processes have been evaluated during OCTAVIUS with both different solvents and process configurations by various partners**
- **Benchmarking cases are used as a common reference to be able to compare them to each other**
- **In Task 13.1 a framework for these benchmarking cases has been established**

Project linkages

- **Task 13.4: Benchmarking**

- **Task 13.2: Optimisation studies (optimised cases with MEA and AMP+PZ as solvents)**
- **Task 25.3: Alternative flowsheets (various flowsheet modifications from literature)**
- **Task 34.4: DMX-1™ evaluation study for bituminous coal case (solvent which demixes into two phases)**

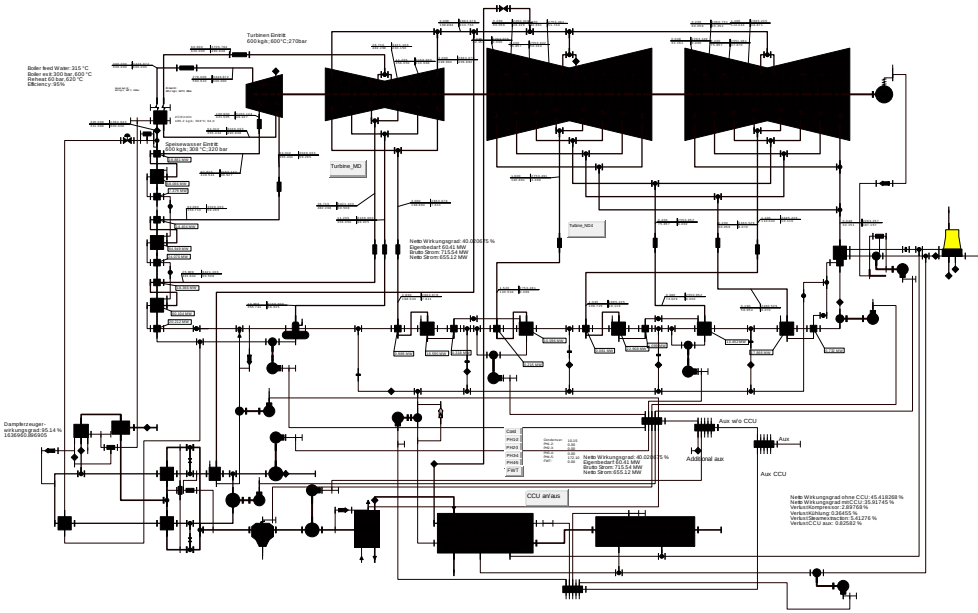
Reference cases

- **Reference cases were established using many assumptions from EBTF guidelines**
- **EBTF: European Benchmarking Task Force - Partners from CAESAR, CESAR and DECARBit**
- **Power plant simulation with Ebsilon Professional at TUHH**
- **Capture plant simulation with CO2SIM by Sintef**
- **Cost estimation by TNO**

Bituminous coal reference power plant

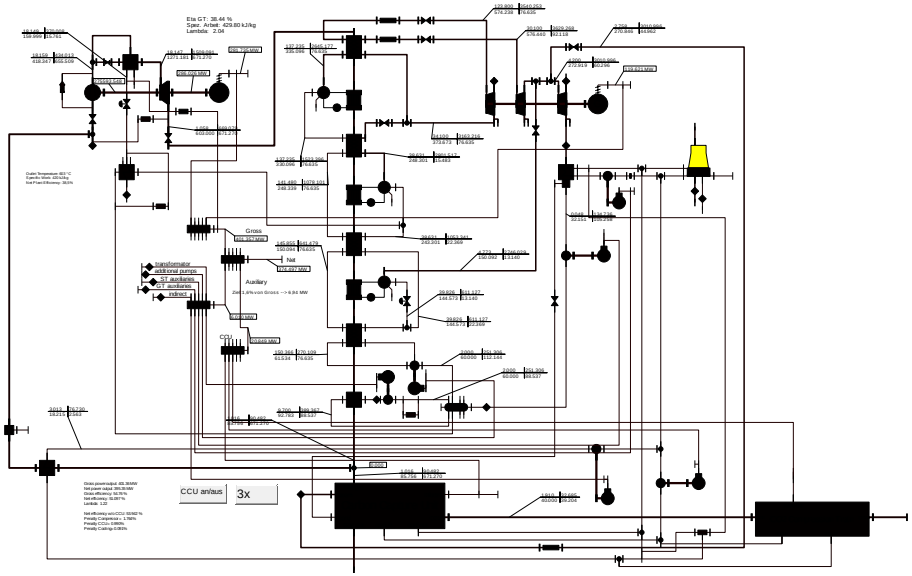
OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

- **800 MW_e bituminous coal case with advanced super critical boiler (ASC)**
- **45.4% net efficiency**
- **300 bar, 600°C live steam**
- **60 bar, 620°C RH steam**



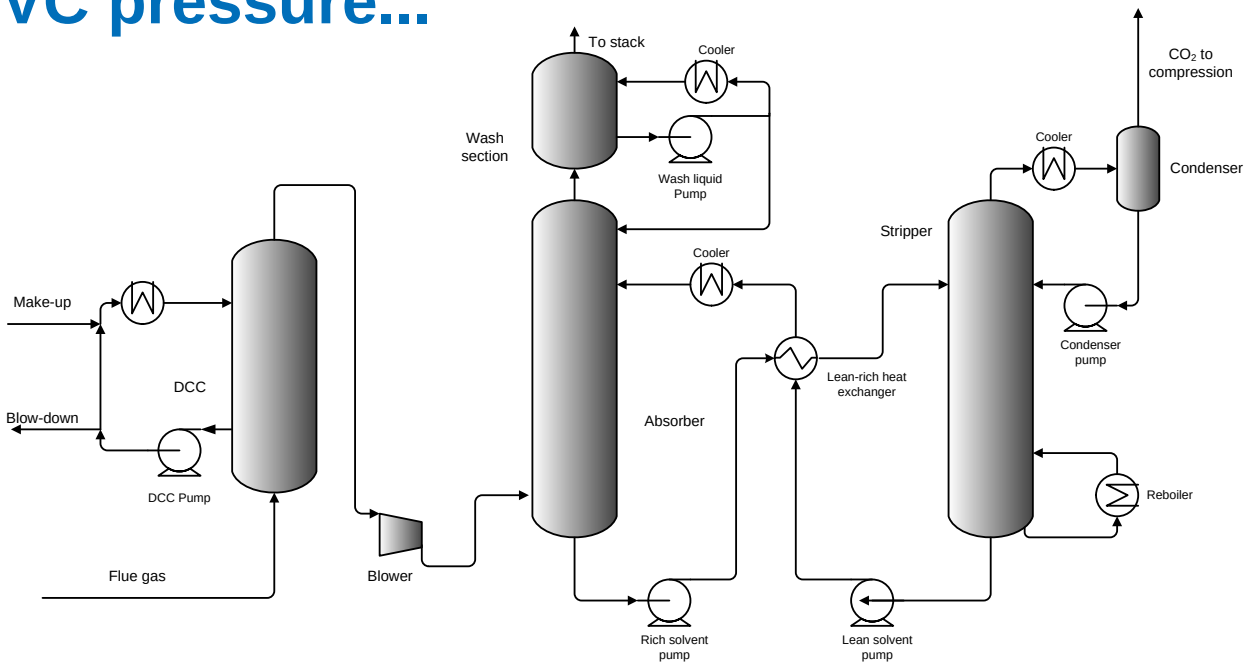
Natural gas reference power plant

- **430 MW_e natural gas combined cycle plant**
- **57.8% net efficiency**
- **One gas turbine with one heat recovery steam generator (HRSG)**
- **Three pressure level HRSG**



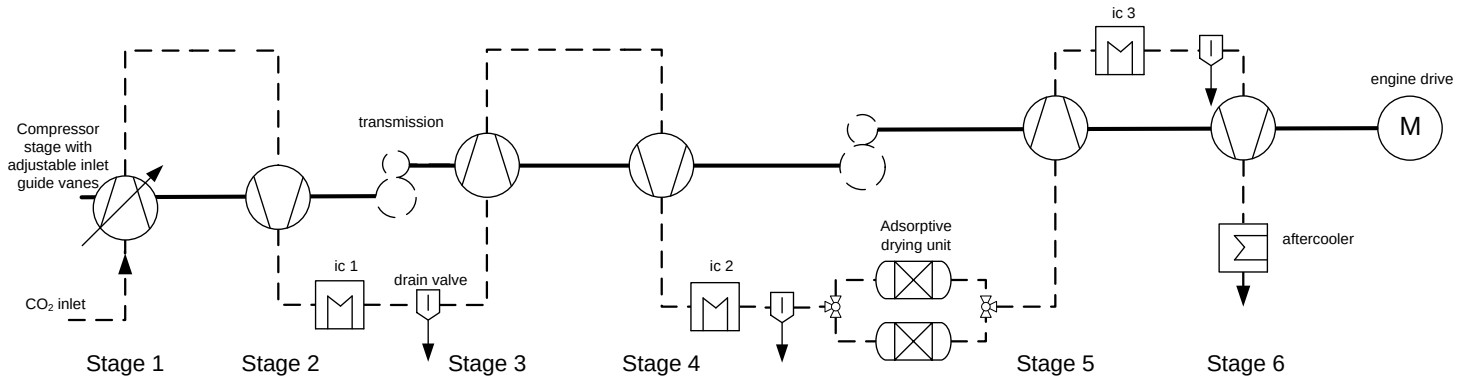
Reference case - Capture plant

- **Modelled by SINTEF**
- **Optimised during Task 13.2**
- **Varied parameters: Solution flowrate, absorber height, LVC pressure...**



Reference case - Compressor

- **Modelled by TUHH**
- **Number of stages depends on CO_2 inlet pressure**
- **Different configurations with intercoolers were evaluated for heat integration potential**



Reference case - Overview

- **Four reference cases were established**
  - **Coal power plant with 30wt% MEA**
  - **Coal power plant with CESAR I (AMP+PZ)**
  - **Natural gas combined cycle plant with 30wt% MEA**
  - **Natural gas combined cycle plant with CESAR I**

Benchmarking criteria

OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

- **Quantitative criteria**
  - **Overall net efficiency penalty**
    - **Specific heat duty**
    - **Specific auxiliary duty**
    - **Specific cooling duty**
    - **Stripper pressure**
    - **Available waste heat sources**
  - **Costing**
    - **Cost of electricity**
    - **Cost of CO_2 avoided**

Benchmarking criteria - Quantitative

- **Quantitative criteria**
  - **Specific heat duty**
    - **Reboiler heat duty provided by steam from IP/LP crossover**
    - **Electric gross output of power plant is reduced**

    → Overall net efficiency is reduced

Benchmarking criteria - Quantitative

- **Quantitative criteria**
  - **Specific auxiliary duty**
    - **Flue gas blower and pumps in the capture plant need electricity**
    - **Electric net output of power plant is reduced**

    → Overall net efficiency is reduced

Benchmarking criteria - Quantitative

- **Quantitative criteria**
  - **Specific cooling duty**
    - **Several heat exchangers in the capture plant have to be cooled with cooling water**
    - **Additional cooling water pumps need electricity**
    - **Electric net output of power plant is reduced**

    → Overall net efficiency is reduced

Benchmarking criteria - Quantitative

OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

- **Quantitative criteria**
  - **Stripper pressure**
    - **Stripper pressure determines the pressure ratio for CO_2 compressor and thus electricity consumption**
    - **Electric net output of power plant is reduced**
    - **Stripper pressure determines the evaporation temperature in the stripper and thus required temperature for steam**

    → Overall net efficiency is reduced

Benchmarking criteria - Quantitative

- **Quantitative criteria**
  - **Available waste heat sources**
    - **Certain waste heat sources can be used to heat up feed water**
    - **Less steam has to be extracted from turbine for feed water preheating**
    - **Electric gross output of power plant is increased**

    → Overall net efficiency is increased

Benchmarking criteria - Quantitative

- **Quantitative criteria**
  - **Overall net efficiency penalty**
    - **Total loss in efficiency due to the different mechanisms**
    - **List of mechanisms for MEA base case with LVC**

Mechanism	Efficiency penalty
Steam extraction	5.60 %-points
Compressor duty	3.29 %-points
Cooling water duty	0.29 %-points
Auxiliary power duty	2.04 %-points
Heat integration	-0.76 %-points
Overall efficiency penalty	**10.46 %-points**

Benchmarking criteria - Quantitative

OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

- **Quantitative criteria**
  - **Costing**
    - **Cost of electricity calculated for reference power plant**
    - **Detailed calculation of capture plant cost, both CAPEX and OPEX, based on capture plant modeling**
    - **Cost of electricity for overall process (power plant + capture plant + CO_2 compressor)**
    - **Cost of CO2 avoided:**

$$\frac{COE_{capture} - COE_{reference}}{CO_2\ Emission_{reference} - CO_2\ Emission_{capture}}$$

Benchmarking criteria - Qualitative

- **Qualitative Criteria**
  - **Emissions to air and water**
  - **Flexibility**
  - **Dynamics and control**

Benchmarking criteria - Qualitative

- **Qualitative Criteria**
  - **Emissions to air and water**
    - **Vapour and aerosol emission**
    - **Possible pollutants are among others:**
      - Amines
      - Ammonia
      - Nitrosamines
    - **One of the main topics in OCTAVIUS (WP 1.2: Basic emission control studies)**
    - **Degradation products are contained in waste water as well**

→ For benchmarking the different solvents are ranked based on results from other tasks; required counter-measures are included into cost calculation

Benchmarking criteria - Qualitative

- **Qualitative Criteria**
  - **Flexibility**
    - **In OCTAVIUS Task 24.2 four different operation concepts were evaluated (e.g. exhaust gas bypass and solvent storage)**
    - **Simulations for MEA only**
    - **Results shall be transferred in a qualitative manner to different solvents and process configurations**

Benchmarking criteria

- **Qualitative Criteria**
  - **Dynamics and Control**
    - **Controllability is affected by complexity of capture plant**
    - **Complexity increases costs and reduces availability**
    - **Complexity is rated based on**
      - number of incidences of heat- and process integration with power plant
      - number of recycle loops

Summary

- **Benchmarking one of the final Tasks in OCTAVIUS**
- **Four reference cases were defined**
- **Different process configurations and solvents are compared**
- **A number of benchmarking criteria are used, both quantitative and qualitative type**

Reference power plants

OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

Thank you for your attention!