ViennaGreenCO_2

Energy efficient CO_2 capture and carbon neutral CO_2 supply chain for greenhouse fertilization at Vienna Simmering

Highlights der Energieforschung 2019
Dekarbonisierung in der Industrie

Vienna, October 8th 2019

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powered by klima+ energie fonds

Presentation outline

- **Part I: Introduction of solid sorbent CO_2 capture**
  - CCS/CCUS as key climate change mitigation
  - CO_2 capture benchmark technology
  - Temperature swing adsorption
  - Reactor design aspects for continuous TSA processes
- **Part II: The ViennaGreenCO_2 project**
  - Project aims, consortium and key figures
- **Part III: The VGCO_2 TSA pilot unit**
  - Selected results from experimental work at TU Wien
  - The ViennaGreenCO_2 TSA pilot unit
- **Part IV: Preliminary results from VGCO_2 piloting campaign**

IPCC 5th AR (2014) Key Messages

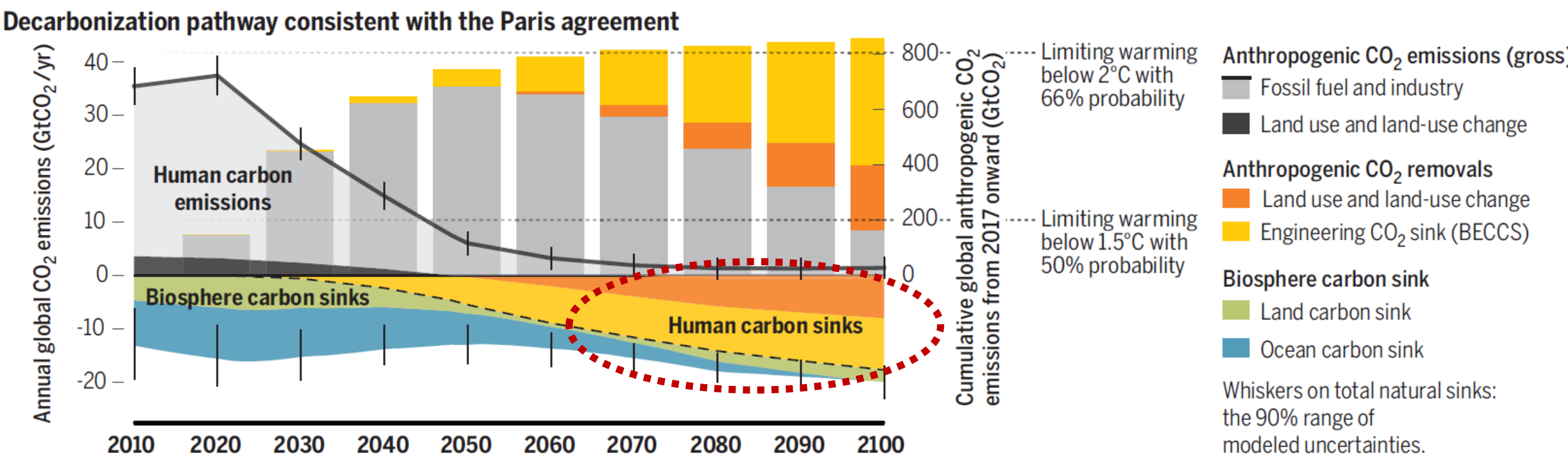
1. **Warming of the climate is unequivocal**
2. **Human activities represent dominant cause for warming** („*extremly likely*“)
3. **Continued GHG emissions cause further climate change** → amplification of already existing risks for natural and human systems

Substantial and sustained reductions of GHG emissions are needed

Climate change mitigation

- 2015: Paris climate argreement: Global warming < 2°C

<u>Roadmap to decarbonisation according to Paris agreement:</u>



Source: J. Röckström et. al., „A roadmap for rapid decarbonisation“, Science, 2017

- **Carbon capture** technologies **required for CCS, CCU and NETs**

Carbon Capture Technologies

Main routes for CO_2 capture

- Pre-Combustion
- Post-Combustion
- Oxy-Fuel

State of the art post combustion technology: Amine scrubbing

Source: http://www.snclavalin.com/en/boundary-dam-iccs

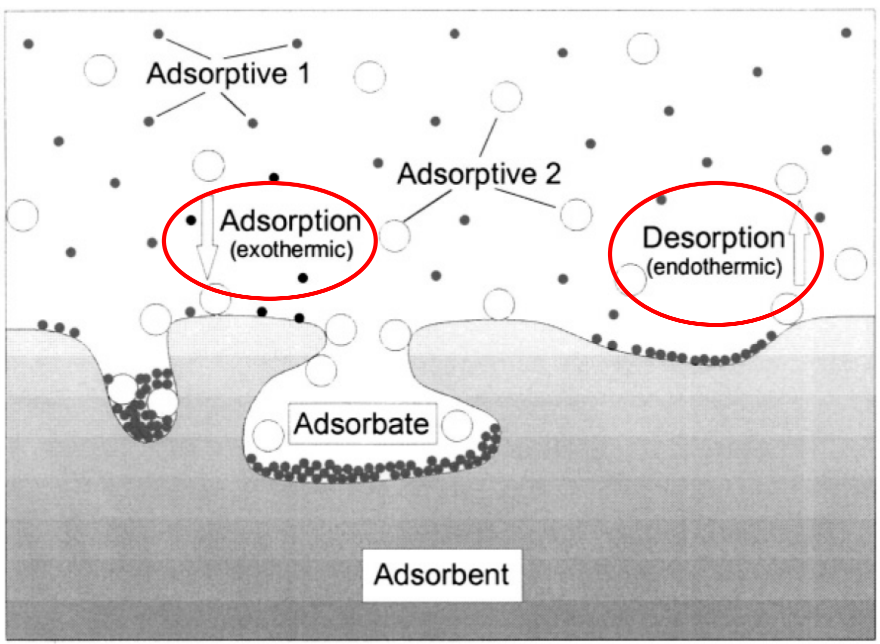
- Existing assets (e.g. power plants, industrial sites) can be retrofitted with Post Combustion CO_2 capture technology

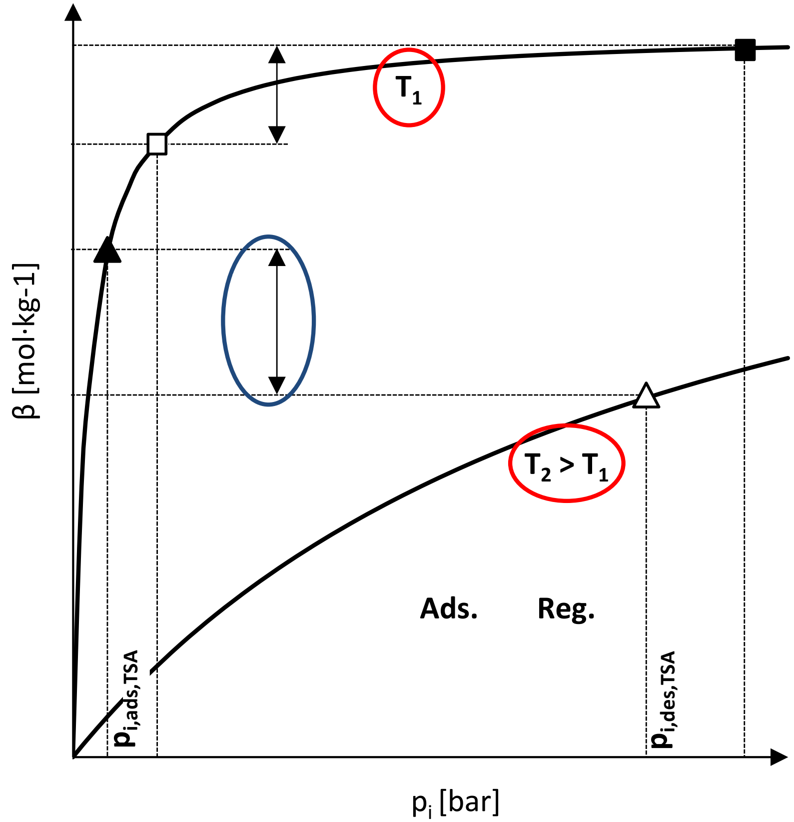
Drawbacks of Amine Scrubbing technology:

- High CAPEX and energy demand, volatility of solvent, corrosion, etc.

Adsorption vs. Absorption

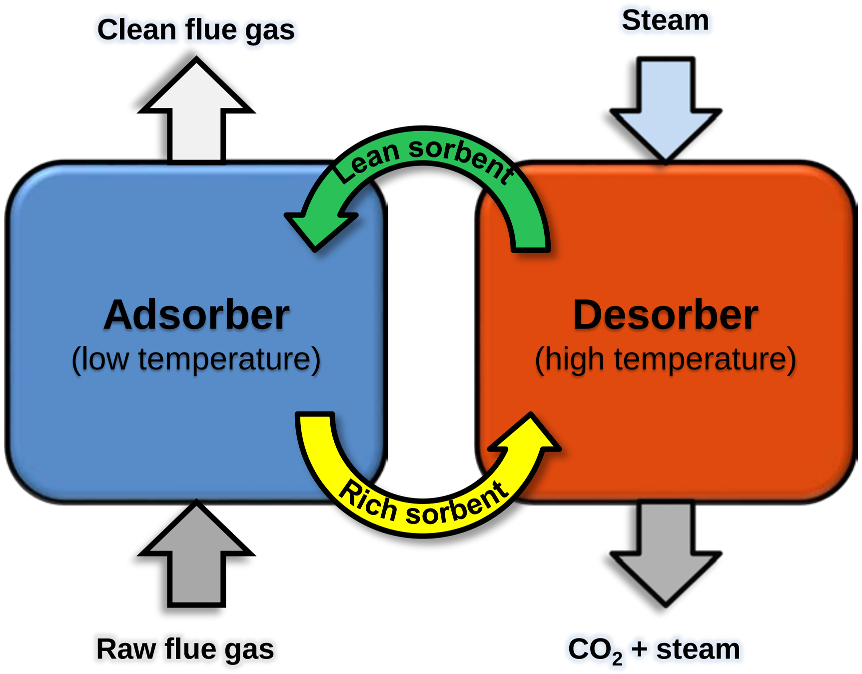
- Amine solvent replaced by solid amine sorbent material for selective CO_2 ADSORPTION: Temperature Swing Adsorption (TSA)





Reactor design demands in TSA

- Separate adsorber and desorber
- Heat management is crucial
- Process heat demand ➔ Min.
- Flue gas throughput ➔ Max.
- Pressure drop ADS➔ Min.



Reactor design demands in TSA

- Separate adsorber and desorber
- Heat management is crucial

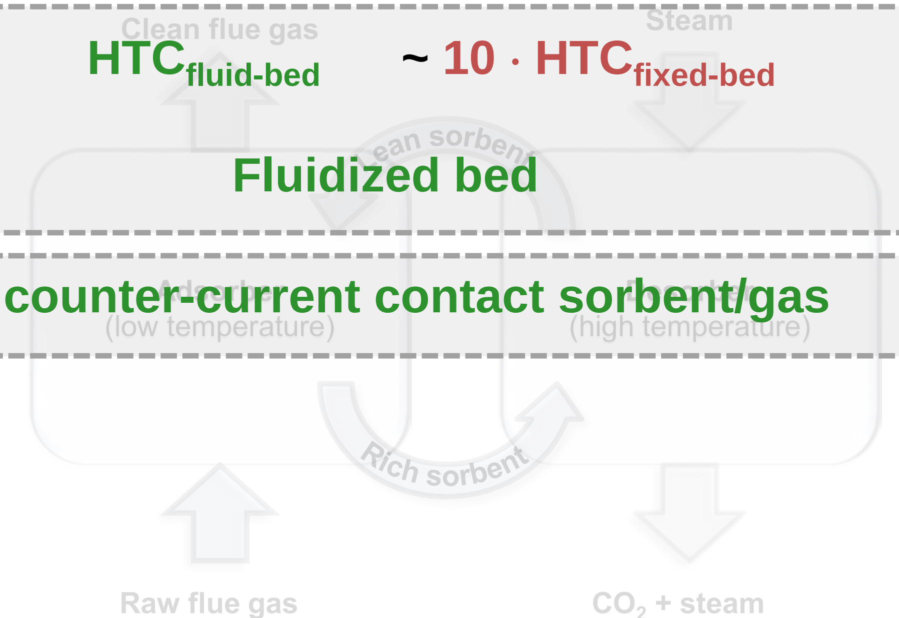
$HTC_{fluid\text{-}bed} \sim 10 \cdot HTC_{fixed\text{-}bed}$

Fluidized bed

- Process heat demand ➔ Min.

counter-current contact sorbent/gas

- Flue gas throughput ➔ Max.
- Pressure drop ADS➔ Min.



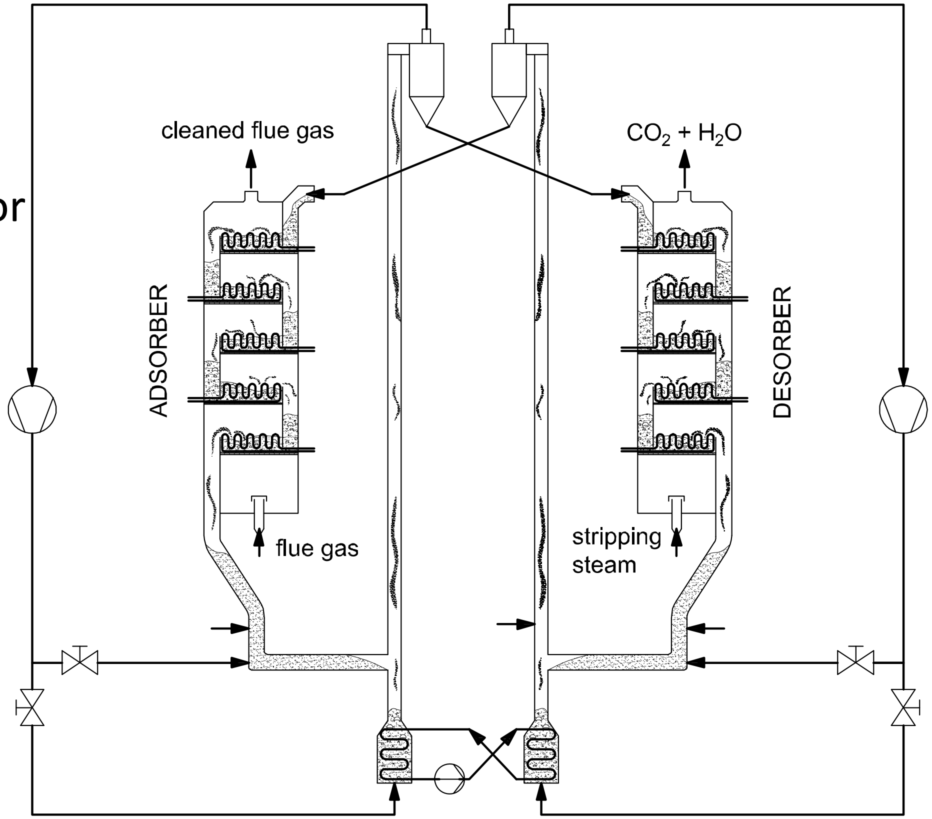
Continuous TSA solid sorbent CO_2 capture process

Improved energy efficiency

- Lower heat capacity of CO_2 carrier
- No evaporation of water in regenerator
- Increased CO_2 transport capacity
- Enhanced heat integration

Reduced capital costs

- Significantly smaller adsorber column
- Lower material standards (e.g. CS)
- Lower effort for emission control



Estimated CO_2 capture cost reduction potential:
-25% compared to state-of-the-art

Part II:

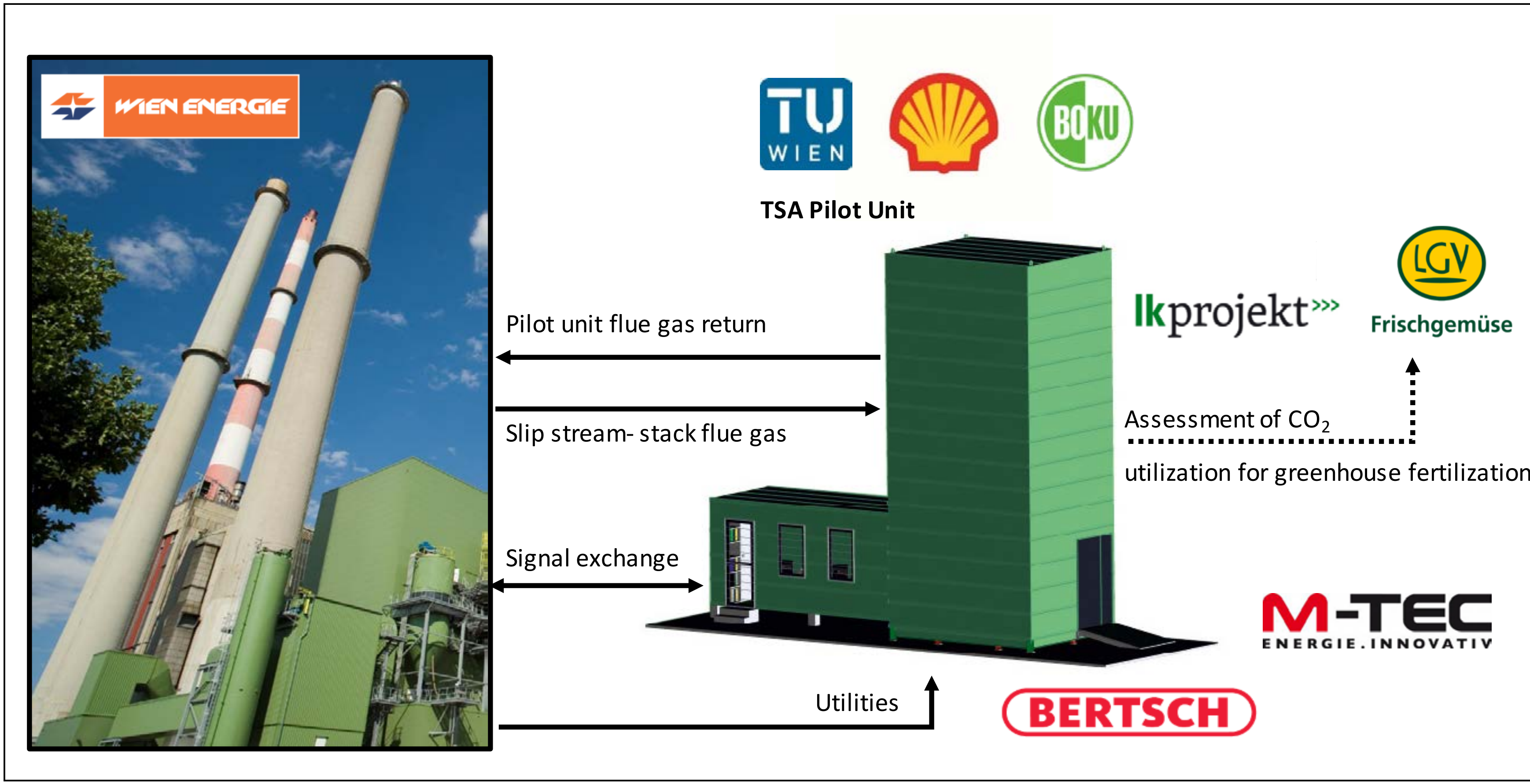
The ViennaGreenCO_2 project

Project Aims

- **Up-scaling of TSA technology** from labscale to ~ 1 tCO_2/day using a system design that is feasible for demonstration at larger scale
- **Long-term** (automated) **operation (>1000h)** of TSA pilot unit
- **Validation of process simulation** tools
- Continuous **techno-economic evaluation** of TSA process (energy demand, CAPEX optimization, heat integration, process emissions, etc.)
- Assessment of **full-scale CO_2 supply chain** in Vienna/Simmering for **greenhouse fertilization**

Host site: Wien Energie power plant site in Vienna

Project consortium



Project key figures

- Total eligible project costs: 4.617.128 EUR
- Total funding powered by klima+ energie fonds : 2.443.500 EUR
- Additional funding : 2.000.000 EUR
- Project start: 01.01.2015
- Project duration: 5 years
- Pilot plant in operation: 2018/2019

Part III:

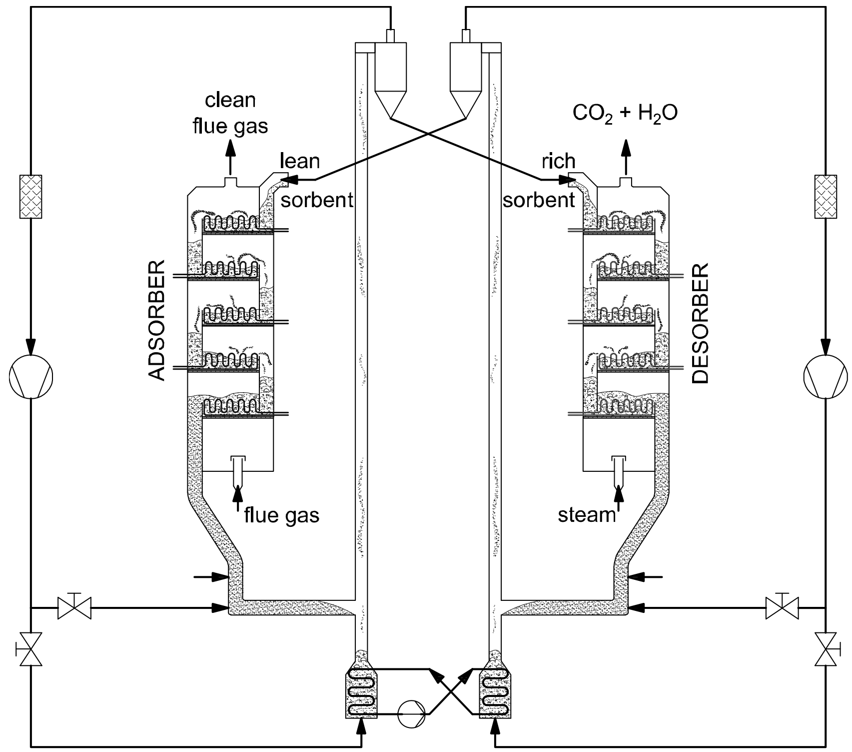
The VGCO$_2$ TSA pilot unit

ViennaGreenCO$_2$

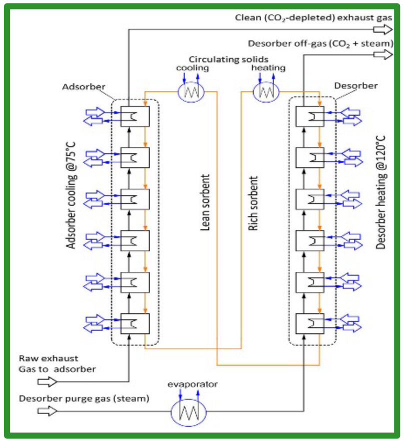
Bench-scale experiments

HTF tests and HEX design

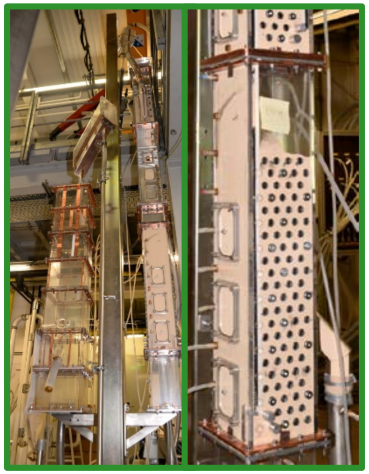
TSA process scale-up and optimization



Process model develop. & simulation



Cold flow modelling



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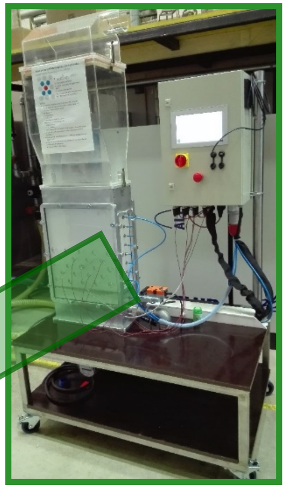
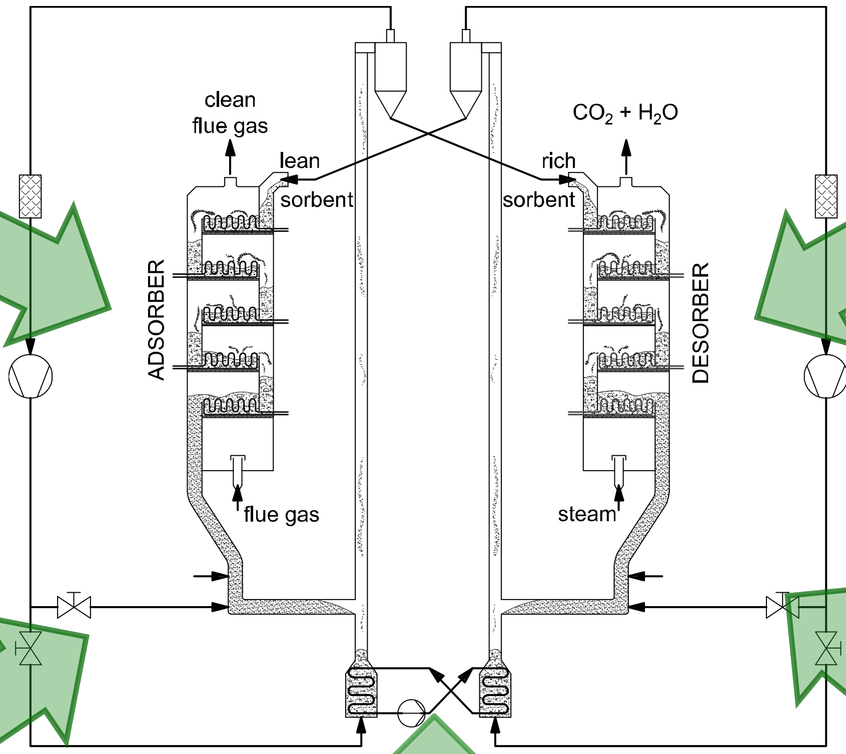
TSA process scale-up and optimization

Bench-scale experiments

HTF tests and HEX design





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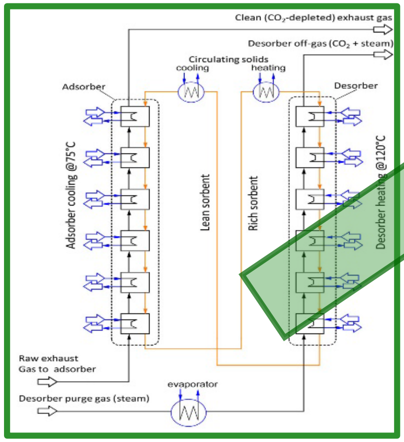

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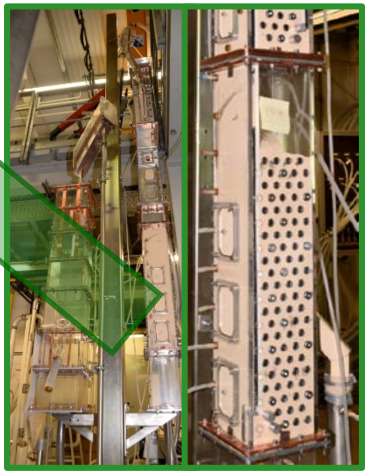

Basic & Detail Engineering,
HSE (Hazid, Hazop, etc.),
Permit application, …

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TSA pilot unit main design parameter

	Design value	Unit
CO_2 capture target		
CO_2 capture capacity	1.0	$t_{CO2} \cdot day^{-1}$
Target CO_2 capture efficiency	90	%
CO_2 feed concentration	4.0	%-Vol.
Operating gas velocity in adsorber inlet	0.7	$m \cdot s^{-1}$
TSA operation		
Adsorber operating temperature	50	°C
Desorber operating temperature	115	°C
Maximum Adsorber pressure drop	50	mbar
Adsorbent properties		
Adsorbent type	amine functionalized	
Adsorbent loose bulk density	500-600	g/l

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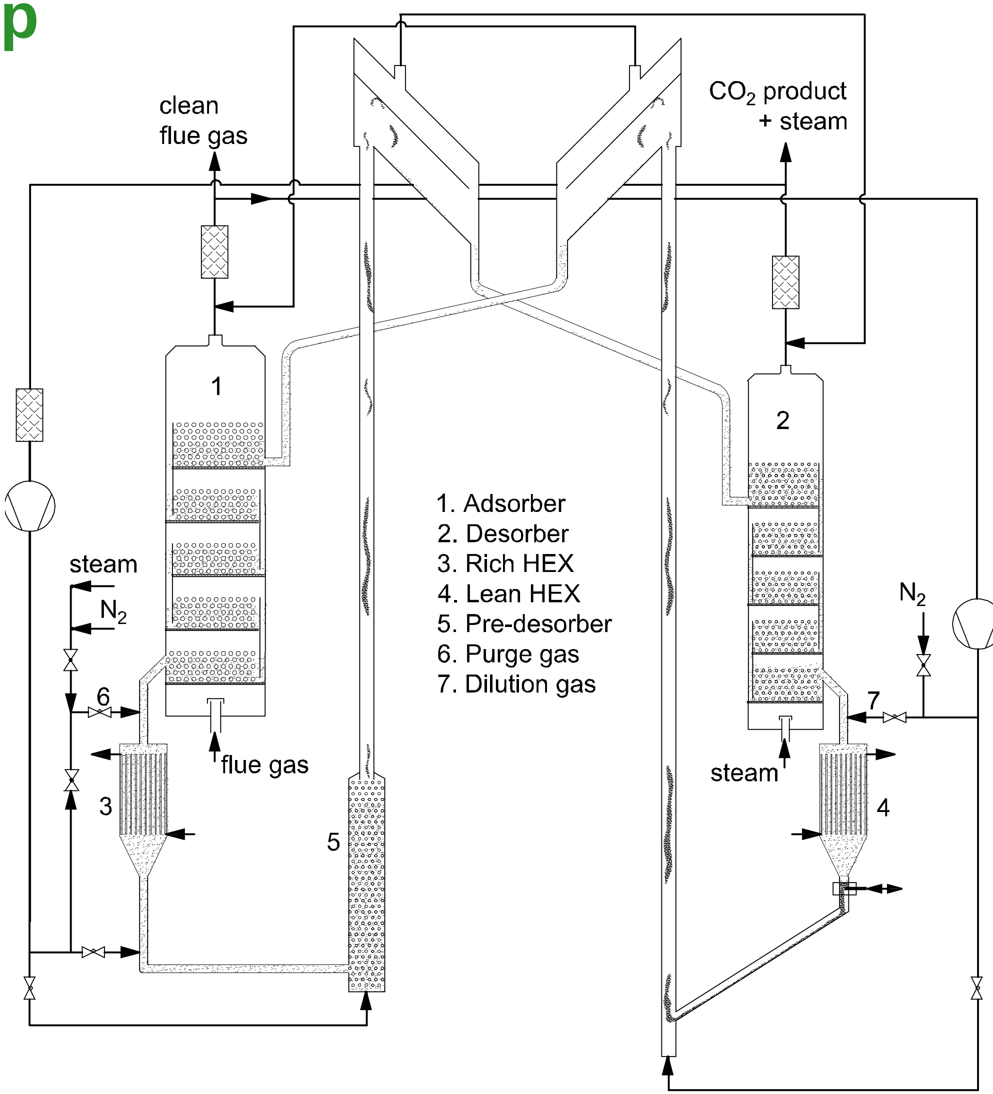
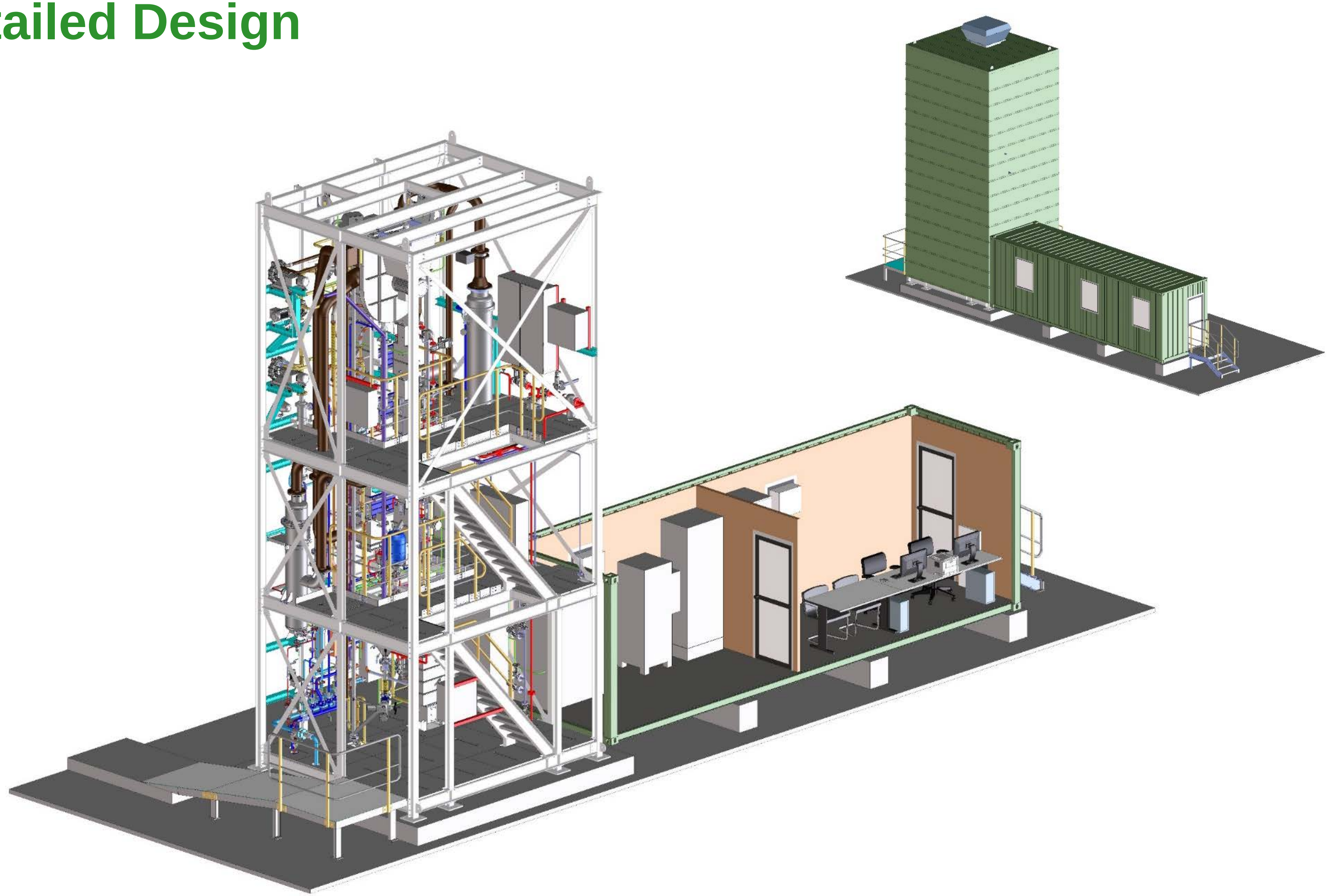
TSA pilot unit reactor setup

- **Adsorber** (5 FB stages with external downcomers, flue gas for fluidization)
- **Desorber** (5 FB stages with internal downcomers, steam/N_2 for fluidization)
- **Pre-Desorber** (in rich riser system, operated with CO_2 product recycle)
- Steam-heated **Rich Heat Exchanger**
- Water-cooled **Lean Heat Exchanger**
- **Mechanical Slide Valve** (below DES) and **L-Valve** (below ADS) for control of SCR and sorbent inventory distribution



Detailed Design



Construction – Main Equipment

Construction – Assembly Pilot unit Container

Construction – Mechanical Completion

Transport: Bludenz → Vienna

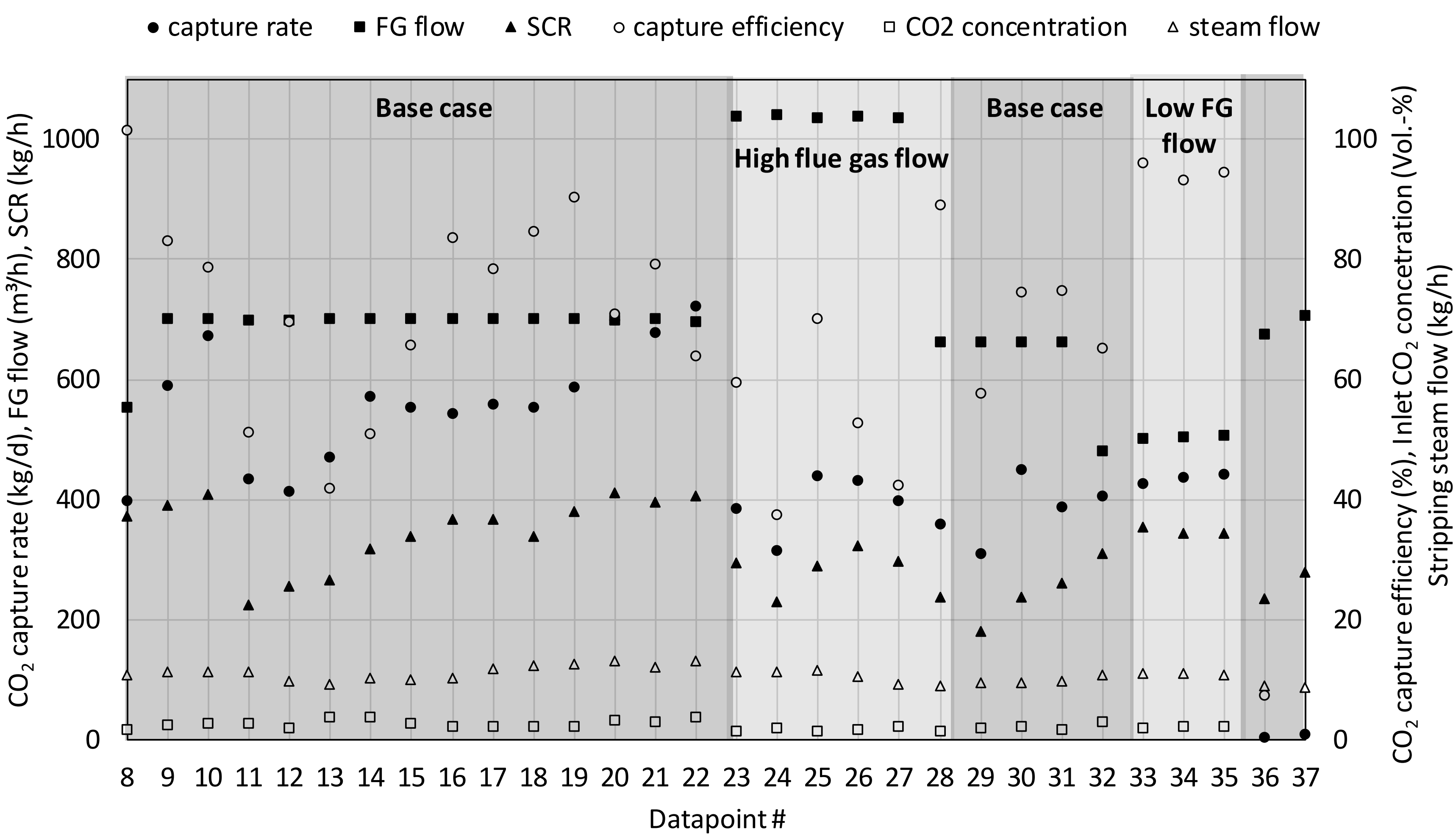
Transport: Bludenz → Vienna

TSA Pilot Unit in Simmering

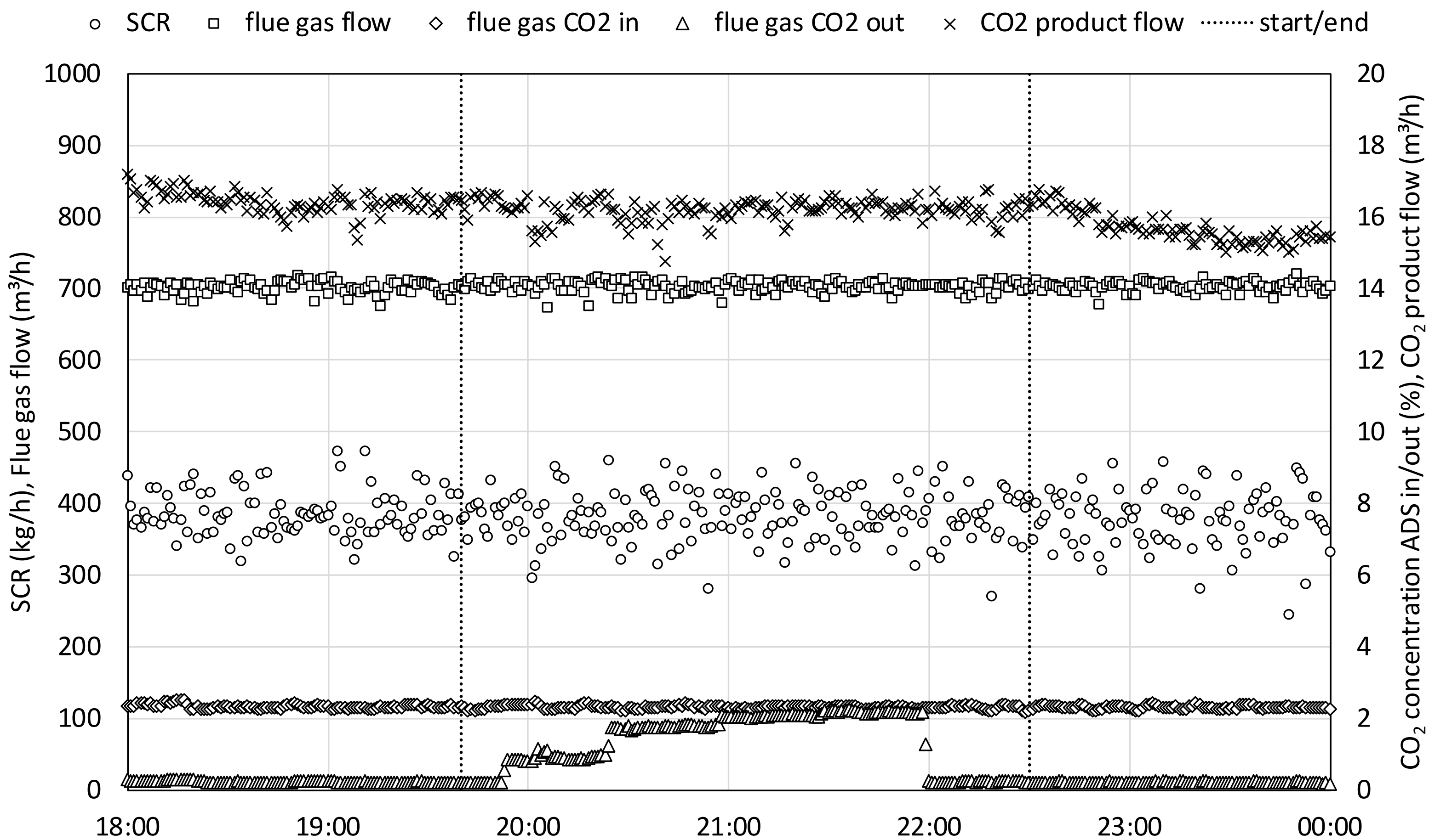
Part IV:

Preliminary results from VGCO_2 piloting campaign

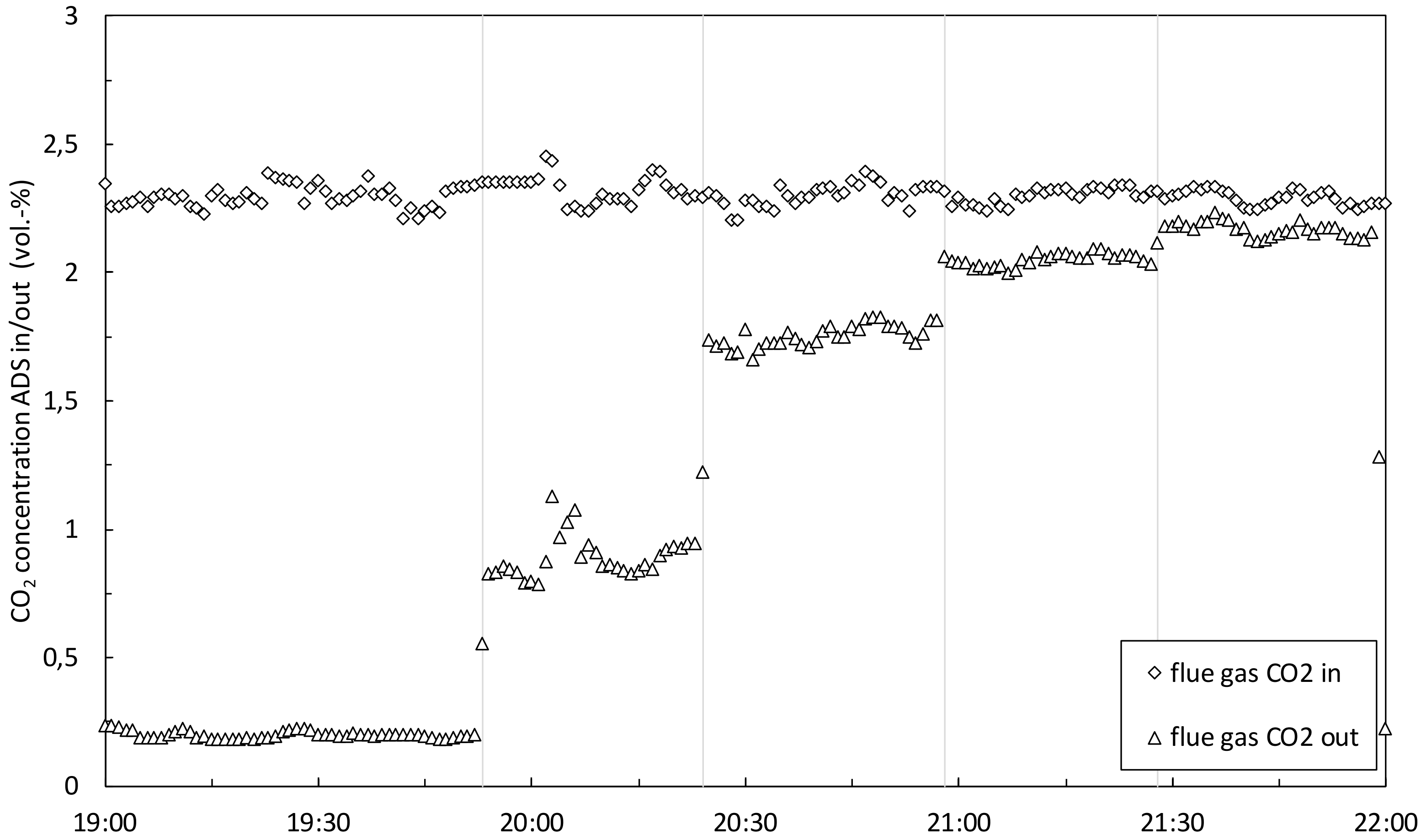
Summary of recorded Datapoints



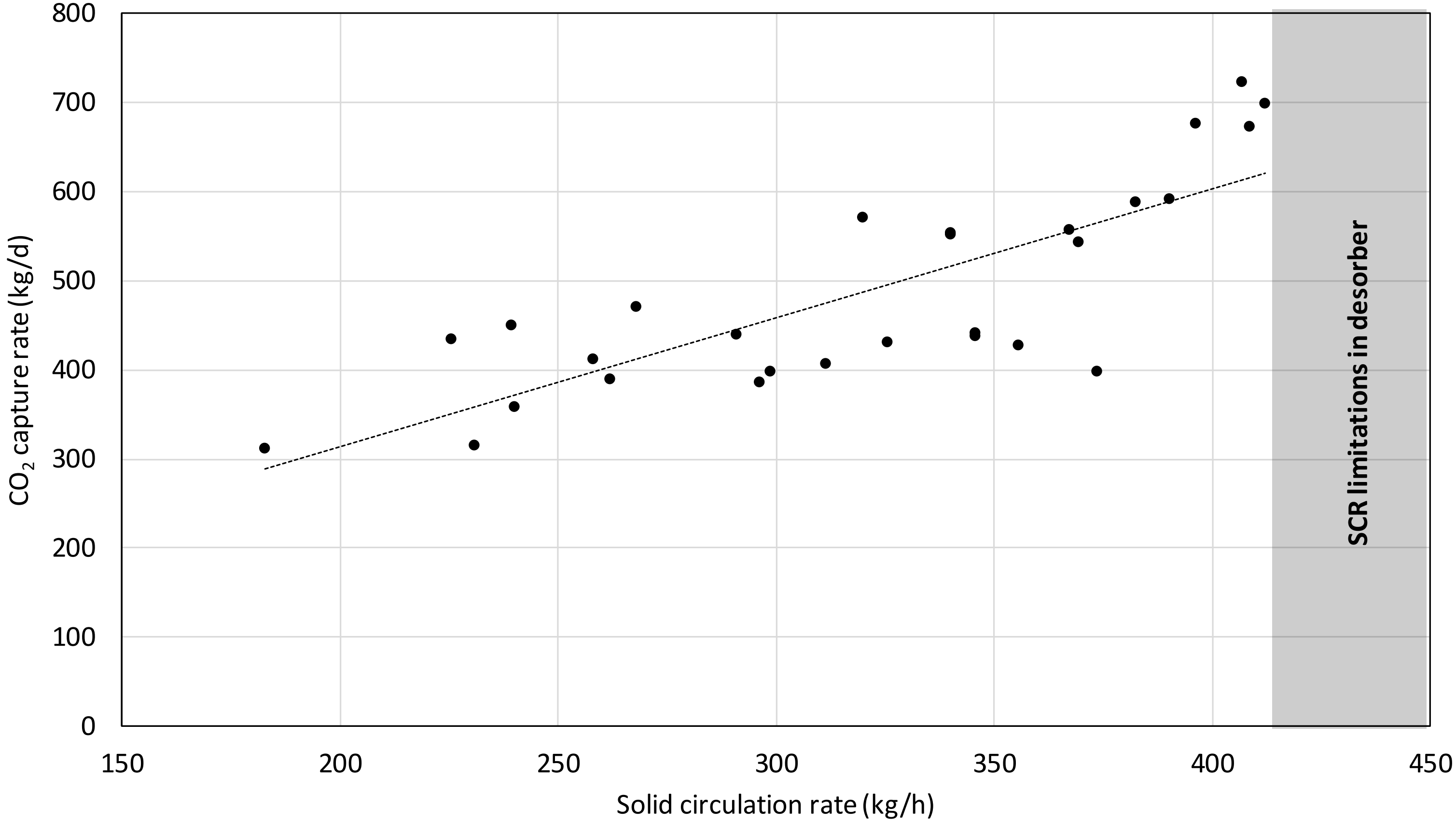
Datapoint #19 - Overview



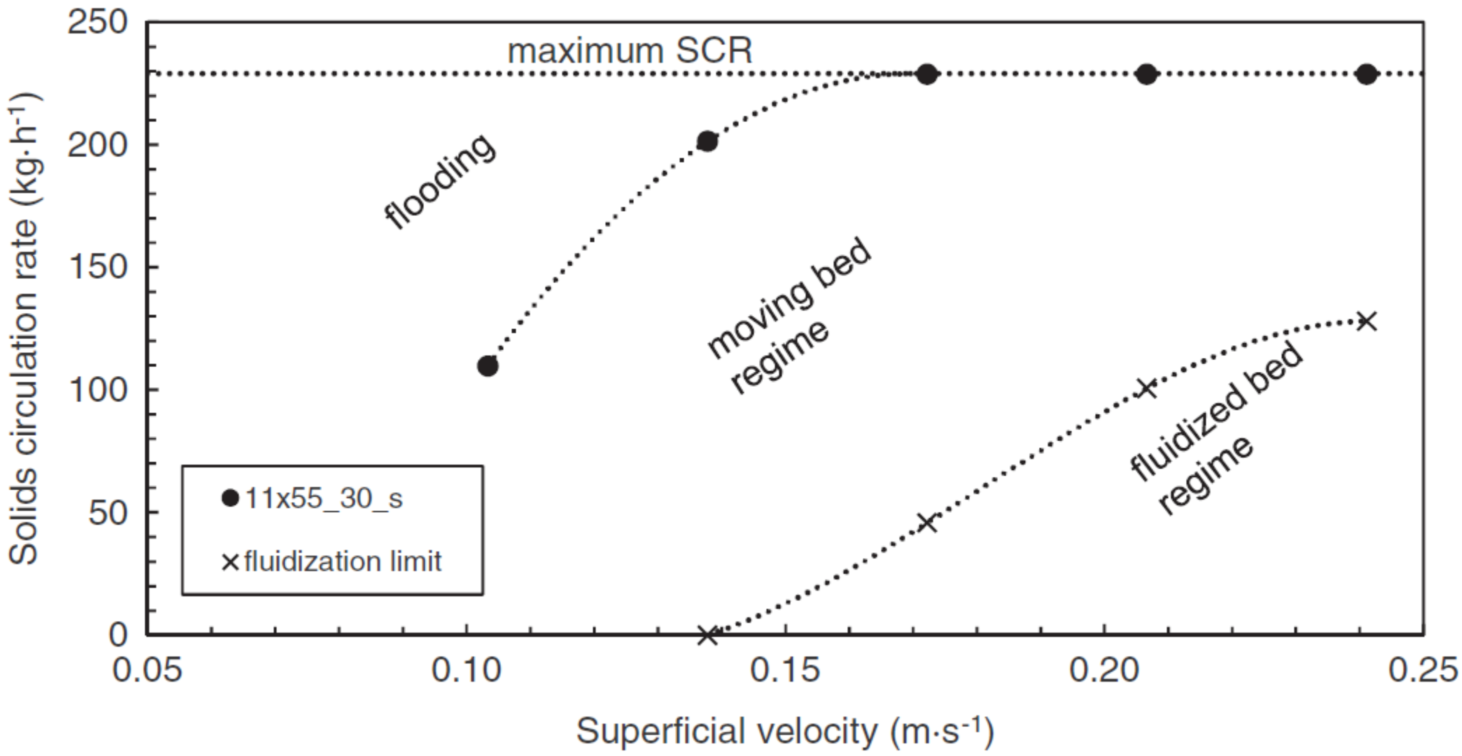
Datapoint #19 – CO_2 profile in Adsorber

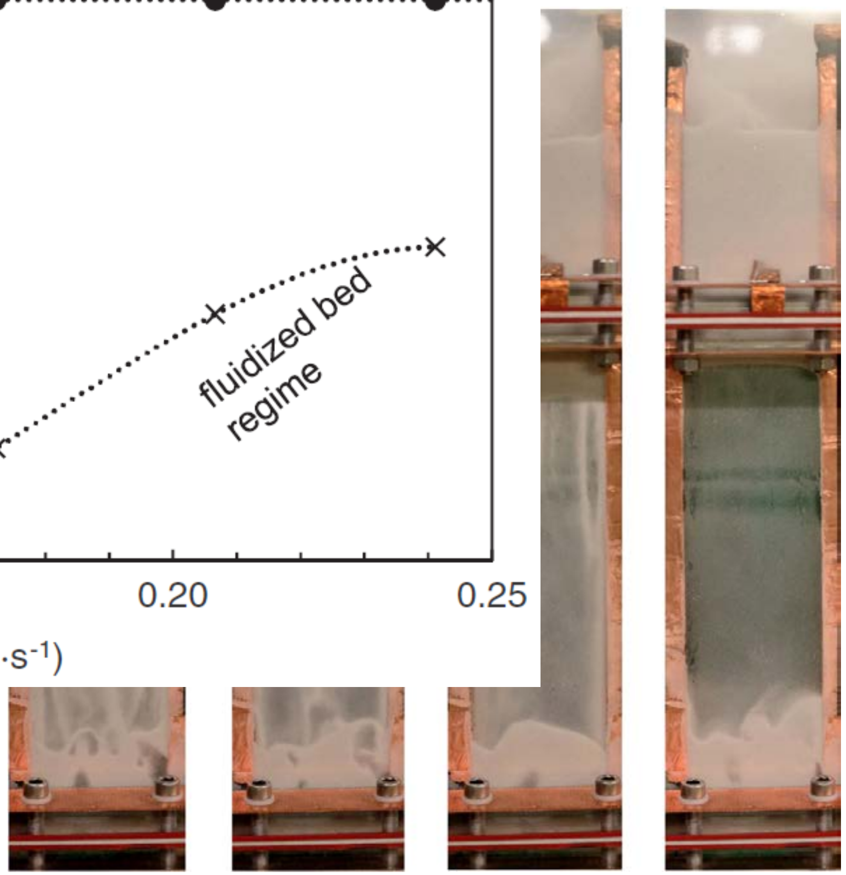


CO_2 capture performance limited by SCR



CO_2 capture performance limited by SCR





Highlights from VGCO$_2$ piloting campaign

- In total **1032 hours** of hot CO_2 capture operation
- CO_2 capture performance limited by solid throughput in Desorber and hence by maximum achievable SCR (~up to 412kg/h)
- CO_2 capture rates of up to **724kg/day** and CO_2 capture efficiency of up to **96.1%** achieved at flue gas feed CO_2 concentrations between **0-4%** and flue gas flow rates from **450 to above 1000m^3/h**
- CO_2 product purity at up to **89,5%** (rest: H_2O 2,3 - 5,3% and N_2 mainly from lean/rich purge)
- O_2 concentration in CO_2 product as low as **56 ppm** (typically around 100 ppm)

Preliminary conclusions from VGCO_2 piloting campaign

- No significant sorbent degradation or attrition
- Process emissions seems to be a key selling point of the technology
- Preliminary results from corrosion coupon testing indicate that solid sorbent technology allows for application of low material standards (e.g. carbon steel)
- Process energy demand is in the range of amine scrubbing systems and further reduction requires application of different amine functionalized sorbent materials (e.g. with amine blends of 1°/2°/3° amines)

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[1] TU Wien, [2] Shell Global Solutions Int. BV, [3] BOKU Wien, [4] Bertsch Energy, [5] Wien Energie

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