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AURORA

Accelerated deployment of integrated CCUS chains based on solvent capture technology

Validation of the CESAR1 model in CO2SIM based on extensive pilot experiments

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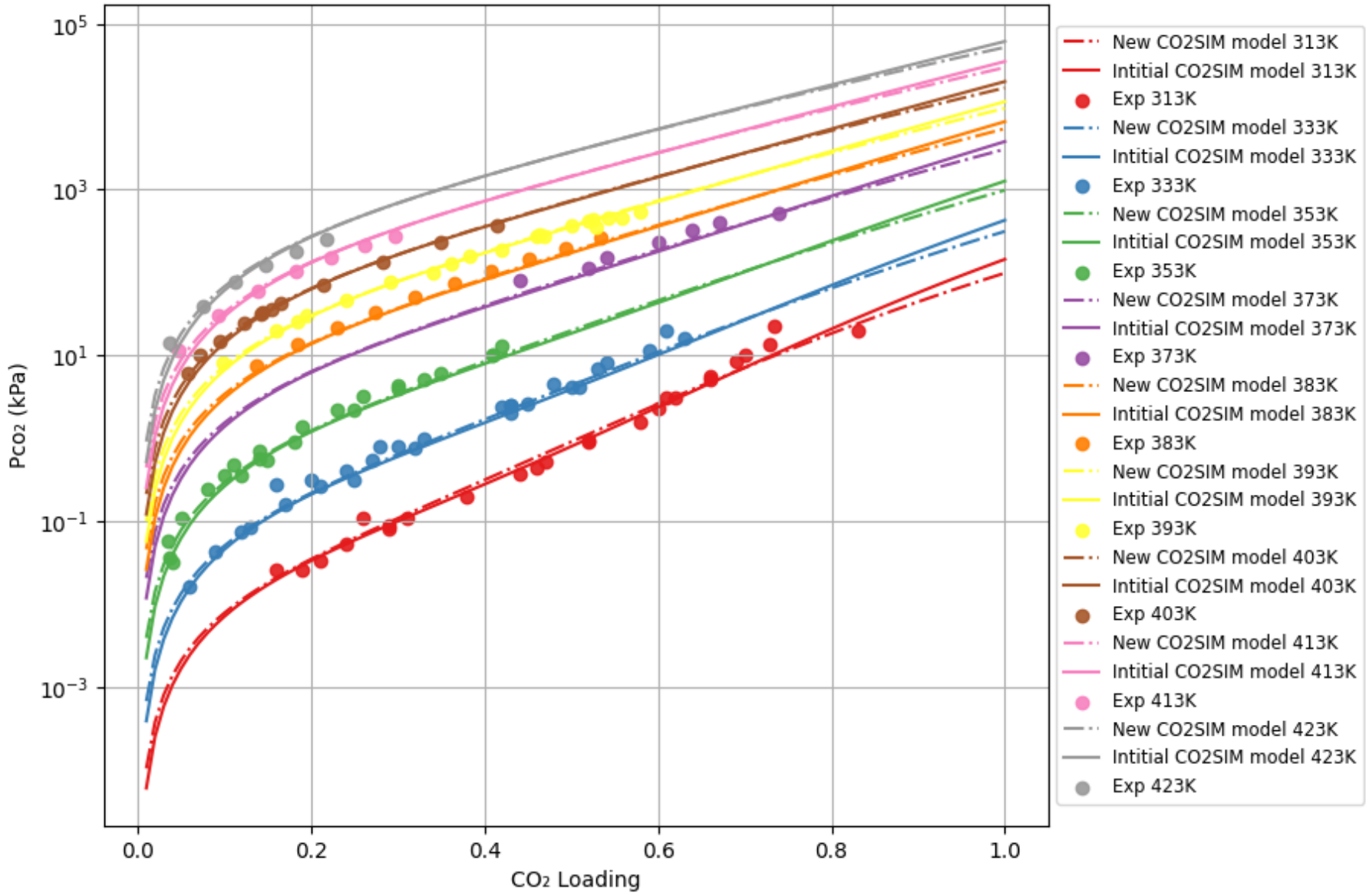
Outline

- Modelling in CO2SIM
- Test campaign at Tiller pilot
- Validation based on selected data from the Tiller campaign
- Results of validation
- Conclusions and further work

Modelling in CO2SIM

- CO2SIM is SINTEF in-house simulator
- Models for about 50 different systems are implemented with different degree of complexity.
- CESAR1 was implemented as part of the CESAR project and updated later, especially now in the AURORA project.
- The CESAR1 solvent is treated as a pseudo-component, but adjusted for the differences in AMP and Piperazine properties.
- The VLE relation is modelled as a "Soft" model, which simplifies thermodynamic representation. This also requires simplified pseudo 2-component kinetics.

VLE fitting of CESAR1: -13 data - sets -New model includes weighting of the exp. data



Test campaign at Tiller pilot (1)

Test matrix based on review article:

Review

Available data and knowledge gaps of the CESAR1 solvent system

Diego Morlando [a], Vanja Buvik [b], Asmira Delic [b], Ardi Hartono [a], Hallvard F. Svendsen [a], Hanne M. Kvamsdal [b], Eirik F. da Silva [b], Hanna K. Knuutila [a]

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Pilot Plant data at high flue and low gas concentration (>15 % and < 2% were missing) and mostly focused at 90% Capture Rate

Test campaign at Tiller pilot (2)

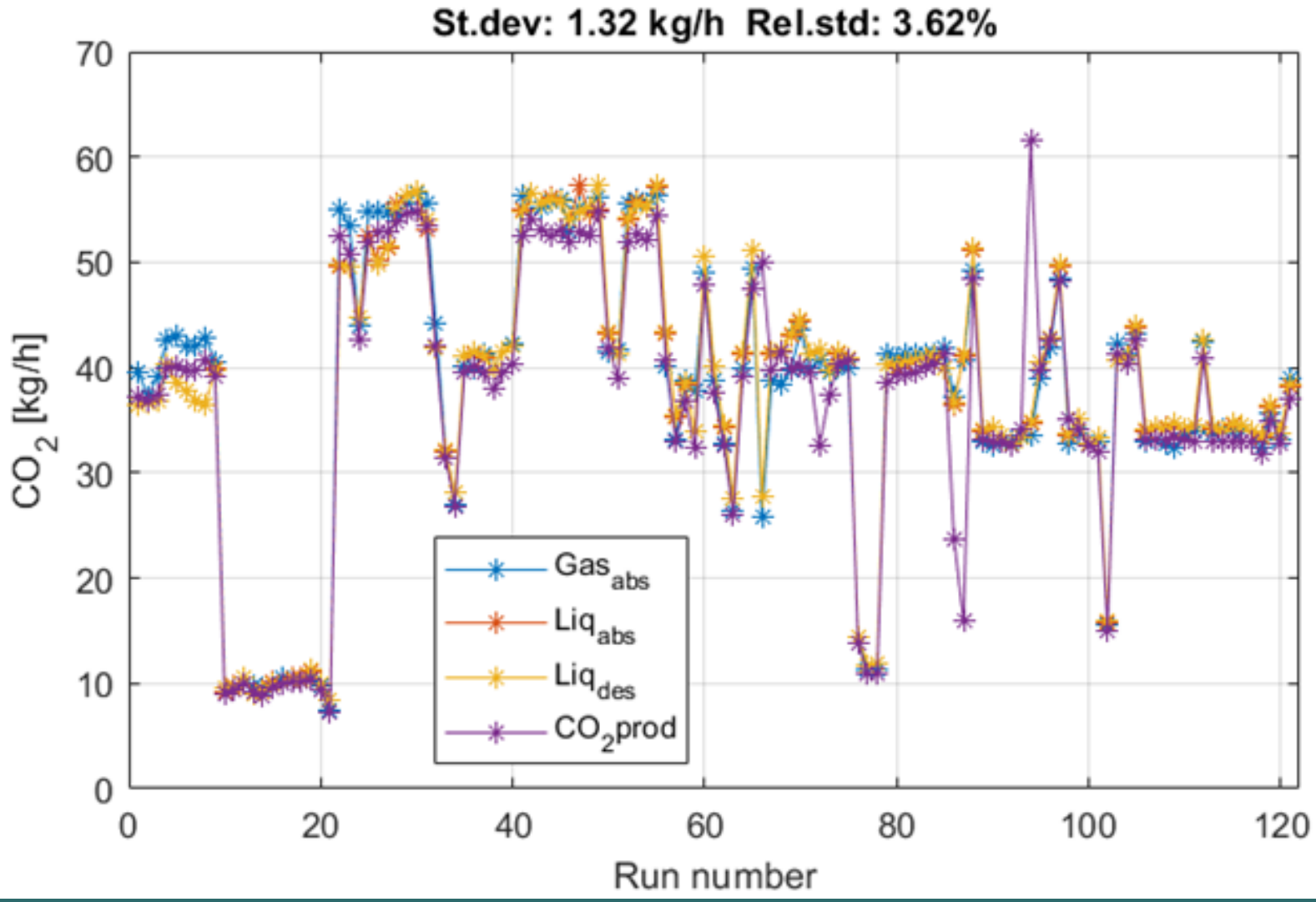
- September 2024-April 2025
- Tests:
  - Parametric studies
    - CO_2 Concentration Flue gas [vol%]: 3, 11 and 18 % (dry basis)
    - CO_2 Capture [%]: 77-98 %
    - Variations in precondition temperatures
    - Variations in desorber pressure
    - Reduced absorber packing height
    - Various gas flow-rates at constant L/G
  - Dynamics
    - Advanced process control and mimicking of a real plant dynamics
  - Emission monitoring and control
  - CO_2 compression and liquefaction
- Results: 121 steady state runs (datasets) and periods with dynamic testing
  - Highly relevant basis for model validation (both steady state and dynamic)

Methodology for conditioning of experimental data for model validation (1)

Four methods for determining mass transfer of CO_2

- Gas_{abs} : The amount of CO_2 transferred from the exhaust gas, calculated from gas rate, the CO_2 gas analysers and temperatures in and out of the absorber.
- Liq_{abs} : The amount of CO_2 absorbed in the liquid, calculated from liquid flow rate and liquid analyses in and out of the absorber.
- Liq_{des} : The amount of CO_2 desorbed from the liquid calculated from liquid flow rate and liquid analyses in and out of the desorber.
- CO_2prod : The amount of CO_2 leaving the desorber, measured by a gas flow sensor and corrected for water content.

Methodology for conditioning of experimental data for model validation (2)

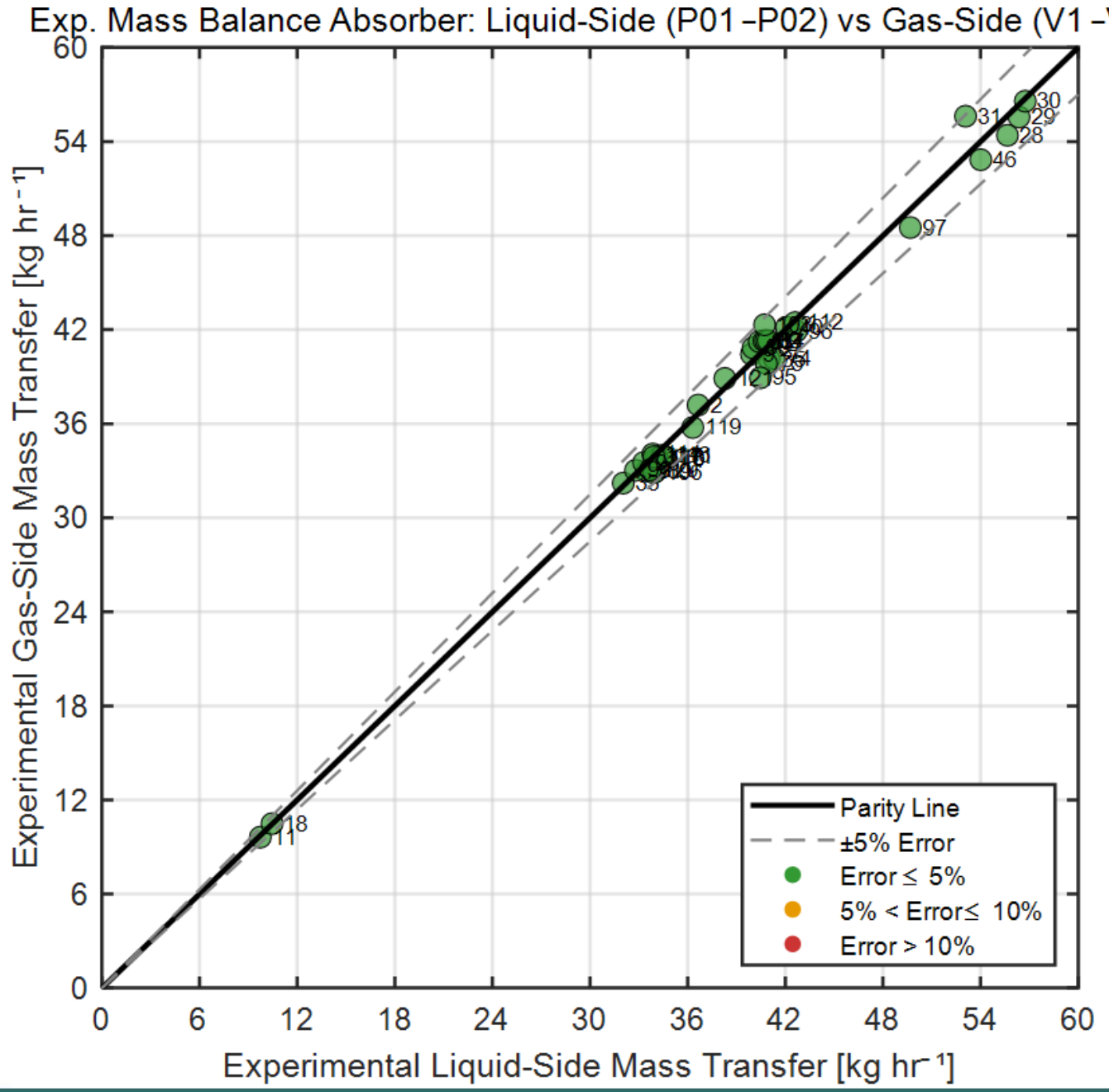


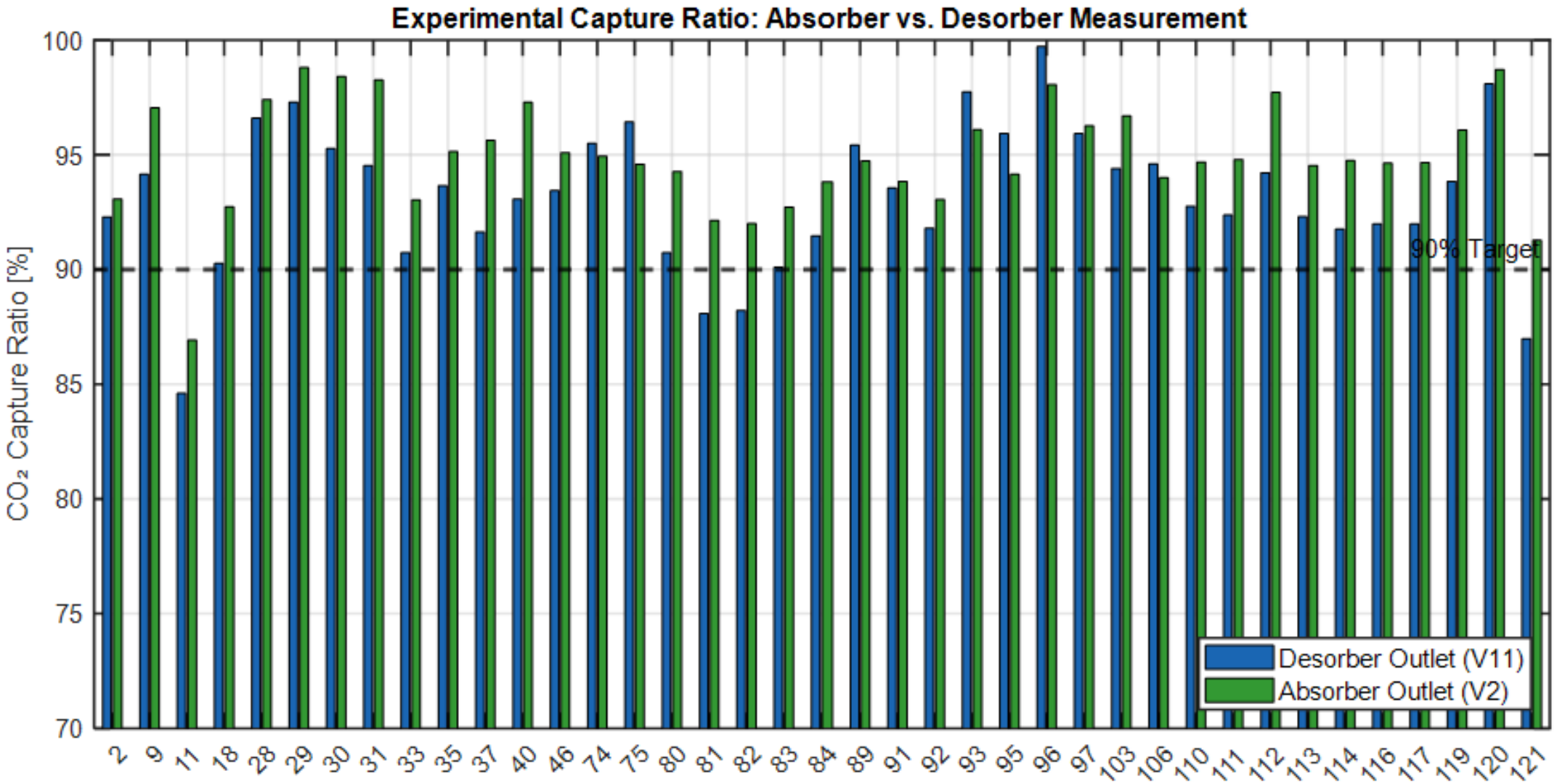
Methodology for conditioning of experimental data for model validation (3)

- For validation, steady state runs are picked out according to a system that guarantees steady-state based on a set of statistical measures
- The method involves measuring presision and accuracy along the mentioned four independent mass transfer as well as time series volatility and skewness
- This guarantees unbiased steady-state and creates a high-confidence dataset.
- The entire set (121 runs) was simulated in the automatic pipeline and the filter selected the runs based on the experimental balance criteria
  - All remaining runs (39) show a representative range as was tested at Tiller

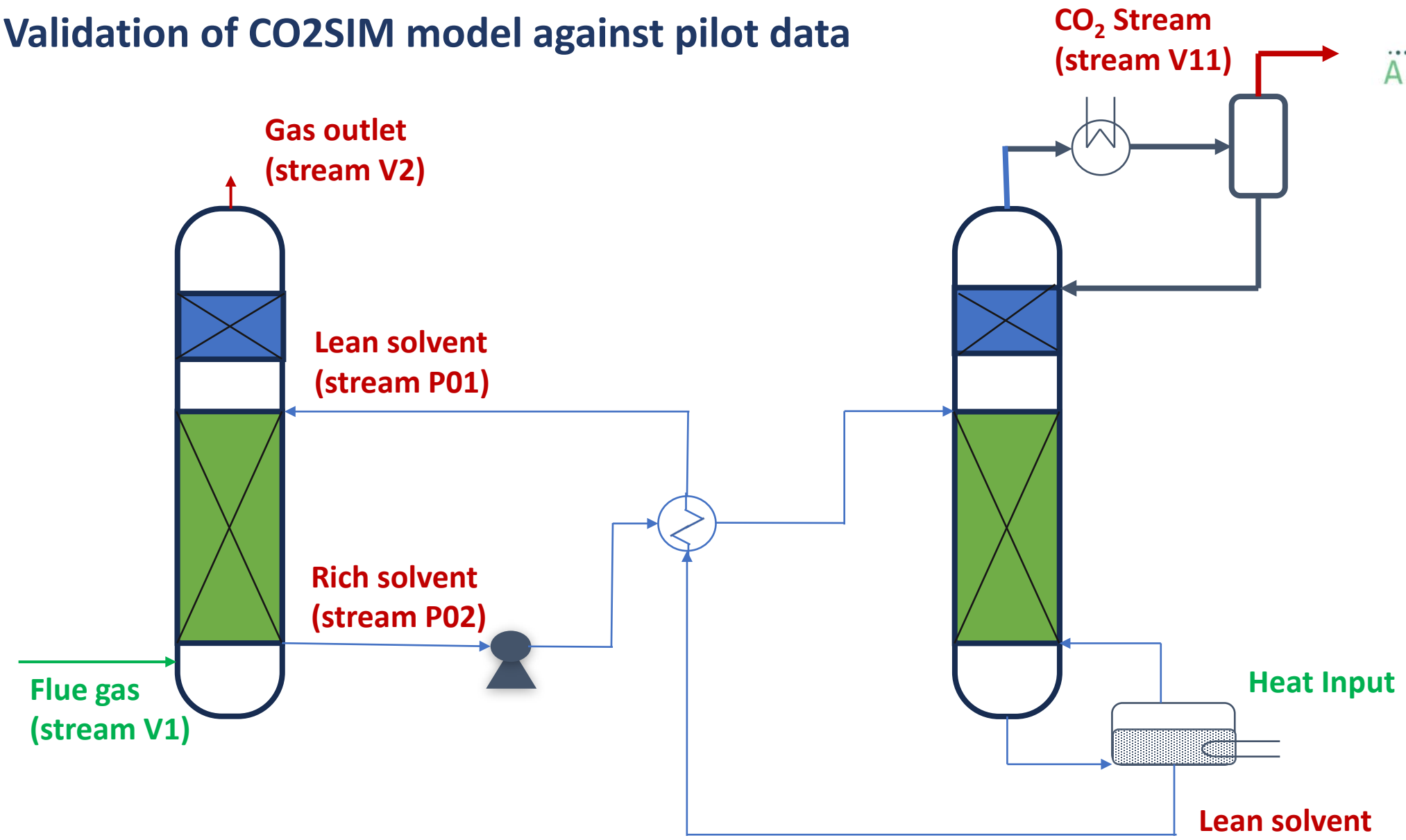
Experimental gas side vs. liquid side absorber

High quality data based on the independent mass balances

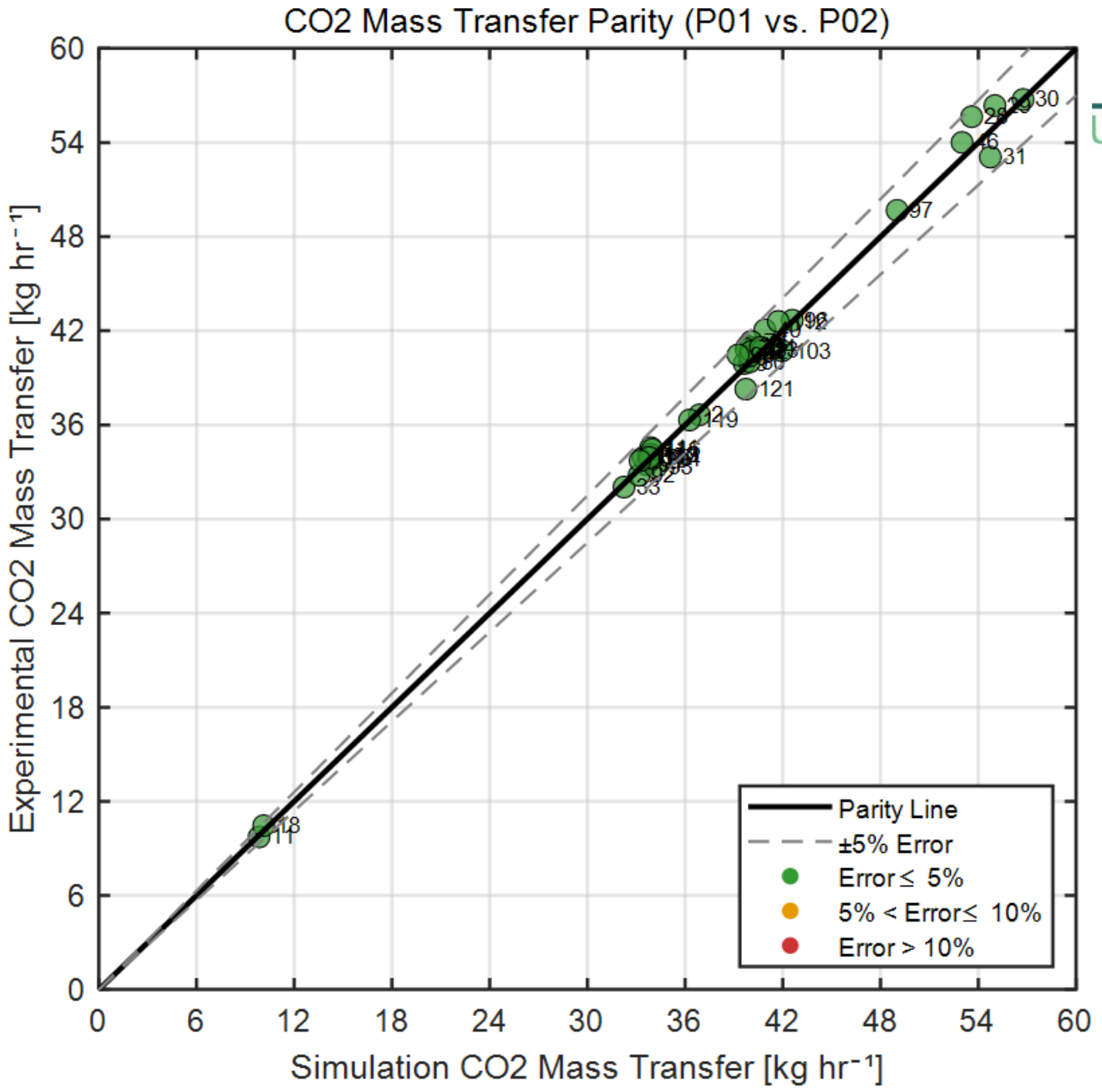


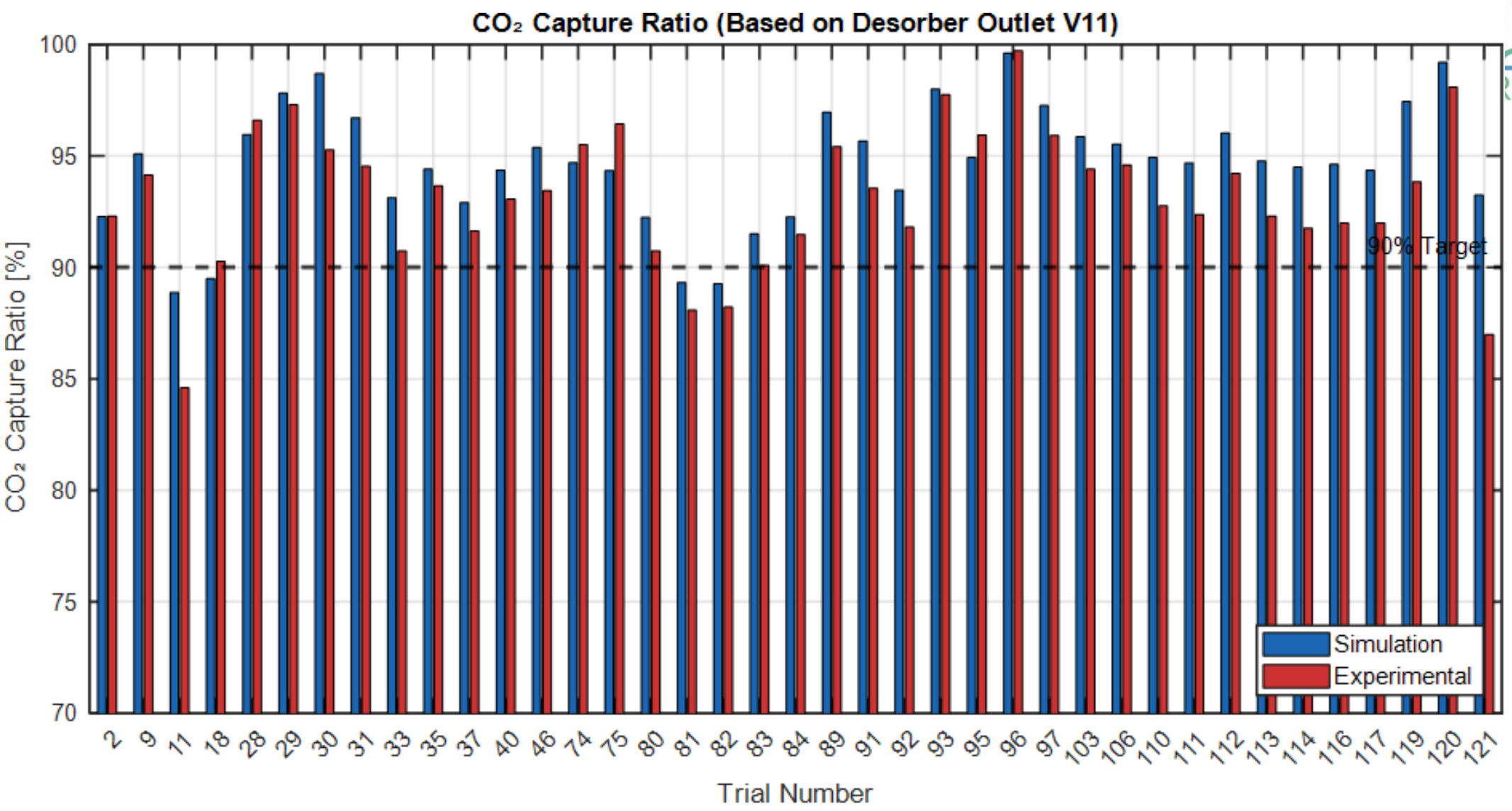

Experimental Capture Ratio: Absorber vs. Desorber Measurement
CO₂ Capture Ratio [%]
100
95
90
85
80
75
70
90% Target
Desorber Outlet (V11)
Absorber Outlet (V2)
2 9 11 18 28 29 30 31 33 35 37 40 46 74 75 80 81 82 83 84 89 91 92 93 95 96 97 103 106 110 111 112 113 114 116 117 119 120 121

Validation of CO2SIM model against pilot data



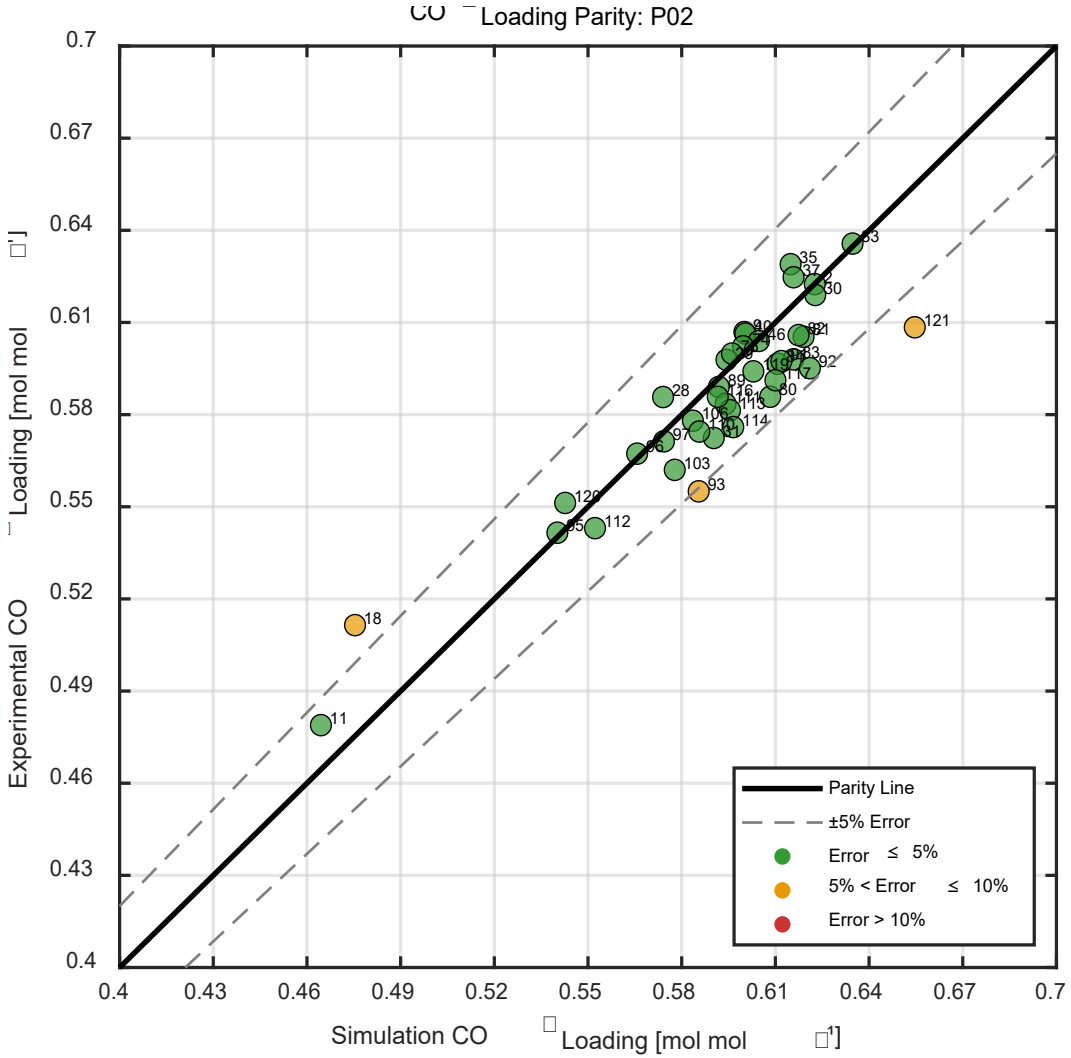
Experimental vs. simulation liquid side absorber Average relative deviation: 1.2%



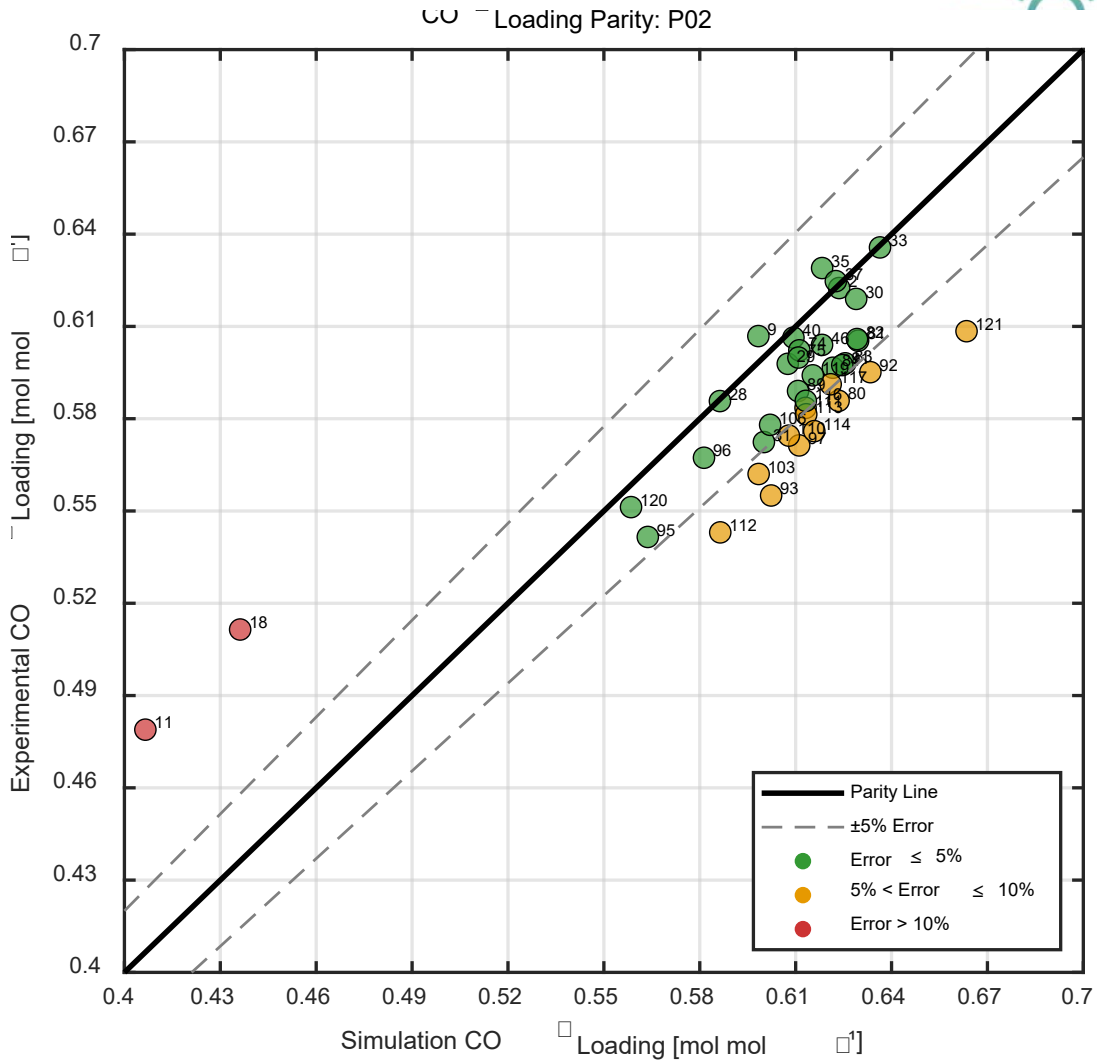

CO₂ Capture Ratio (Based on Desorber Outlet V11)
CO₂ Capture Ratio [%]
100
95
90
85
80
75
70
90% Target
Simulation
Experimental
2 9 11 18 28 29 30 31 33 35 37 40 46 74 75 80 81 82 83 84 89 91 92 93 95 96 97 103 106 110 111 112 113 114 116 117 119 120 121
Trial Number

Rich loading

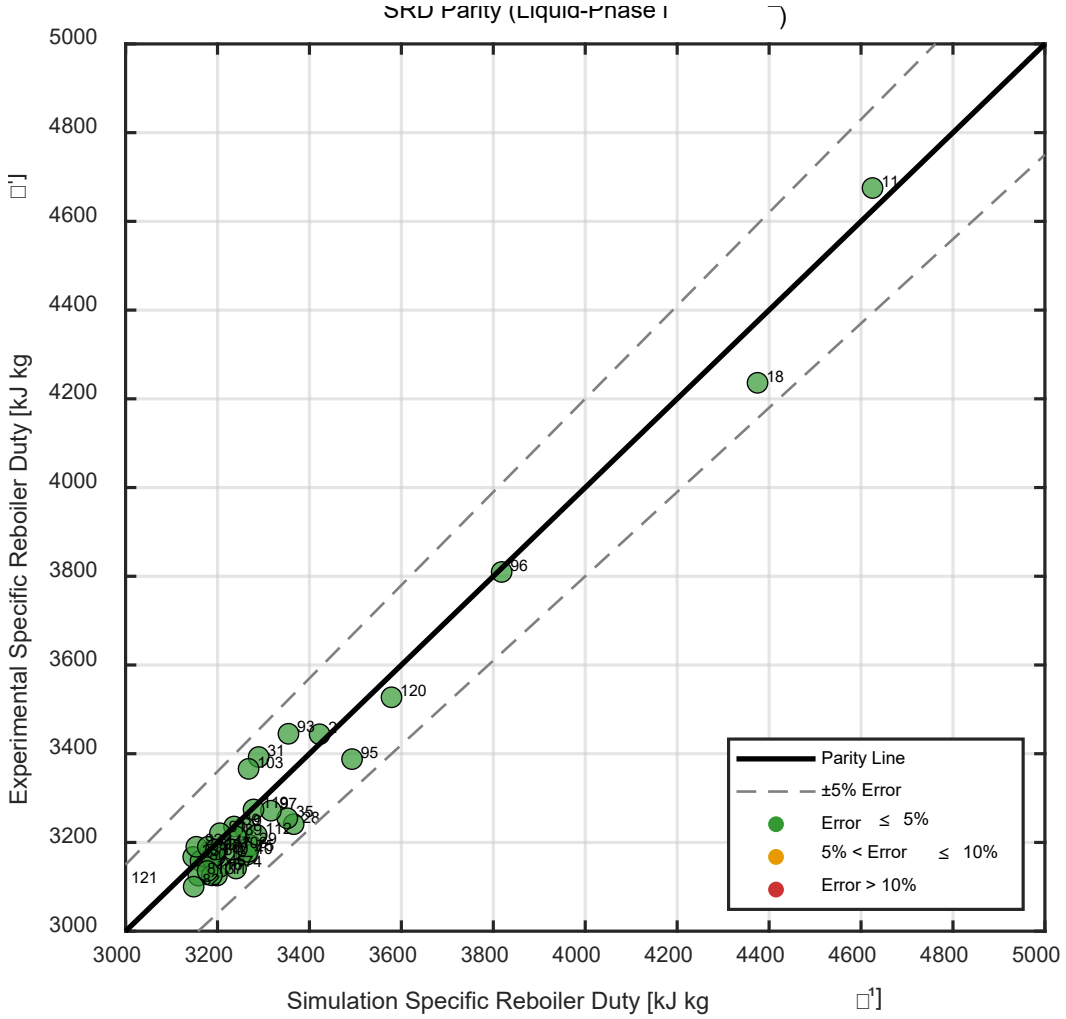
Absorber

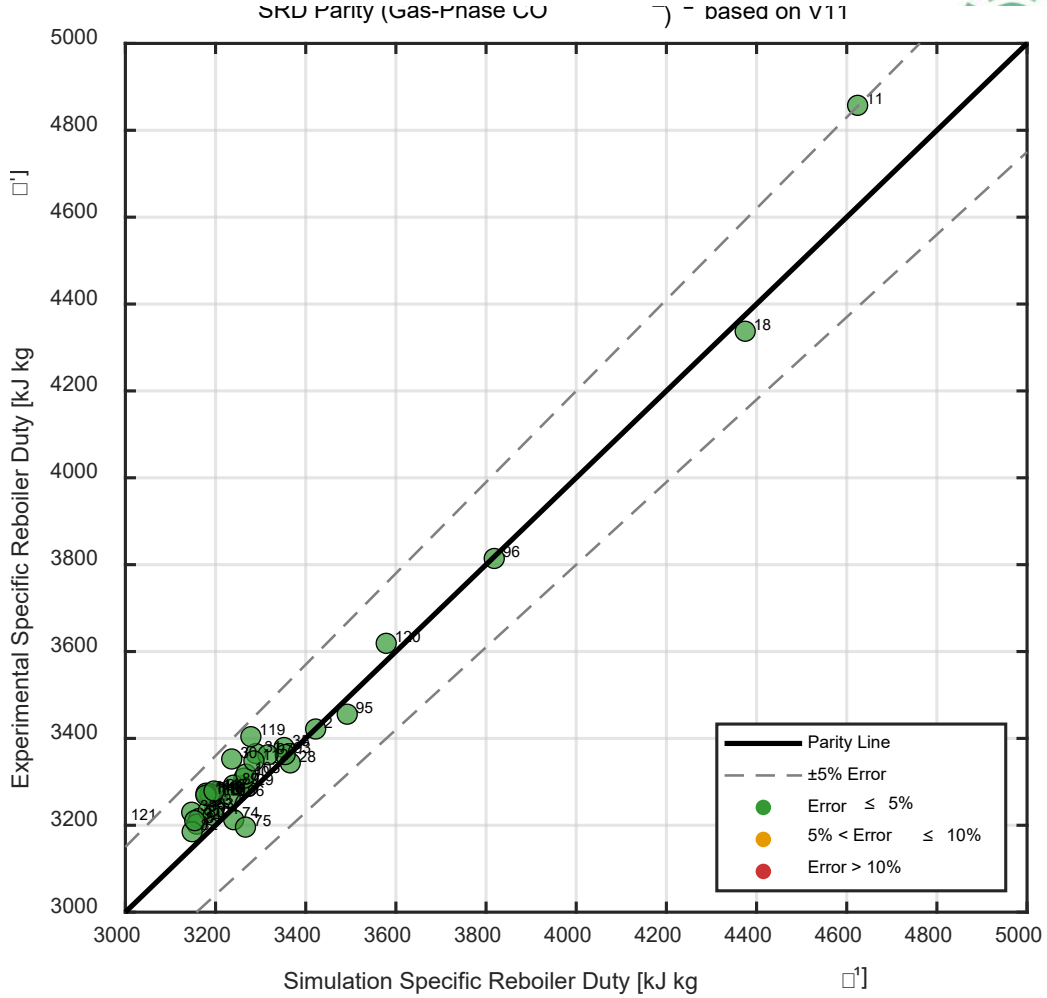


Closed plant simulation



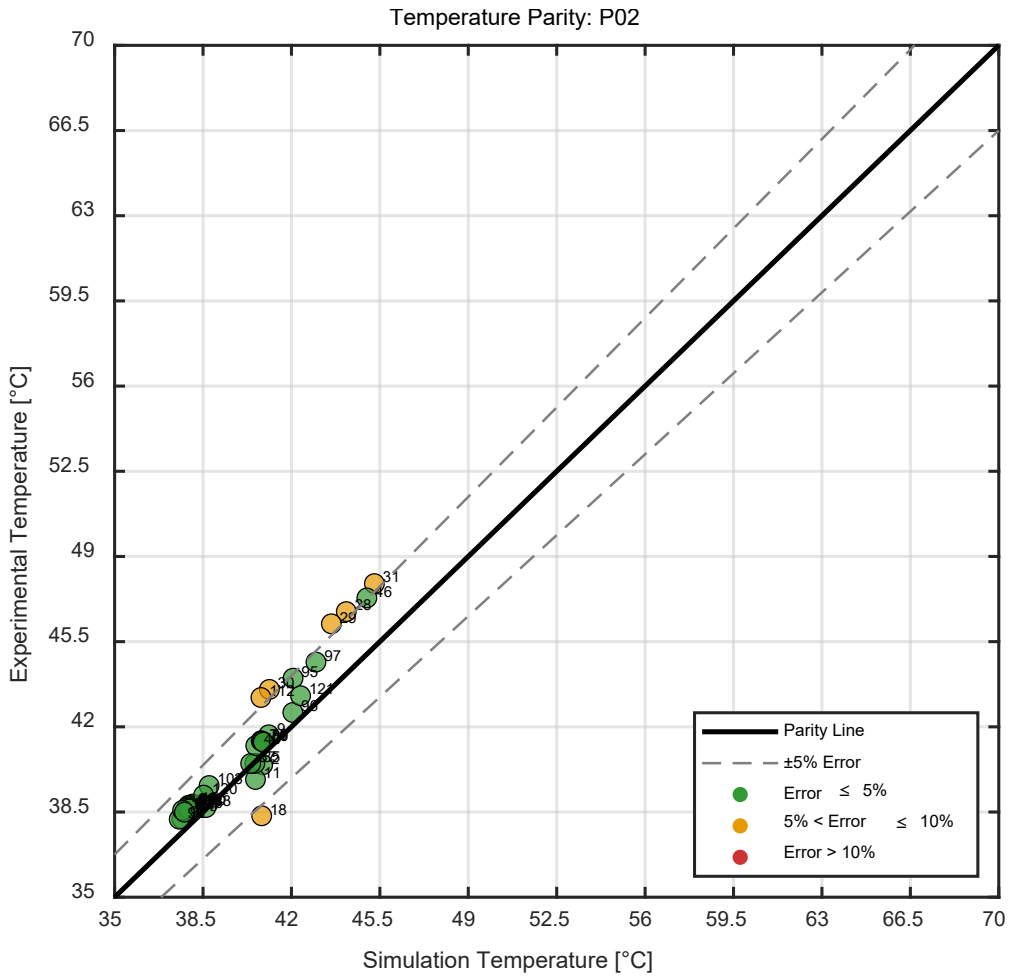
**Full plant simulations as shown here yield larger loading deviations particularly at low CO_2 inlet, red dots, contrary to the "open loop" simulations, with lower deviations.*



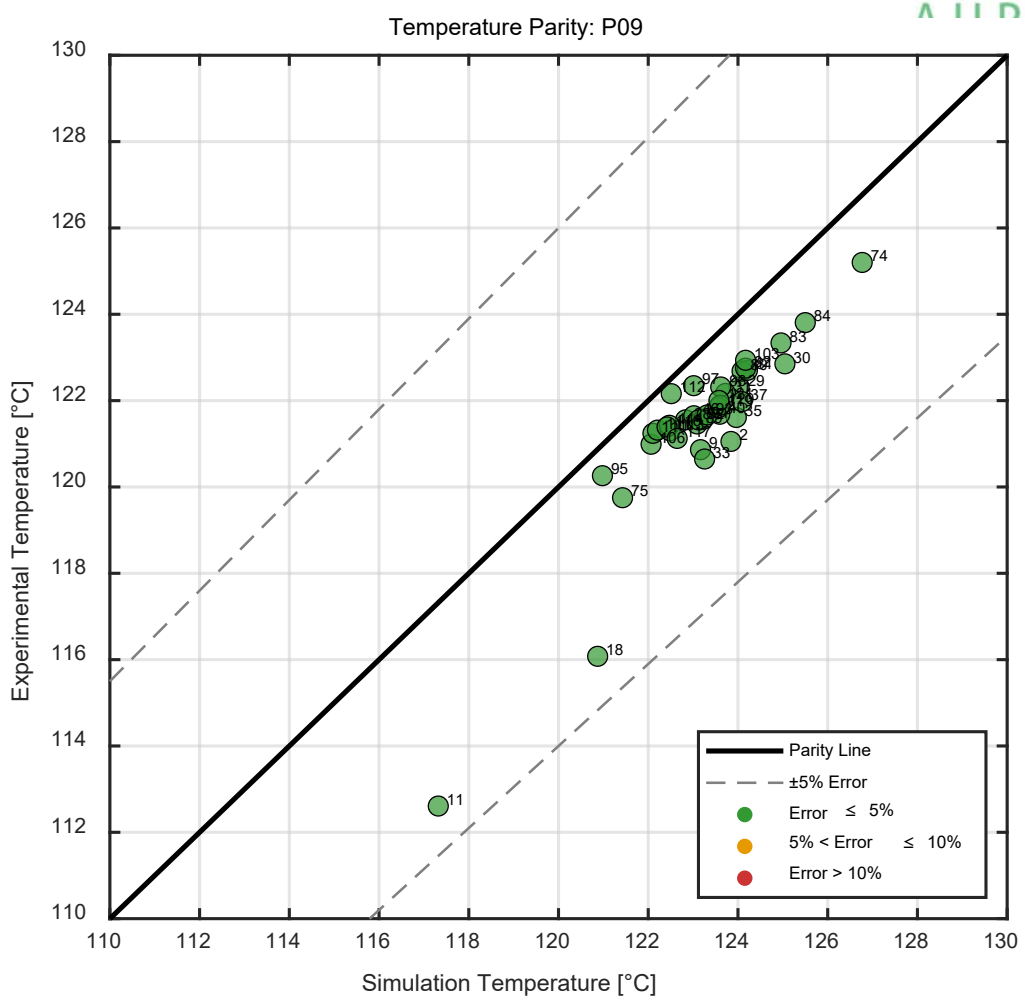


All SRD's for the 39 runs found by the steady state filter are simulated within the 5% error-band. Showing that the cyclic capacity is good even though some of the loading ranges for the extreme cases are somewhat off.

Absorber liquid outlet temperature (rich)

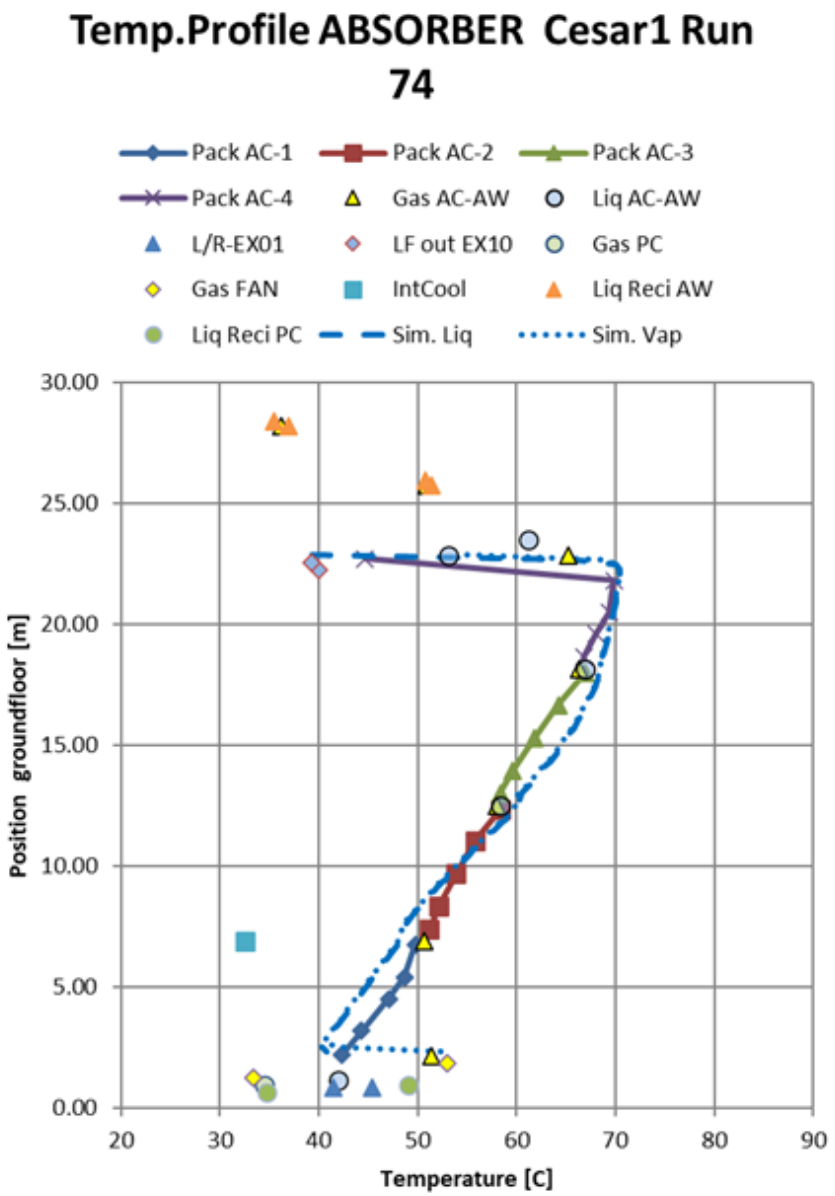


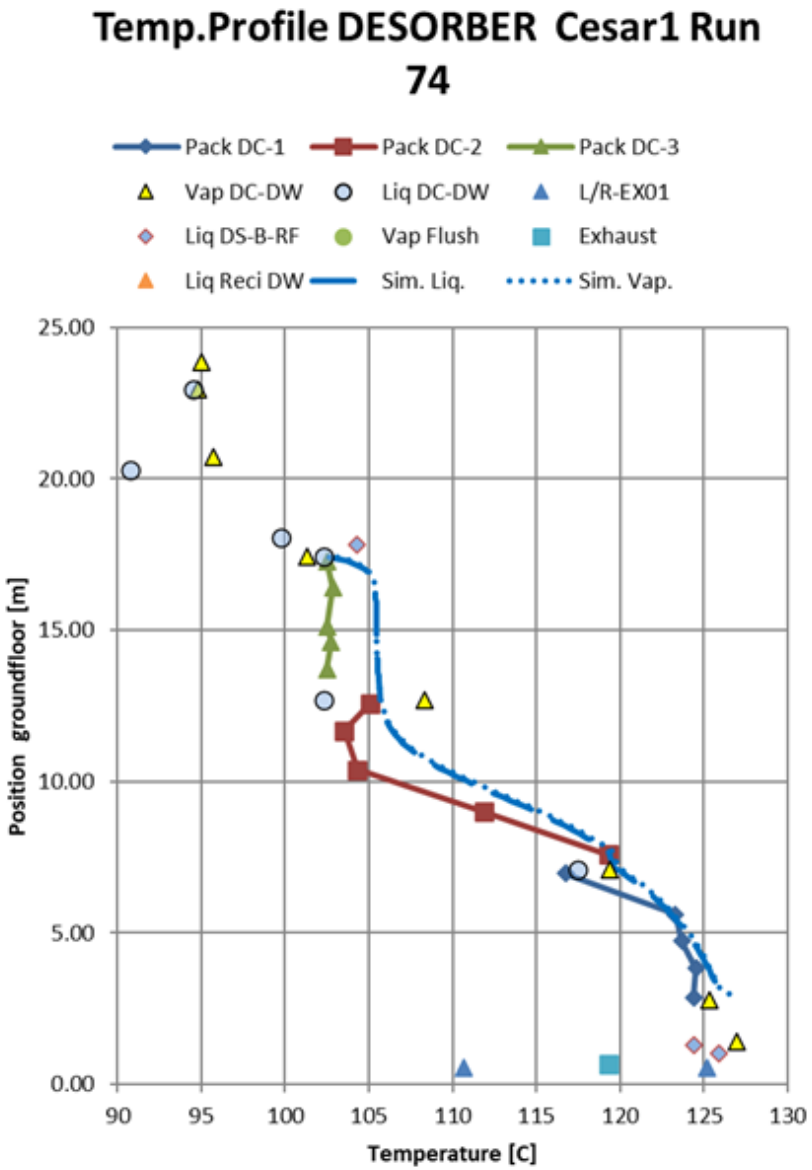
Reboiler temperature(lean)



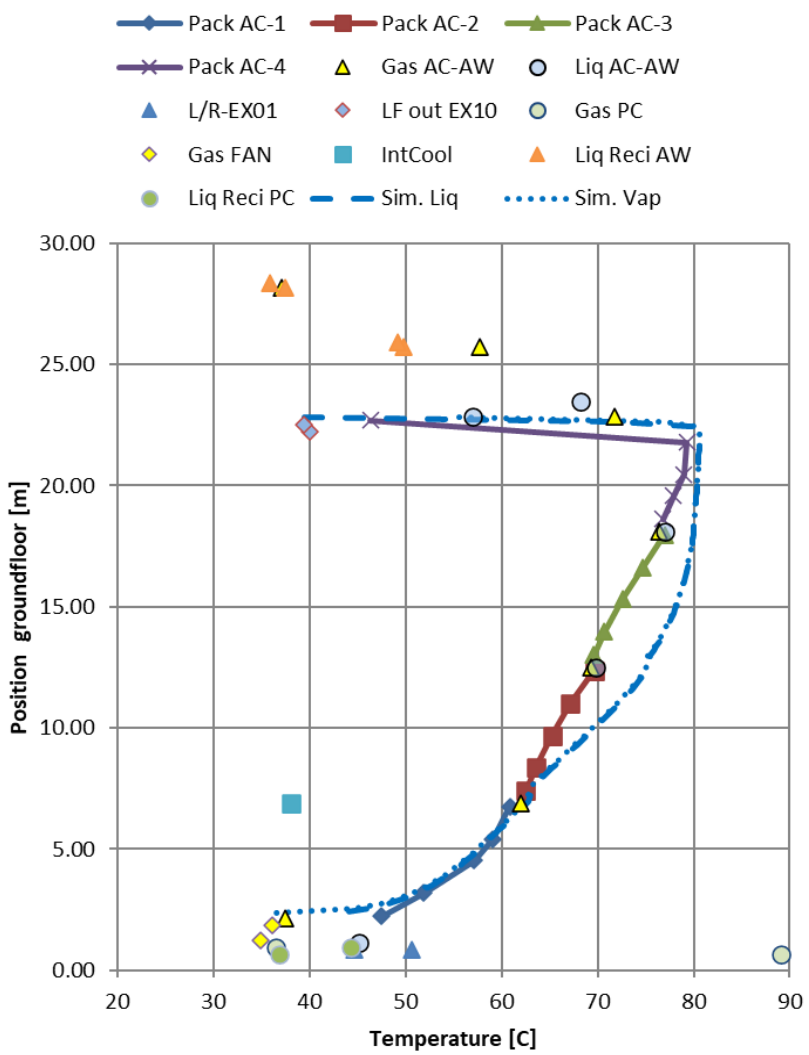
Temperatures along the plant show pretty good match, indicating good energy balances and property sub-models (heat of reaction and enthalpy flows).

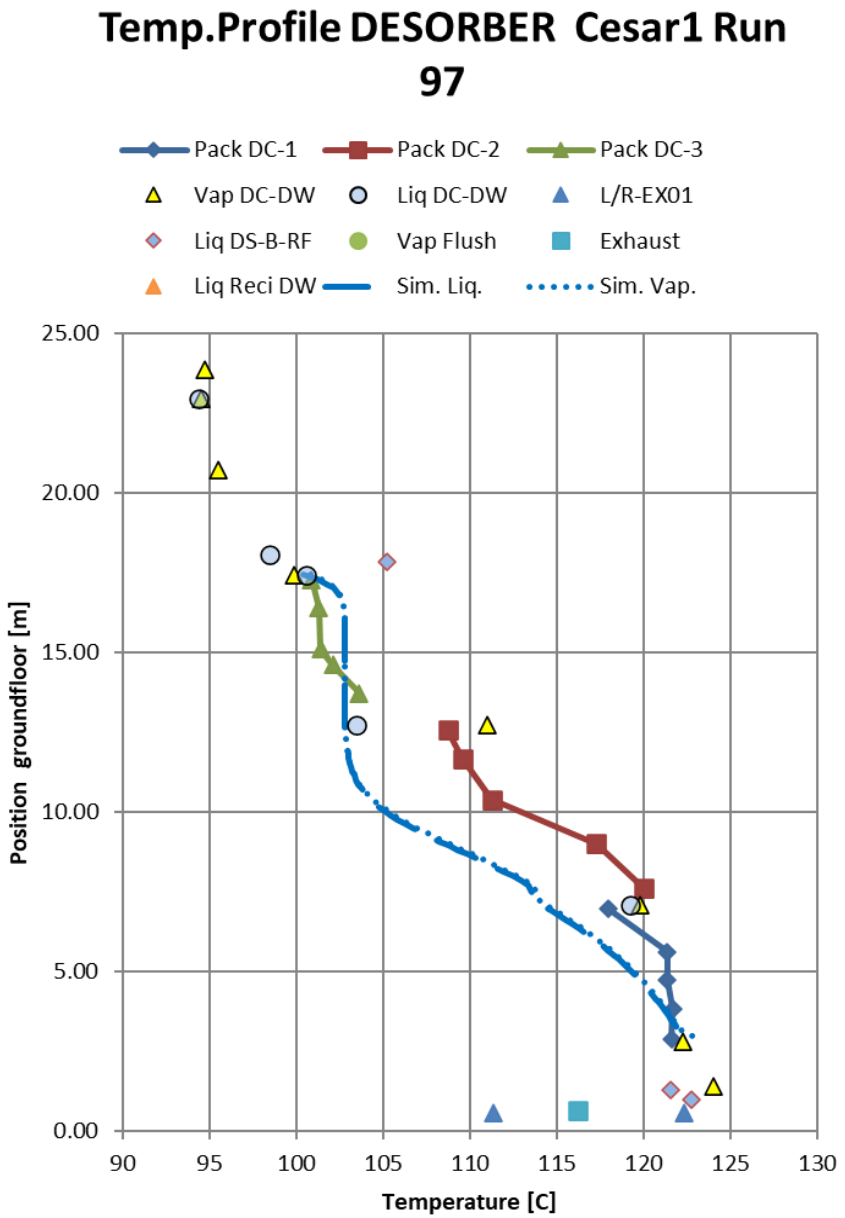
12% CO2


Temp.Profile ABSORBER Cesar1 Run 74
Pack AC-1
Pack AC-2
Pack AC-3
Pack AC-4
Gas AC-AW
Liq AC-AW
L/R-EX01
LF out EX10
Gas PC
Gas FAN
IntCool
Liq Reci AW
Liq Reci PC
Sim. Liq
Sim. Vap
Position groundfloor [m]
Temperature [C]
30.00
25.00
20.00
15.00
10.00
5.00
0.00
20
30
40
50
60
70
80
90


Temp.Profile DESORBER Cesar1 Run 74
Pack DC-1
Pack DC-2
Pack DC-3
Vap DC-DW
Liq DC-DW
L/R-EX01
Liq DS-B-RF
Vap Flush
Exhaust
Liq Reci DW
Sim. Liq.
Sim. Vap.
Position groundfloor [m]
Temperature [C]
25.00
20.00
15.00
10.00
5.00
0.00
90
95
100
105
110
115
120
125
130

18% CO2


Temp.Profile ABSORBER Cesar1 Run 97
Pack AC-1
Pack AC-2
Pack AC-3
Pack AC-4
Gas AC-AW
Liq AC-AW
L/R-EX01
LF out EX10
Gas PC
Gas FAN
IntCool
Liq Reci AW
Liq Reci PC
Sim. Liq
Sim. Vap
Position groundfloor [m]
Temperature [C]
30.00
25.00
20.00
15.00
10.00
5.00
0.00
20
30
40
50
60
70
80
90


Temp.Profile DESORBER Cesar1 Run 97
Pack DC-1
Pack DC-2
Pack DC-3
Vap DC-DW
Liq DC-DW
L/R-EX01
Liq DS-B-RF
Vap Flush
Exhaust
Liq Reci DW
Sim. Liq.
Sim. Vap.
Position groundfloor [m]
Temperature [C]
25.00
20.00
15.00
10.00
5.00
0.00
90
95
100
105
110
115
120
125
130

Conclusions and further work

- Has developed a systematic approach for selection of the best datasets for validation
- From 121 to 39 steady state runs using a statistical based approach
  - The filtered runs represent still the extent of operating conditions for the whole pilot campaign
- Both the experimental and simulated results for the filtered datasets show similar accuracy with no significant systematic error
  - Successful model implementation
- The steady state runs with low CO_2 concentration show higher deviations.
  - Has improved the representation of heat loss (as function of liquid circulation rate).
  - Systematic deviations in overall loading ranges at very low CO_2 concentration flue gases.
  - Still some more work needed on the kinetic model.
  - Will check out further improvements
- Will also validate against TCM pilot data

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QUESTIONS?

Thank you!

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