New project for CO_2 value chain evaluation: Cement cArbon Storage Pilot for Emission Reduction (CASPER)

DTU Chemical Engineering

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CASPER

Funding: INNO-CCUS[1]
Timeframe: 2023-2026
Total budget: DKK 14.6 million DKK
DTU budget: 10 million DKK
Main goal: Evaluate the whole CCS value chain
Project leader: Philip Loldrup Fosbøl, DTU CERE

[1]Innomission roadmap, part of Innovationsfonden

Overall Project Objectives

The project will assess the feasibility of CCS for cement production by:

- Capturing and conditioning CO_2 from cement flue gas
- Measuring CO_2 quality and comparing it with relevant storage standards
- Evaluating the effect of impurities on CO_2 transport preparing for future infrastructure development

Aalborg Portland

- Produces 2.4 million tons cement per year
- Denmark's largest emitter of CO_2 accounting for 4% of DK’s total emissions
- Emissions due to the chemical process of burning limestone
- 2030: capture up to 1.4 million tons CO_2 per year
- Captured CO_2 transported by pipeline to on-shore storage facility

Flue gas content

Flue gas data	Unit	Median	Emission limit (daily average)
Temperature	°C	132	-
CO_2	Vol%, Wet	18-20	-
H_2O	Vol%, Wet	33.8	-
O_2	Vol%, Wet	6.9	-
N_2 + Ar	Vol%, Wet	46,3	-
CO	mg/Nm^{3,*}	718	1500
SO_2	mg/Nm^{3,*}	0.9	50
HCl	mg/Nm^{3,*}	0	10
NO_x**	mg/Nm^{3,*}	268	500
NH_3	mg/Nm^{3,*}	20.0	30
TOC	mg/Nm^{3,*}	5	10
Dust***	mg/Nm^{3,*}	9.5	20

*dry @ 10% oxygen,1013 hPa, dry, 0 °C

**NO_x is assumed to be 94% NO, 5% NO_2 and 1% N_2O

*** Filter trips occur with typical frequency of 1 per week with duration of app. 1 min

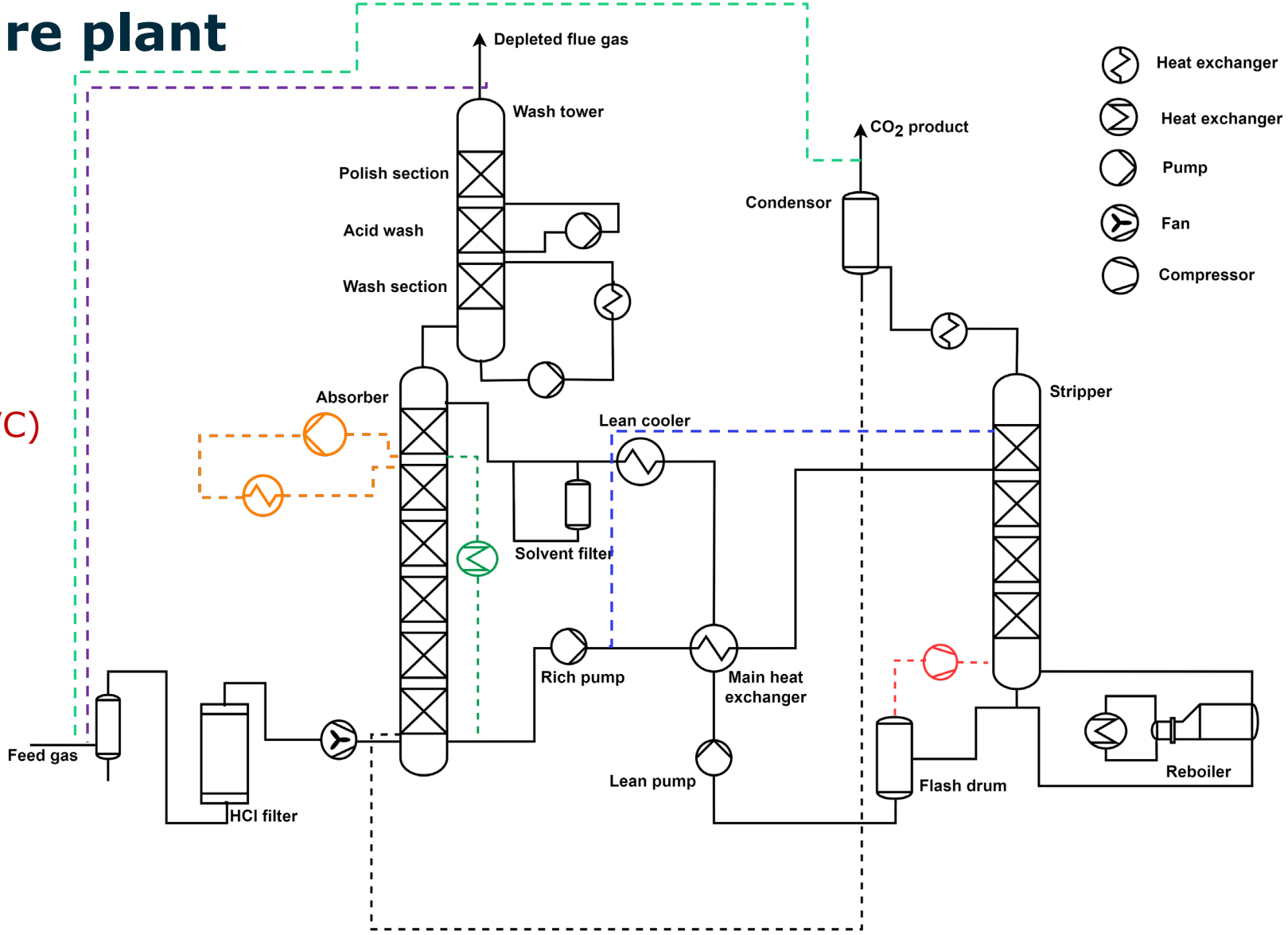
Installation Aalborg Portland, Denmark

Mobile CO_2 capture plant

- Designed by the Technical University of Denmark and Pentair Union Engineering
- Constructed by Pentair Union Engineering
- Absorber: 19.36 m
- Stripper: 17.54 m
- Packing material: random Flexiring 5/8 inch, 316 (Koch-Glitsch)
- Exhaust gas flow rate: 145 kg/h
- More than **20 advanced configurations**:
  - Lean vapor compression (LVC)
  - Rich and lean solvent recycle
  - Intercooling (IC)
  - Cold rich solvent split (CRSS)

Mobile CO_2 capture plant

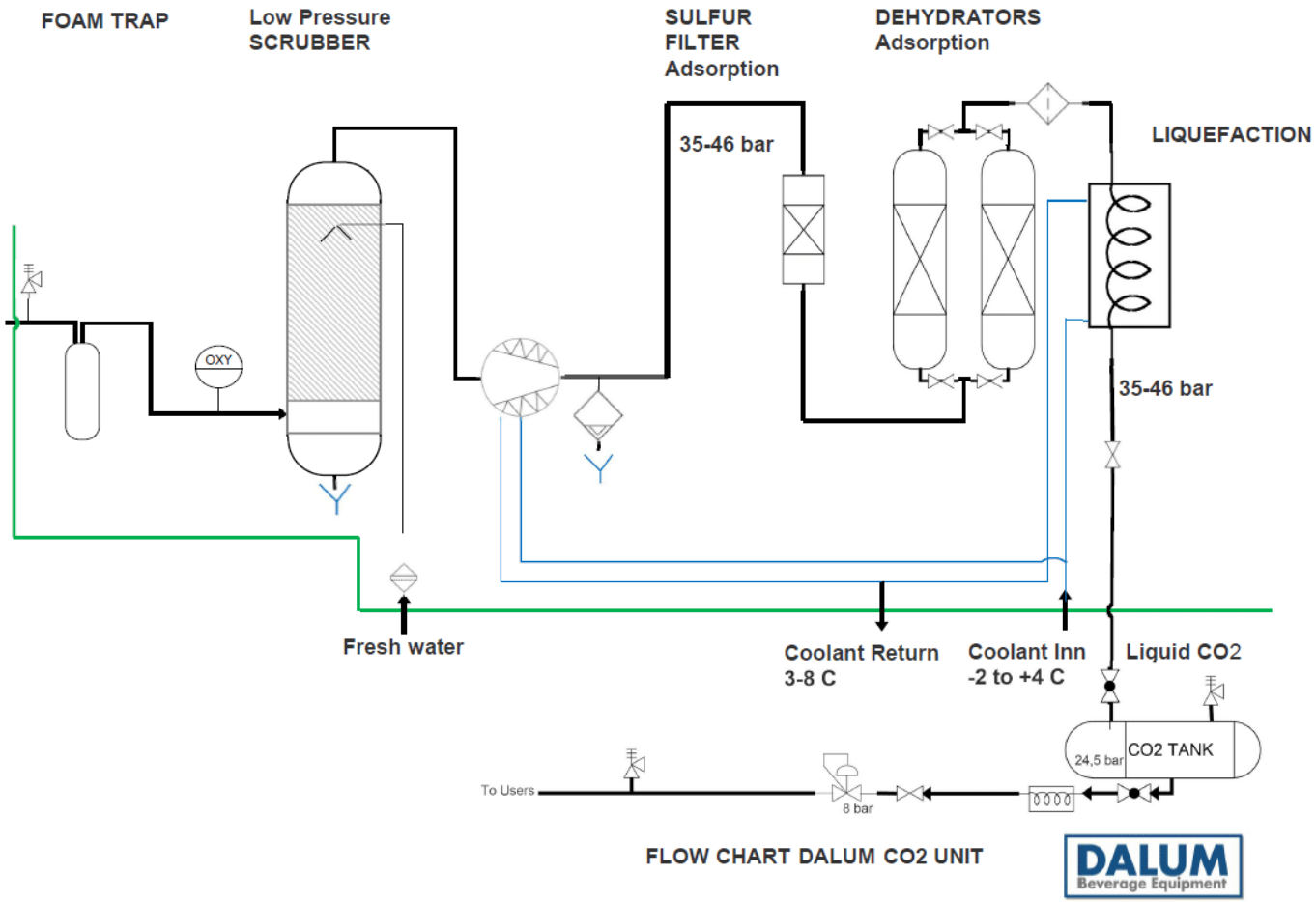
- CO_2 product recycle
- Depleted flue gas recycle
- Cold rich solvent split (CRSS)
- Intercooling (IC)
- Rich solvent recycle (RR)
- Lean vapour compression (LVC)



Liquefaction unit & storage

- Liquefaction unit: Dalum Beverage Equipment
  - Production: 0-18 kg/h liquid CO_2
  - Delivers > 99.9% pure CO_2
  - Pressure: up to 46 bar (delivers 15 bar)
- CO_2 storage tank:
  - Capacity: 950 L (1070 kg CO_2)
  - Design temperature: -196 °C
  - Operation: 15 bar, -30 °C

CO_2 liquefaction unit

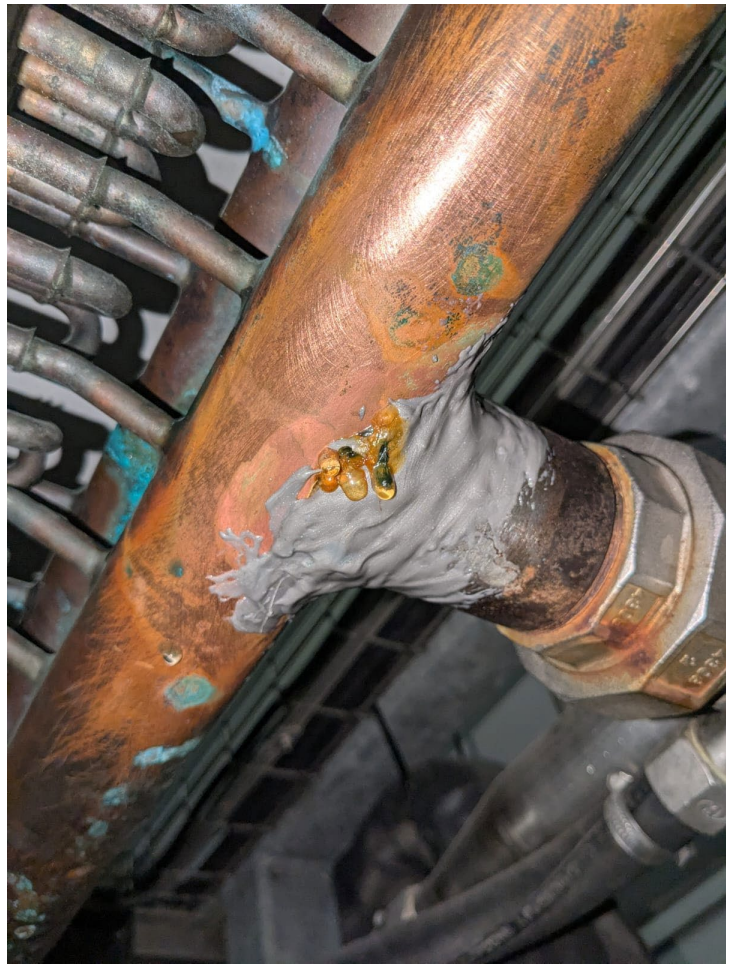


Commissioning - filter

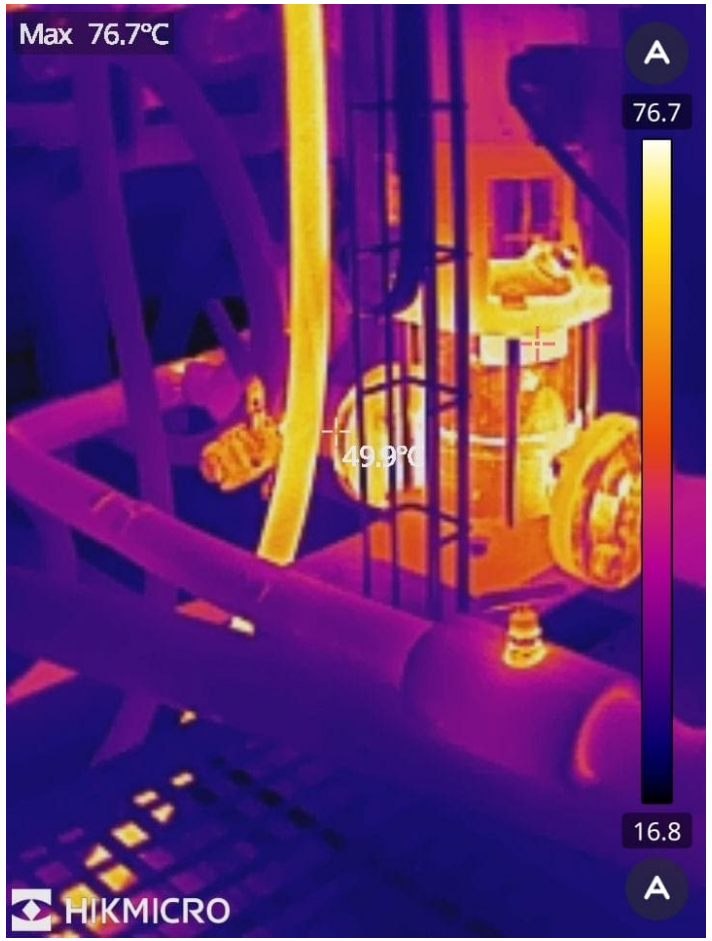
Old filter

New filter

Commissioning – cooler



Commissioning – critical components



Heat loss

HE malfunction

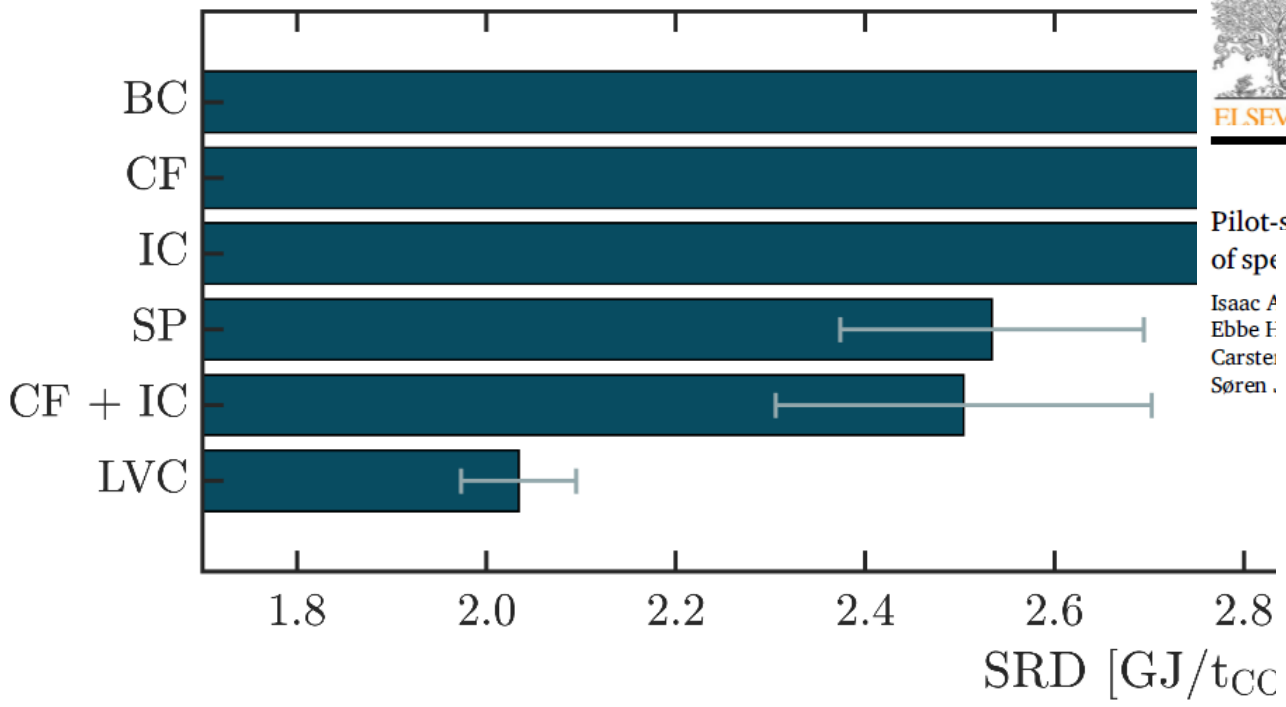
CESAR1 formulation

CESAR1 formulation:
27 wt% AMP and 13 wt% PZ

Modified CESAR1 formulation:
26 wt% AMP and 6 wt% PZ

Performance of process configuration

- Lean Vapour Compression (LVC): 42% energy reduction



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Pilot-scale CO_2 capture in a cement plant with CESAR1: Comparative analysis of spe

Isaac A
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Carste
Søren .

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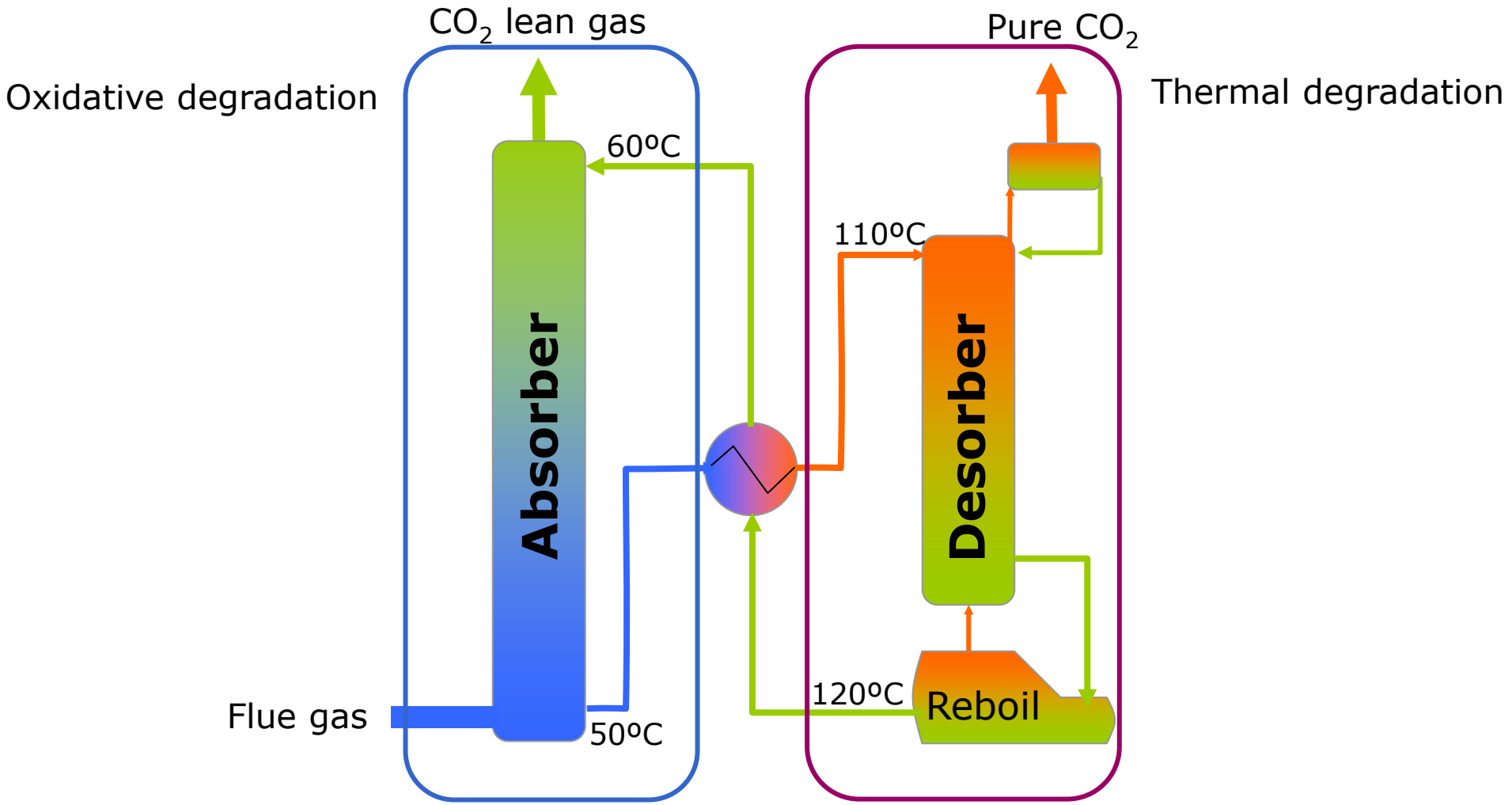
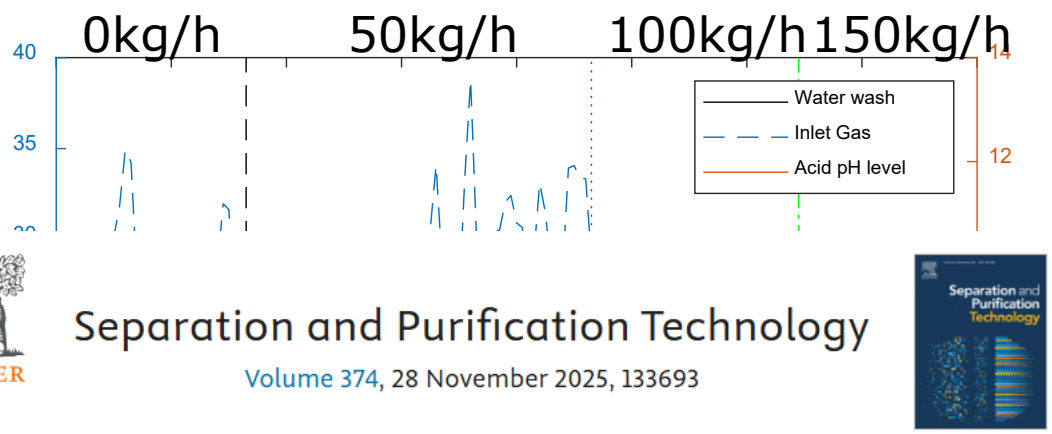
Pilot-scale CO_2 capture in a cement plant with CESAR1: Higher stripper pressure reduces energy demand and compression work but increases solvent degradation

Isaac Appelquist Løge [a,*], Can Demir [a], Sai Hema Bhavya Vinjarapu [a], Randi Neerup [a], Ebbe Hauge Jensen [b], Jens Kristian Jørsboe [a,b], Maria Dimitriadi [a], Vanja Buvik [f], Halil Halilov [c], Carsten Fritzner Frøstrup [a], Istvan Gyorbiro [a], Nomiki Kottaki [a], Asams Nelliparambil Jayan [e], Søren Jensen [d], Jakob Lindkvist Karlsson [d], Philip Loldrup Fosbøl [a]

Solvent degradation & emissions



Solvent emission from Aalborg Portland



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Separation and Purification Technology

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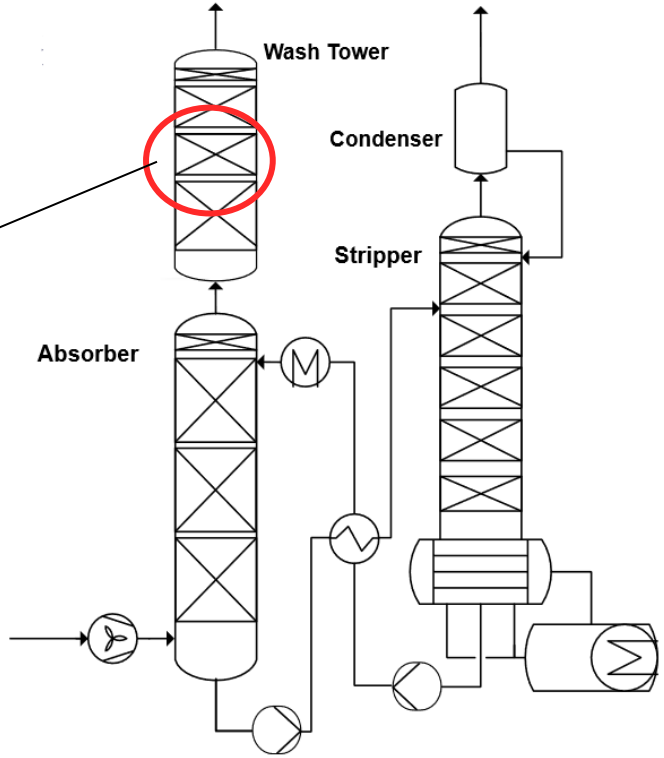
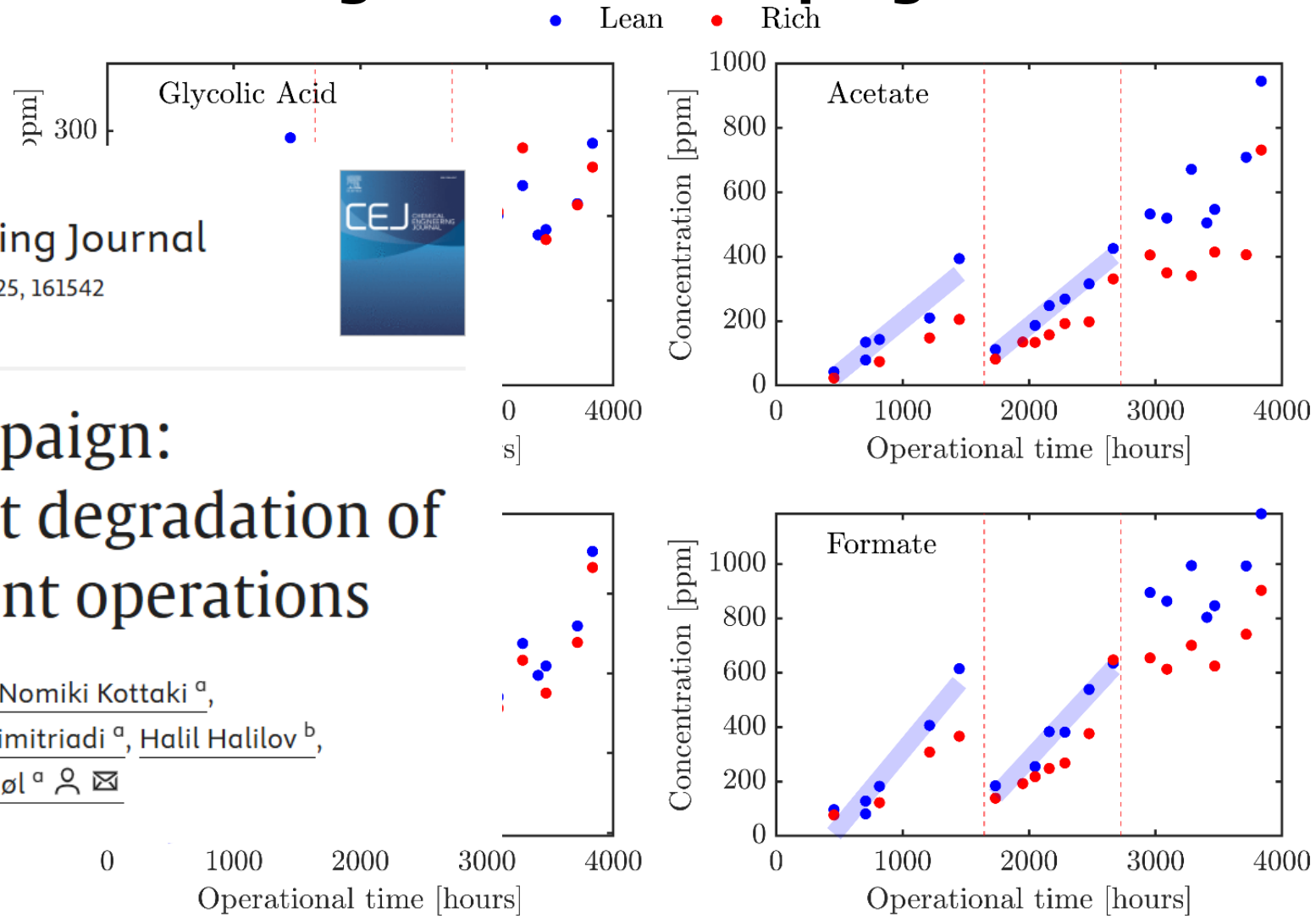
Pilot-Scale CO_2 capture in a cement plant with CESAR1: Emission control with acid wash and absorber intercooling

Maria Dimitriadi [a], Isaac Appelquist Løge [a], Randi Neerup [a], Søren Jensen [b], Jakob Lindkvist Karlsson [b], Lars Piilmann Brorholt [c], Frantz Bræstrup [c], Halil Halilov [d], Sebastian Nis Bay Villadsen [a], Jens Abildskov [e], Philip Loldrup Fosbøl [a]



- Reduction of Ammonia levels
- Change in pH
- No effect with circulation changes

Solvent degradation from Aalborg Portland campaign



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CO_2 capture pilot campaign: Understanding solvent degradation of CESAR1 in cement plant operations

Randi Neerup [a], Kalle L. Øbro [a], Isaac A. Løge [a], Nomiki Kottaki [a], Carsten F. Frøstrup [a], Istvan Gyorbiro [a], Maria Dimitriadi [a], Halil Halilov [b], Søren Jensen [c], Jakob L. Karlsson [c], Philip L. Fosbøl [a]

Upcoming events

- Measuring campaign, autumn 2025
  - DTU: Gasmet FTIR (CO_2)
  - DTU: Protea FTIR (flue gas, depleted flue gas)
  - Evida: (CO_2)
  - DTI: TOF-MS (flue gas, depleted flue gas)
- Optimization campaign
  - End 2025 to early 2026
- Expected end: winter 2026
- CO_2 utilization:
  - Contact DTU: plf@kt.dtu.dk and rand@kt.dtu.dk

Acknowledgement

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Thanks to the project partners:

Thank you for listening

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