# Thermochemical Energy Storage for the Seasonal Balance of Surplus Electricity and Heat Demand in Domestic Buildings

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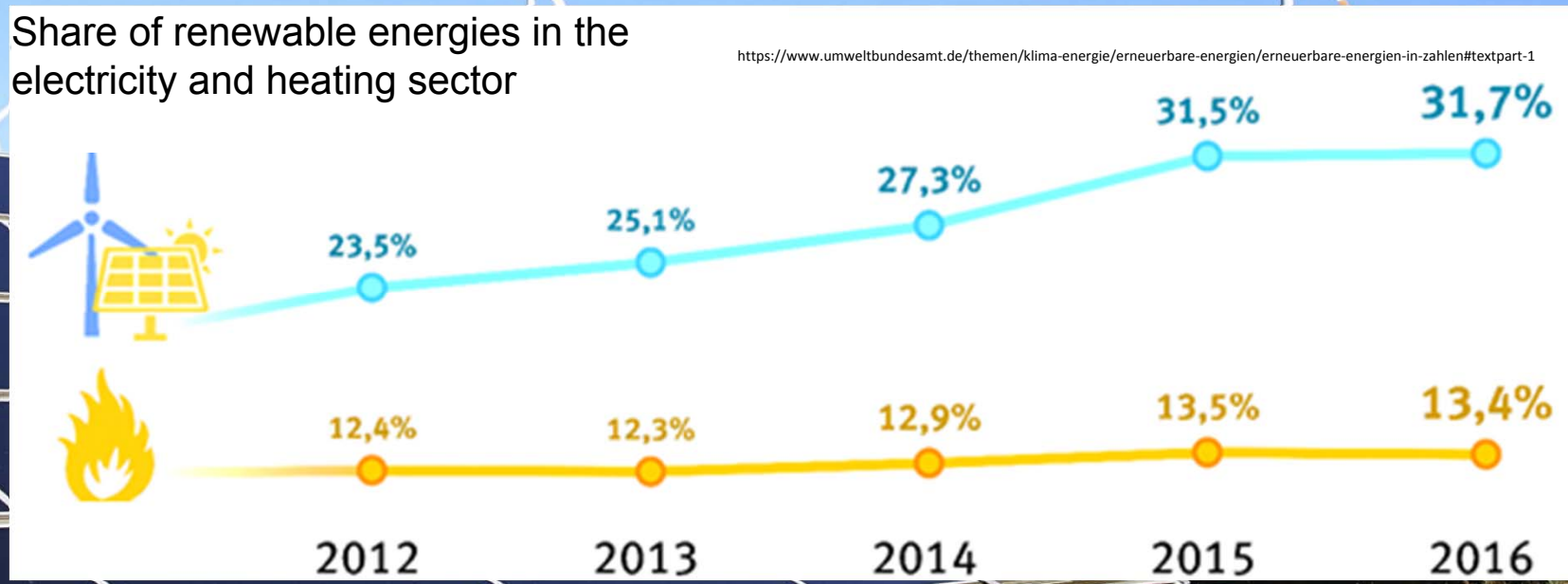
DLR

„The **heat demand** of buildings accounts **for„30 % of the overall yearly $CO_2$ emissions in Germany**“

„German Energy Transition mainly focusses on **renewable electricity** production from **wind + photovoltaic**“



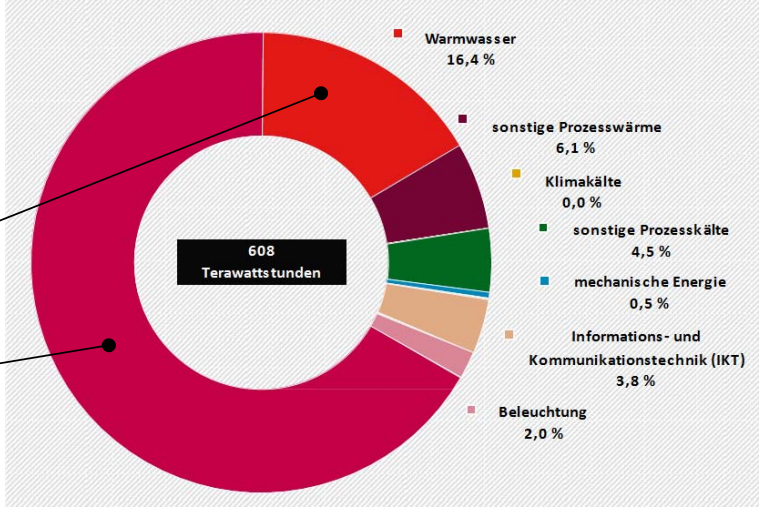
# Balance of supply and demand?

- > 2/3 of end energy consumption in households (germany) is thermal energy :

  ~16 % daily hot water
  ~65 % seasonal (space heating)

- Excess“ electric power: :

  - mostly during the summer period
  - during daytime (low or no demand)



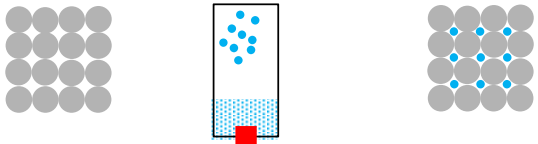


→ Seasonal balance of surplus electricity and heat demand

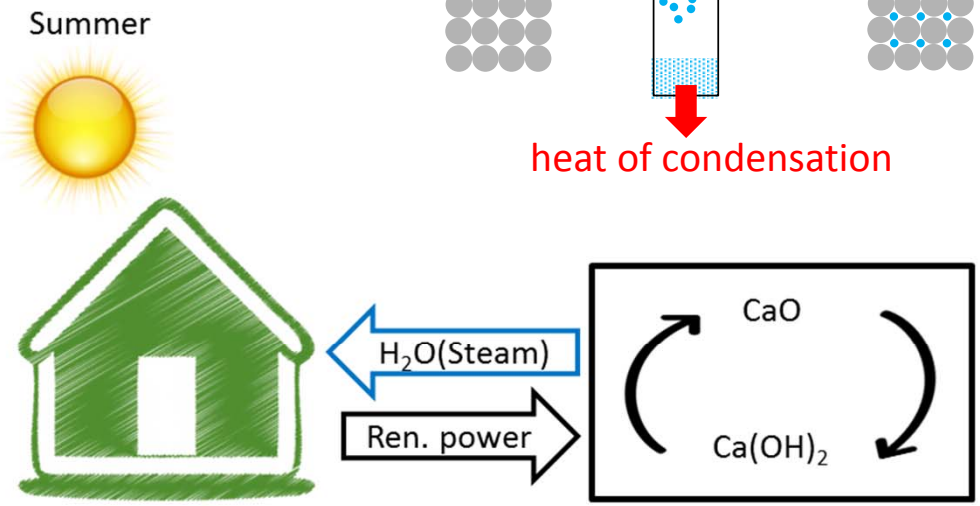
# Thermochemical energy storage with Calcium Hydroxide

Heat

$$CaO_{(s)} + H_2O_{(g)} \rightleftharpoons Ca(OH)_{2(s)} + \Delta H$$

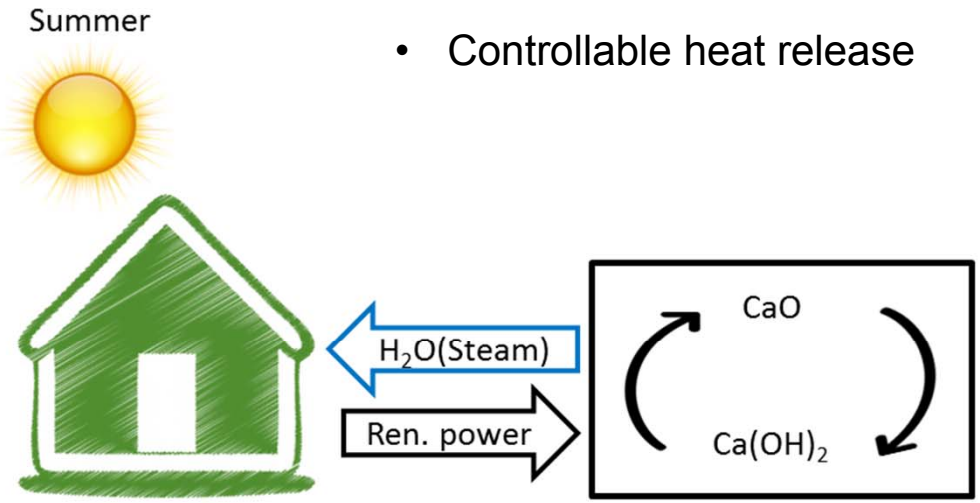


heat of condensation



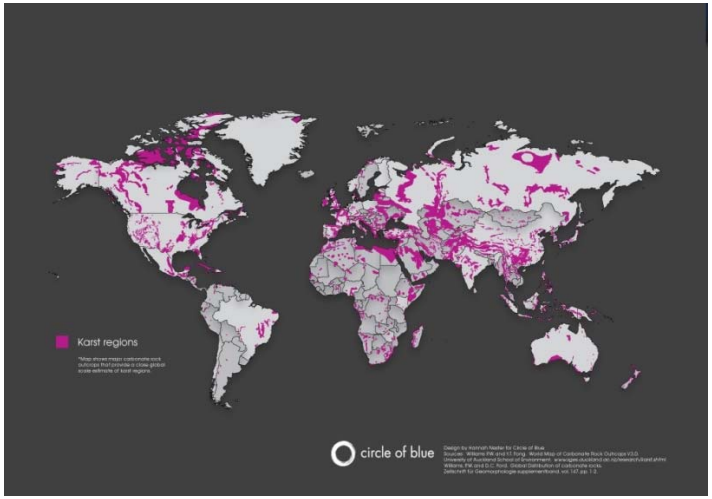
# Thermochemical energy storage with Calcium Hydroxide

- Chemically stored energy is **free of losses**
- High energy storage density **~ 200 kWh/m³**
- Controllable heat release



# Why Calcium Hydroxide (limestone)?

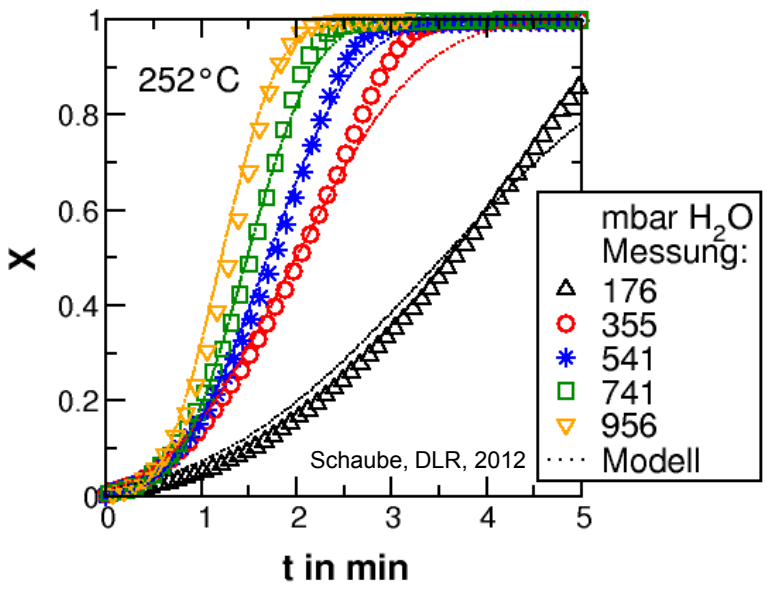
- Worldwide availability
- Cheap raw material – 80 €/t
- Reversible reaction for thousands of cycles



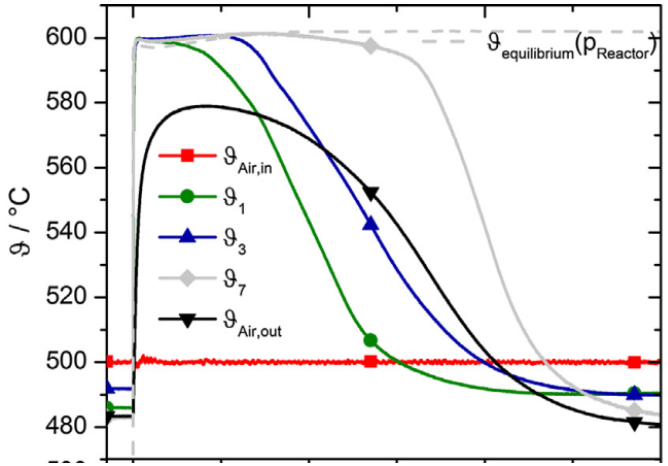

- Enviromentally friendly and nontoxic
- Sustainable recycling

# Material properties

- Fast reaction kinetics - **complete conversion < 5 min.**
- Revesible and cycling stable




- Characterisation of operation modes in lab scale:
  - Discharge with **water vapour from 350 – 600 °C**
  - Discharge with **liquid water up to 200 °C**

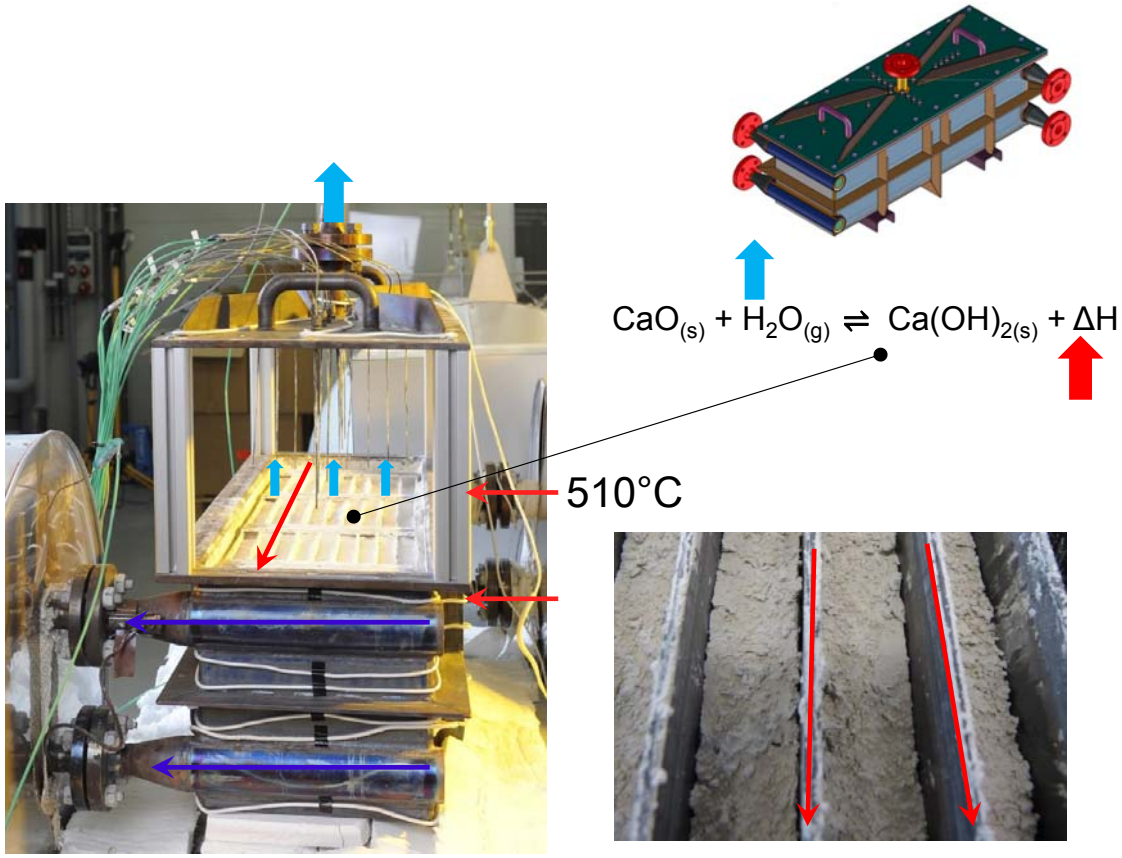



*Schmidt et al. (2017) Power generation based on the Ca(OH) 2 / CaO thermochemical storage system – Experimental investigation of discharge operation modes in lab scale and corresponding conceptual process design; Applied Energy*

# Pilot reactor operation

- Indirectly heated fixed bed:
  - 10 kWh capacity (25 kg)
  - 8 kW thermal power
- Seasonal storage:

→ Large capacity vs. small power




*Schmidt et al. (2014) Experimental results of a 10 kW high temperature thermochemical storage reactor based on calcium hydroxide; Applied Thermal Engineering*

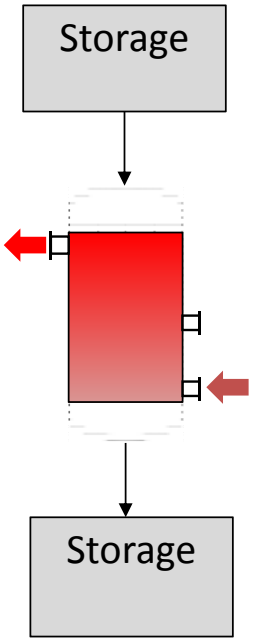
**→ Upscaling economically not viable**

# Operation principle for seasonal storage

- Detachement of power and capacity
- Poor thermal conductivity (~0.1 W/m*K)

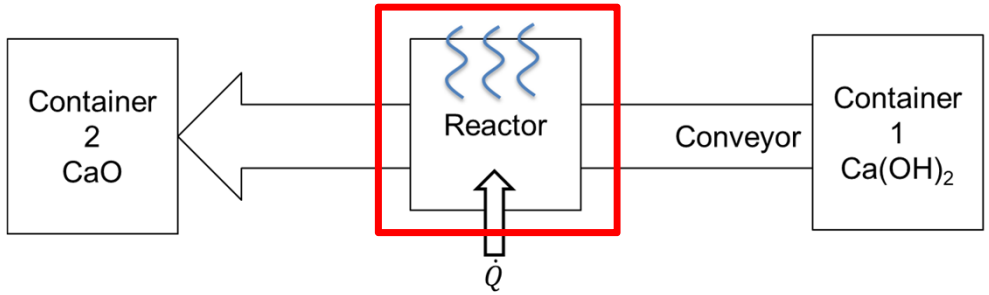
  → narrow heat exchanger geometry
- Fine, porous and adhesive ($d_{50}$ ~ 5 µm)

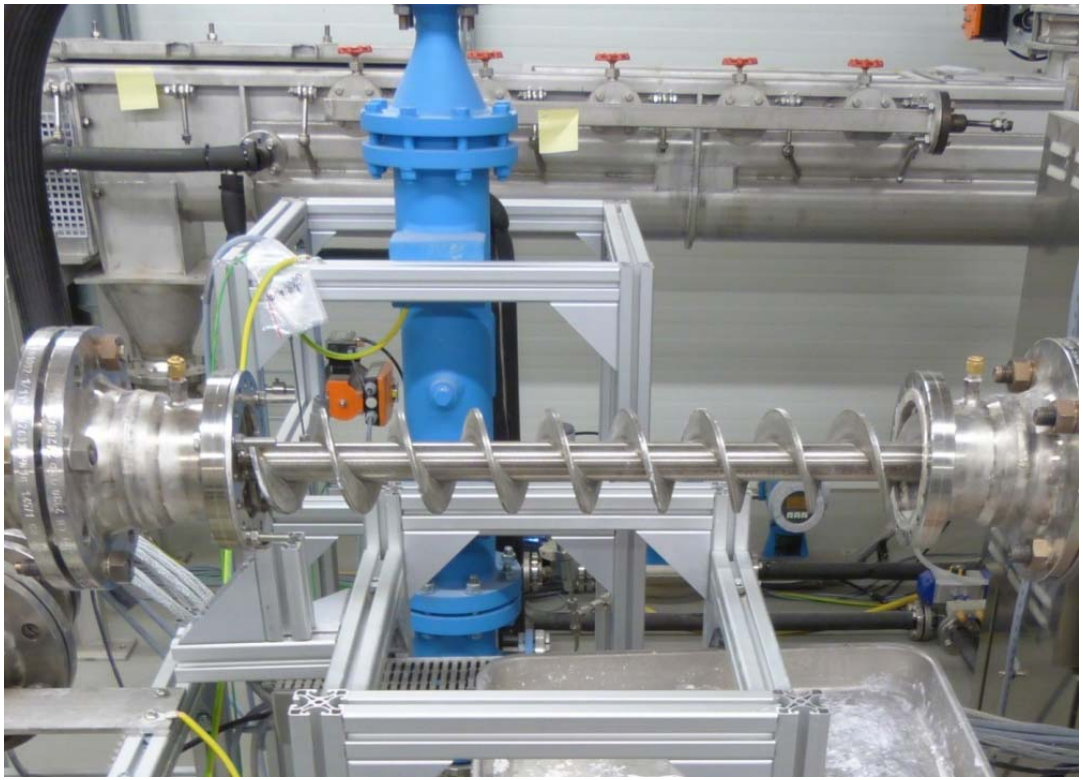
  → poor flowability

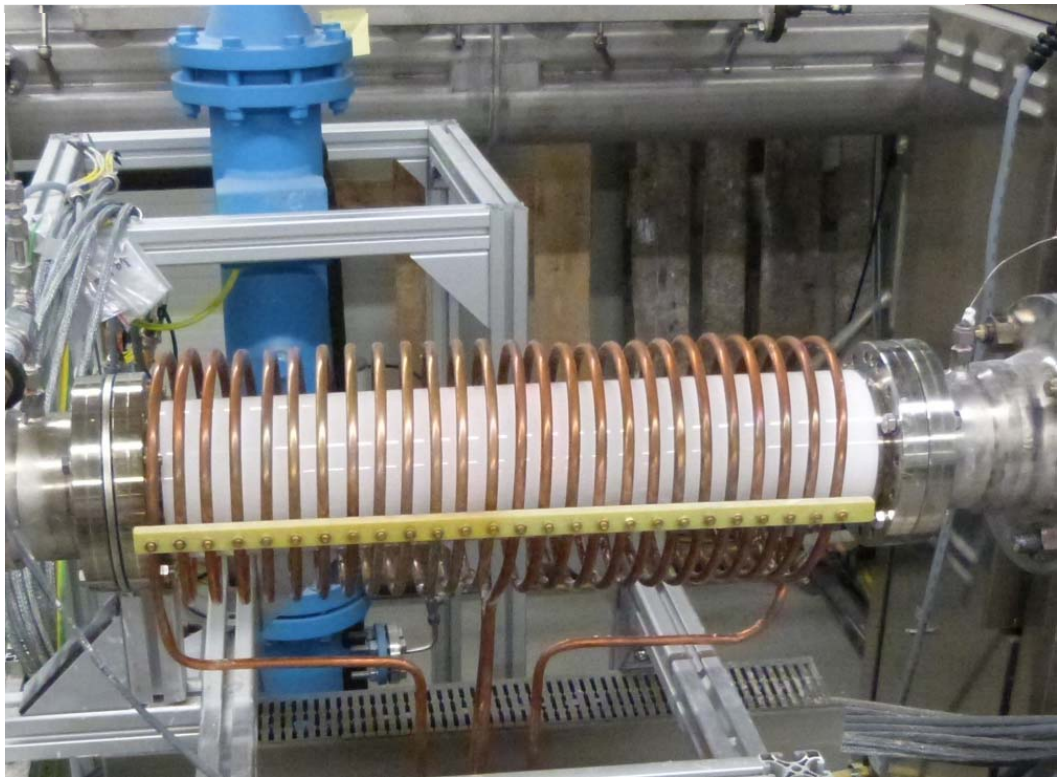



→ Current approaches:
1. Mechanically assisted reactor concept
2. Modification of material

# Approach: heated rotating surface



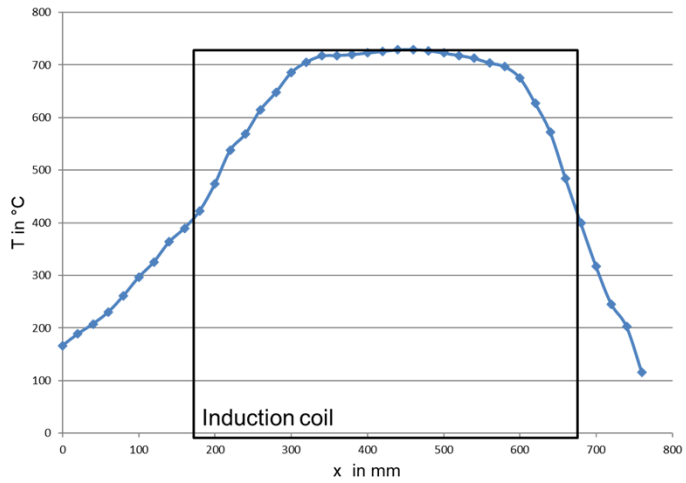





# Multifunctional testbench

# Operation mode & results

- Quasi-continuous conveying
  - Residence time ~2h @ ~700°C



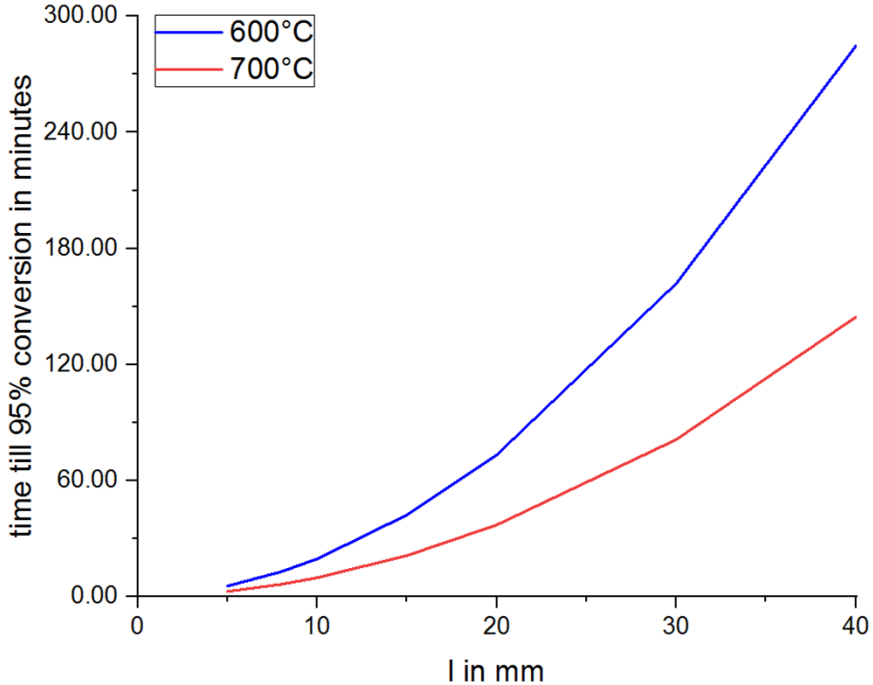

- **Proof of principle**

→ Conversion of about 95%

# Current work

- Optimization problem: transportation vs. heat transfer


http://www.kraemer-kraus.de/english/finned-tubes-heating-systems_spiral-finned-tubes.htm




→ Analysis in a cold flow test set up

# Summary

- Thermochemical reactions are predestined for seasonal storage for 2 reasons:

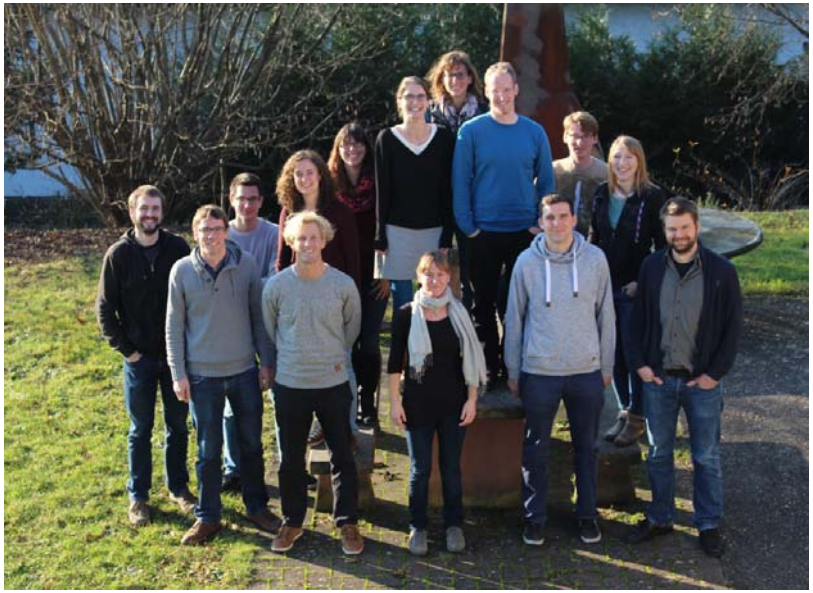
  - Chemically stored potential is **free of losses**
  - Controllable heat release -> **„Heat on demand“**

- Calcium hydroxide (limestone) is an interesting energy storage material:

  - Environmental friendly and nontoxic
  - Abundantly available -> **very cheap**
  - Reaction with water -> easy handling and safe integration in house

- Technology development is challenging mainly due to unfavourable bulk properties:

  - Transport of the material
  - Cost effective and compact reactor designs



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