Pilot-Plant Investigation of High-Temperature Thermochemical Energy Storage Based on the Material System $CaO/Ca(OH)_2$ in a Bubbling Fluidized Bed

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Agenda

Motivation

Pilot Reactor FluBEStoR

Experimental Procedure

Results

Thermochemical Energy Storage

Basics

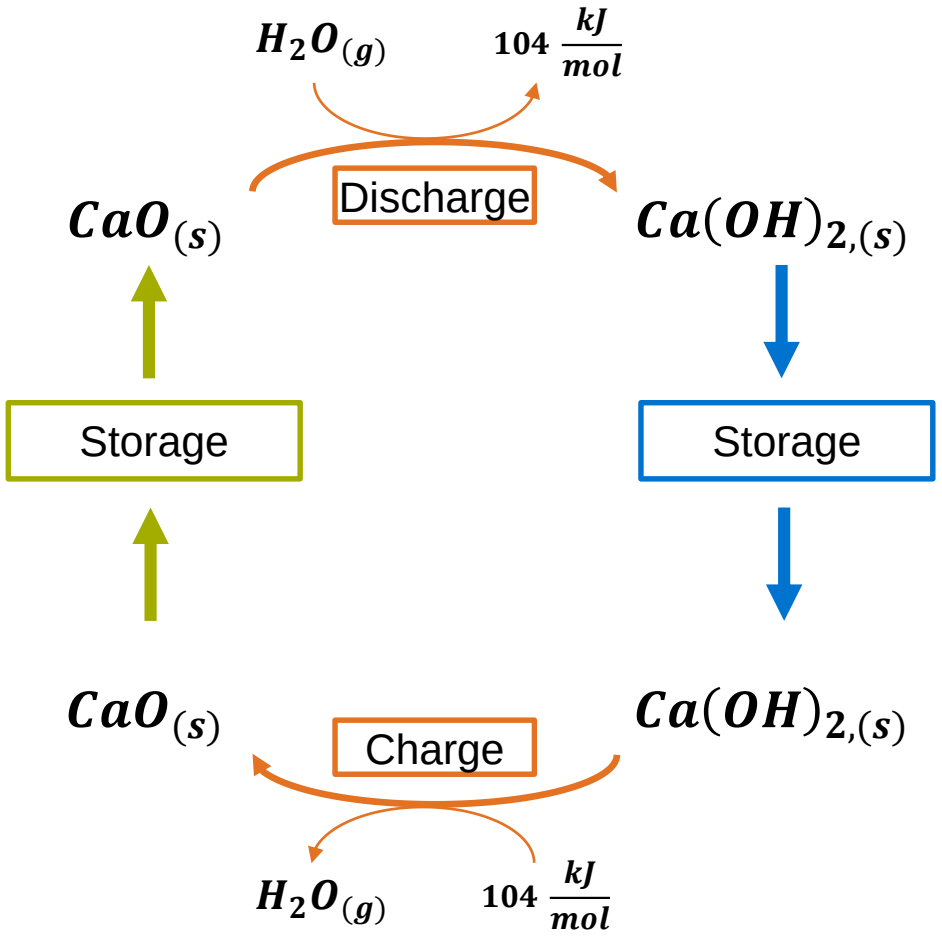
Principle: Heat storage in reaction enthalpy of gas-solid reaction

State of the art: Long term storage < 150 °C

Goal: (scalable) heat storage > 150°C, here: **400 °C - 600 °C**

Material System: Calcium Oxide – Calcium Hydroxide

Advantages[1]:
+ Cheap, abundant, Non-toxic
+ Theoretically no losses during storage period
+ High storage density
+ Decoupling of capacity and power[2,3]



Material System

Challenges

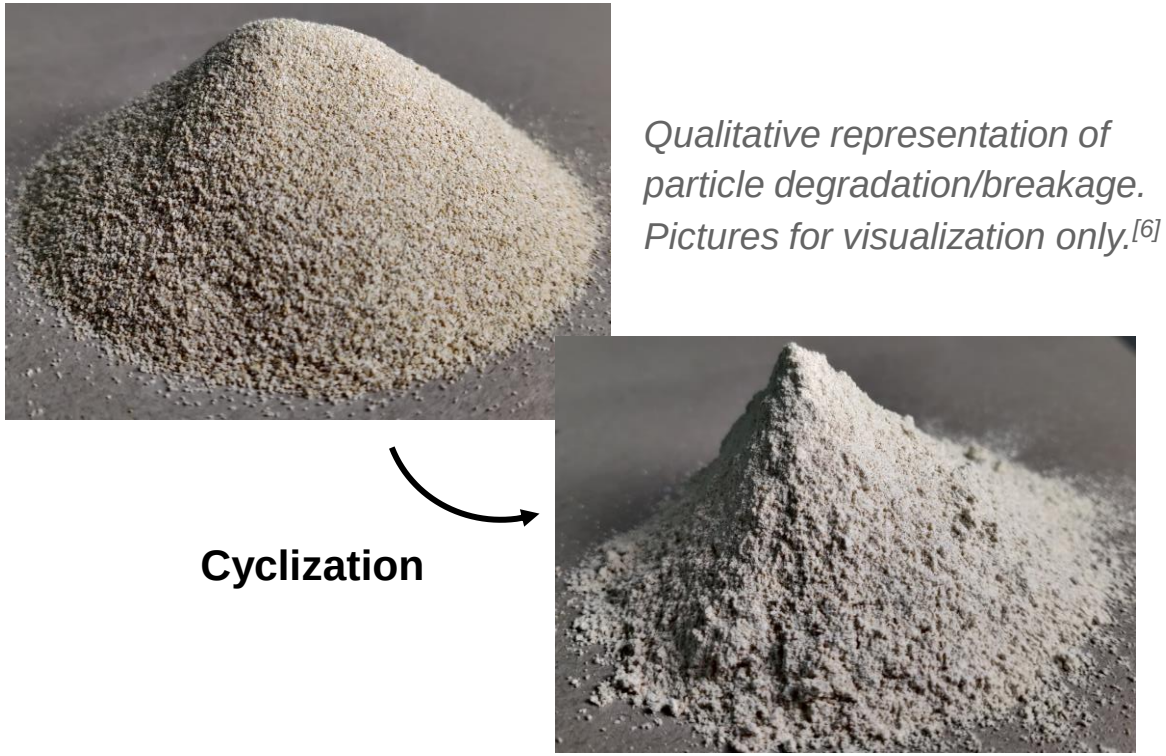
Challenges:

- Powdery material
- Agglomeration (in fixed bed)[2,3]
- **Heat transfer (limits power)[4]**

  → **Fluidized bed**

- **Mechanical material stability (limits process)[3,5]**

  → **Particle degradation/breakage**

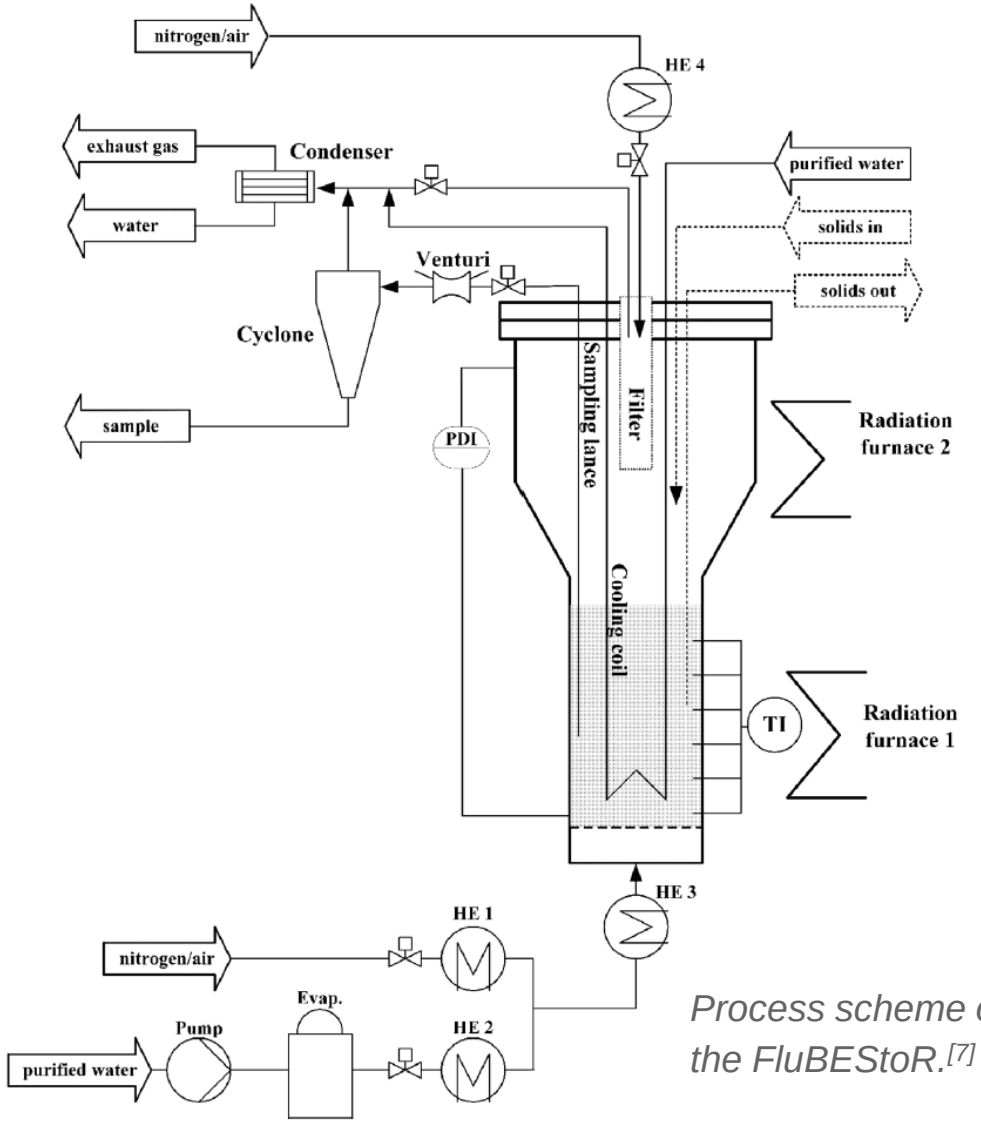


Qualitative representation of particle degradation/breakage. Pictures for visualization only.[6]

The Pilot Reactor

FluBEStoR – Fluidized Bed Energy Storage Reactor

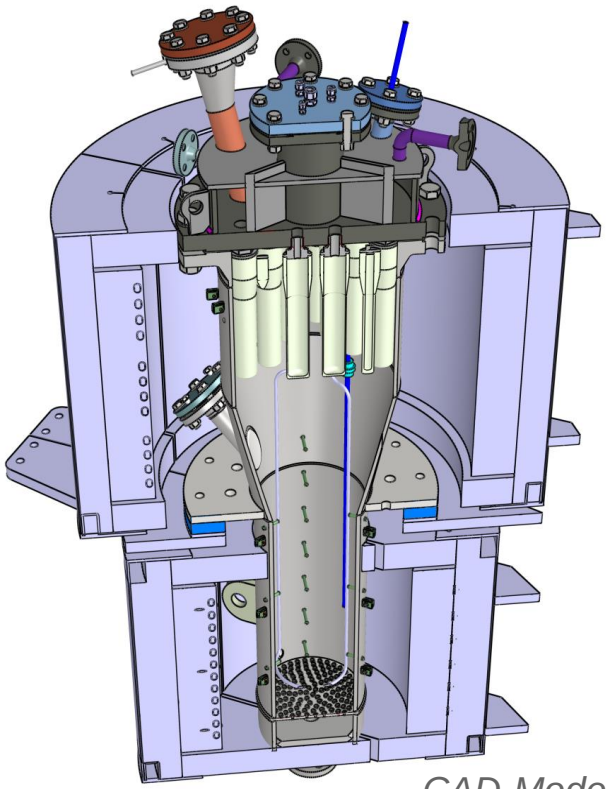
- Operation at up to 700 °C and 6 bar_g
- Reactor volume 100 L and reaction volume 30 L
- Fluidization in pure steam, pure nitrogen and/or mixtures
- Port for continuous storage material dosage
- Blow-back Filter system with sintered metal filter cartridges
- Cooling coil: 4.4 kW
- Radiation furnace: 14 kW top, 40 kW bottom



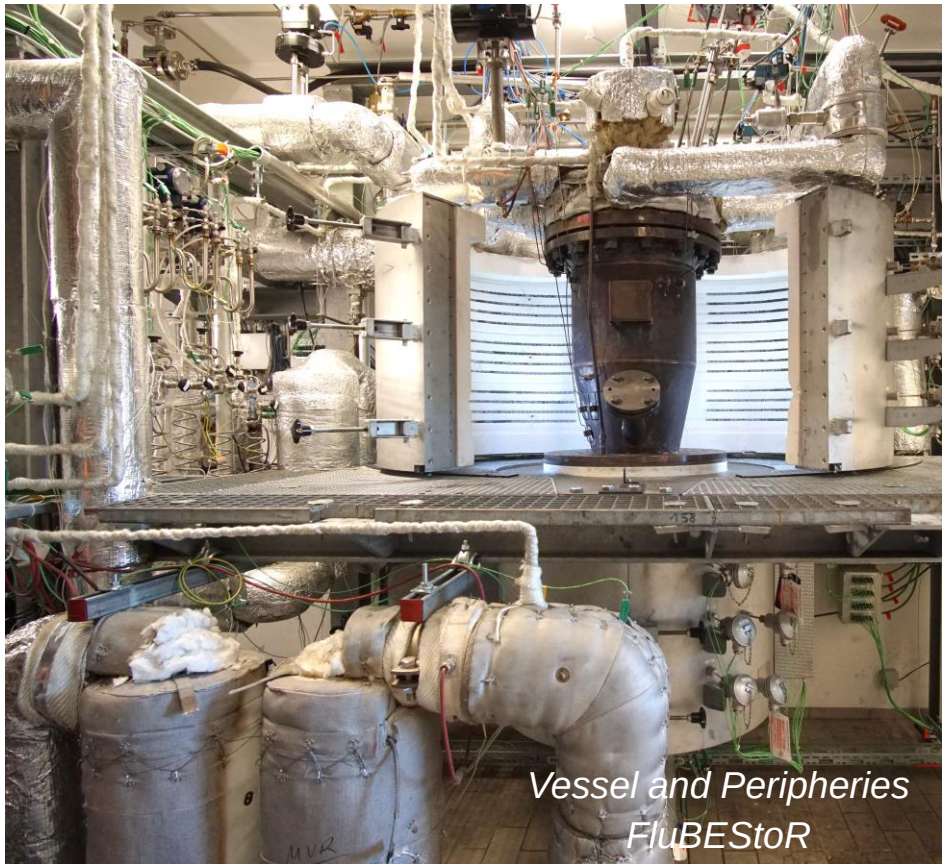
Process scheme of the FluBEStoR.[7]

The Pilot Reactor

FluBEStoR – Fluidized Bed Energy Storage Reactor



CAD-Model of FluBEStoR

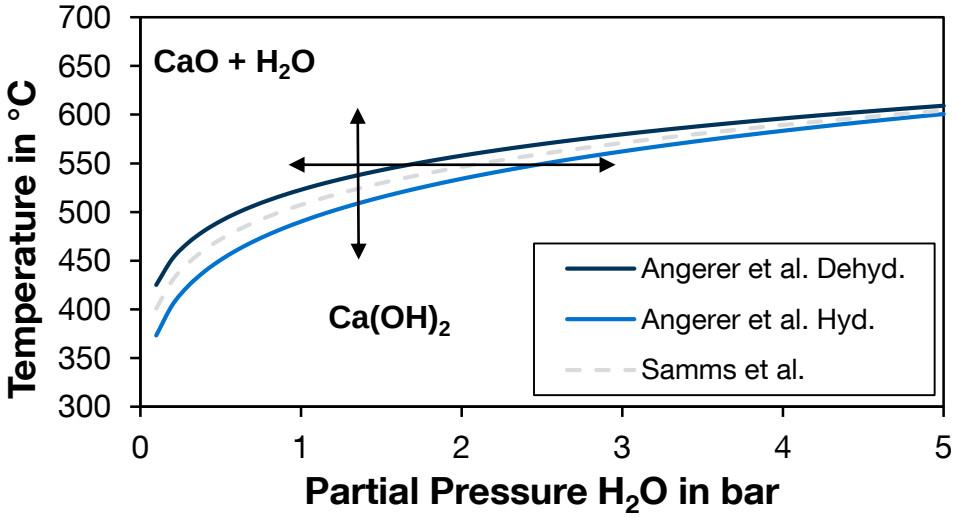


Vessel and Peripheries FluBEStoR

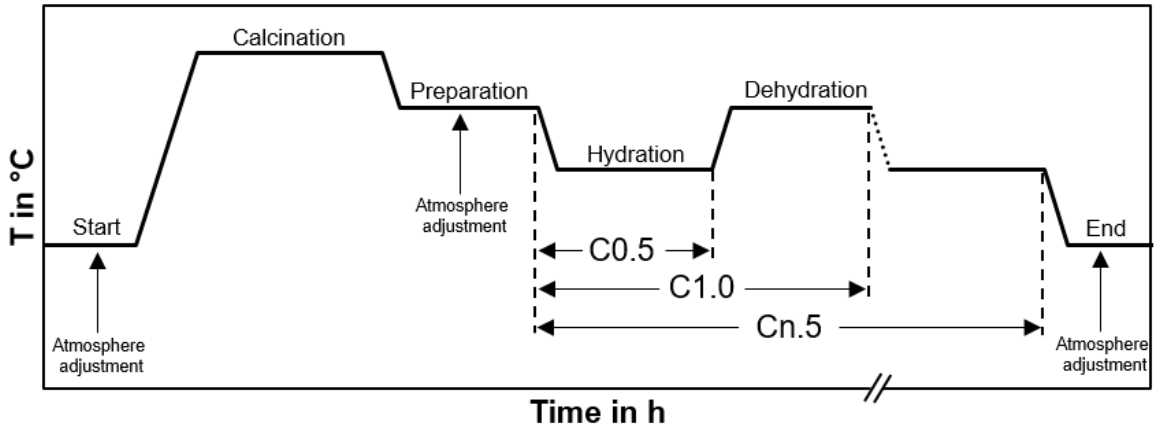
Vessel FluBEStoR

Operation of the Pilot Reactor FluBEStoR

Experimental Procedure



Apparent reaction equilibrium of $CaO/Ca(OH)_2$ according to Angerer et. al[8] and theoretical equilibrium according to Samms et. al.[9]

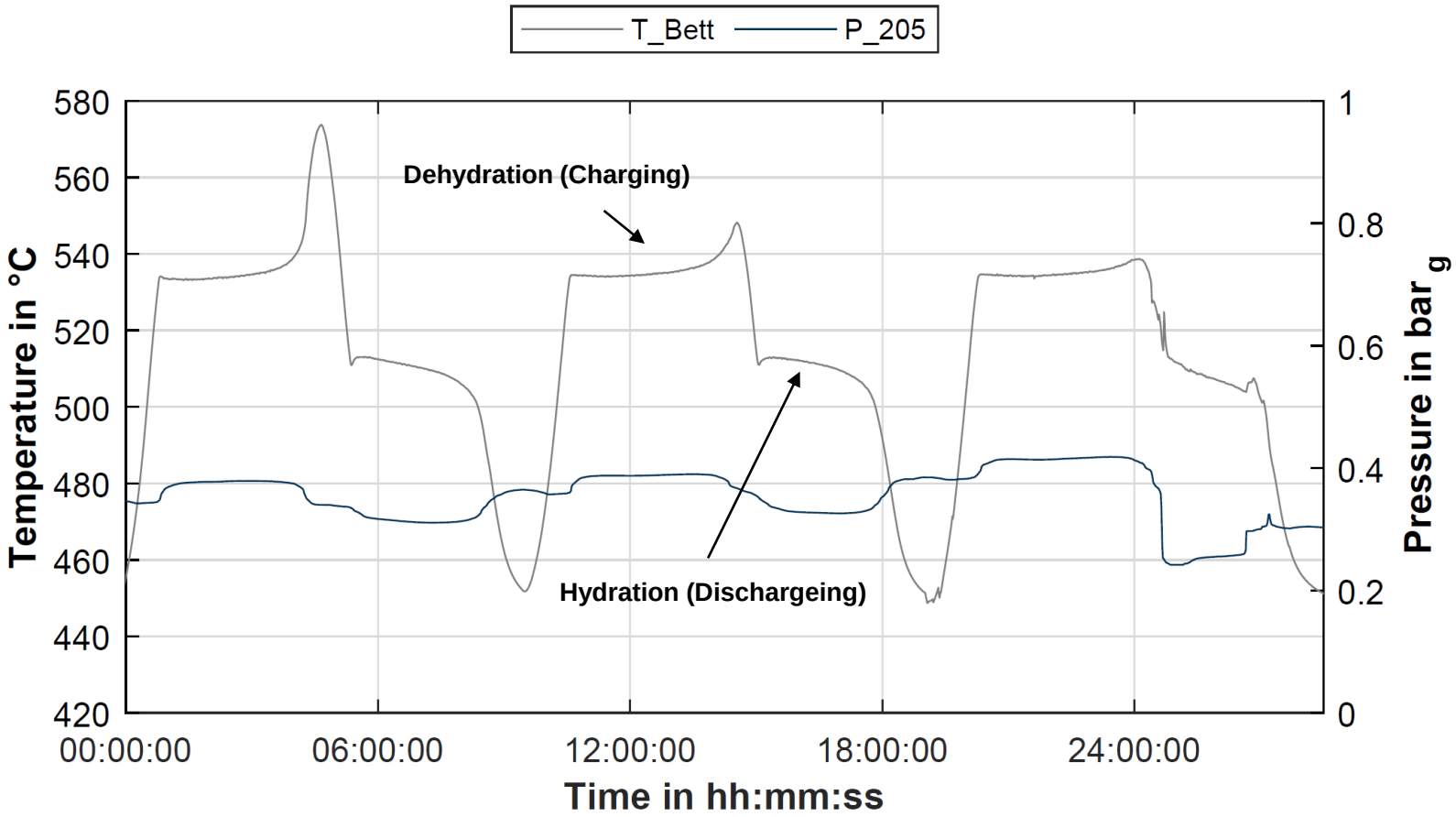


Experimental procedure for cyclisation of the storage material[10]

- Material: 250 - 400 µm $CaCO_3$, 26.4 kg
- 700 °C (Calc.) 456 °C (Hyd.), 586 °C (Dehyd.)
- u_0 = 15 cm/s
- Sampling 4 (8) L material every five storage cycles for analyzes in cold model

Results

FluBEStoR - C6.0 to C8.5:



Temperature and pressure profiles for C6.0 to C8.5 of 26.4 kg storage material in the pilot-scale reactor FluBEStoR

Classification According to Geldart

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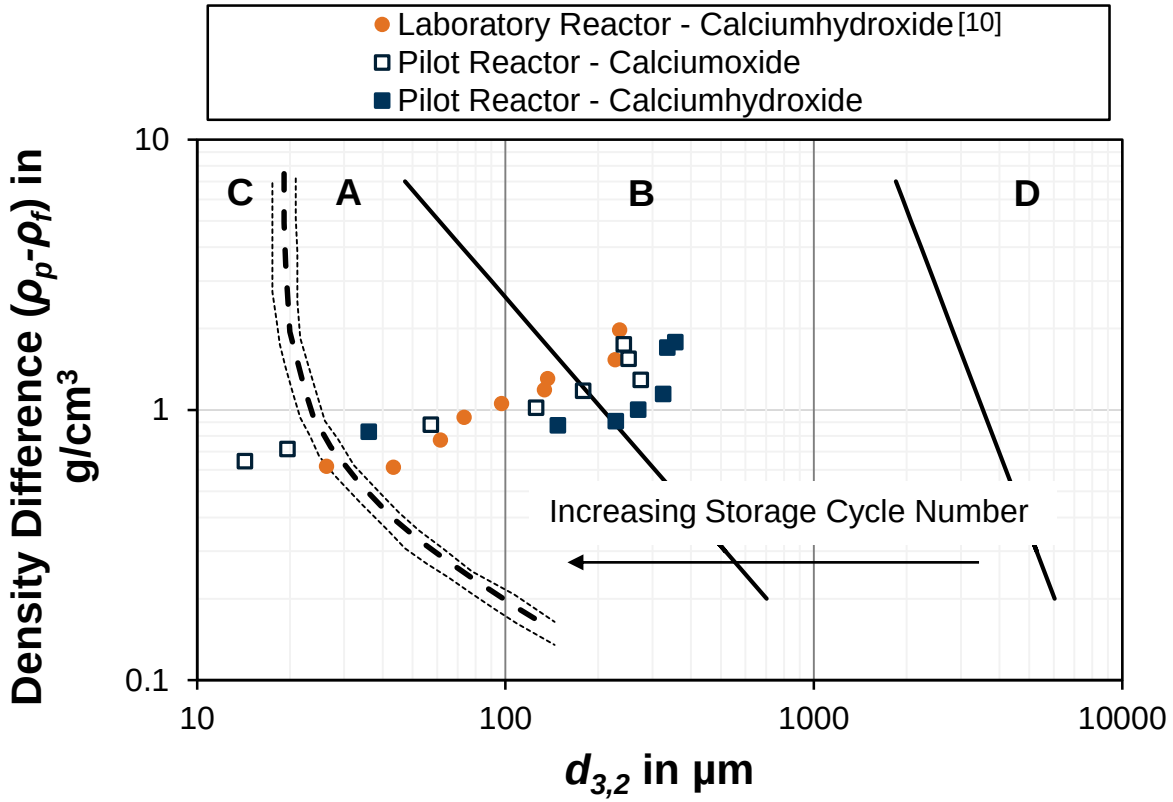
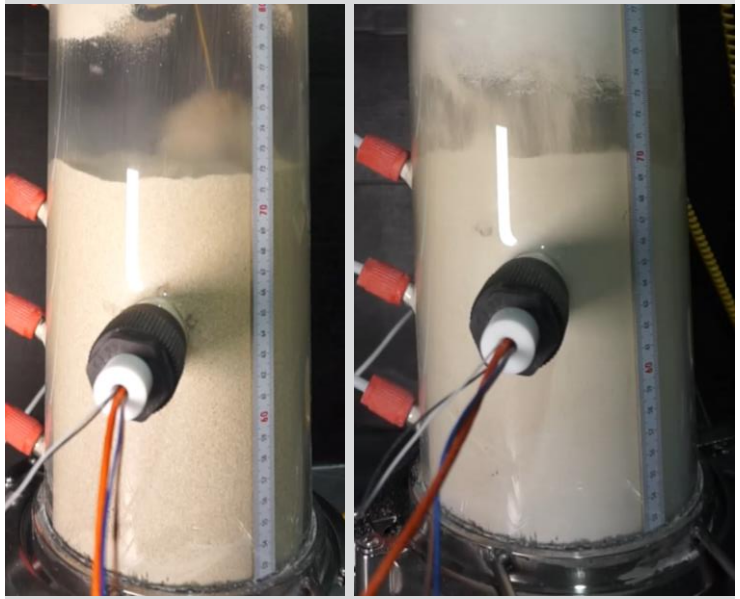


Geldart diagram adapted from [11] for transition A-B and B-D, evaluated for water vapour at 500°C and 1.5 bar and from [12] for the C-A transition. Results on cyclisation of CaO/Ca(OH)$_2$ in pure steam. [13]

Cycled Ca(OH)$_2$ at 0.15 m/s

$d_{3,2}$ = 355 µm $d_{3,2}$ = 148 µm



Fluidization test Rig described by Becker [13]

Samples of varying $d_{3,2}$ tested in a fluidization test rig.

Summary

- Thermochemical Energy Storage utilizing **$CaO/Ca(OH)_2$** is promising for applications at **400 °C - 600 °C**
- Challenges in the technical development are **low heat conductivity** and the **mechanical particle stability**
- **Proof of technical feasibility** in pilot-scale Fluidized bed reactor – 26.4 kg Storage Material
- **Characterization of storage material** breakage throughout storage cycles and its influence on **fluidization properties**

Freeboard of the pilot-scale reactor FluBEStoR

Thank you for your attention!

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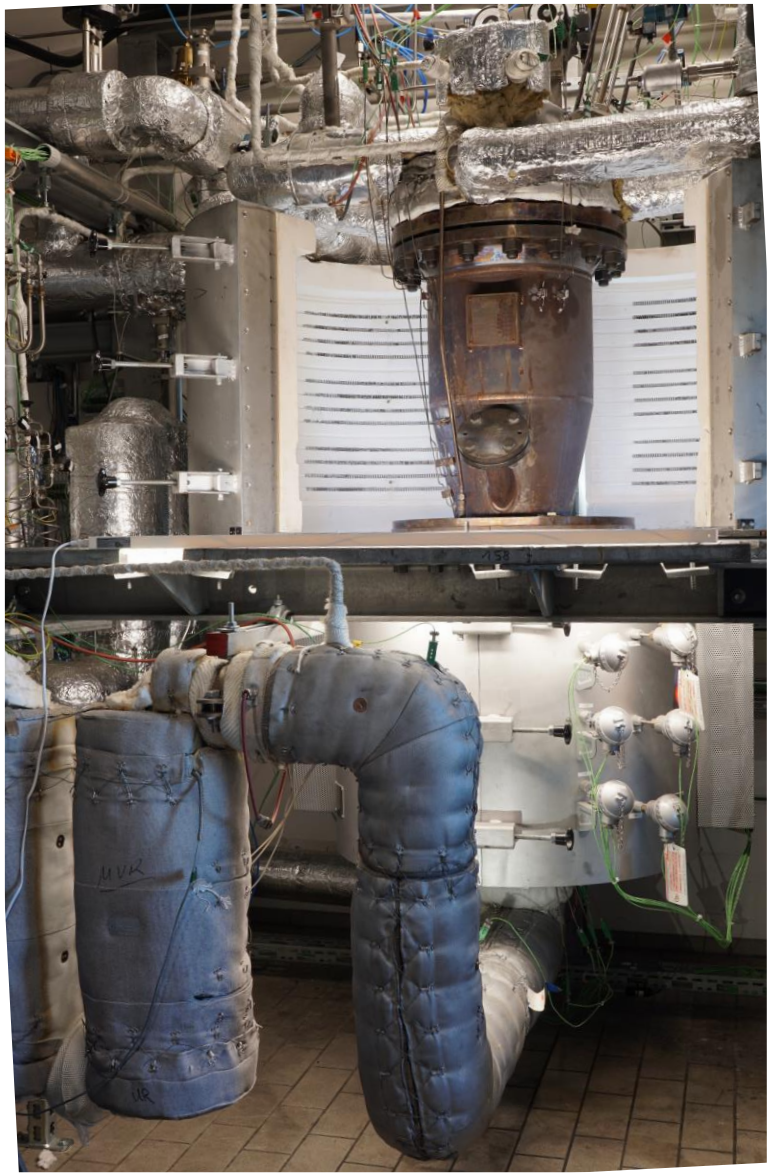

Pilot-Scale Reactor FluBEStoR

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