Improving Powder Flowability by Adding Nanoparticles for Thermochemical Heat Storage with Moving Reaction Bed

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Thermochemical Heat Storage
Application & Potential

Application:

- Storage of industrial waste heat
- Reduction of energy generation cost
- Base load capability of renewable energy systems

Potential:

- High storage densities
- Long-term and loss-free storage
- Heat release at any time
- Possibility of heat transformation

Thermochemical Heat Storage
Reaction System

Reversible Gas-Solid-Reaction:

$$CaO_{(s)} + H_2O_{(g)} \rightleftharpoons Ca(OH)_{2(s)} + 99{,}5\ kJ/mol$$

Temperature range ~ 400-700 °C

➔Main advantage: Low price (55-65 € / ton)

- Poor thermal conductivity and permeability of $CaO/Ca(OH)_2$
  - ➔High demand on reactor geometry leads to high costs
  - ➔Adjustment of reactor to required power
  - ➔Supply of capacity in cheap tanks

➔Material flow through the reactor is essential!

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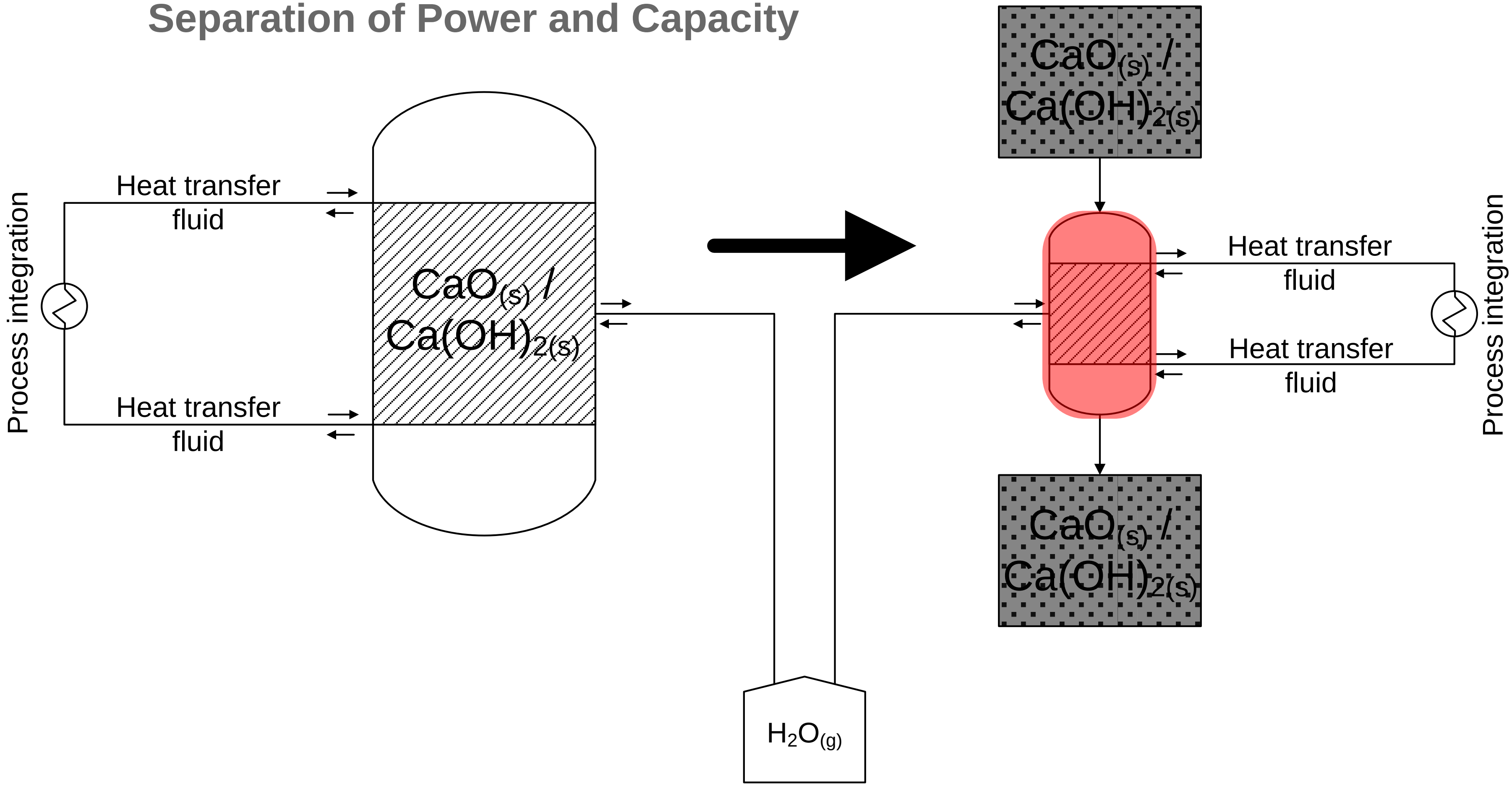
Motivation
Separation of Power and Capacity



Challenge
Poor Powder Properties

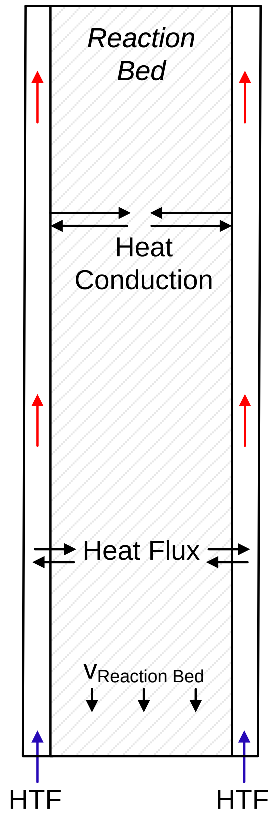


Plate heat exchanger

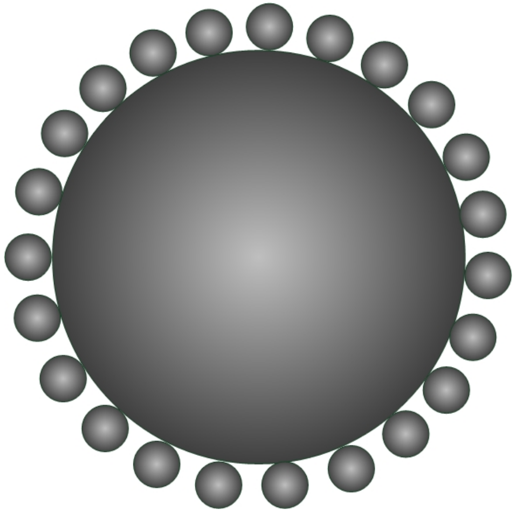
Low thermal conductivity

vs

Poor flowability

Approaches

➔Pellets unstabile during cycling



➔Increasing the roughness of particle surface

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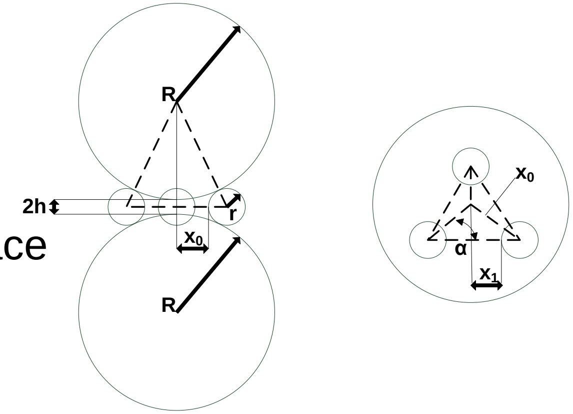
Modification of Material
Increasing the Roughness of Surface

Extension of Van-der-Waals Eq. :

$$F_{VdW} = \frac{C_H}{6}\left[\frac{R \cdot r}{a^2(R+r)} + \frac{R^2}{(2a_P)^2 \cdot 2R}\right]$$

➔ Increasing of the roughness of the surface and distance between the particles by addition of nano particles



State of the art:

- [1] Improving powder flowability in bulk and pharmaceutical industries
- [2] Combination of nano particle agglomerates with CaO to improve fluidization behavior for CO_2 adsorption

➔Coating of $Ca(OH)_2$ by nano particles in order to improve flowability is uninvestigated

[1] K.Köpker et al., *Application of nano particles*, Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Wuerttemberg,2007

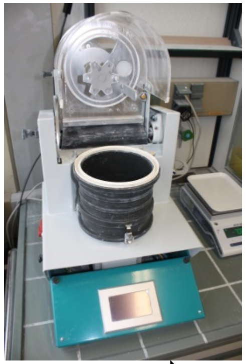
[2] Pontiga et. al, *Dry fas-solid carbonation in fludized beds of Ca(OH)2 and nanosilica/Ca(OH)2 at ambient temperature and low CO2 pressure,* Chemical Engineering Journal, 2013

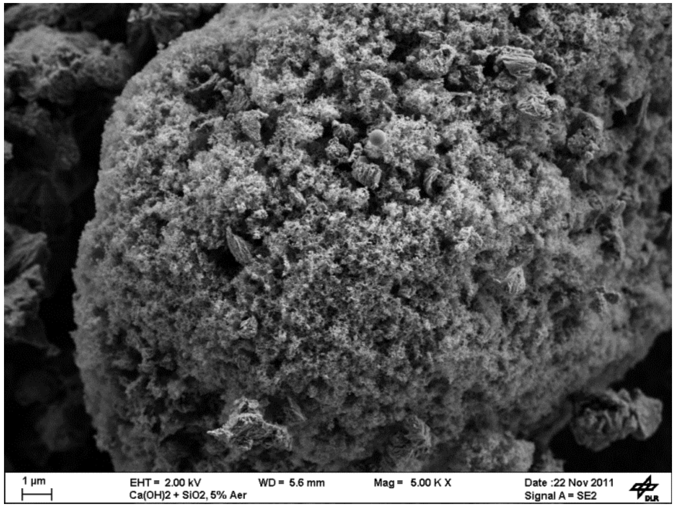
Dry particle coating

$Ca(OH)_2$

+

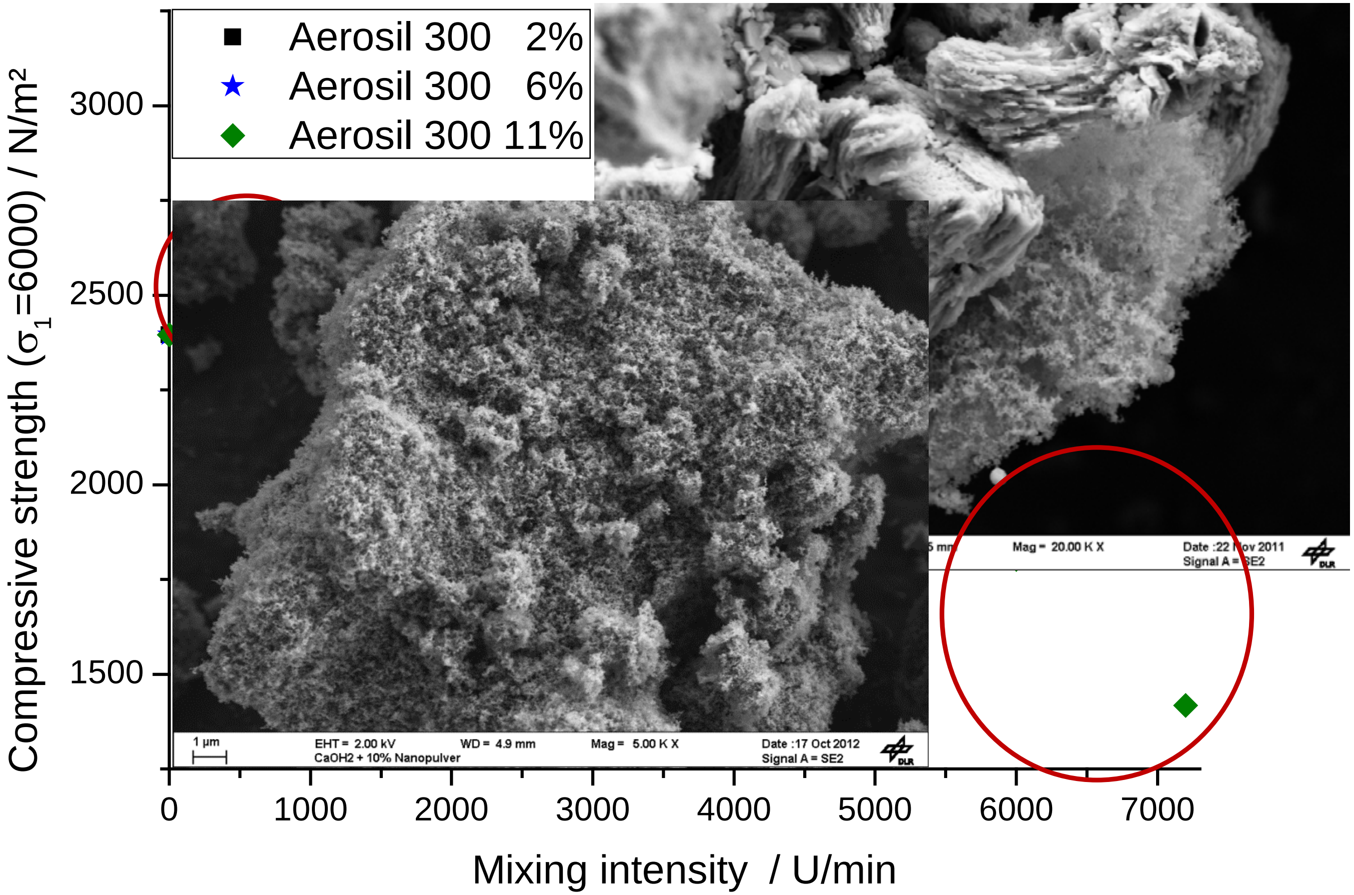
0,5 - 15% Aerosil 300





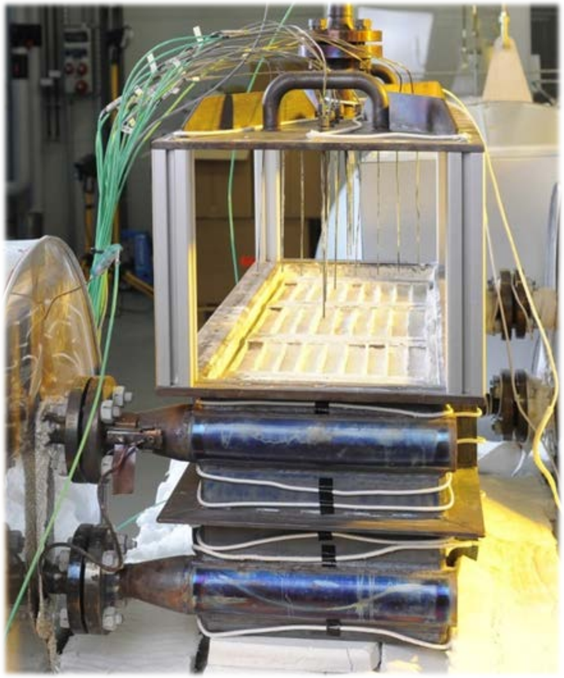
Results of Material Modification

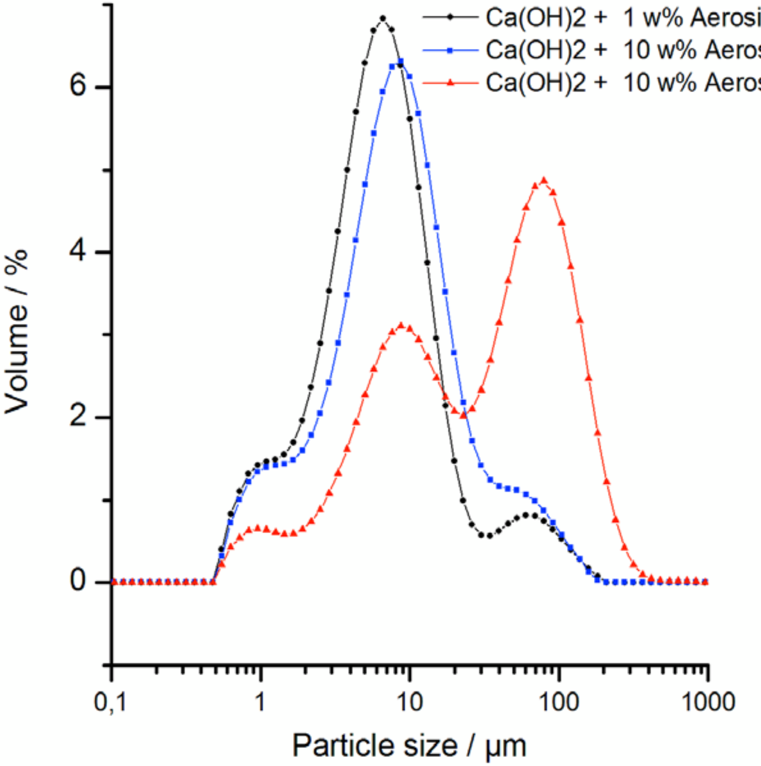
Effects of Variable Power Inputs



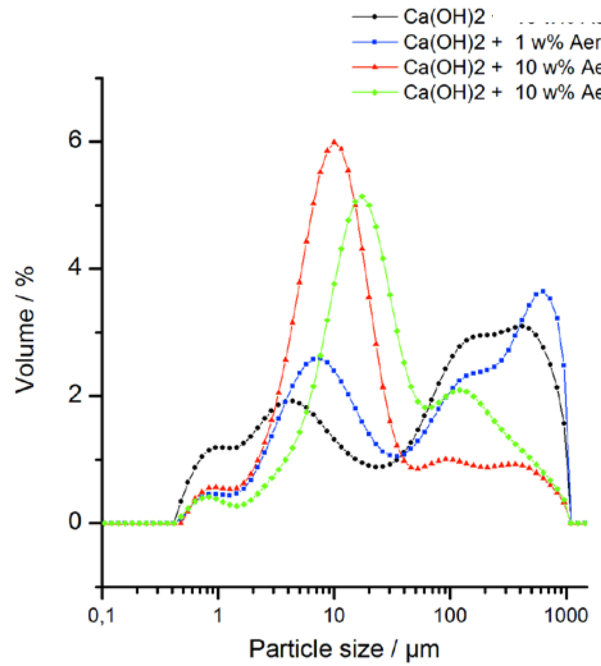
Cycling stability

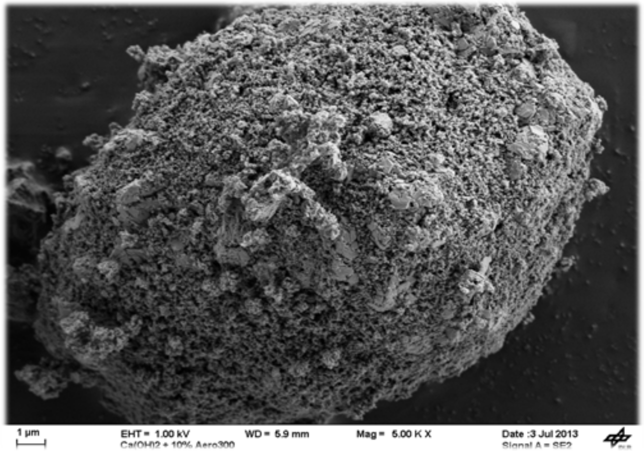
Tests in pilot-scale reactor

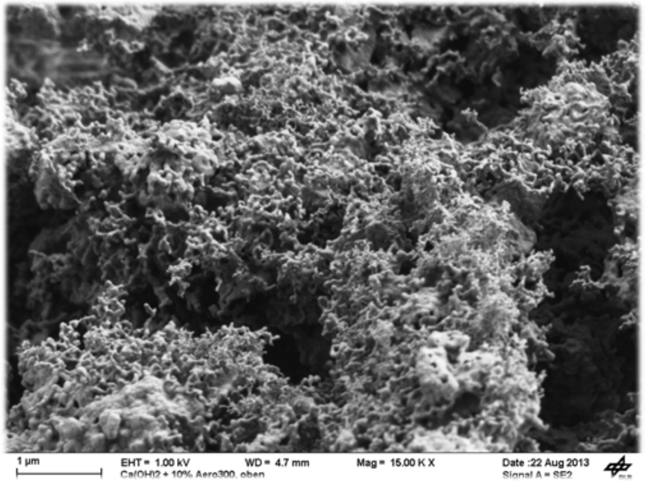




Cycling stability
After Cycling







➔Calcium silicates lead to

- **Reduction of storing capacity**
- **Hardening of surface structure**

Roßkopf et al., *Investigations of Nano Coated CaO/Ca(OH)$_2$ Cycled in Thermochemical Storage*, in preparation

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Conclusion & Outlook

- Thermochemical Heat storage based on $Ca(OH)_2$ demands a flow-through of the reactor
- Improvement of $Ca(OH)_2$ flowability by adding nano particles at ambient conditions is shown
- Homogeneous flow through thermochemical reactor at room temperature achieved
- Cycling stability is proven over 10 cycles in pilot-scale reactor

➔ Flow behaviour during thermochemical reaction will be investigated

Thank you for your attention

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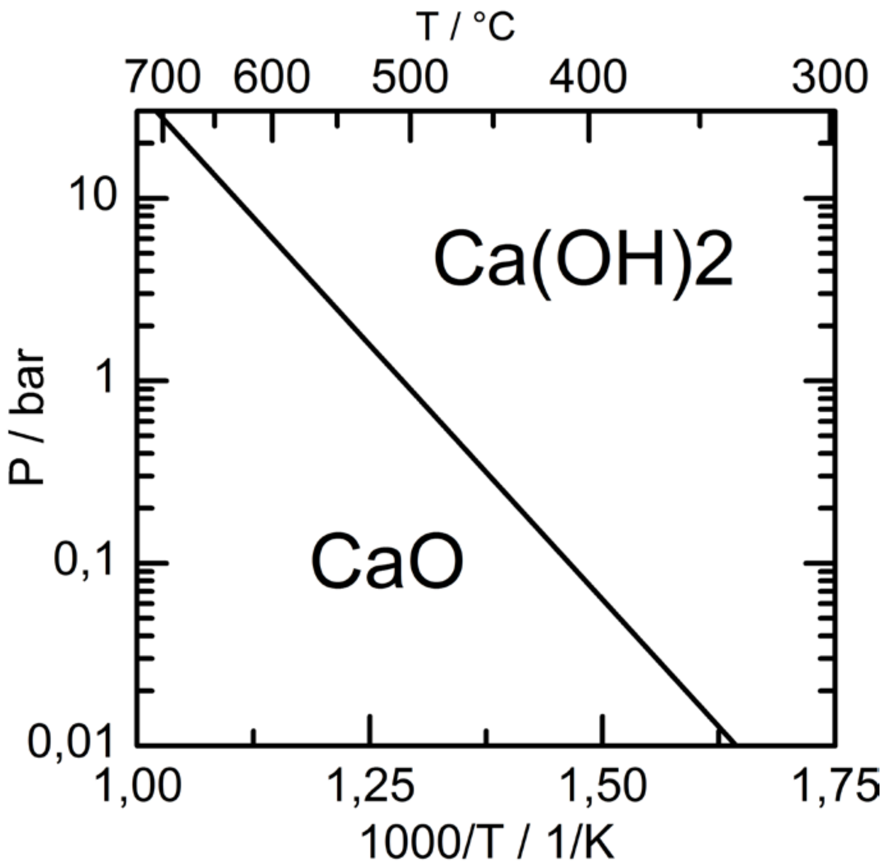
Thermodynamic equilibrium



Storage densities

Typical storage densities in kWh/m³:

- Sensible, mortar, ΔT=50K	25 - 30
- Sensible, Water, ΔT=50K	50
- Latent, solid-liquid	50 - 100
- Physical oder chemical sorption	50 - 140
- Thermochemical reaction	100 – 700

- Storage capacity in 1 kg Ca(OH)2	0,373 Wh
- Storage capacity of pilot-scale reactor	~200 kWh/m³

Particle size
Pelletizing the material

- Increase of weight force by increasing the particles diameter

➔ Problem: Volume change of the material by chemical reaction leads to tensions within the pellet

➔ Cracking of the pellet after few cycles in thermochemical reactor