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# Thermochemical Energy Storage Employing Fluidized Bed Technology: Experimental Investigations with $CaO/Ca(OH)_2$ on a 21kWh Reactor

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FLUIDIZATION XVI

GUILIN, CHINA

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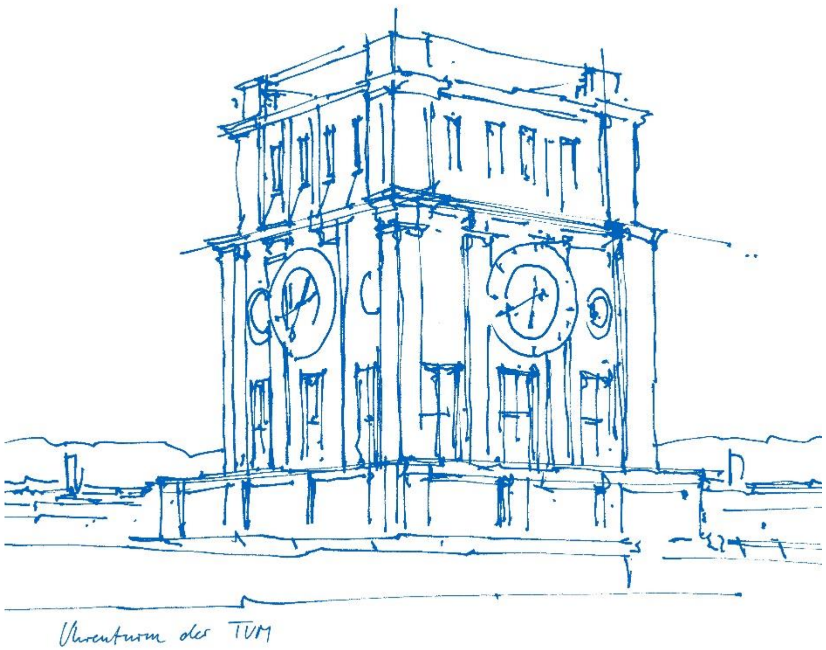


# Agenda

**Introduction:**
Thermochemical Energy Storage Systems

**Prelimenary Experiments:**
Fluidisation Test Rig, Lab Scale Reactor, TGA

**Motivation & Open Questions**:
Heat Tranfser and Particle Stability

**The Fluidized Bed Reactor FluBEStoR:**
Setup and Experimental Procedure

**Experimental Data**

# Thermochemical Energy Storage (TES)

## Background & Potential

- First experimental investigations by Samms & Evans in 1967
- Water-based gas-solid-reactions advantageous
  → e.g. $CaO(s) + H_2O(g) \leftrightarrow Ca(OH)_2(s) + 104\ kJ/mol$
- Advantages:
  - Cheap storage material
  - No losses over time
  - High energy density
- Status Quo: Fixed bed and moving bed reactors [1]
- Current research: Moving bed [2] & fixed bed reactors [3]
- Advantages of fluidized bed reactors for TES:
  - Improved mass- and heat transfer
  - superior mixing properties
  - Simple scalability & compact design
  - Continuous operation allows decoupling of reactor volume and capacity

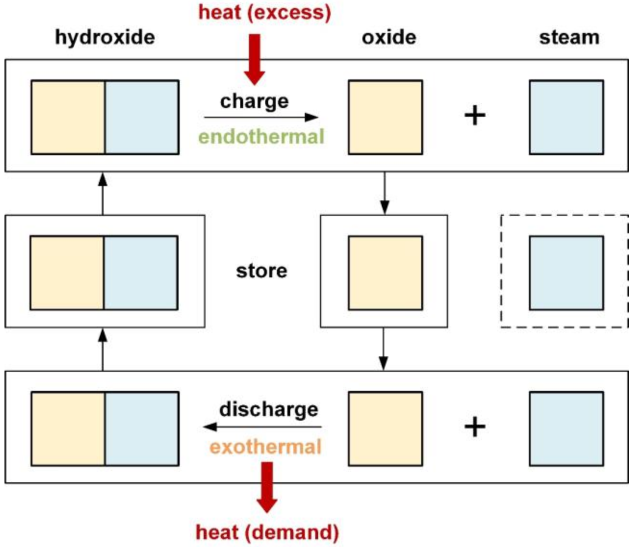



Illustration of the principle of thermochemical energy storage

# Preliminary Experiments

**Fluidization test rig with heat transfer probe**

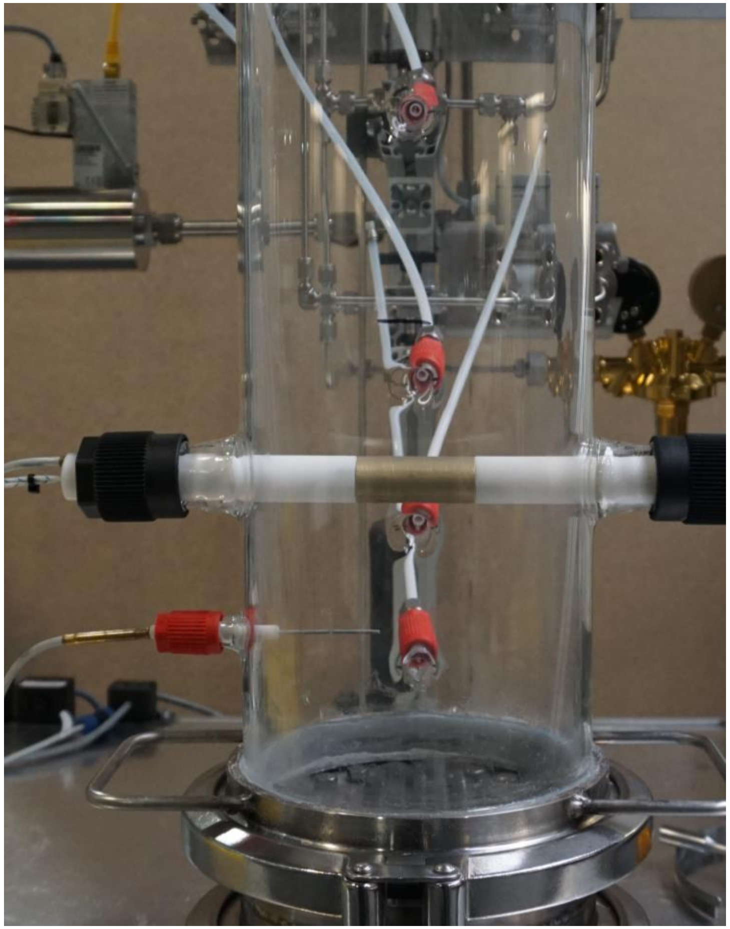
- Cylindrical columns (glass) with ID of 140 mm
- Dehumidified Nitrogen at ambient temperature as fluidization agent
- Overall perimeter heat transfer probe (OP-HTP), cp. [4,5]

**Lab-scale fixed bed reactor**

- Nitrogen and steam supply (direct evaporator)
- Radial flow trough porous material container
- Approx. 300 ml of storage material
- Temperature and pressure measurement

**TGA unit**

- Investigation of reaction kinetics
- Characterization and improvement of materials



# Motivation & Open Questions

## Heat-Transfer and Particle Stability in the Fluidized Bed

**Heat Transfer**

- Has been identified as limiting factor for overall process [6]
- Successful measurements in fluidized bed cold model (ambient conditions)

**Cycle Stability**

- Cycle stability so far not or hardly proven in literature
- Comminution processes in the process through three aspects:
  - Induced by chemical reaction
  - Induced by thermal stress
  - Mechanical forces in fluidized bed

**Combination**

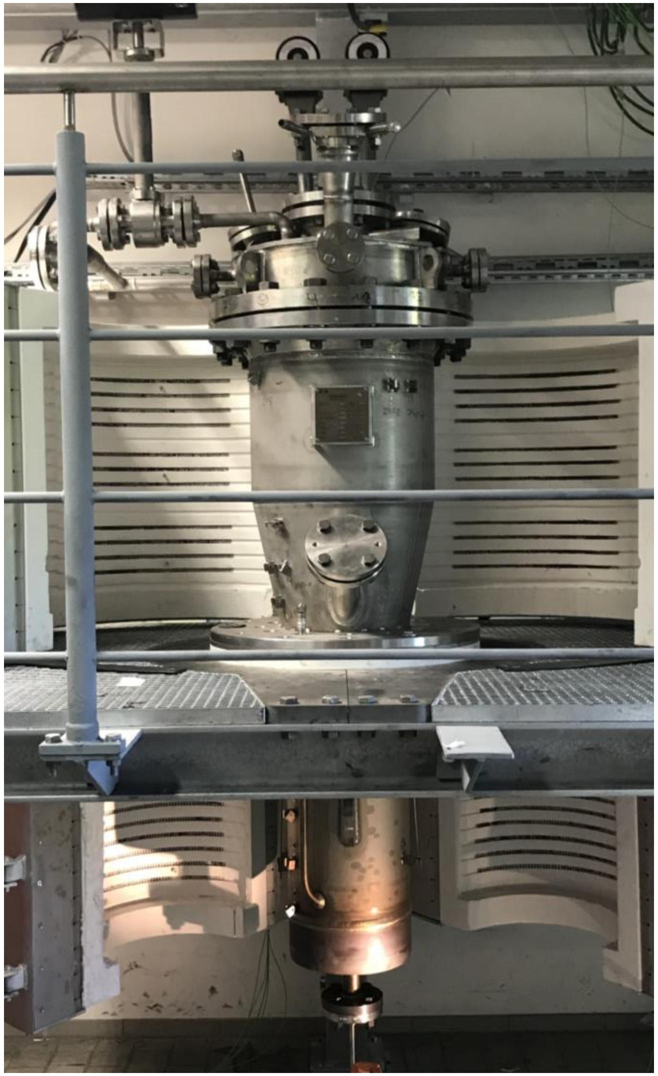
- Small quantity of fine materials leads to improvement of heat transfer temperature (higher collision factor → lower contact time)
- Too high a proportion of fine materials results in deterioration of heat transfer temperature (defluidisation)

**Conclusion**

- Definition of optimum operating point with specific fine fraction
- Particle stability for long term/high cycle experiments
- Estimation of heat transfer coefficients under operating conditions

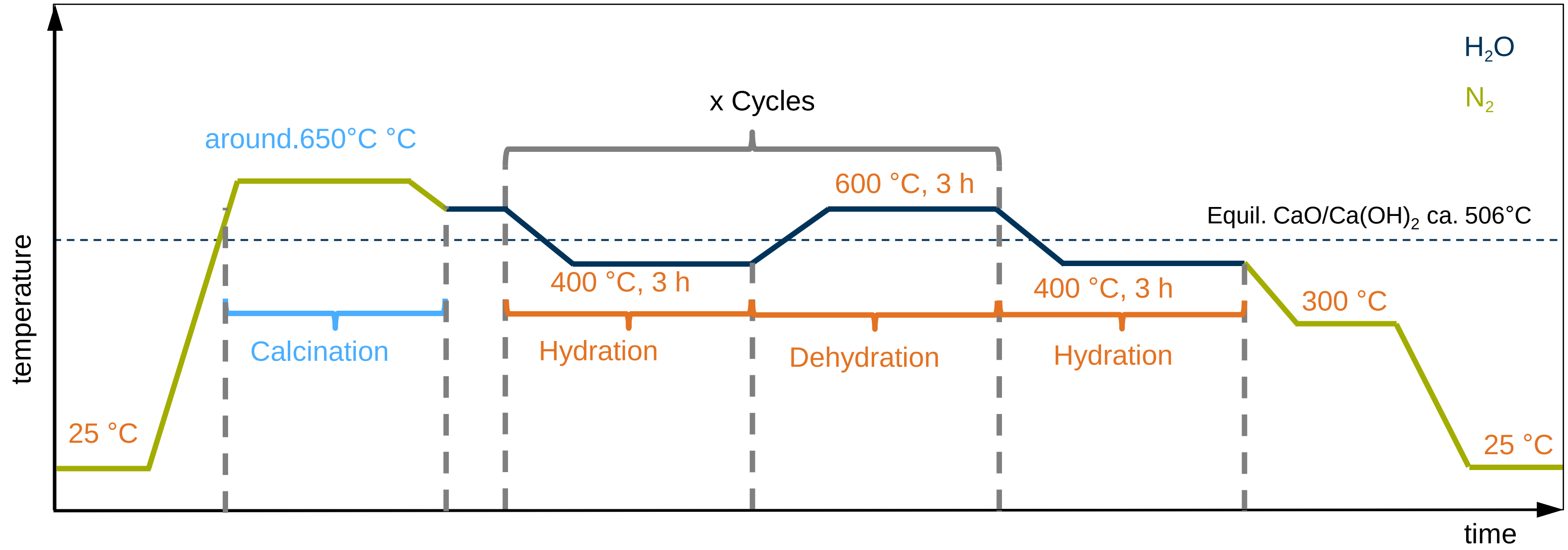
# FluBEStoR

- Mounting plate with insulation ring
- Reactor torso
  - Temperature measurements
  - Gasinlet, gasbox and gas distributor plate
  - Flange for supplying bulk material
- Reactor-head
  - Sintered metal filter cartridges
  - Gasoutlet
  - Suction lance for solid sampling
  - Flange for material input in continuous operation mode
- Cooling coil (4,4 kW)
- Radiation furnace
  - 14 kW top
  - 40 kW bottom



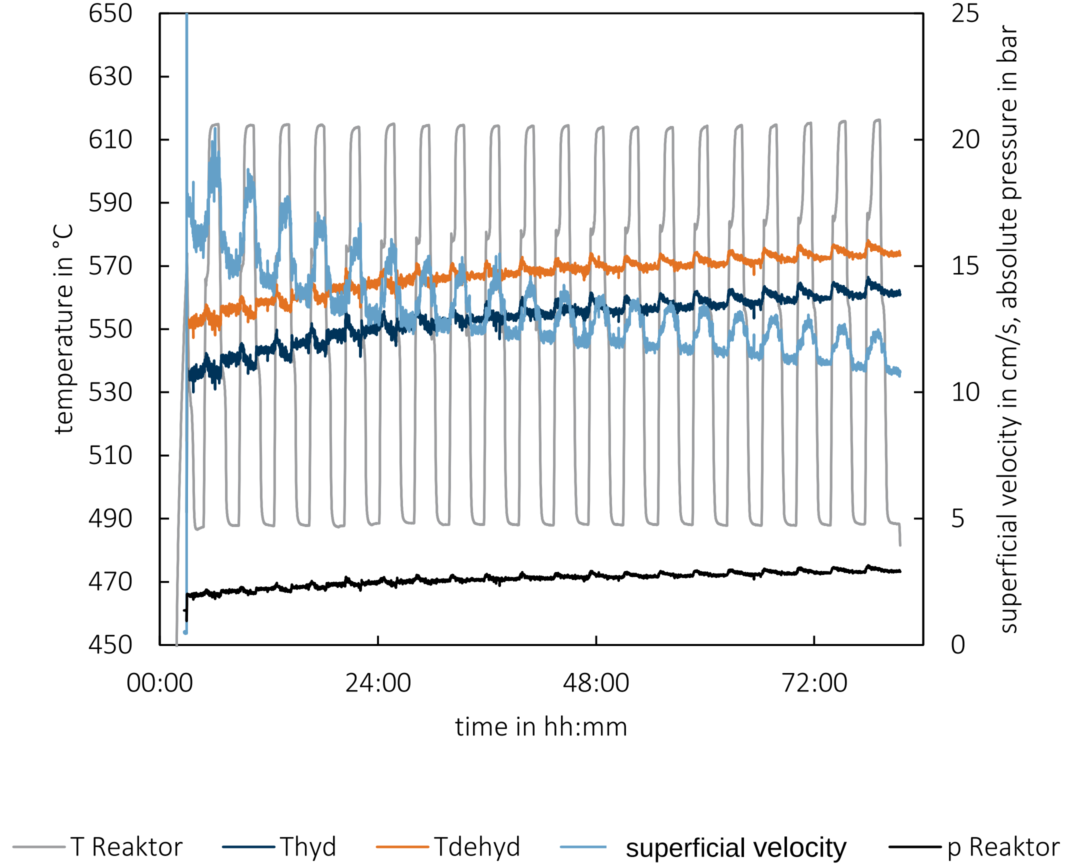
# Exemplary FluBEStoR-Experiment

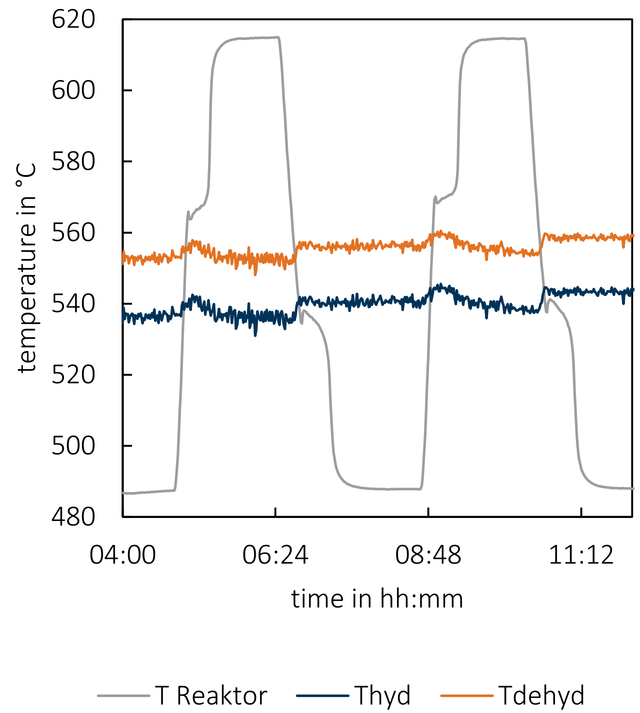
- “In-house” Calcination of $CaCO_3$ at around 650°C in pure nitrogen → stable CaO
- One “Cycle” consists of complete hydration and dehydration
- Conversion close to chemical equilibrium is “gentle”
- Reaction itself is limited by heat input and -output
- Material analytics: Particle size analysis, TGA/ignition loss, scanning electron microscopy, BET, particle- & bulk density



# Experimental Data

## 20.5-cycle experiment on lab scale reactor



# Thank you for your attention!

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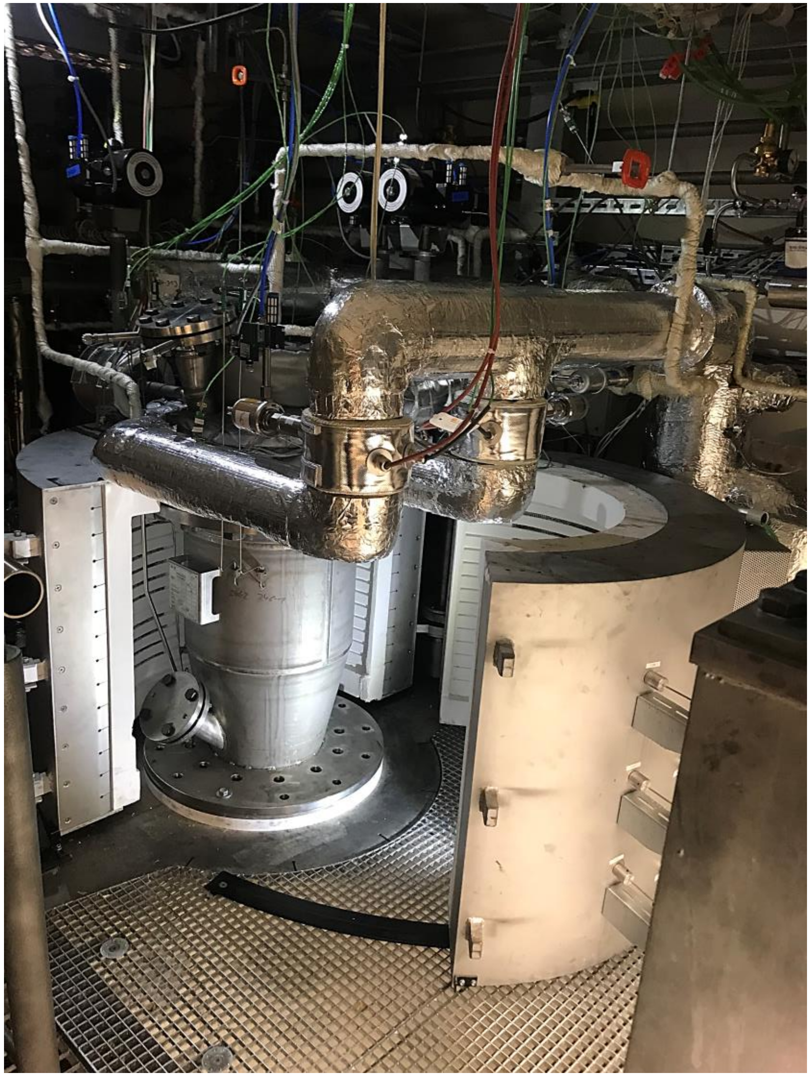

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For additional literature on reactor see:

Wuerth M, Becker M, Ostermeier P, Gleis S, Spliethoff H. Development of a Continuous Fluidized Bed Reactor for Thermochemical Energy Storage Application. ASME. J. Energy Resour. Technol. 2019;141(7):070710-070710-6. doi:10.1115/1.4043629