GCCMAX, a novel solvent for carbon capture from natural gas combined cycle (NGCC) power plant

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Abstract- Natural gas is globally a premier source of energy. Especially, with the shale gas boom, its application has an exponential growth. Nevertheless, the natural gas has the highest hydrogen to carbon ratio among all hydrocarbons and the dilute exhausts of natural gas combustion pose significant challenges for carbon capture. The present research exploits a variety of tools and methods developed in our research centre (Centre for Process Systems Engineering - CPSE) in collaboration with Process Systems Enterprise (PSE) and Carbon Clean Solutions (CCS) for research into GCCMAX, a novel and patented solvent developed by Carbon Clean Solutions, applicable for carbon capture from natural gas combustion. The undertaken studies are comprehensive and include pilot plant studies, developing key process indicators, comparison with benchmark MEA scenarios, scale-up, Natural Gas Combined Cycle (NGCC) power plant integration, and flexibility optimization in terms of load reduction.

Problem Statement

Given the nominal power load, design the carbon capture process, so that the overall process is optimal and will remains flexible with respect to prospective variations in the power load.

Solution Strategy

Optimization under uncertainty programming:

$$Objective = \frac{1}{Nscen} * \sum_{s=1}^{Nscen} TAC_s$$

Subject to

- Constraints associated with physical systems (equipment, thermodynamics)
- Technical Constraints (Solvent degradation)
- Control Constraints (90% CO2 Capture)
- Disturbances (Composition and flowrate of flue gas equivalent to 100%, 75%, 50% power load)

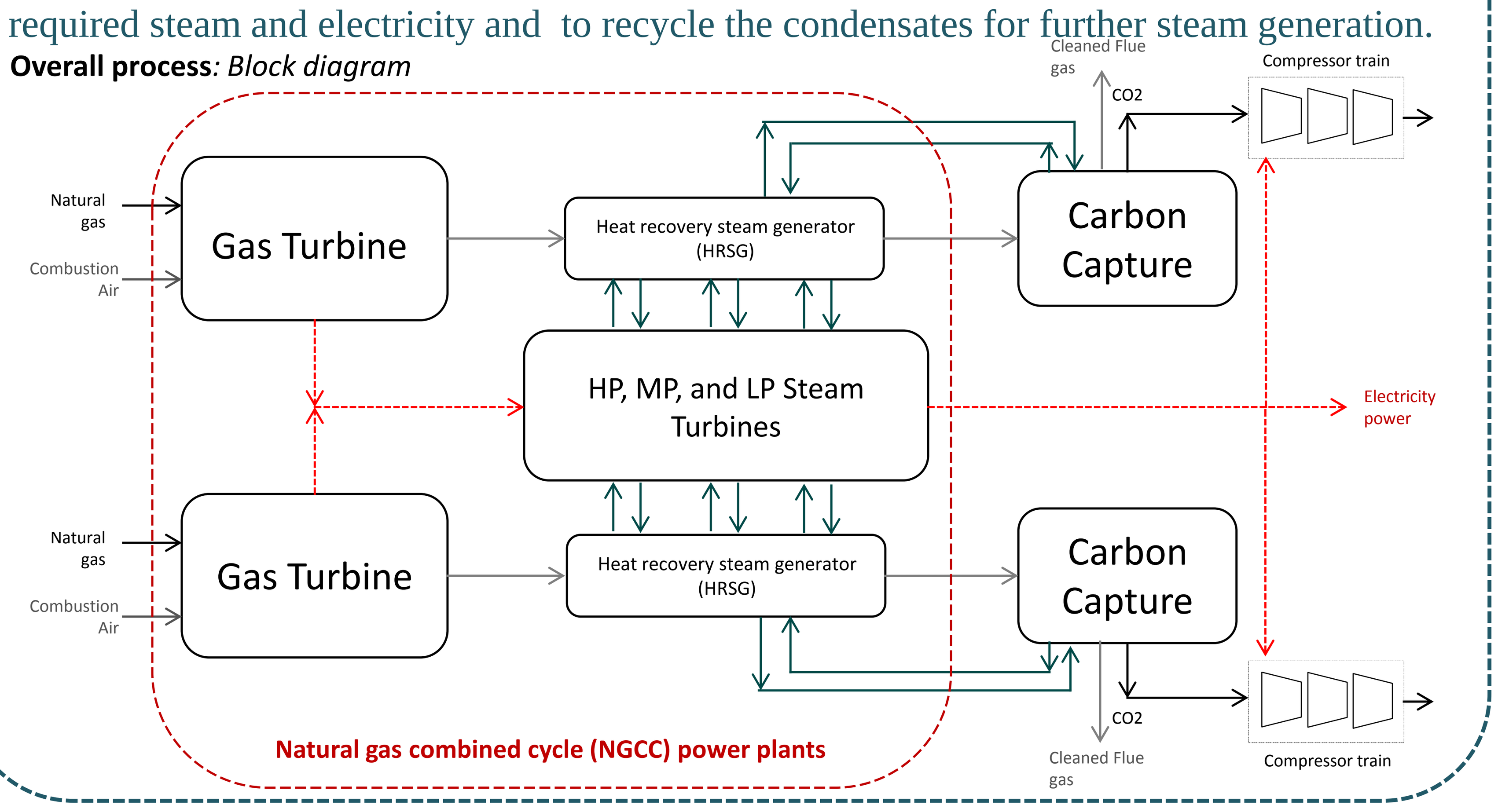
Optimization decision variables

- Design decisions: Absorber, Desorber, Heat Exchangers
- Recourse decisions: Circulation flowrate, Reboiler steam flowrate

Overall process flow diagram

The natural gas combined cycle (NGCC) power plant is integrated to the carbon capture and compression networks in four points. Flue gas is fed to carbon capture plant for separation. In addition, carbon capture and compression trains relies on the power plant to supply the required steam and electricity and to recycle the condensates for further steam generation.

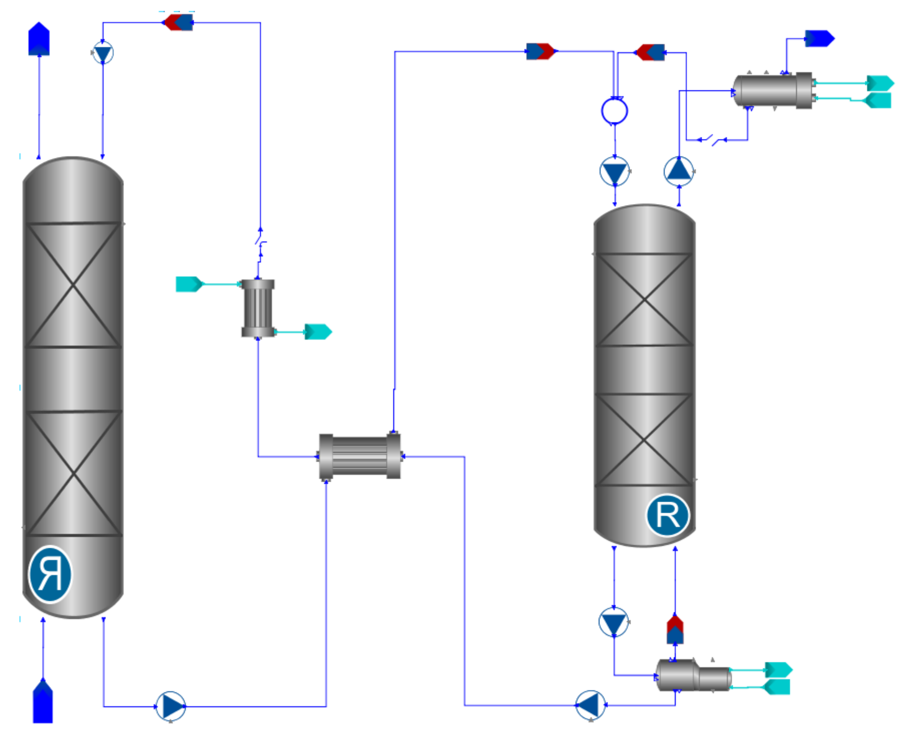
Overall process: *Block diagram*



Solvent-based carbon capture

Model characteristics:

- ✓ rate-based modelling of mass and heat transfer phenomena,
- ✓ representation of chemical reactions based on statistical associating fluid theory (SAFT)
- ✓ Quantification of ease of CO2 separation based on key process indicators



GCCMAX solvent

KPIs		50% load	75% load	100% load
Heating duty	MJ/ton CO2	2156.04	2223.64	2271.96
Cooling duty	MJ/ton CO2	1653.47	1763.02	1723.00
Packing Volume	m3/ton CO2 hr-1	27.014	19.55	15.34
Circulation rate	ton solvent/ton CO2	46.35	45.48	43.23

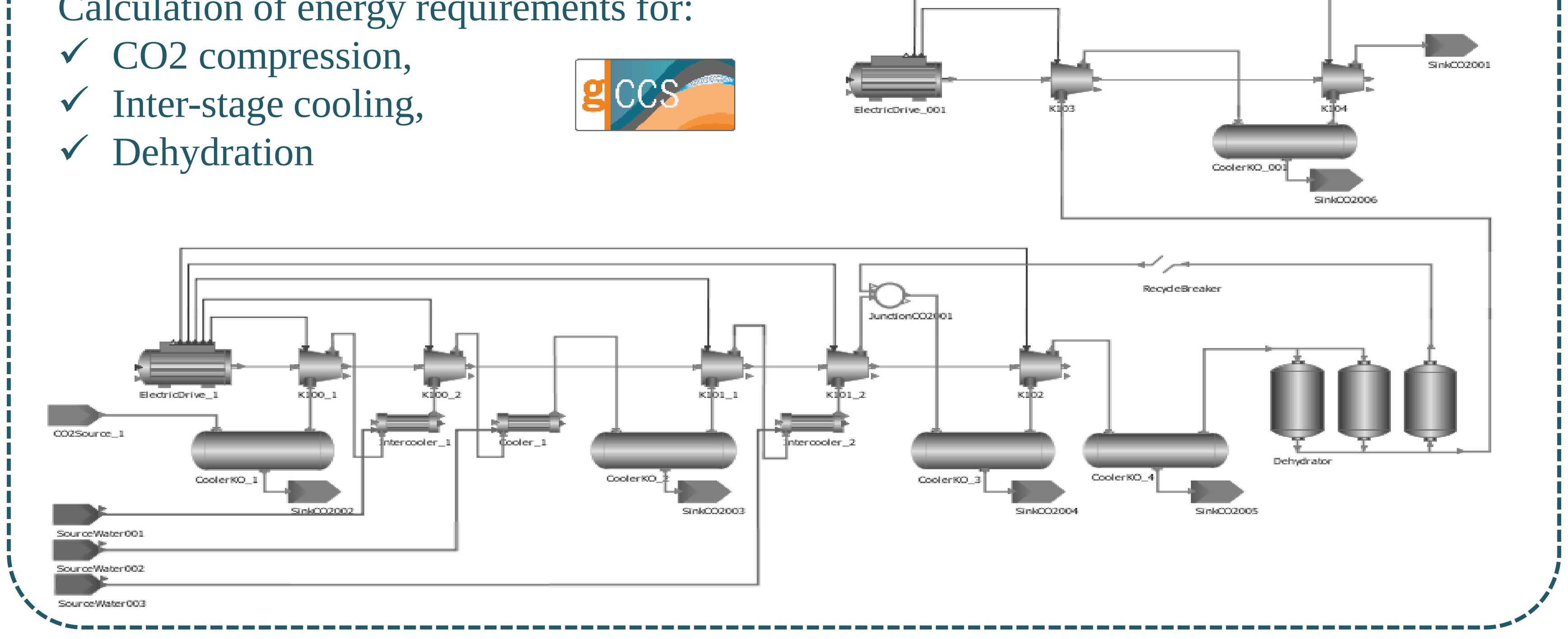
MEA reference solvent

KPIs		50% load	75% load	100% load
Heating duty	MJ/ton CO2	3247.9	3303.5	3290.6
Cooling duty	MJ/ton CO2	4533.6	4633.8	4538.6
Packing Volume	m3/ton CO2 hr-1	50.8	36.8	28.8
Circulation rate	ton solvent/ton CO2	54.6	52.3	49.3

CO2 compression

Calculation of energy requirements for:

- ✓ CO2 compression,
- ✓ Inter-stage cooling,
- ✓ Dehydration

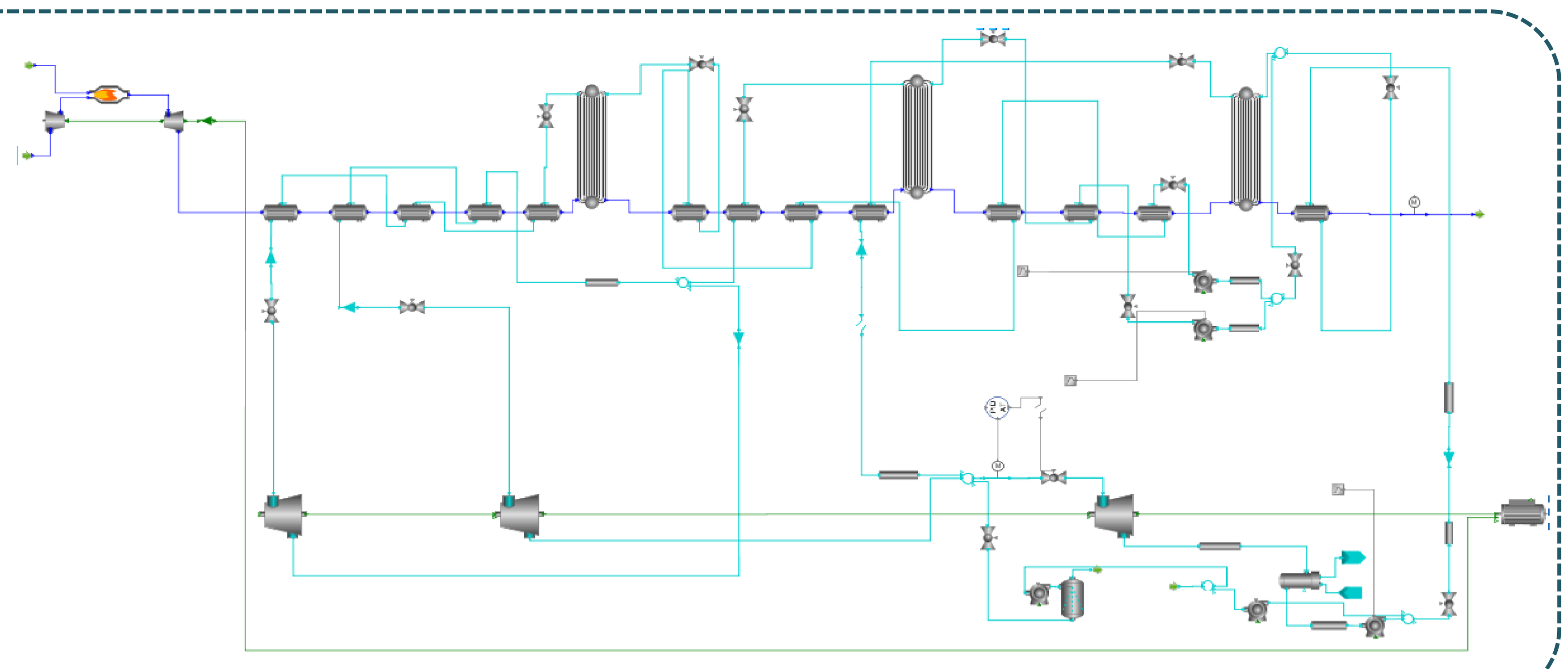


Natural gas combined cycle (NGCC) power plant

Model characteristics:

- ✓ Control of temperature turbine exhaust gases,
- ✓ pressure-driven calculation of flow

NG flowrate (kg/s)	Flue gas Flowrate (kg/s)	CO2 (mass fraction)	Comp (MW)	Net produced electricity (MW)	Overall energy efficiency (%)
26.87	1214.8	0.058325	-	747.18445	57.8
26.87	1214.8	0.058325	10.34	688.44	53.3
21.08	1022.6	0.054355	7.94	502.49	49.6
15.25	801.5	0.050176	5.82	335.93	45.8



Conclusion - The present research studied the energetic and technical implications of carbon capture and compression from natural gas fired flue gas using a novel solvent called GCCMAX. The features of interest include scale-up, power plant integration and flexibility optimization and comparison with MEA reference solvent. It was observed that carbon capture and compression have significant implications for the overall efficiency of the power plant. For the case of GCCMAX significant improvements were observed in terms of the heating and cooling energy requirements, solvent circulations, required packing and solvent spillage from top of the absorber compared to MEA reference solvent.

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