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Reboiler duties at ultra-high CO_2 capture rates with MEA and CESAR1

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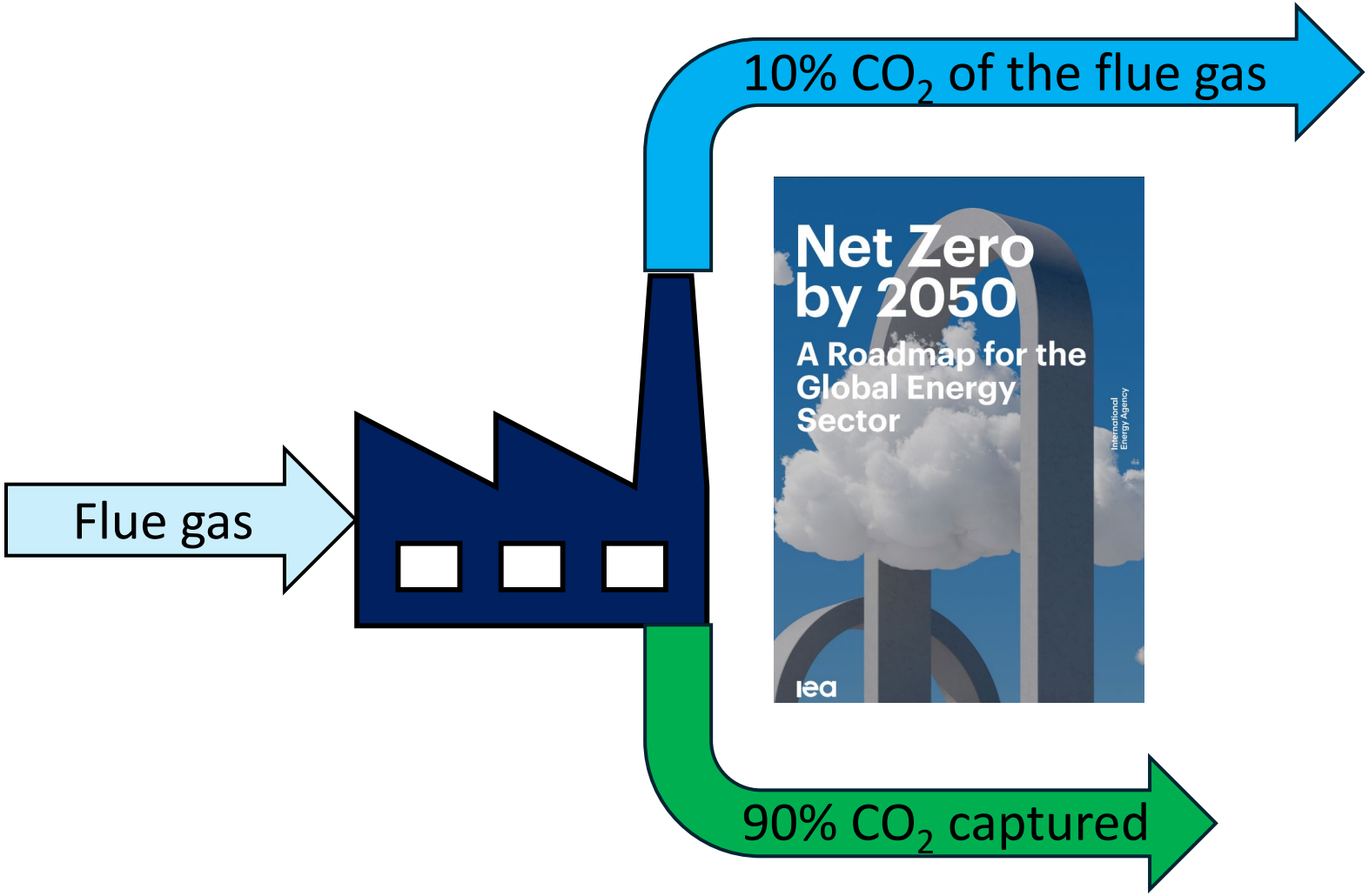
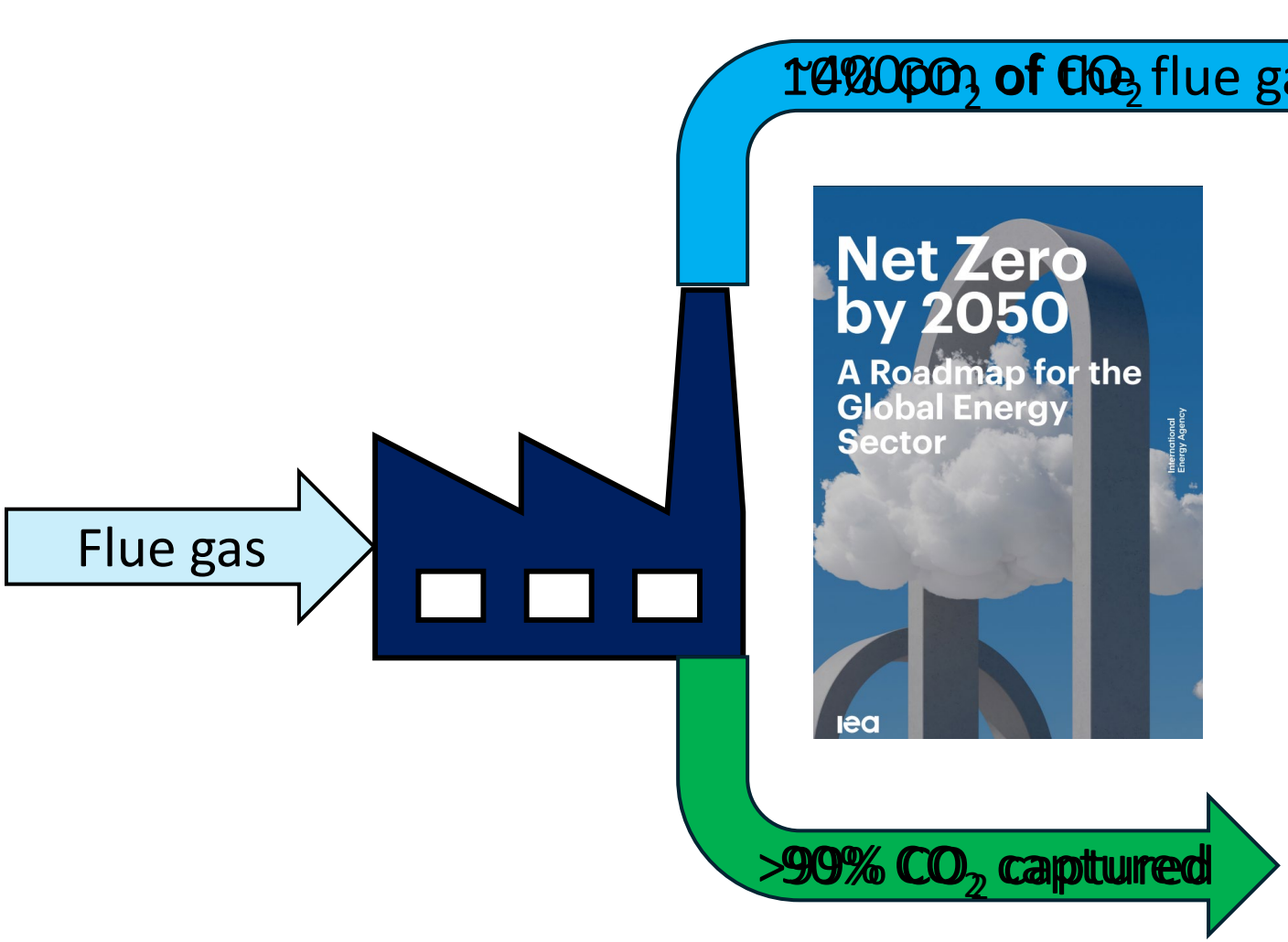
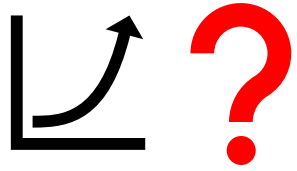
Beyond 90% CO_2 capture



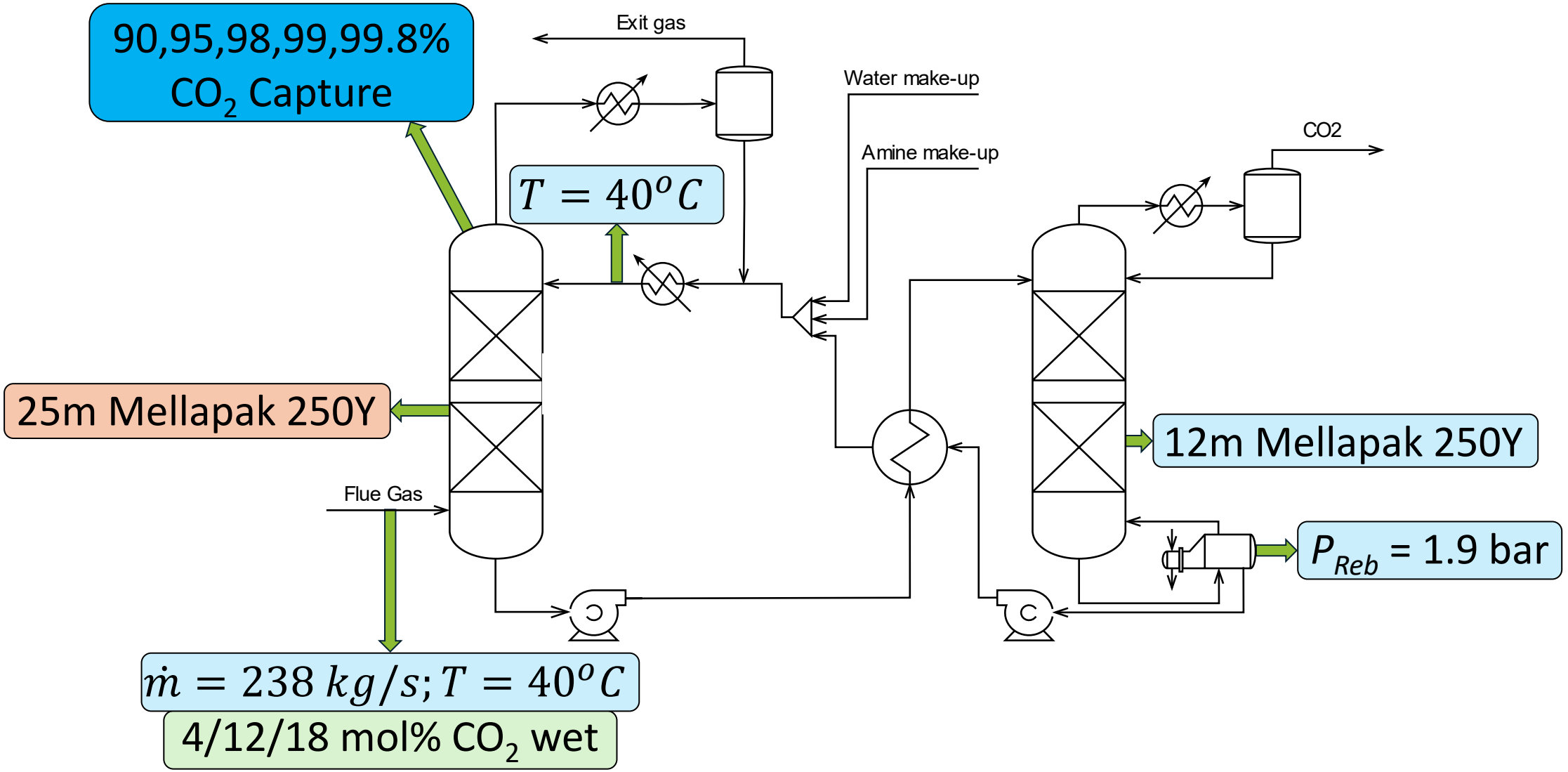
Beyond 90% CO_2 capture



- Technically feasible ☑
- What is energy performance of MEA and CESAR1?



Design of this work

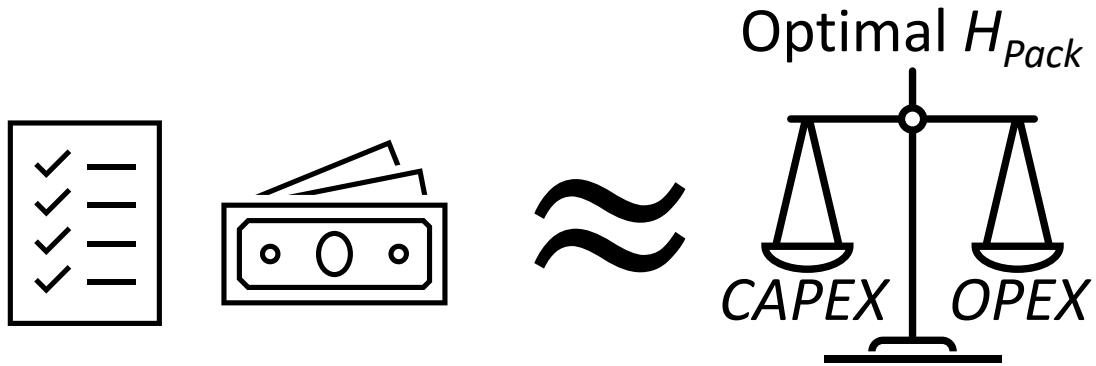


Scope of this work

How does energy performance of MEA and CESAR1 depend on:

- High CO_2 capture rates
- CO_2 content in the flue gas
- Absorber packing height

Does cost analysis agree to the optimal absorber sizing obtained from simulations?



Validation of MEA and CESAR1 models: VLE

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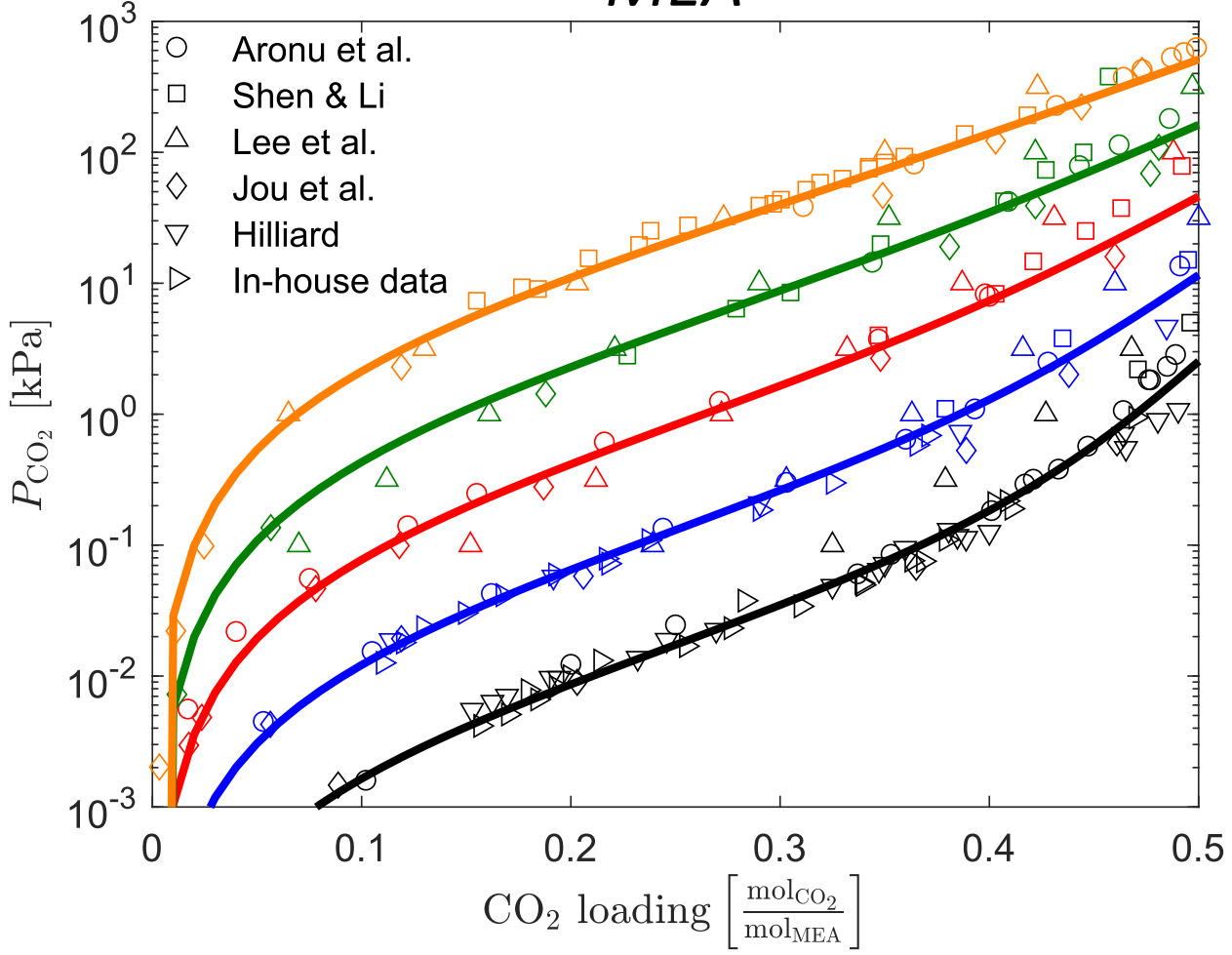
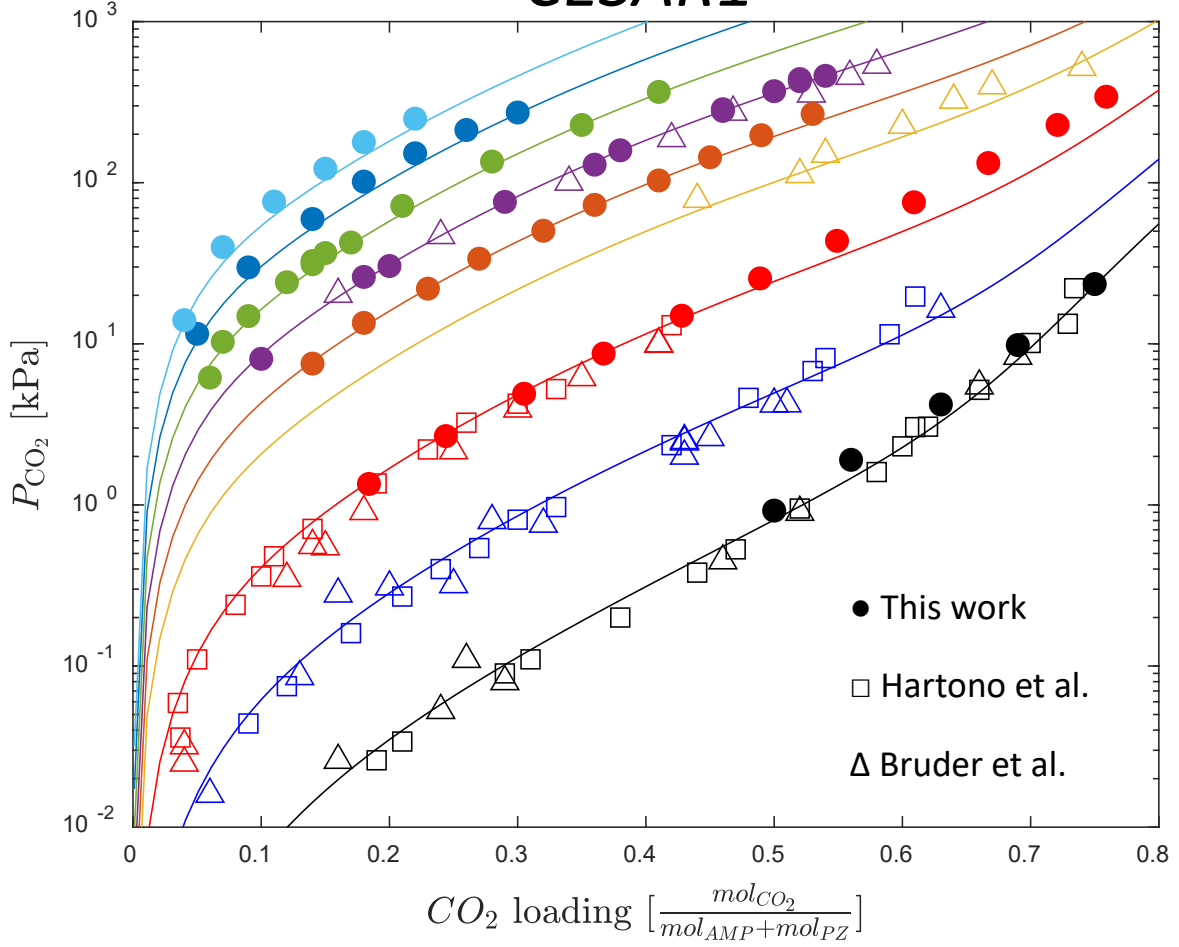
MEA



CESAR1



Adapted from "Thermodynamics data for CO_2 absorption in aqueous 2-amino-2-methyl-1-propanol (AMP) and piperazine (PZ) solutions: CO_2 solubility, N_2O solubility, heat of absorption of CO_2, pH and liquid speciation". Morlando et al. (2025)

Validation of models: pilot plant data

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MEA

NTNU
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SINTEF

Experimental validation of a rigorous absorber model for CO_2 postcombustion capture

Tobiesen et al. https://doi.org/10.1002/aic.11133

Experimental validation of a rigorous desorber model for CO_2 post-combustion capture

Tobiesen et al. https://doi.org/10.1016/j.ces.2008.02.011

Post combustion CO_2 capture by reactive absorption: Pilot plant description and results of systematic studies with MEA

Notz et al. https://doi.org/10.1016/j.ijggc.2011.11.004

CESAR1

CO2 TECHNOLOGY CENTRE MONGSTAD

Development of process model of CESAR1 solvent system and validation with large pilot data.

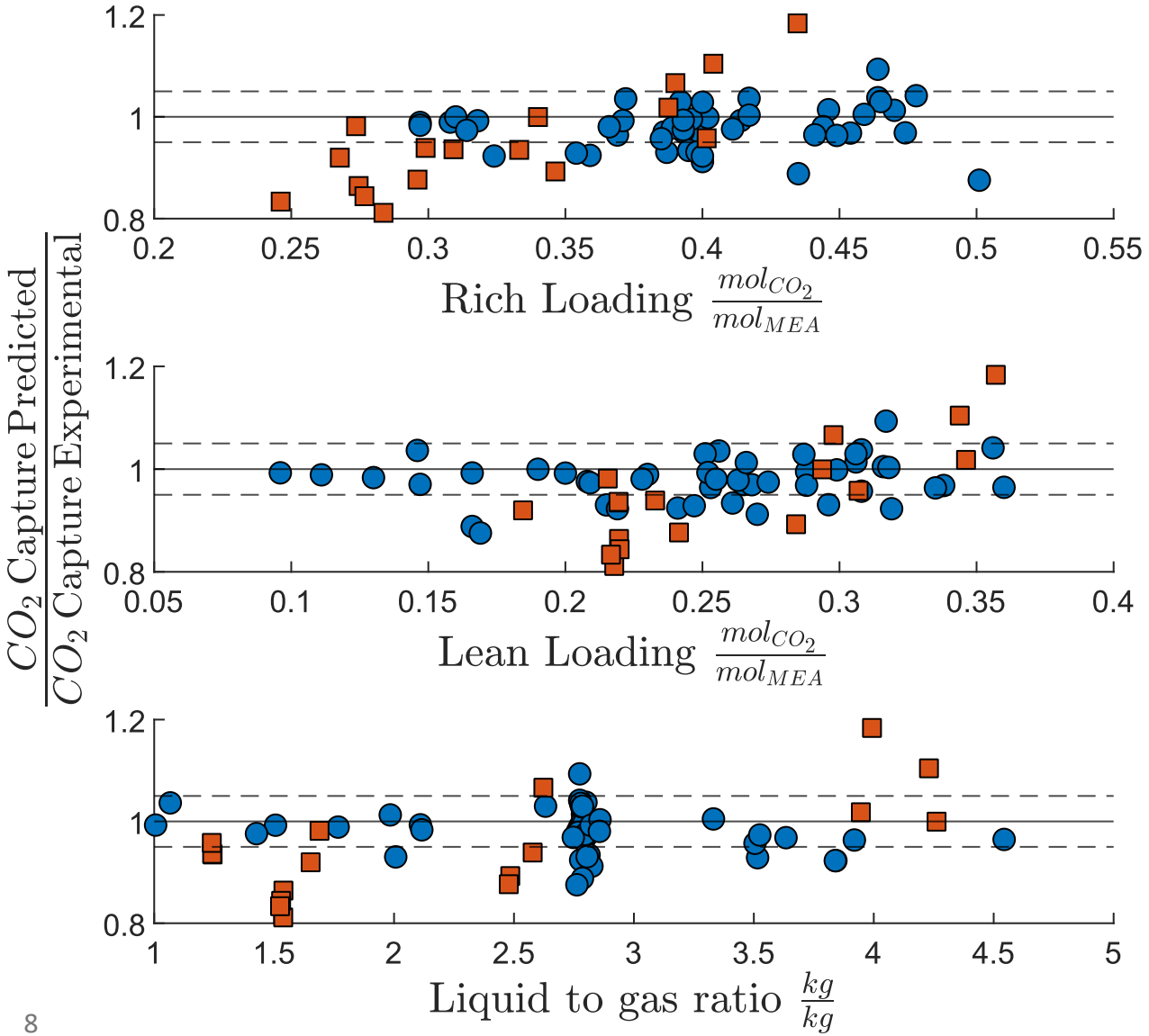
Morgan et al. http://dx.doi.org/10.2139/ssrn.4276820

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

Pilot plant study of two new solvents for post-combustion carbon dioxide capture by reactive absorption and comparison to monoethanolamine.

Mangalapally et al. https://doi.org/10.1016/j.ces.2011.06.054

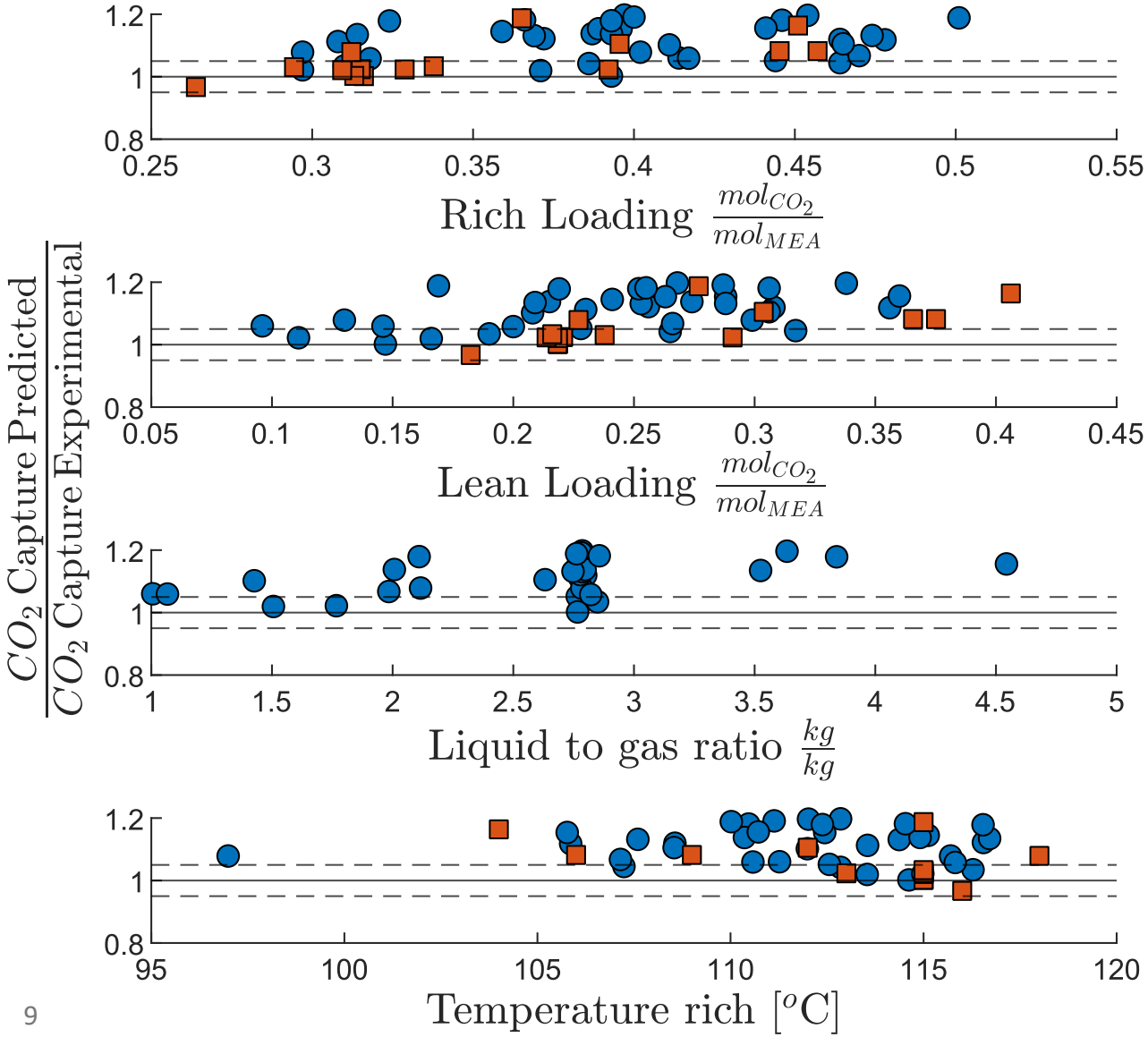
Absorber validation: MEA



$$AARD_{\alpha_{rich}} = 2.3\%$$

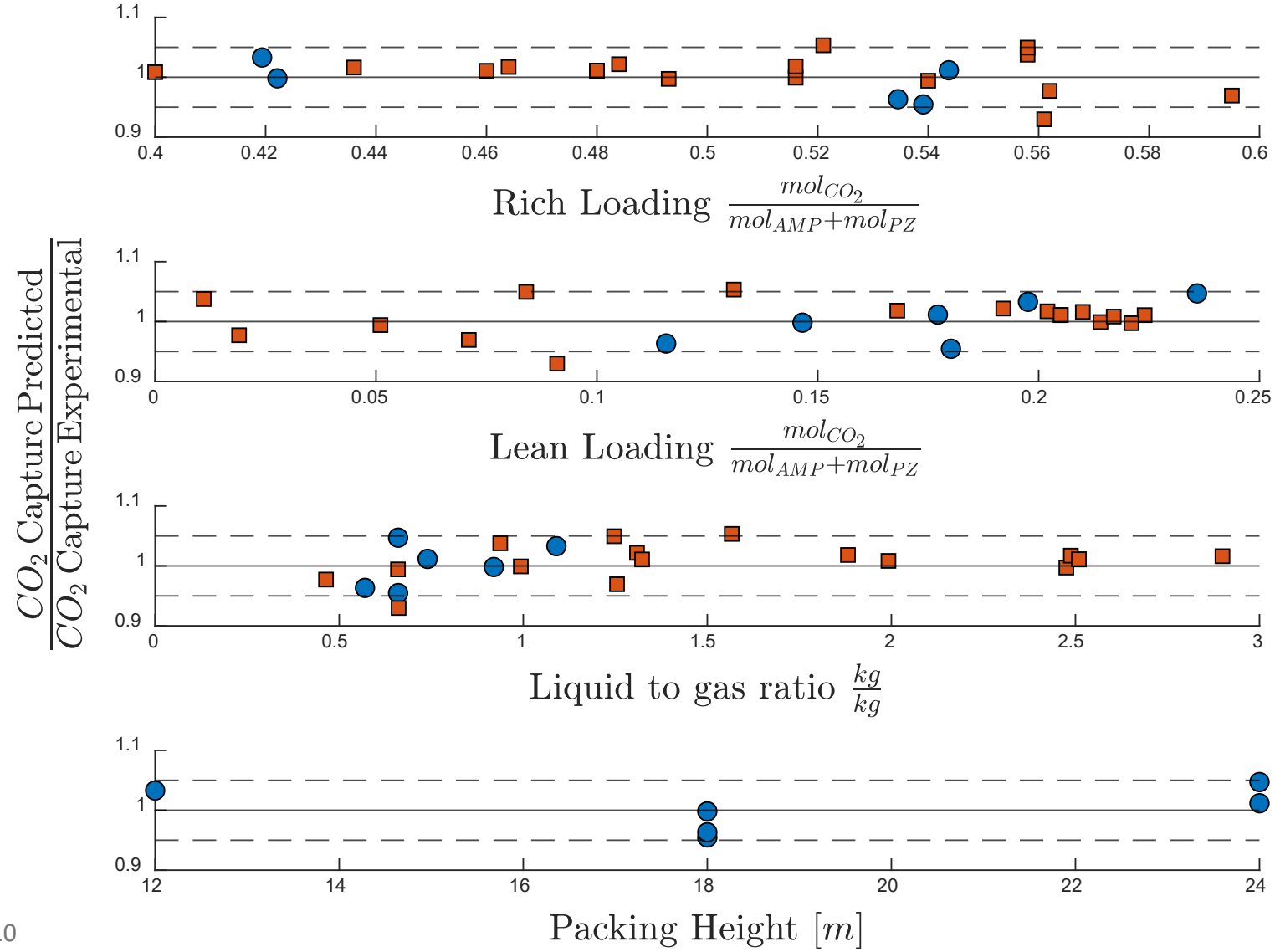
$$AARD_{Capture} = 5.1\%$$

Stripper validation: MEA



$$AARD_{SRD} = 11.6\%$$

Absorber validation: CESAR1

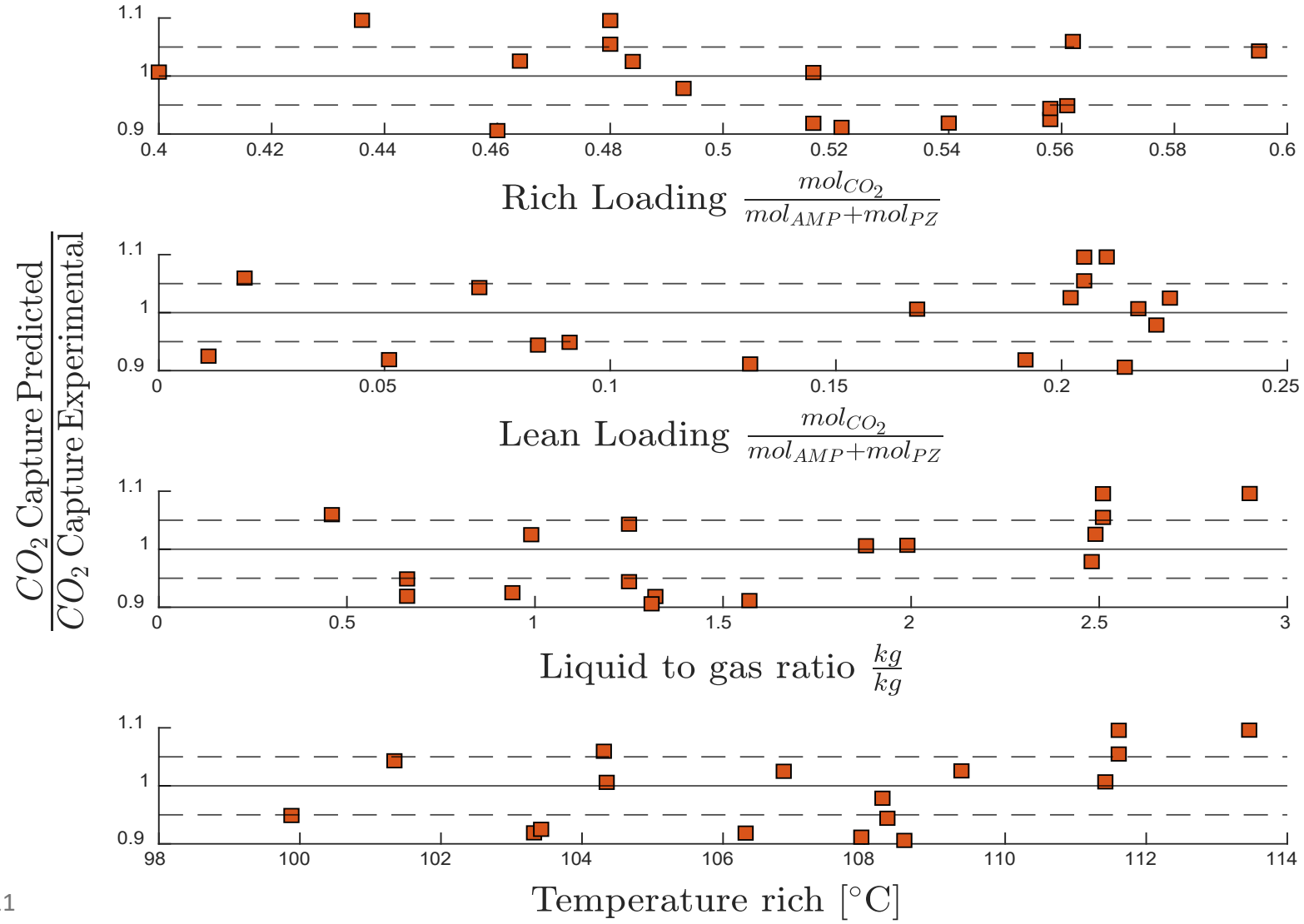


TCM
Kaiserslautern

$$AARD_{\alpha_{rich}} = 2.3\%$$

$$AARD_{Capture} = 2.7\%$$

Stripper validation: CESAR1



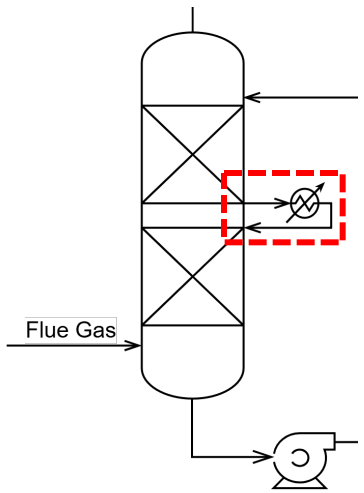
Kaiserslautern

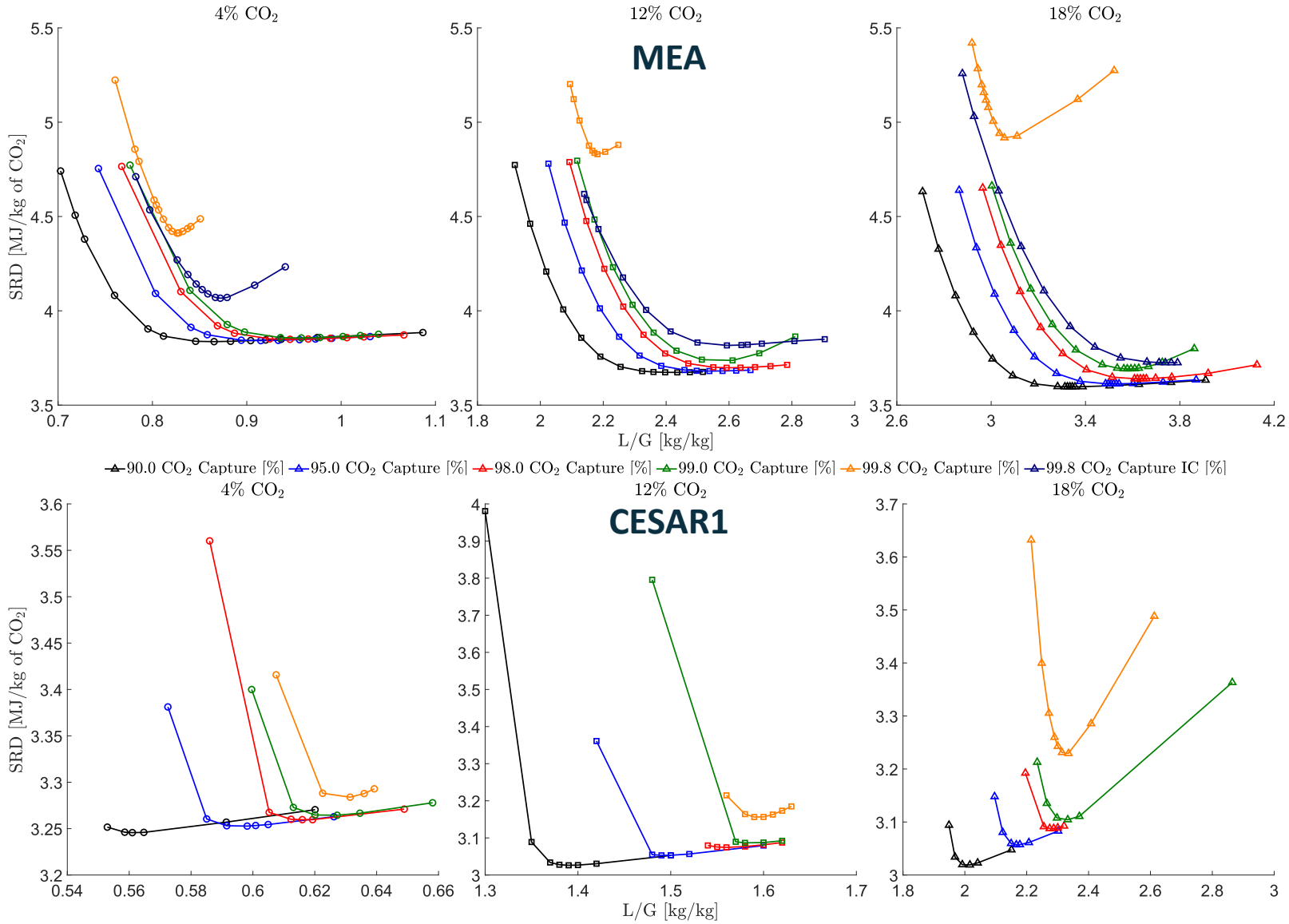
$$AARD_{SRD} = 4.8\%$$

SRD at 25m absorber: MEA & CESAR1

- SRD increases with increasing CO_2 capture

- MEA: intercooler needed to increase driving force at 99.8% CO_2 capture





CO_2 capture effect on MEA and CESAR1

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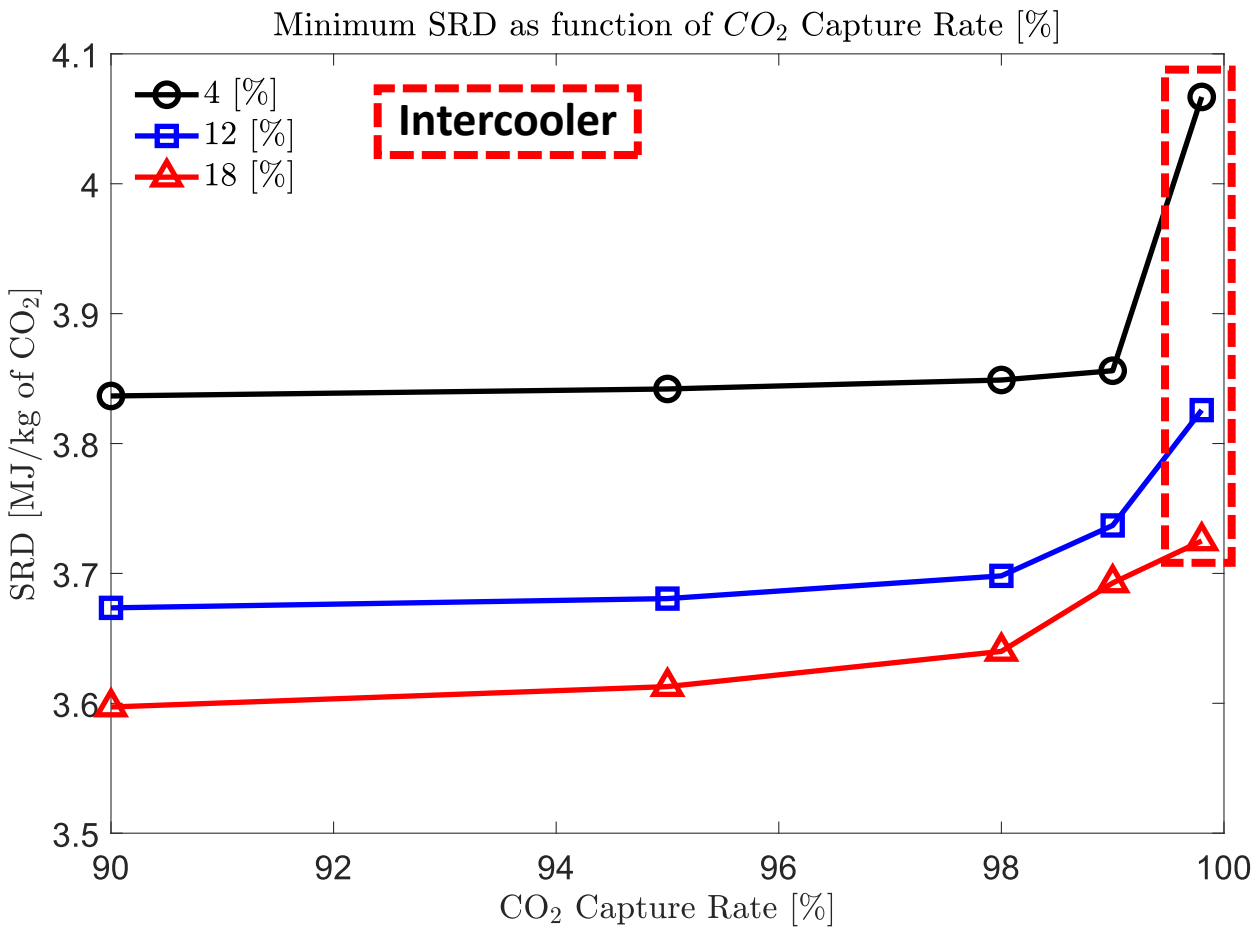
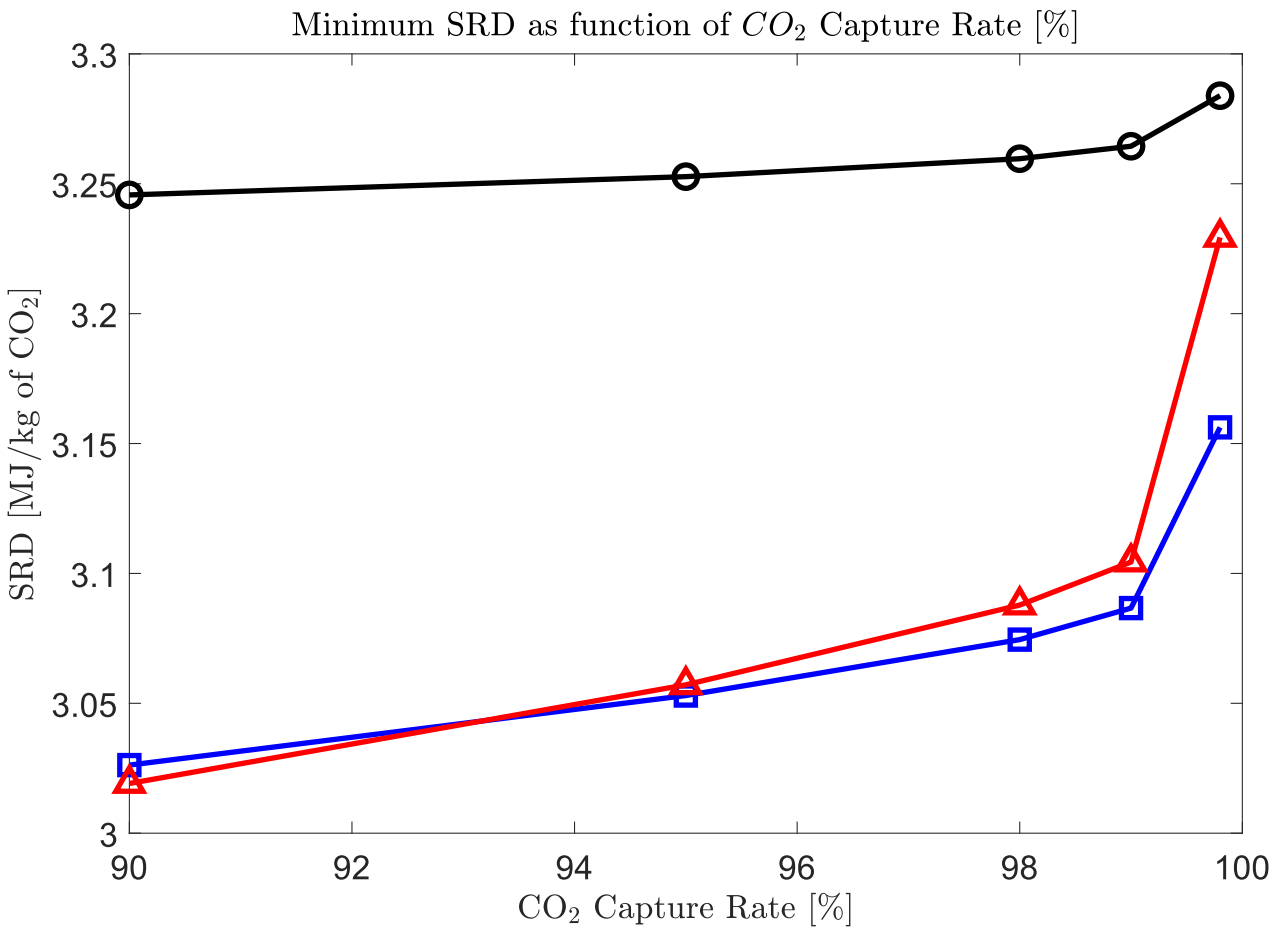
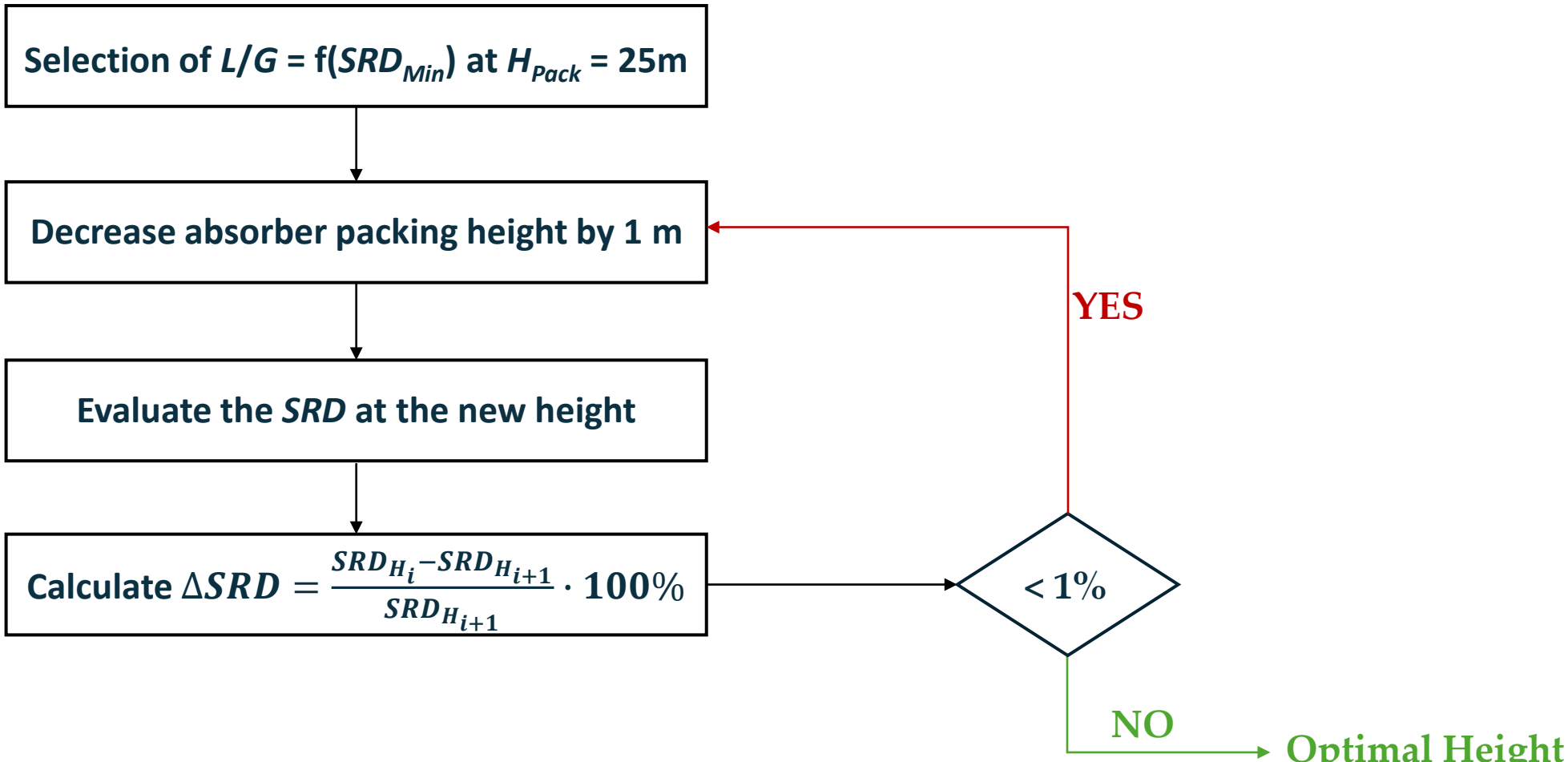
MEA



CESAR1



Absorber height reduction: Approach



Absorber height optimization:

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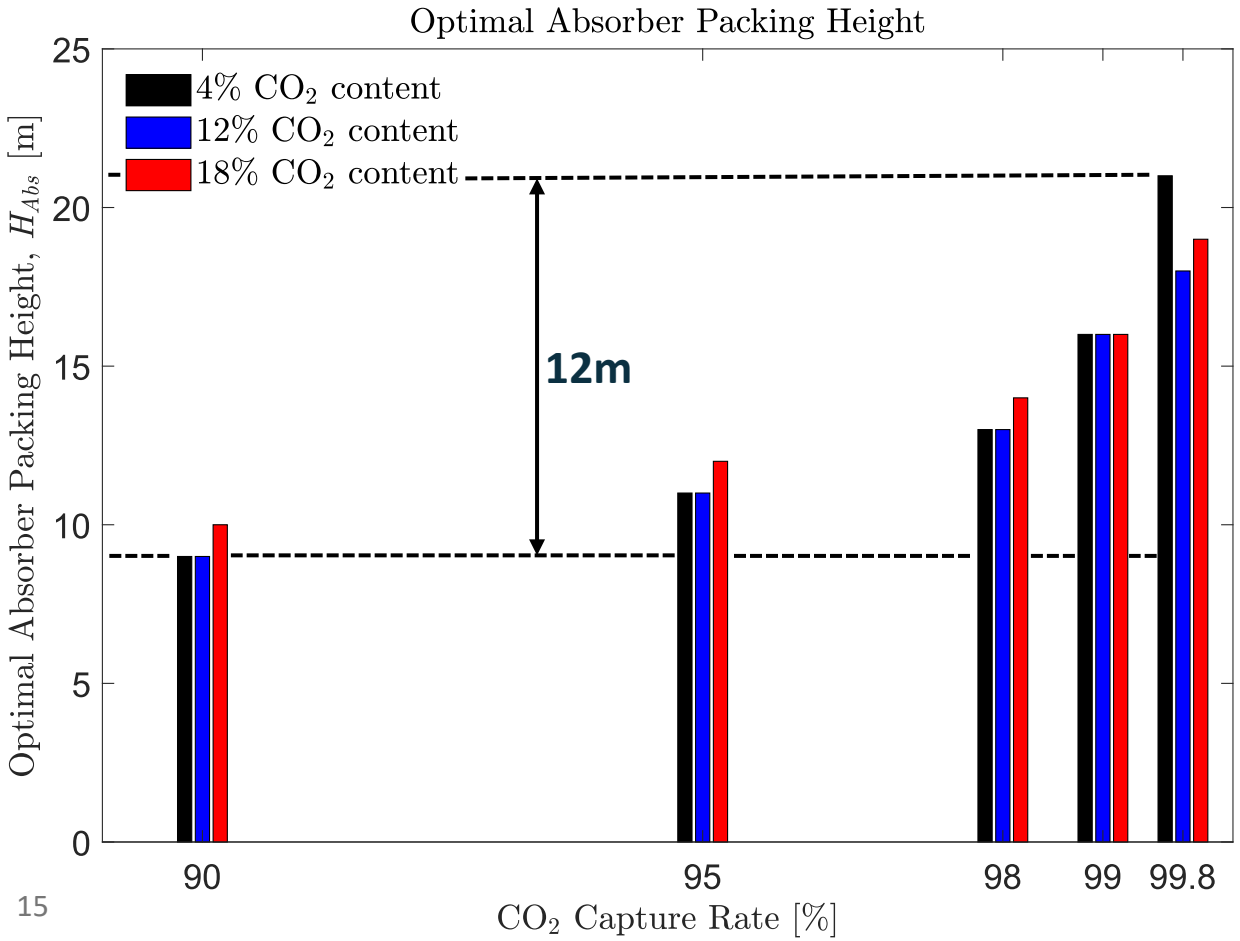
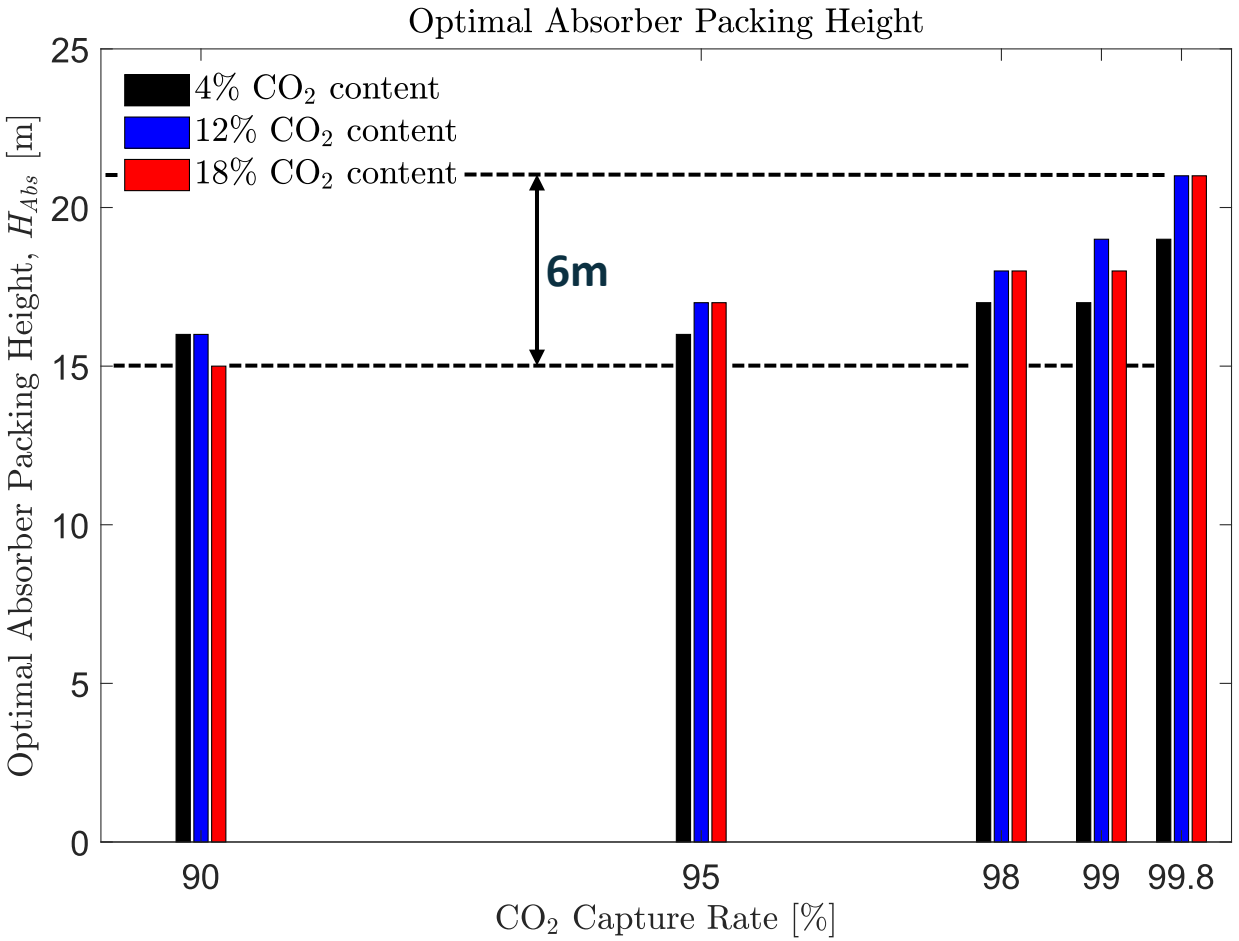
MEA



CESAR1



Does cost analysis agree with simulations?

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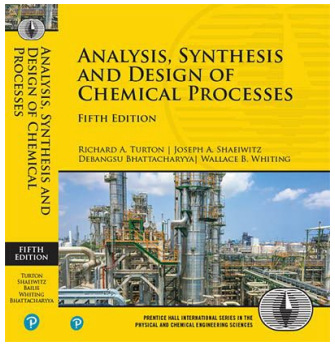
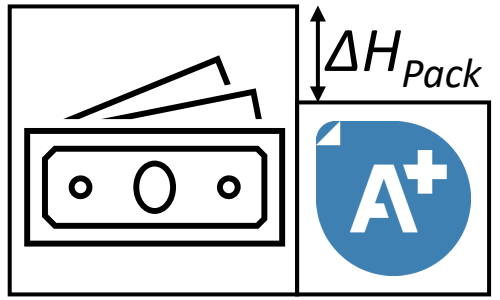
- Techno-economic assessment based on the book by Turton et al.
- Analysis qualified as Class 3 (Accuracy of +40% & -25%)



- Based on techno-economic assessment for MEA:
  1. Economics suggested higher optimal absorber packing height than simulations
  2. Difference in absorber packing height becomes bigger at higher CO_2 content



- Choice of materials and cost of utilities (steam) affect optimal absorber design

Conclusions and future work

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- MEA and CESAR1 can successfully operate up to 99.8% CO_2 capture
- Intercooler is needed for MEA
- CO_2 capture rates and CO_2 inlet concentration affected optimal absorber packing height
- MEA required lower absorber packing heights than CESAR1: by 6 to 2m for 90-99% CO_2 capture respectively
- Cost analysis for MEA suggested to use higher absorber packing heights than simulations

Future work will focus on techno-economic assessment for CESAR1 and comparison with MEA

Acknowledgements

- This work was carried out as a part of SUBPRO-Zero, a Research Centre at the Norwegian University of Science and Technology (project code 100589). The authors gratefully acknowledge the project support from SUBPRO-Zero, which is financed by major industry partners and NTNU.
- This research has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101096521 (the AURORA project).

Thank you for your attention!

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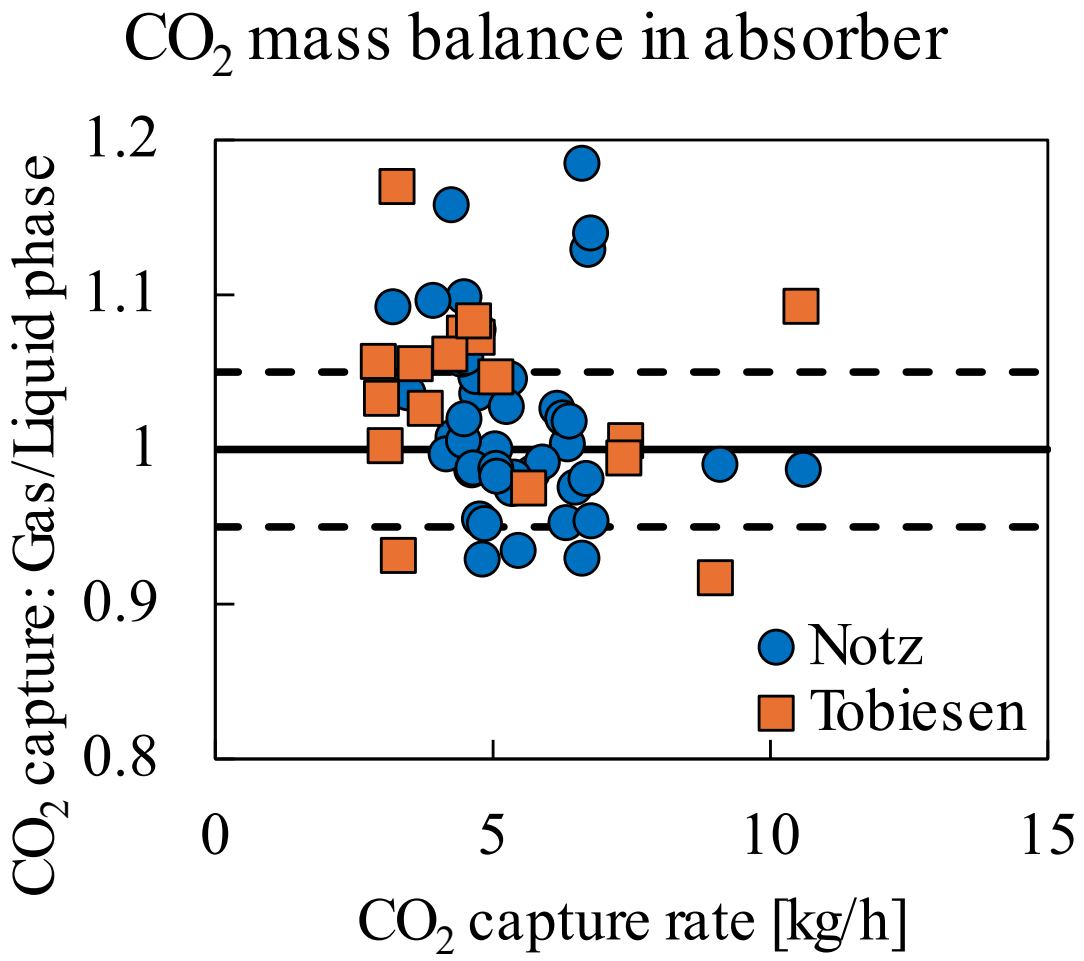
Suplementary Slides

CO_2 mass balance in absorber pilot data: MEA



Loadings for MEA and CESAR1 at 25m

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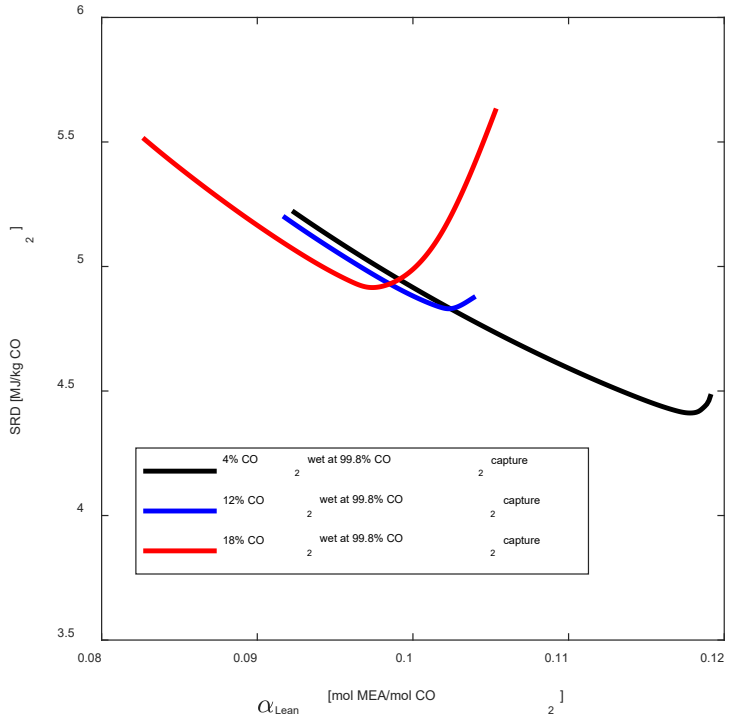
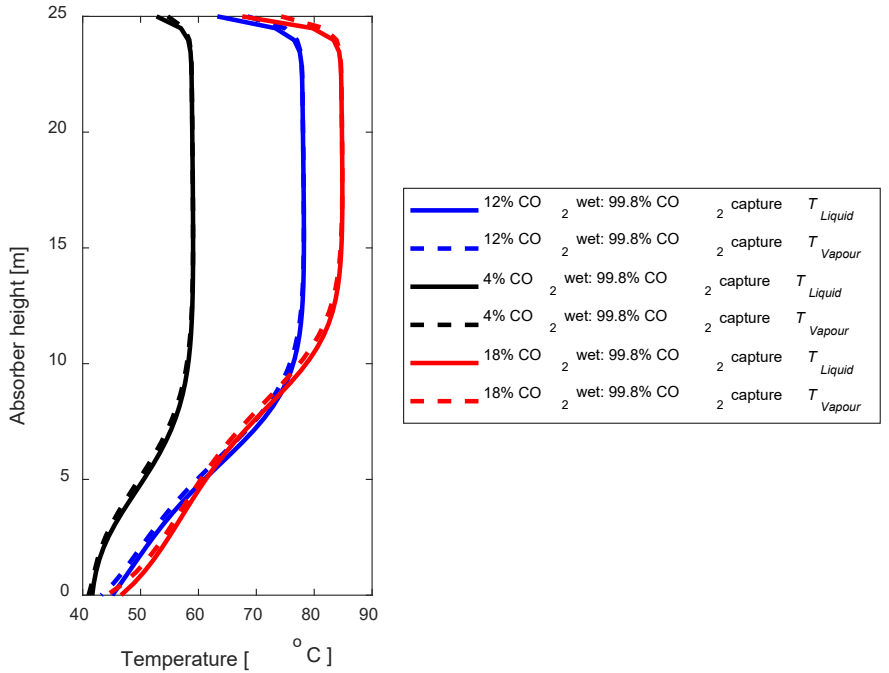
	MEA								
	Lean loading [mol CO_2 / mol MEA]			Rich Loading [mol CO_2 / mol MEA]			Cyclic capacity [mol CO_2 / mol MEA]		
%CO_2 wet in flue gas	4%	12%	18%	4%	12%	18%	4%	12%	18%
90% CO_2 capture	0.171	0.183	0.175	0.483	0.502	0.512	0.312	0.320	0.337
95% CO_2 capture	0.171	0.178	0.172	0.483	0.502	0.510	0.312	0.324	0.338
98% CO_2 capture	0.171	0.173	0.168	0.482	0.500	0.507	0.311	0.327	0.339
99% CO_2 capture	0.171	0.169	0.158	0.481	0.496	0.503	0.311	0.327	0.346
99.8% CO_2 capture + IC	0.135	0.170	0.168	0.477	0.488	0.500	0.341	0.318	0.332

	CESAR1								
	Lean loading [mol CO_2 / mol AMP + PZ]			Rich Loading [mol CO_2 / mol AMP + PZ]			Cyclic capacity [mol CO_2 / mol AMP + PZ]		
%CO_2 wet in flue gas	4%	12%	18%	4%	12%	18%	4%	12%	18%
90% CO_2 capture	0.057	0.055	0.055	0.573	0.653	0.654	0.516	0.598	0.599
95% CO_2 capture	0.060	0.055	0.053	0.572	0.644	0.641	0.512	0.589	0.588
98% CO_2 capture	0.060	0.055	0.053	0.570	0.636	0.631	0.510	0.580	0.578
99% CO_2 capture	0.060	0.054	0.055	0.568	0.633	0.624	0.508	0.579	0.569
99.8% CO_2 capture + IC	0.055	0.046	0.043	0.564	0.624	0.615	0.509	0.579	0.572

4%/12%/18% CO_2 wet concentration

- Temperature pinching at all CO_2 contents at 99.8% CO_2 capture
- Intercooler is needed for MEA





Partial pressures of CO_2 at the top of absorber

Results from simulation	P_{CO2} in exit gas [kPa]		
	4% CO_2 inlet	12% CO_2 inlet	18% CO_2 inlet
90% CO_2 capture	0.435	1.420	2.279
95% CO_2 capture	0.218	0.715	1.152
98% CO_2 capture	0.087	0.287	0.463
99% CO_2 capture	0.044	0.143	0.231
99.8% CO_2 capture + IC	0.009	0.029	0.046

VLE in Aspen Plus V14	P_{CO2} in VLE based on results loading [kPa]		
	4% CO_2 inlet	12% CO_2 inlet	18% CO_2 inlet
90% CO_2 capture	0.005	0.005	0.005
95% CO_2 capture	0.005	0.005	0.005
98% CO_2 capture	0.005	0.005	0.005
99% CO_2 capture	0.005	0.004	0.004
99.8% CO_2 capture + IC	0.003	0.005	0.005

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