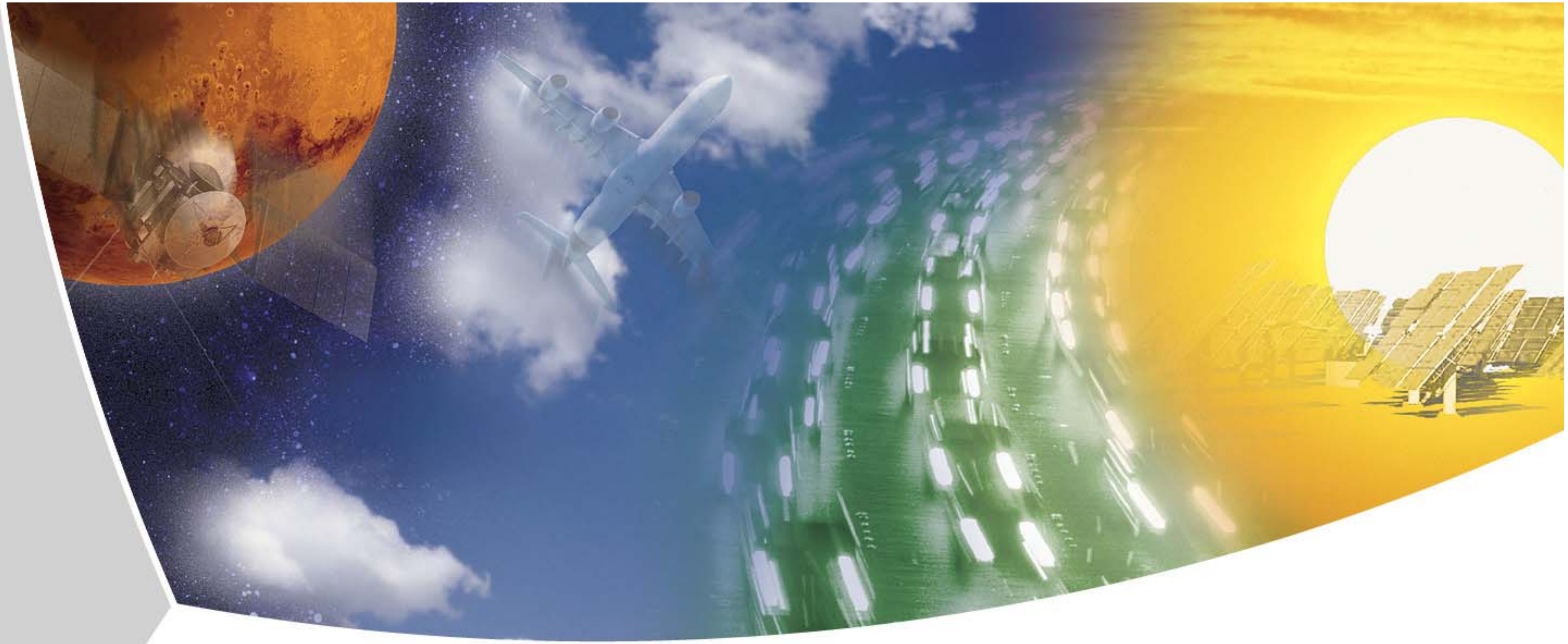
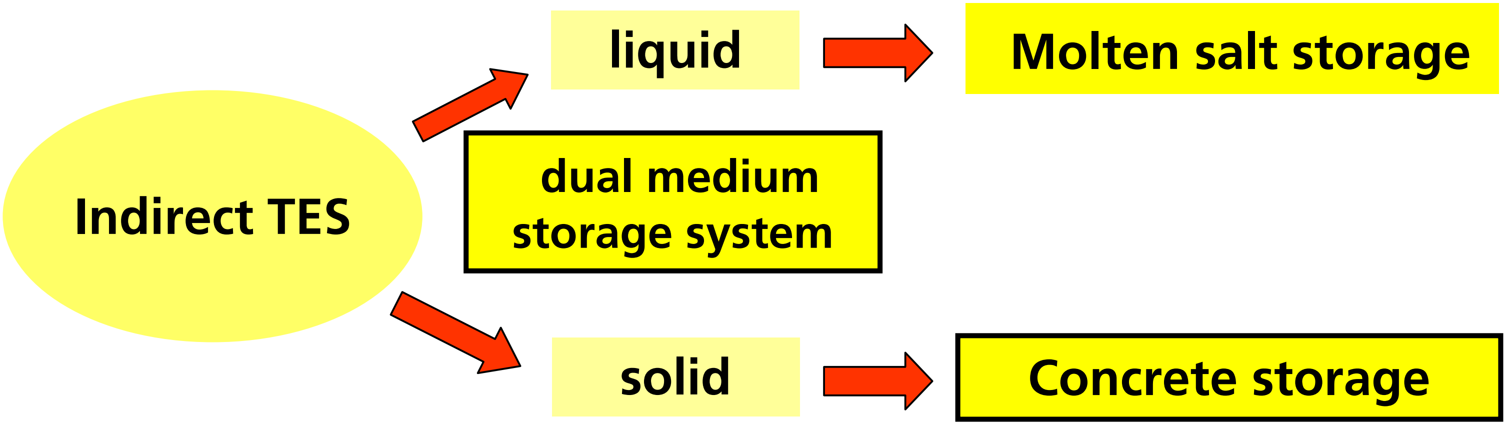


Thermal Energy Storage
Concrete & Phase Change TES

Rainer Tamme

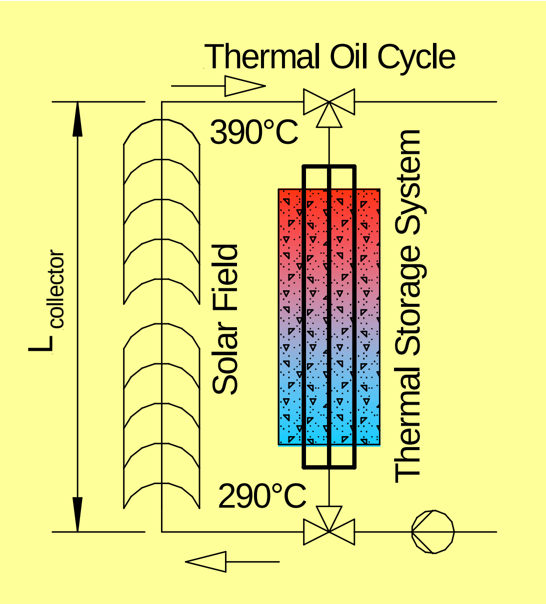
Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

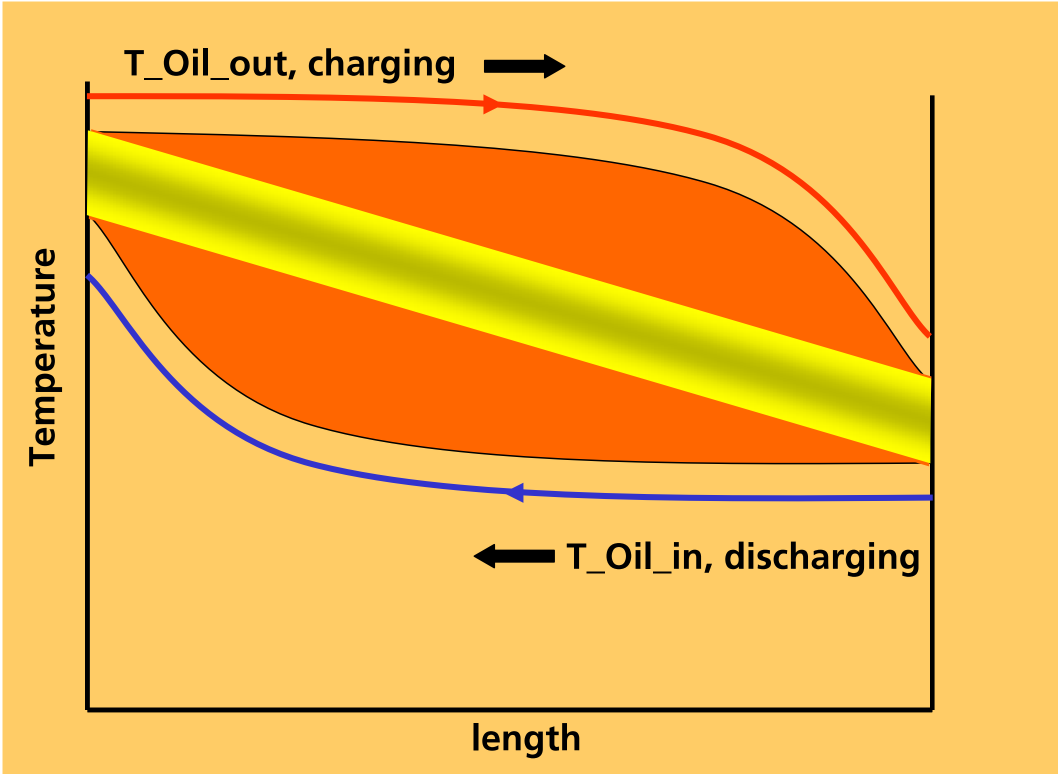
Concrete Storage
Motivation



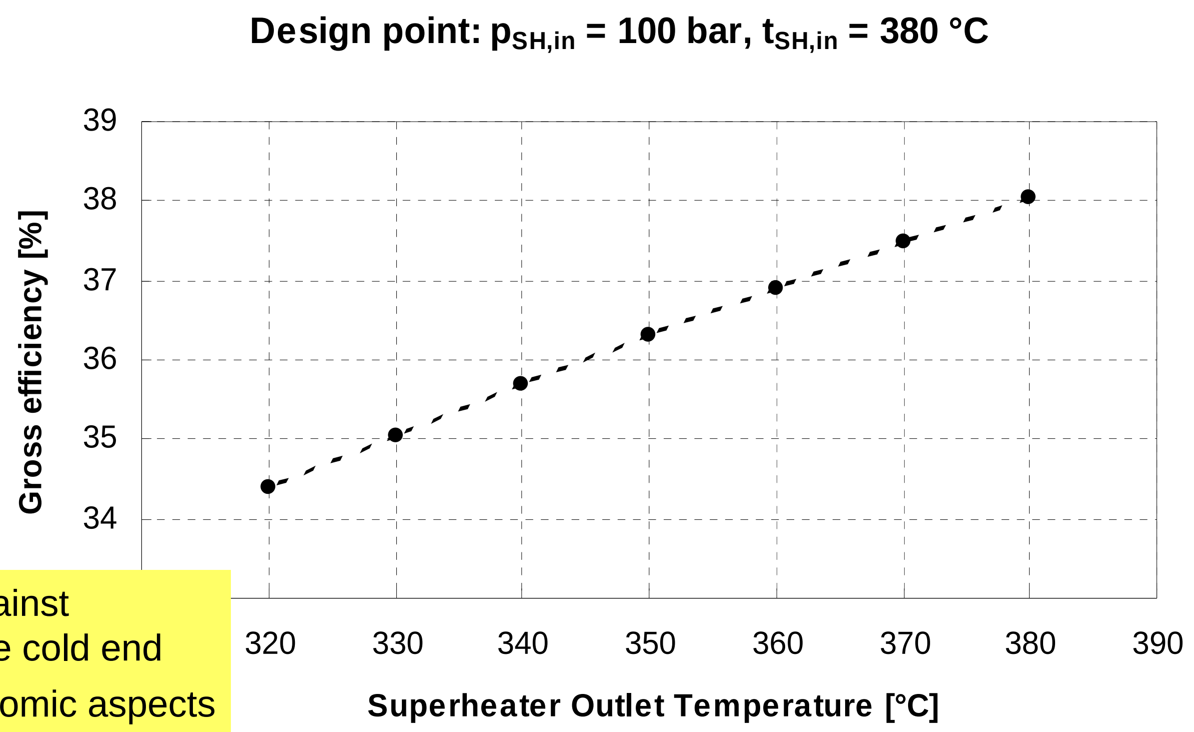
- Economic and reliable TES
- Cost target < 20 € / kWh TES capacity
- modular and scalable design
- flexible to large no. of sites, construction materials and feed stock

Concrete Storage
Basic Considerations of Indirect TES Systems





Basic Considerations
Consequences



- No technical constraints against temperature decrease at the cold end
- Decrease is limited by economic aspects
- Storage integration is a specific issue of indirect TES systems

Concrete Storage
Road Map

Phase 1: 11/2001 – 12/2003
SCIENTIFIC PROJECT
⇨ feasibility demonstration
⇨ contractor DLR, sub-contractor SIEMPELKAMP
⇨ project funded by BMU

Phase 2: 03/2004 – 09/2006
JOINT INDUSTRIAL/SCIENTIFIC RESEARCH PROJECT
⇨ pre-commercial design
⇨ contractors DLR, ZUEBLIN, FLAGSOL
⇨ project funded by BMU

Phase 3: 2007 – 2008
upcsaling and plant integration

Phase 4: > 2008
pilot storage – commercial supplier

ZÜBLIN

Results Phase 1

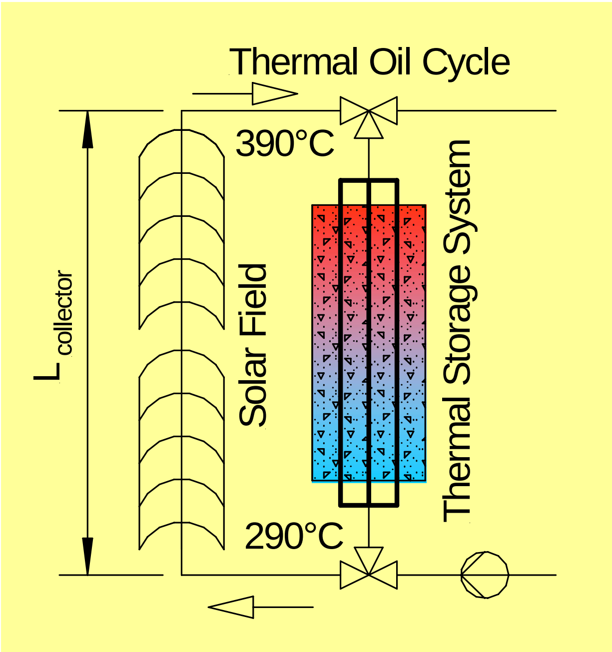
- Feasibility of Solid Media TES Storage Concept successfully demonstrated
- Concrete preferred against castable ceramic
- Cost goal 20 €/kWh capacity can be achieved
- Cost are dominated by the heat exchanger

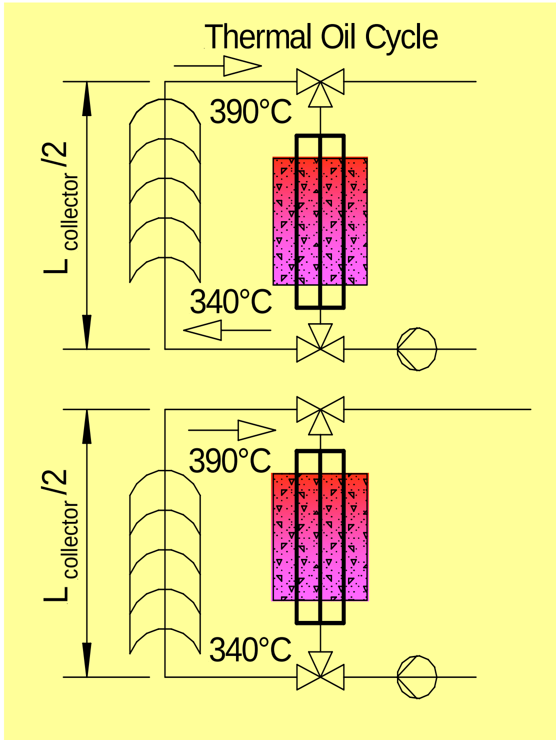
Objectives Phase 2
03/2004 – 09/2006

- to investigate long term behavior of the concrete module
- to develop commercial design
- to investigate approaches for cost reduction
- to identify optimized storage integration and operation strategies

DLR	ZUEBLIN	FLAGSOL
Thermal engineering	Storage material	Storage requirement specification
Design model validation	Commercial design	
Storage integration strategies	Storage module manufacturing	Assessment of operation and plant integration strategies
Testing		

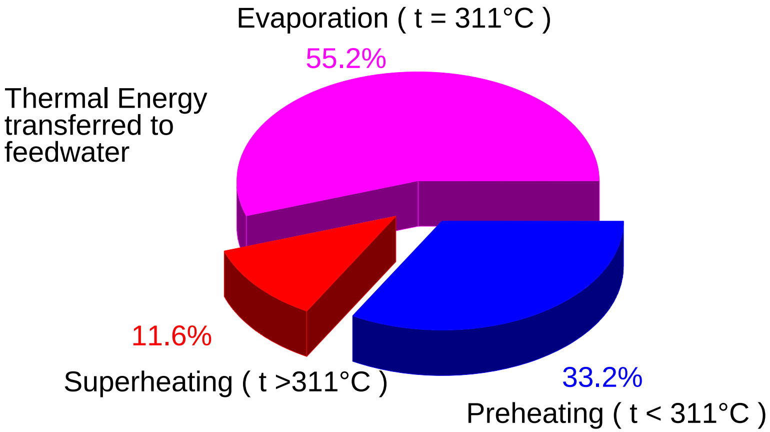
Storage Integration
options for modular charging and discharging operation

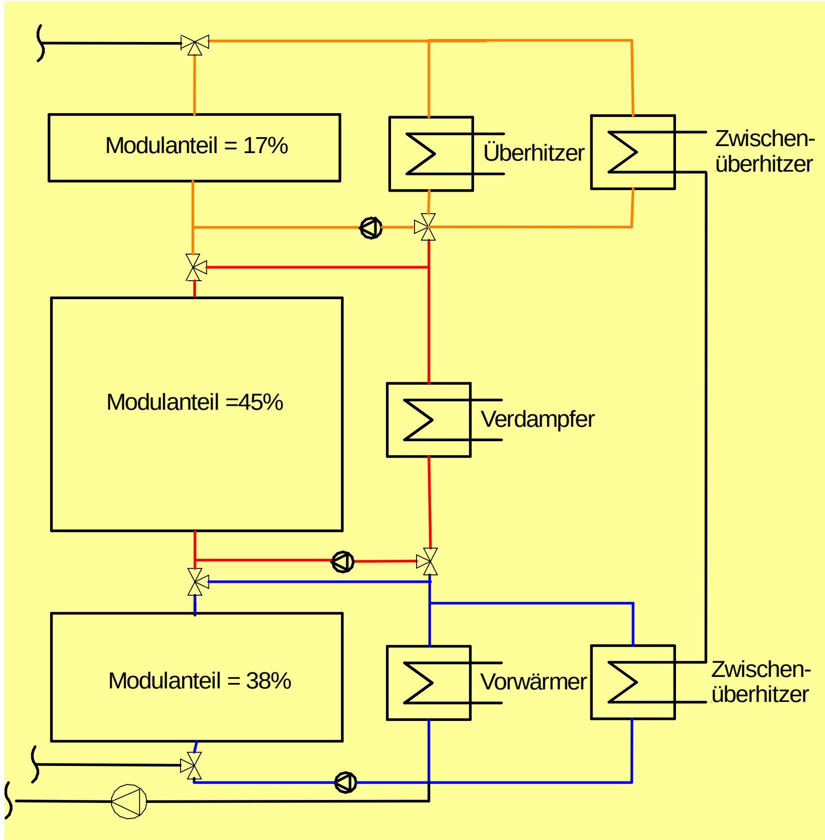




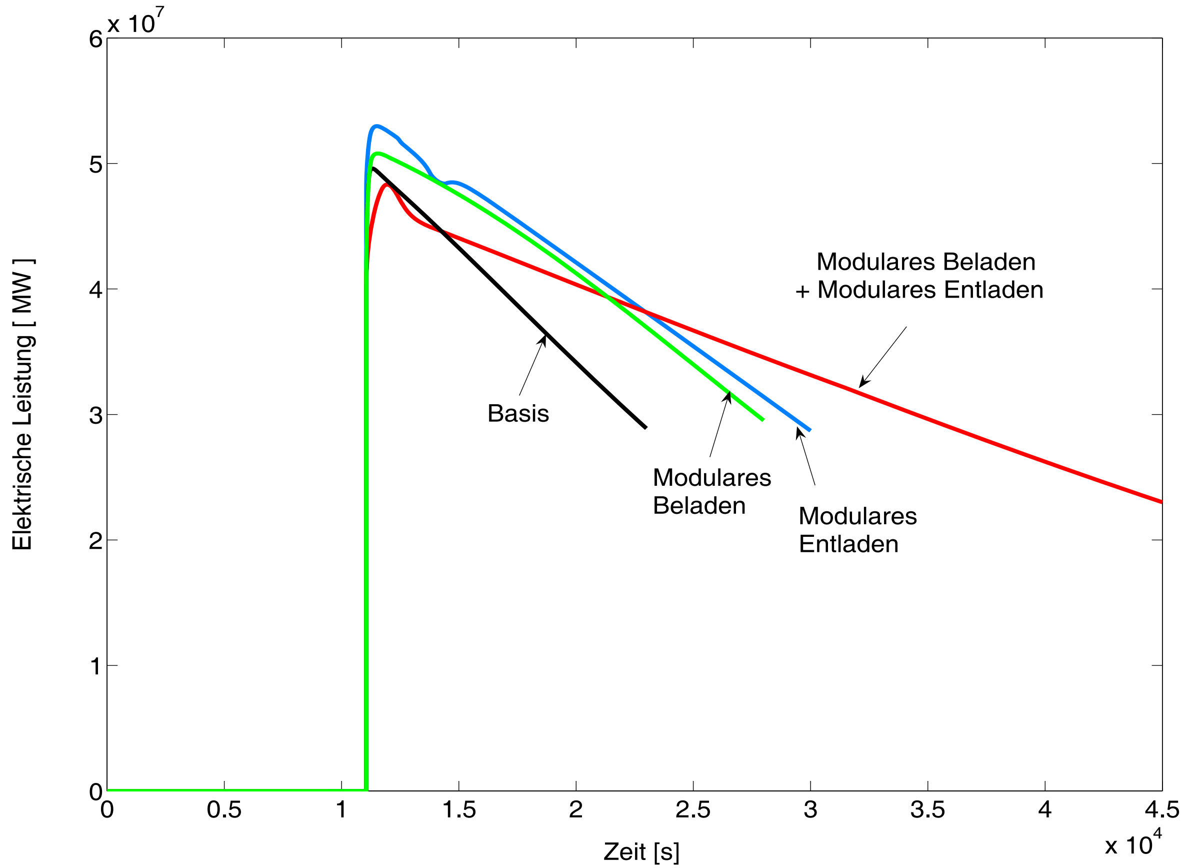
Storage Integration

options for modular charging and discharging operation



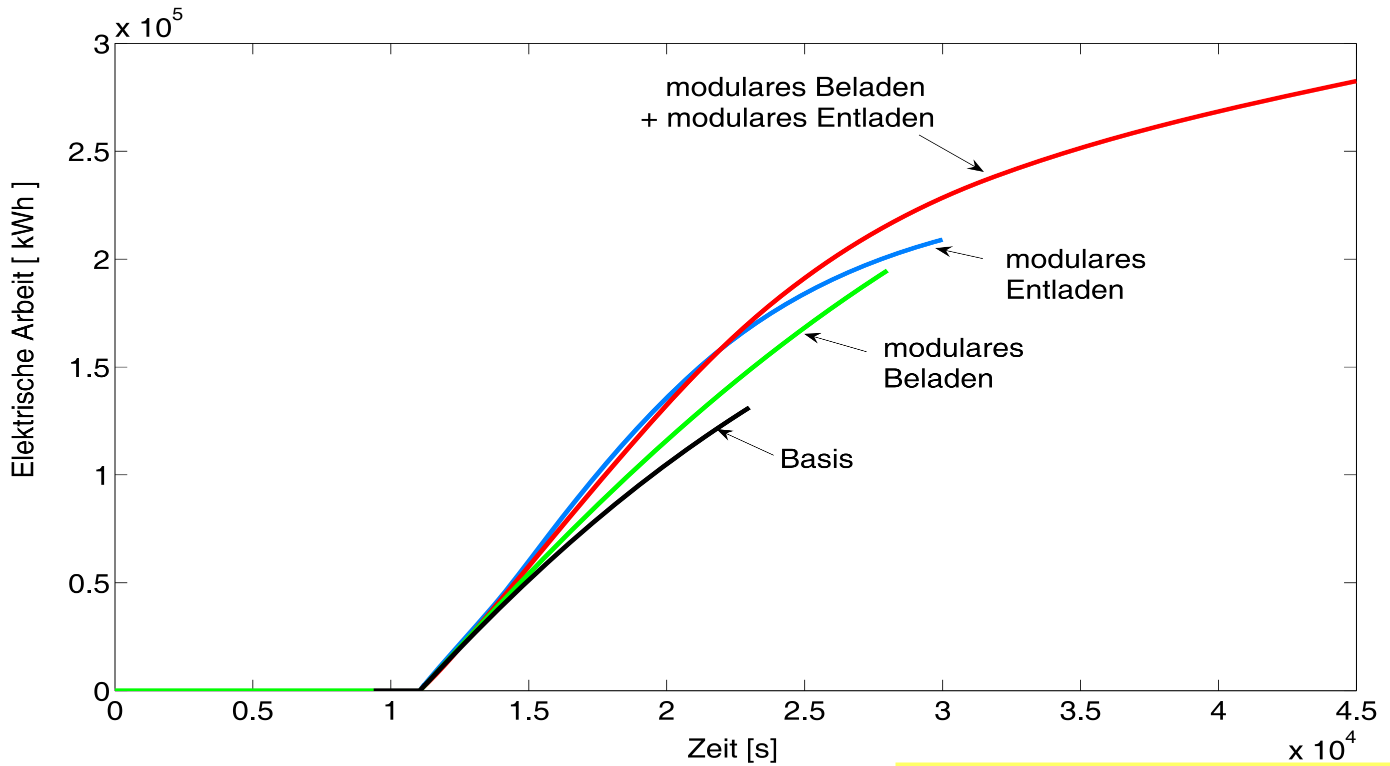


Modular charging and discharging
gain in power output capacity



Modular charging and discharging

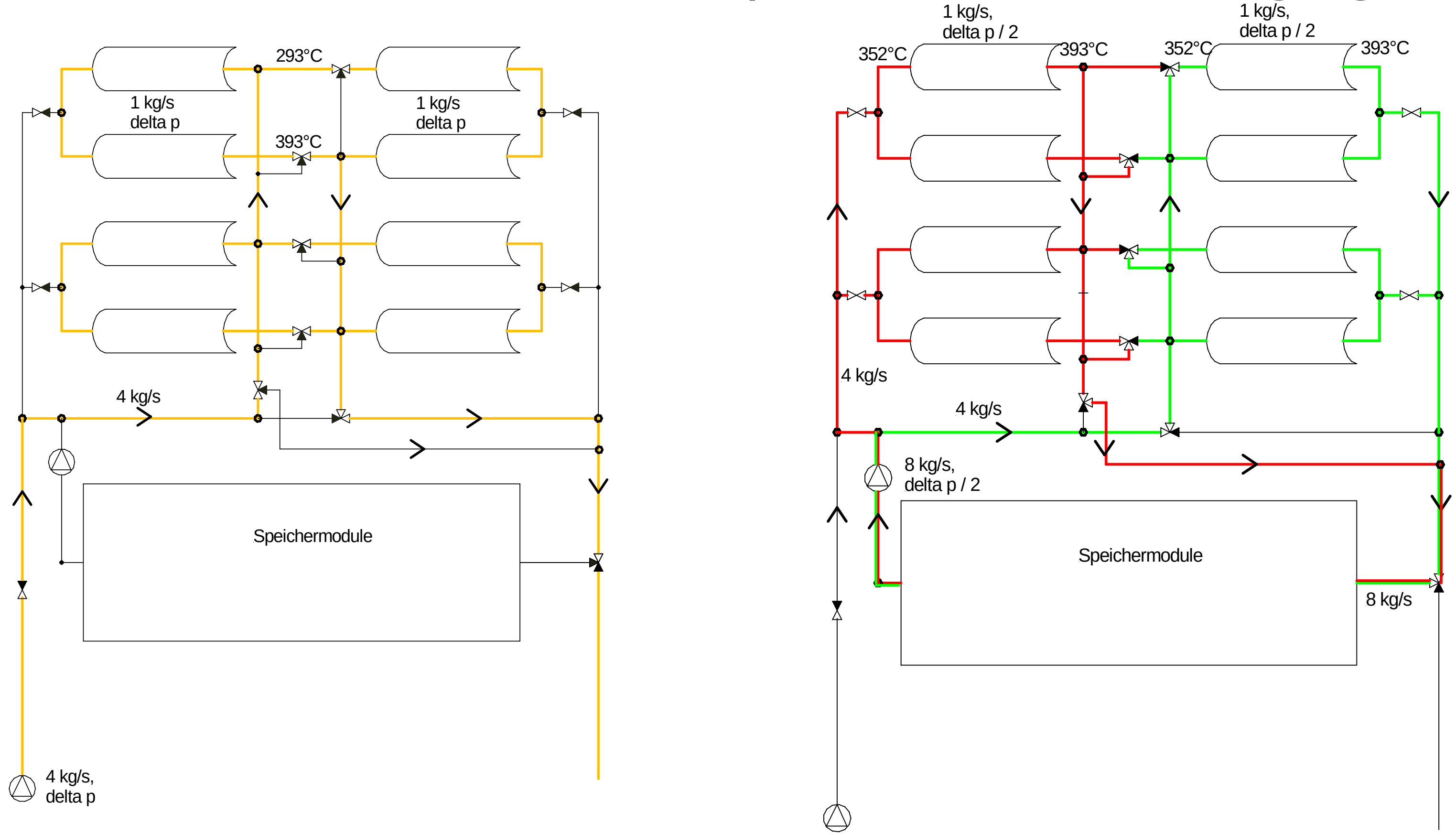
gain in capacity



base case	**100%**
modular charging	**148%**
modular discharge	**159%**
modular charge/Discharge	**215%**

Modular charging and discharging

more effort in BOP – Example 2 modules charging



Economic assessment currently performed by FLAGSOL

Approaches for Cost Reduction

Metallic tubular heat exchanger covers 65-75 % of total cost

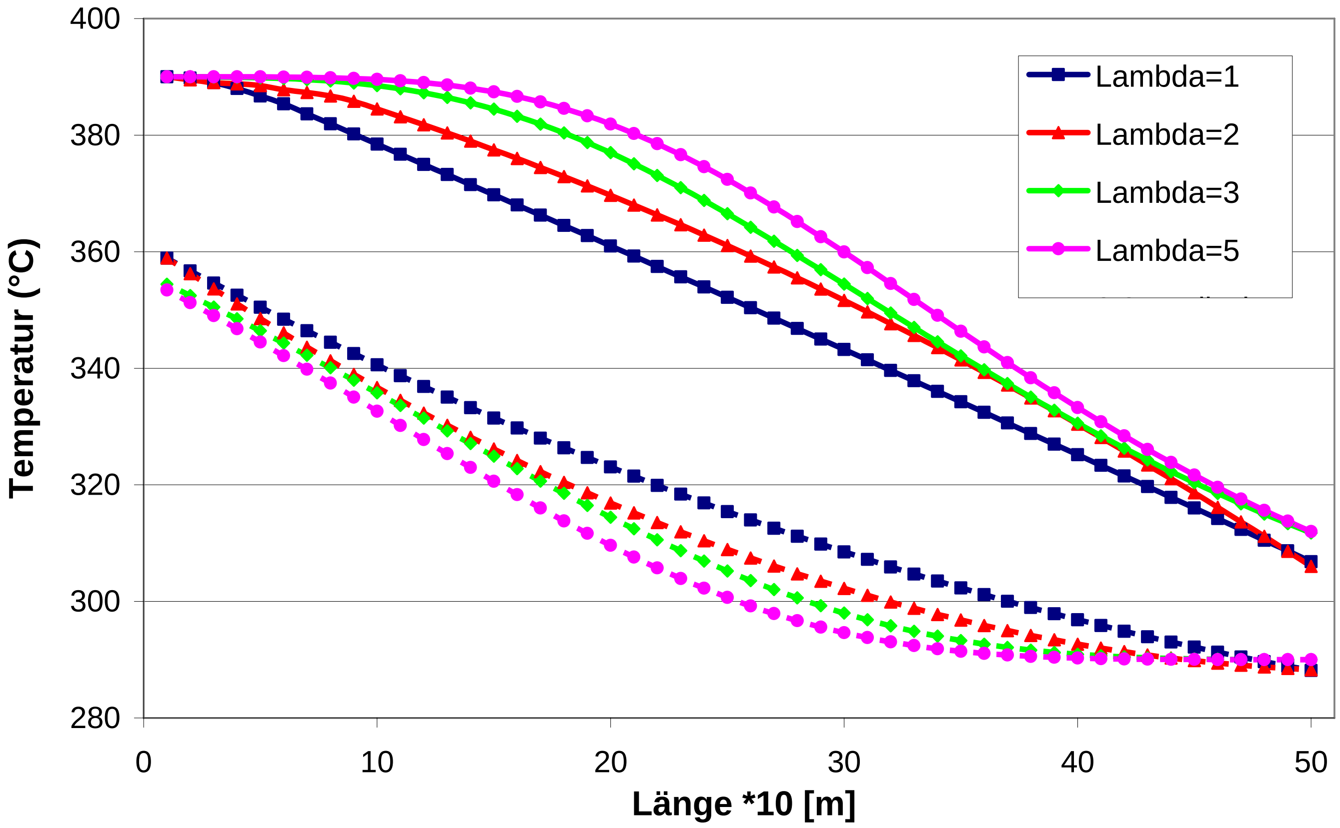
Assessment of alternative design concepts to reduce No. of tubes

Development of modified concrete with improved properties

Approaches for Cost Reduction
Improved storage materials

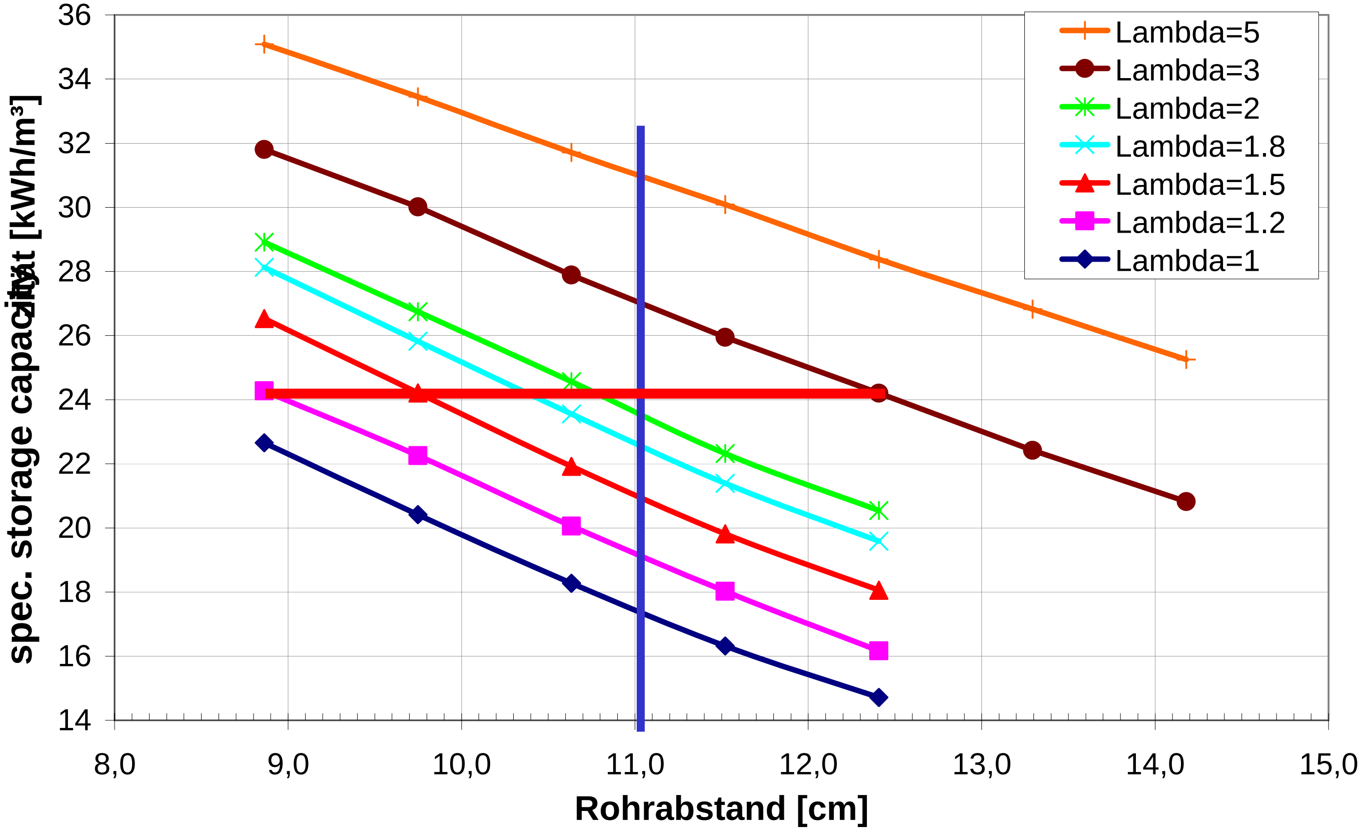
Key issue

Thermal conductivity of the storage material



Example:
Average material temperature for different heat conductivity
(tube distance 10 cm)

Influence of Heat Conductivity

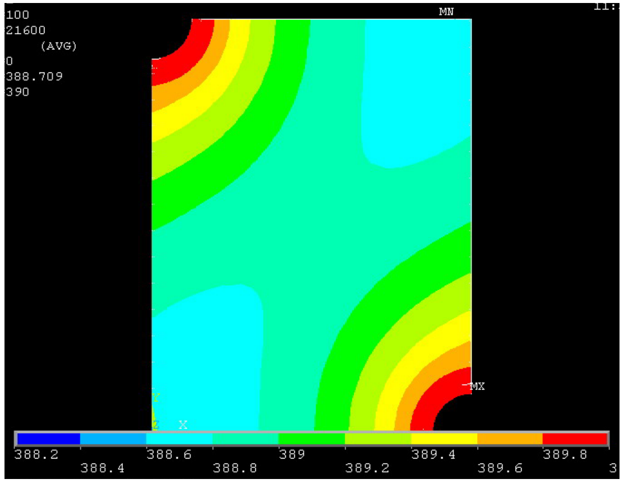


Influence of heat conductivity and tube distance on the spec. storage capacity

Improvement of concrete storage material
testing of concrete modifications

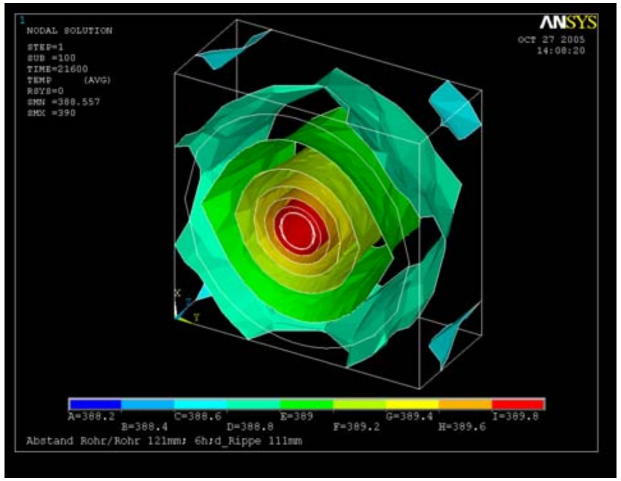
Improving Heat Conductivity
fins and reinforcement mesh

temperature profile 6 h
steel fin



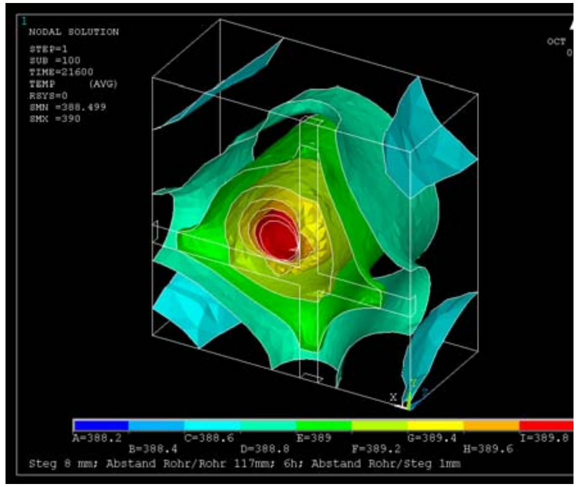
1mm fins
segment 110mm x 85mm

temperature profile 6 h
circular fin



ø 111mm, s=1mm
front view

temperature profile 6 h
reinforcement mesh



mesh dimension 8mm
front view

Economic assessment performed by ZÜBLIN

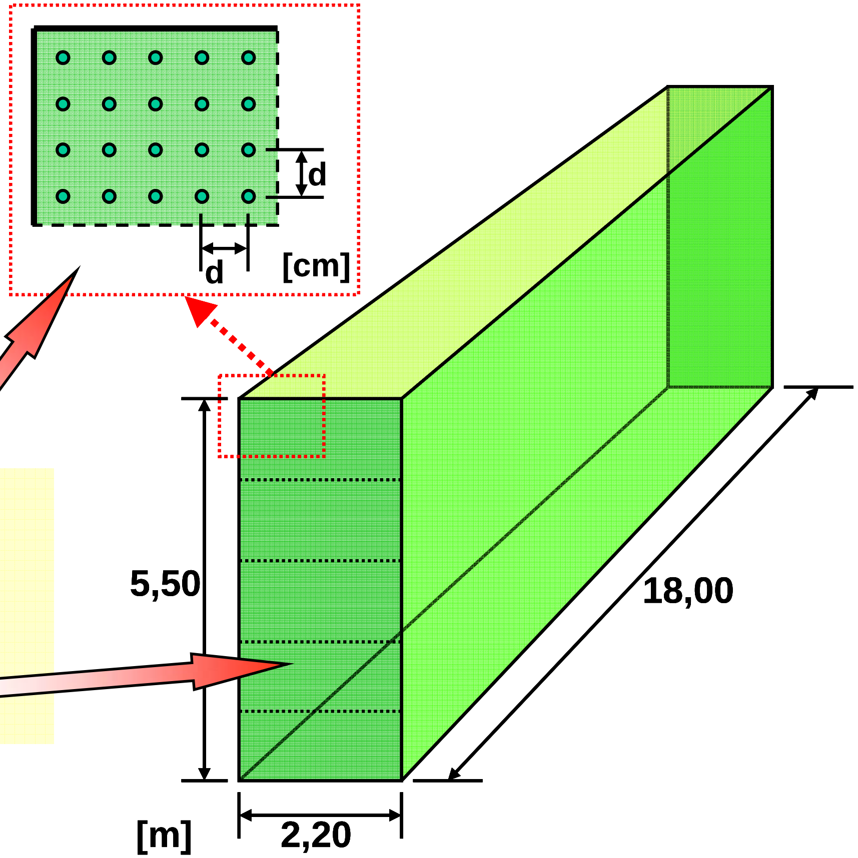
Pre-commercial design
Basic Concrete Module

ZÜBLIN

Basis Module 5,5m x 2,2m x 18m
5 tubular heat exchanger elements
1,1m x 2,2m x 18m
Volume 218 m³
Mass 545 t
Storage capacity ~ 5 MWh_{th}

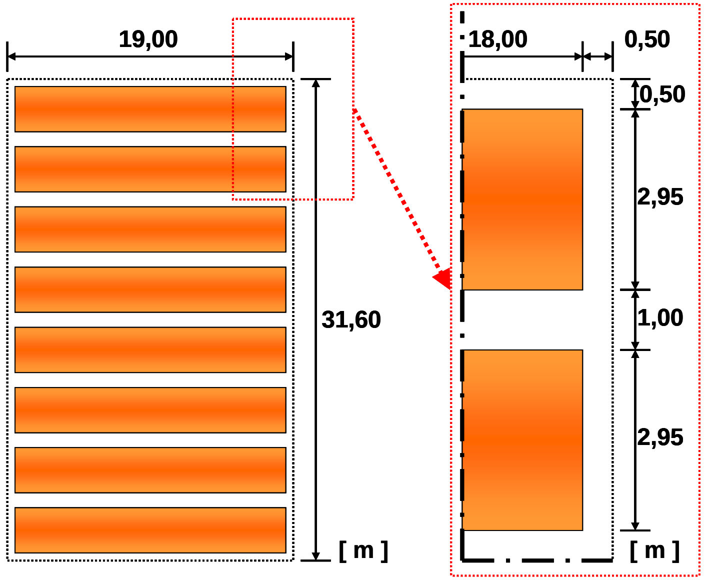
Main knowledge

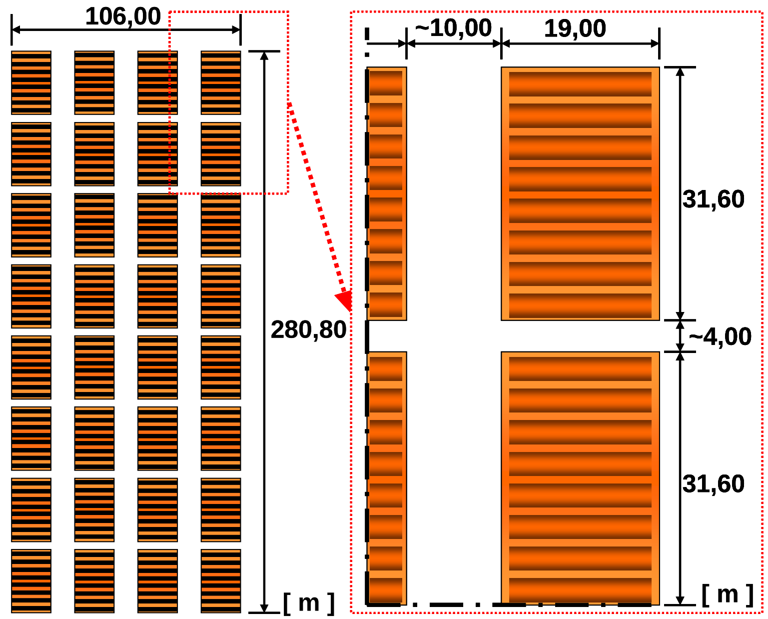
- Detailed design
- Concrete material



Pre-commercial design
Total storage plant with 32 Blocks

ZÜBLIN





<u>TES block of 8 modules</u>
Parallel HTF flow
Headers,welding outside of concrete
Access for maintenance and inspection

Conceptual layout of 6h concrete TES for 50 MW plant

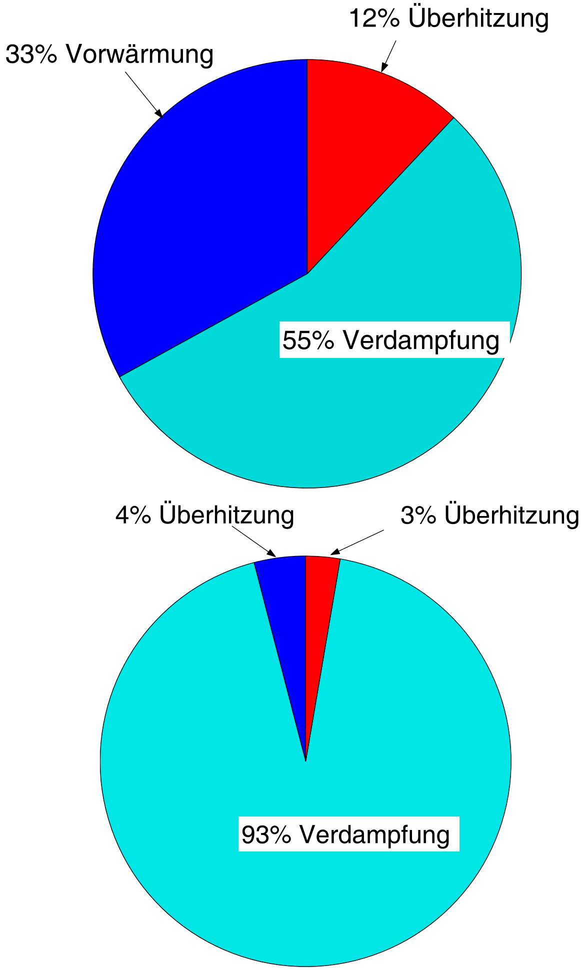
Current Activities Phase 2 JOINT INDUSTRIAL/SCIENTIFIC RESEARCH PROJECT

- Assessment of heat exchanger design variations (March 2006)
- Test storage construction derived from the basic TES element (June 2006)
- Storage testing (second half 2006)
- Assessment of concrete TES plant integration and operation strategies

Phase Change TES
Motivation

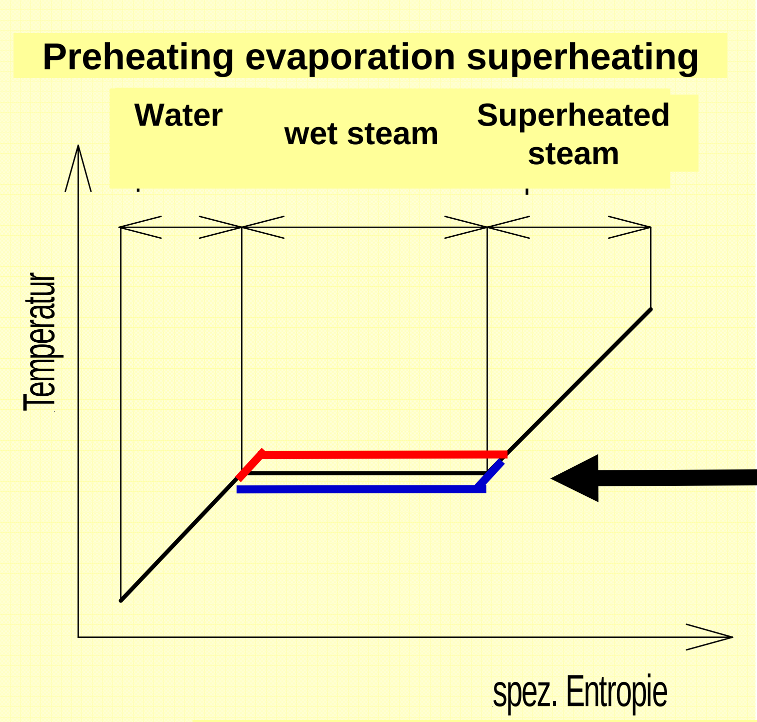
TES development for through plants with direct steam generation

TES development for waste steam recovery and process steam generation

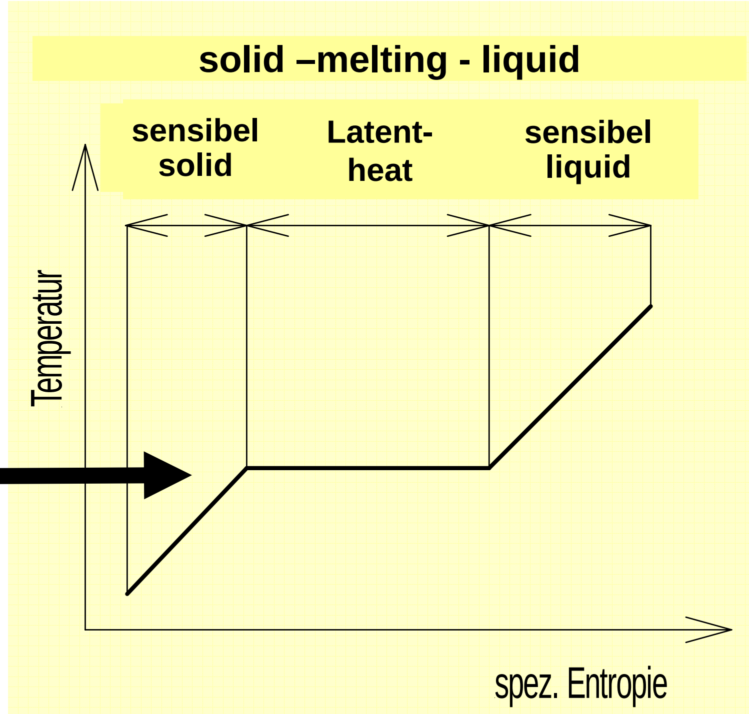


Correlation Storage Medium/Working Fluid

T profile for HTF water/steam

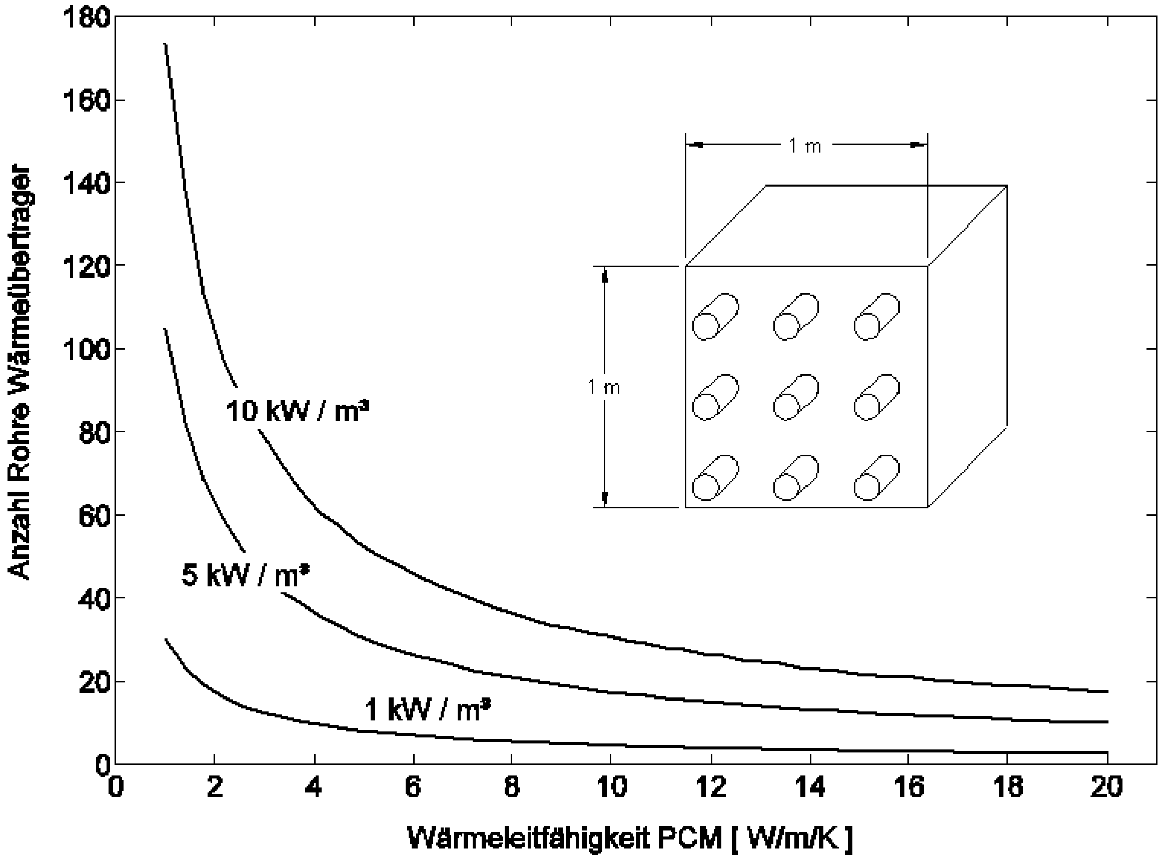


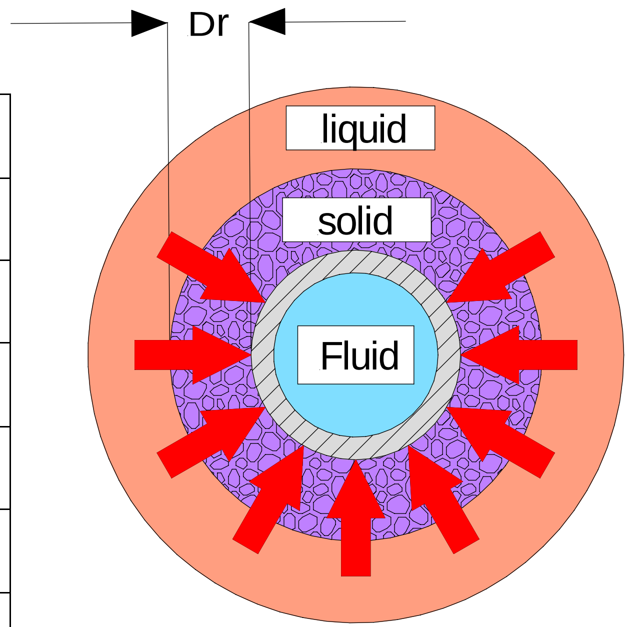
T profile for solid/liquid PCM



significant advantage of PCM storage
due to constant temperature during steam generation

Bottle neck Heat Transfer

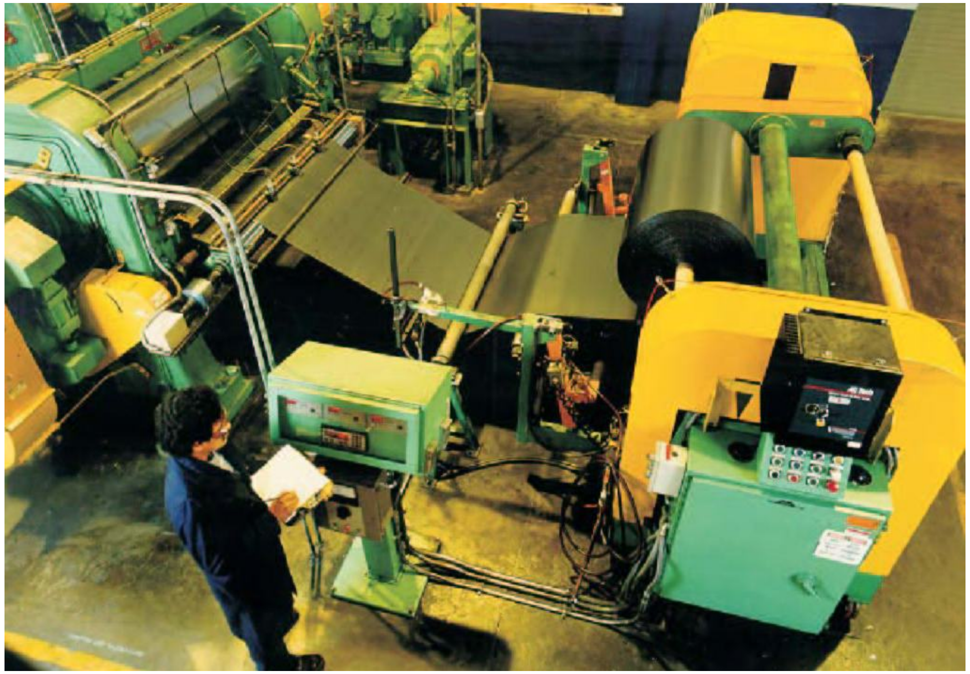


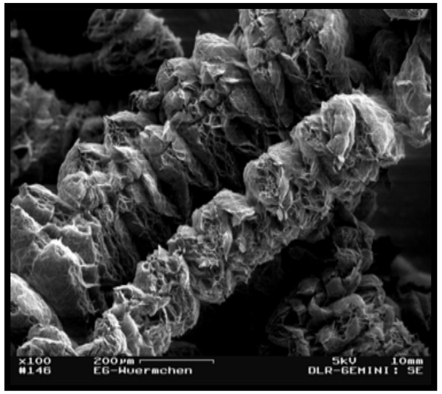


Heat transfer controlled by thermal conductivity

Materialkonzept PCM/Graphit

SGL CARBON GROUP

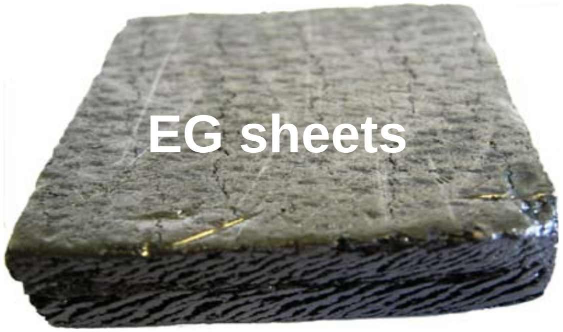


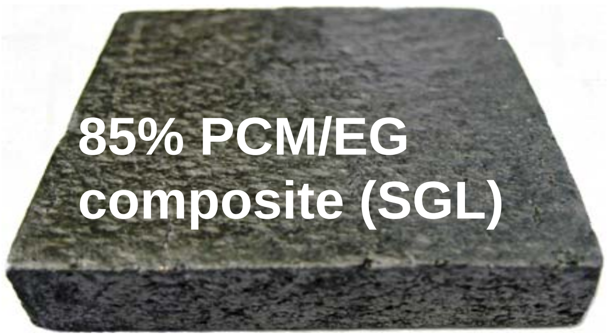


Manufacturing Routes

SGL CARBON GROUP

- Infiltration
- cold compression
- hot compression

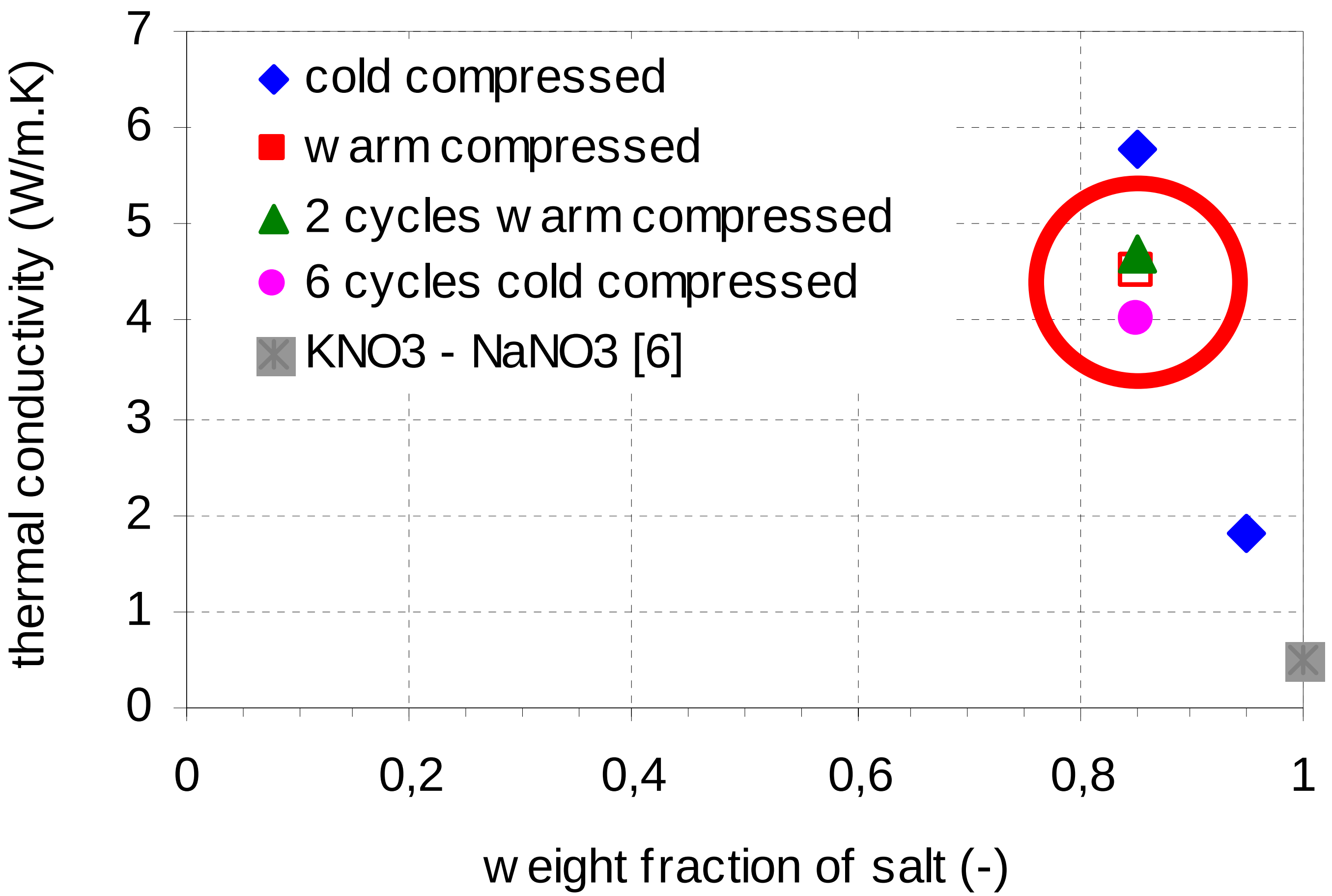




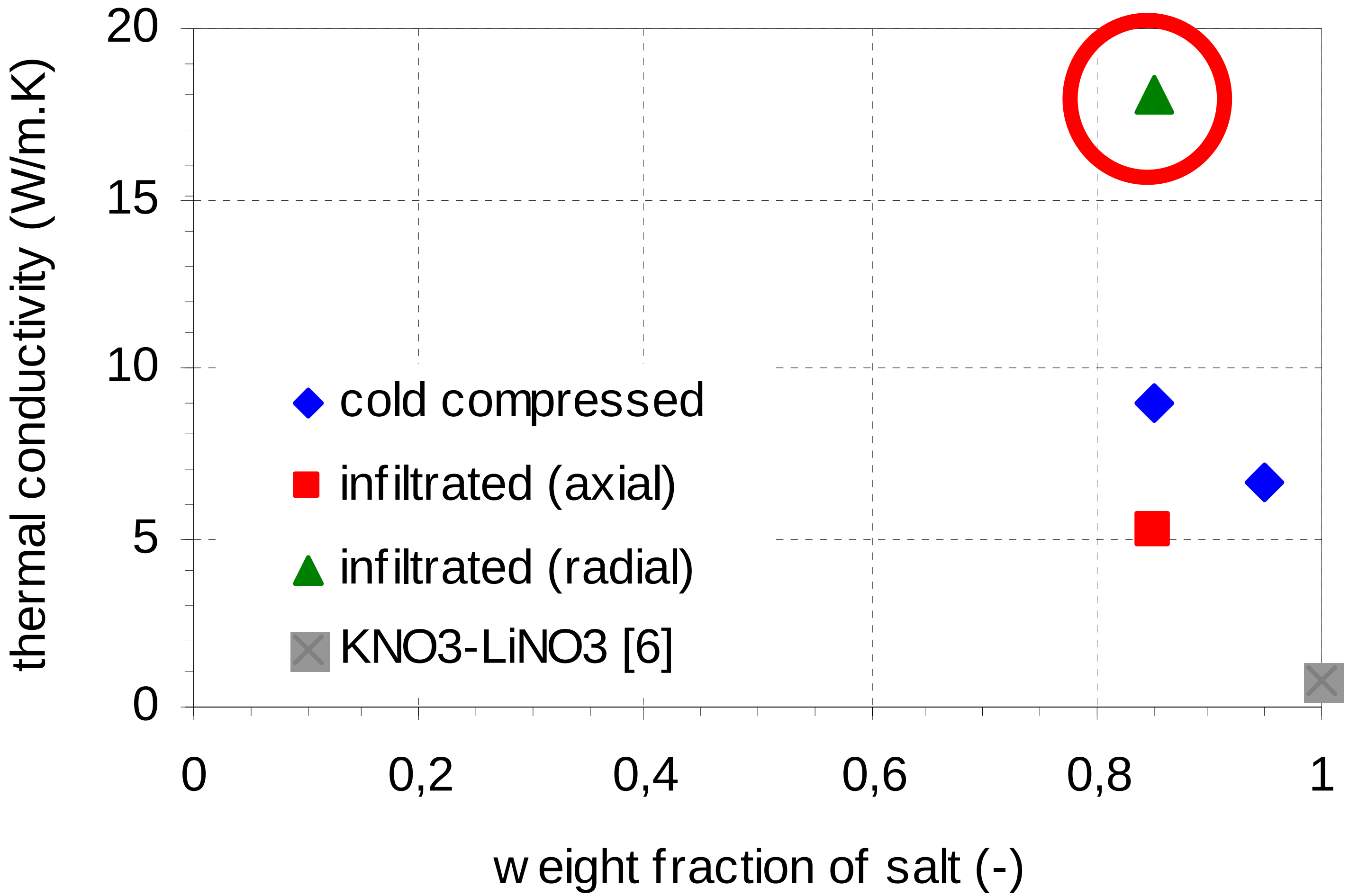
Selected
85% PCM/EG
composites

Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Results KNO_3-$NaNO_3$



Results KNO_3-$LiNO_3$



Current Phase Change TES Activities

- **European Project DISTOR**

Manufacturing of EG/Nitrate Salts PCM

Testing of 10 kW storage modules in the lab

100 kW Proof-of-Principle Storage testing at PSA

- **National Project**

Development of a pilot storage for industrial application