Nano Innovation 2026 Rome, 14-18 September
Conference & Exhibition

CESAR-1-based post-combustion carbon capture for natural gas combined cycle power plants: a techno-economic assessment

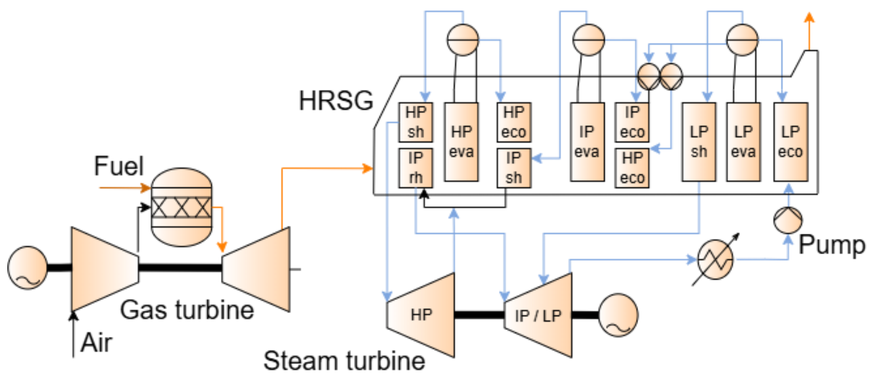
Francesca Rita Famà [a], Daniele Ferrario [b], Umberto Pasqual Laverdura [a], Giuseppina Vanga [a], Maria Luisa Grilli [a]
[a] Department of Energy Technologies and Renewable Sources, C.R. Casaccia, Rome
[b] Department of Energy, Politecnico di Milano, via Lambruschini 4, Milano, Italy
(*) francesca.fama@enea.it

Abstract

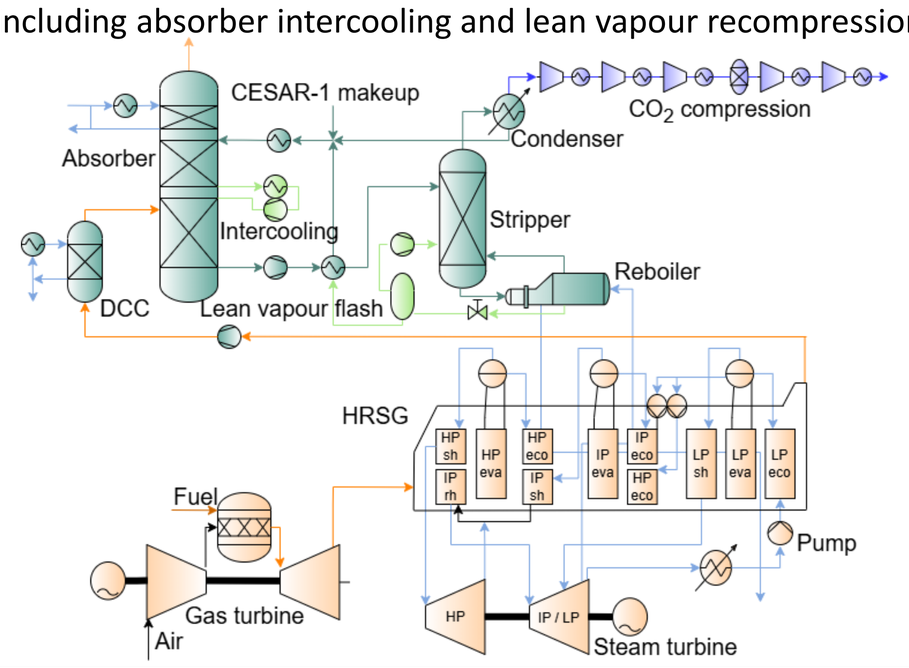
Amine-based post-combustion CO_2 capture and storage (CCS) is technically mature but remains constrained by high costs and energy penalties, particularly for NGCC power plants. This work evaluates an advanced CCS configuration based on the CESAR-1 solvent (aqueous AMP + piperazine), enhanced with absorber intercooling and lean vapour recompression, using rate-based Aspen Plus simulations with a validated eNRTL thermodynamic framework. Compared to the reference NGCC plant, the CCS-integrated configuration achieves a 95% carbon capture rate and a 94% reduction in specific CO_2 emissions, at the cost of a 6 percentage-point drop in net electrical efficiency (55% to ~49%). The specific primary energy consumption for CO_2 avoided is 2.2 MJ/kgCO_2, lower than conventional MEA-based systems (3–3.5 MJ/kgCO_2). The levelized cost of electricity rises by 16% (135 to 156 €/MWh), remaining competitive with other low-carbon technologies, with a cost of CO_2 captured of 88.1 €/tCO_2 and cost of CO_2 avoided of 135 €/tCO_2. These results support CESAR-1-based post-combustion capture in NGCC plants as a viable pathway toward near-zero CO_2 emissions with competitive energy and economic performance.

Problem statement

Process flow diagrams of the reference NGCC power plant and the CCS-integrated configuration including absorber intercooling and lean vapour recompression.

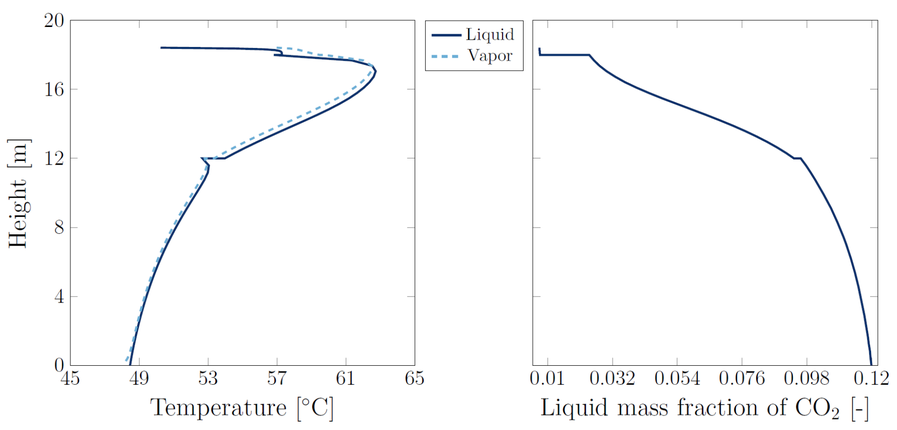


Combined cycle	
Fuel composition [% mol.]	CH_4,C_2H_6,C_3H_8,C_4H_{10},CO_2,N_2 89,7,1,0.1,2,0.9
Compressor pressure ratio [-]	18.1
Turbine inlet temperature [°C]	1360
Evaporation pressure levels [bar]	HP,IP,LP 130,28,4
Maximum steam temperature [°C]	SH,RH 565,565

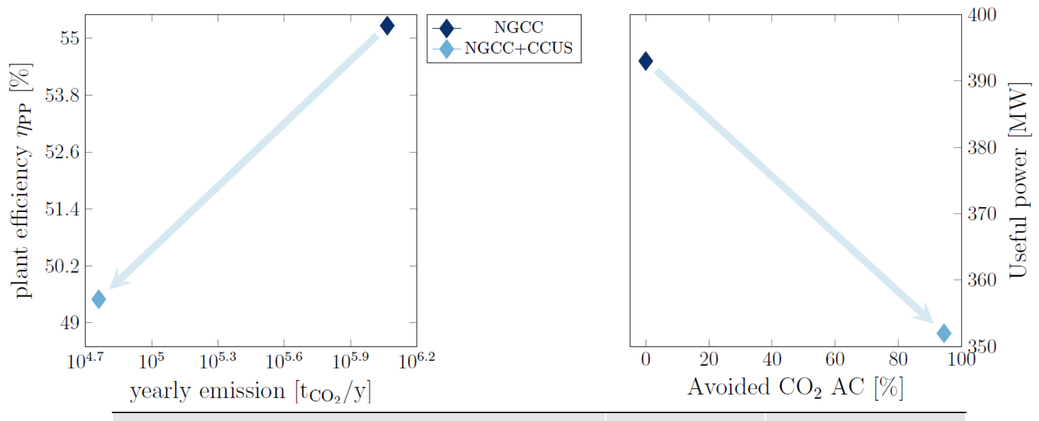


Capture unit	
Solvent composition [% mol.]	AMP,CO_2,H_2O,PZ 8.9,1.5,84,5.6
Packing type [-]	MellaPack 250Y

Simulation results

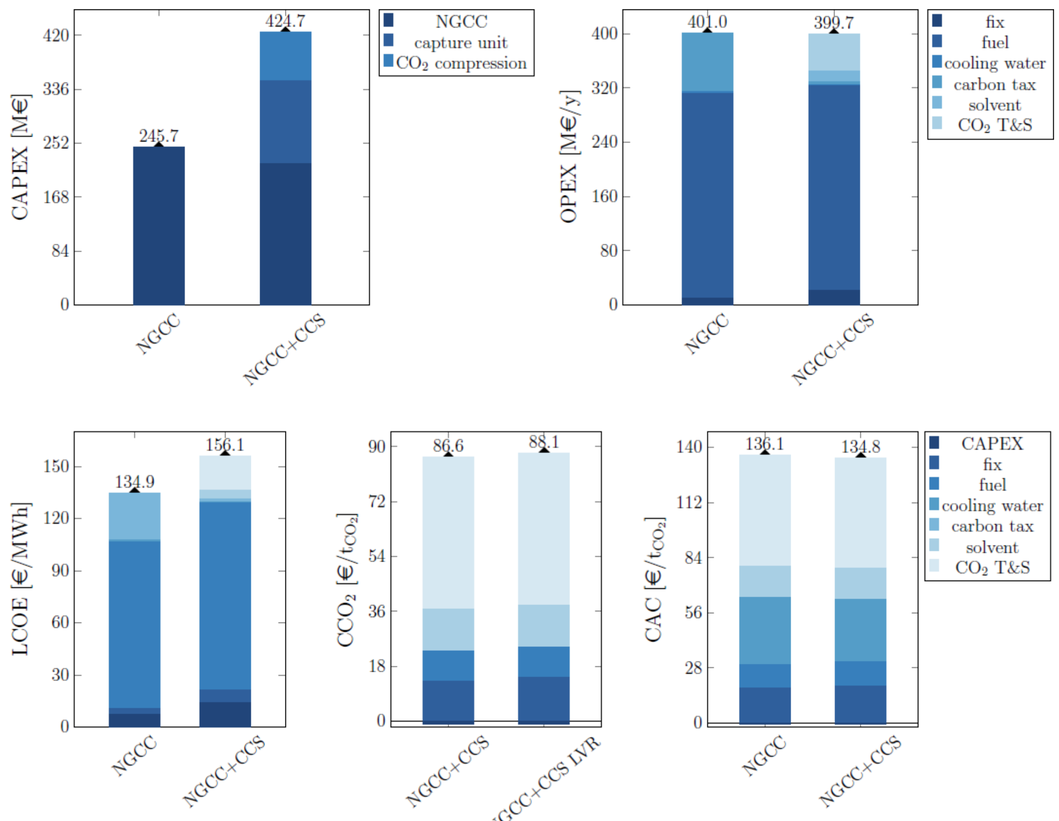


- A pronounced bulge is observed above the intercooling section, near the top of the column, followed by a flatter region below it.
- The liquid solvent enters the top of the absorber with a CO_2 mass fraction of 0.72% and exits at the bottom with 12%.



Parameter	NGCC	NGCC+CCS
Plant efficiency [%]	55.3	49.5
Eciency penalty [%-points]	-	5.8
Useful power [MW]	393	350
SPECCA [MJ/kgCO_2]	-	2.2
CO_2 avoidance rate [%]	-	94.5

Economic results



- CAPEX of the reference NGCC plant is approximately half that of the CCS-integrated configurations, whereas OPEX amounts to approximately 400 MN/y for all configurations.
- CCS integration increases the LCOE by 16%, from 135 N/MWh to 156 N/MWh.
- Fuel cost has a strong impact on LCOE, a more limited impact on CCA, and none on CCO 2, whereas CO 2 T&S becomes the largest contributor to CCO 2 and CCA, followed by CAPEX, fixed OPEX, and solvent.

RdS RICERCA DI SISTEMA
Ministero dell'Ambiente e della Sicurezza Energetica
NICE-Italy
MUR Ministero Università della Ricerca
PCH2R