Thermal Energy Storage

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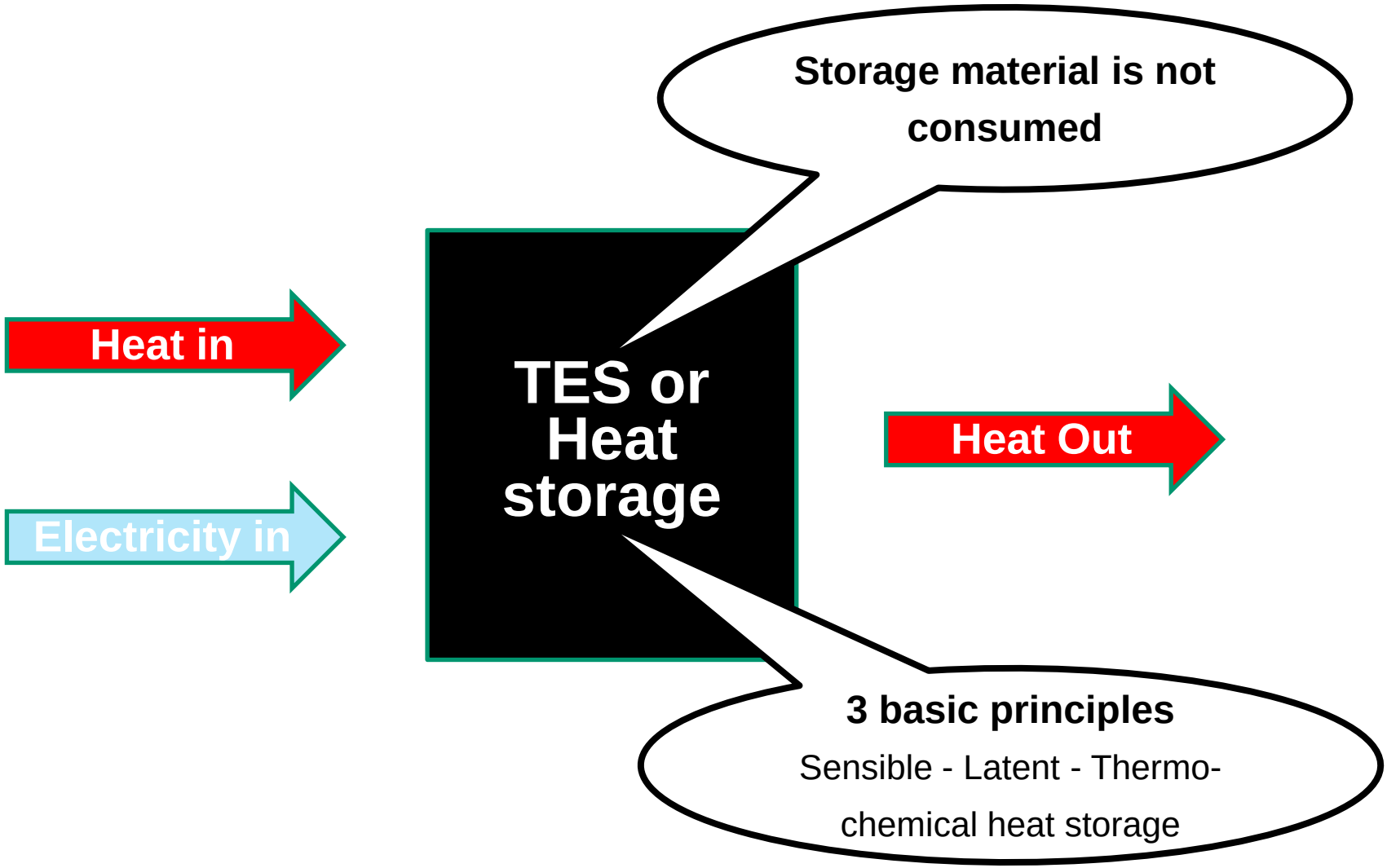
Rational for Thermal Energy Storage

Driven by national and European energy strategy

and climate protection policy:

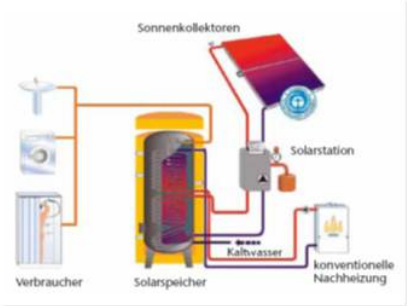
- To increase share of Renewable Energy Sources
- To reduce use of fossil fuels for heat generation
- To increase efficiency in the private and in industrial heating sector
- To increase competitiveness of national and European industry by offering more efficient products and processes

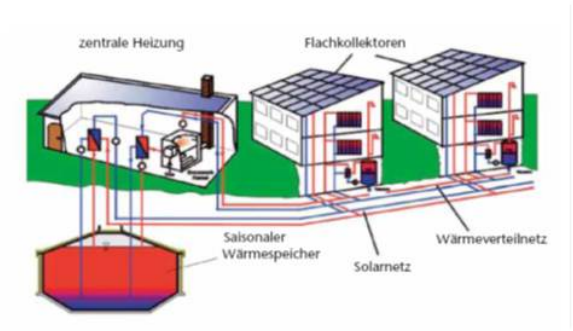
Definition


Storage material is not consumed
Heat in
Electricity in
TES or Heat storage
Heat Out
3 basic principles
Sensible - Latent - Thermo-chemical heat storage

Needs for TES Systems (I)
Increased implementation of solar thermal systems

Small scale and centralised solar cooling and heating in buildings



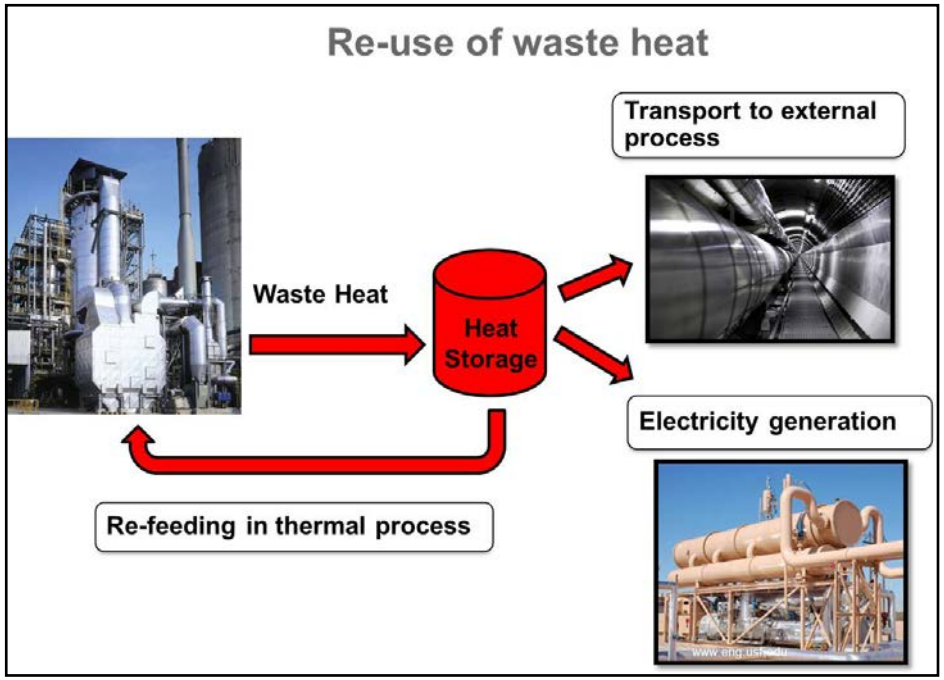


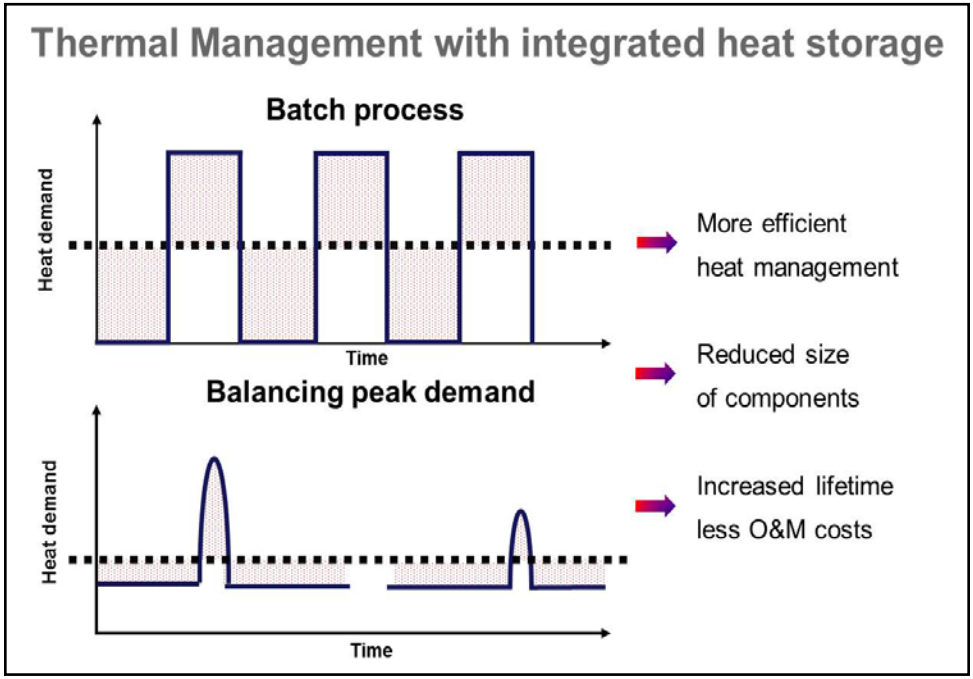
solar process heat generation

solar thermal power plants

Needs for TES Systems (2)
More efficient thermal processing

Industrial waste heat recovery & Thermal management



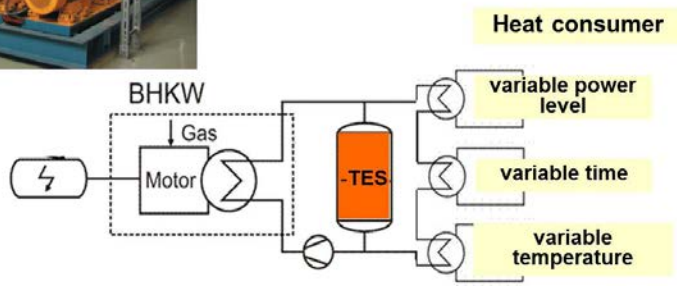


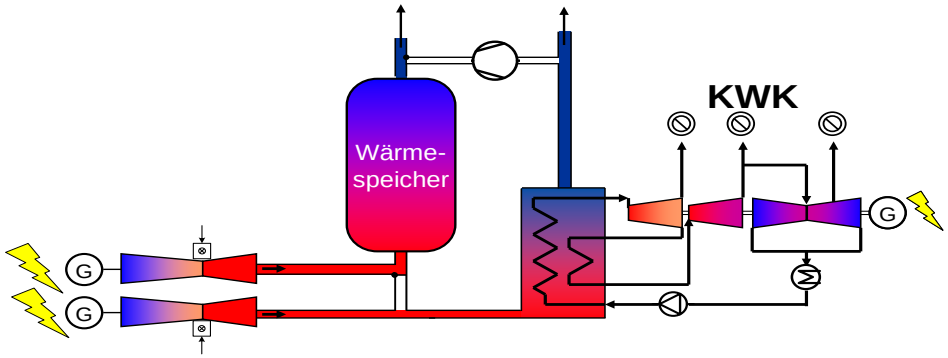
Needs for TES Systems (3) - **Electricity generation**

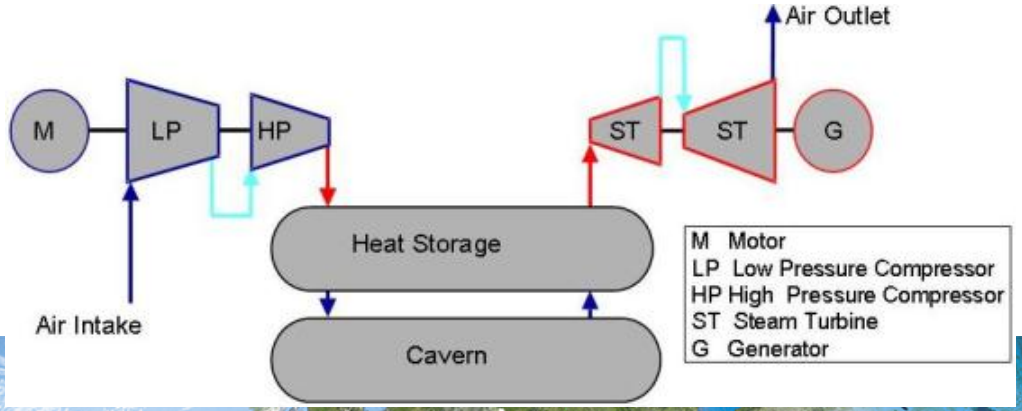
- to support CHP implementation
- to make power plants more flexible
- to make adiabatic compressed air energy storage plants possible

TES integration into CHP systems

- decoupling of power and heat generation
- supply of heat at variable
  - power level
  - time
  - temperature level







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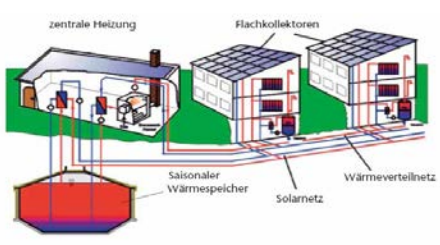
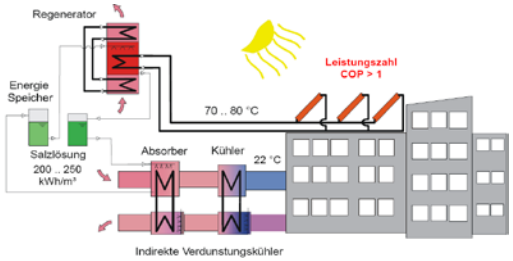
Challenges to implement Thermal Energy Storage

Broad range of applications and temperatures



- **0 – 100 ° C** **100-300 ° C** **300 -1000 ° C**



- Power range from kW to MW / Capacity from kWh to GWh
- Short term – minutes/hours – till long term storage – days/weeks/months
- Temperature range 0 – 1000 ° C
- Various heat transfer fluids: water, steam, refrigerants, oil, liquid salt, air etc.

SINGLE storage technology cannot meet all requirements!

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Fundamental principles to store heat

Sensible Heat

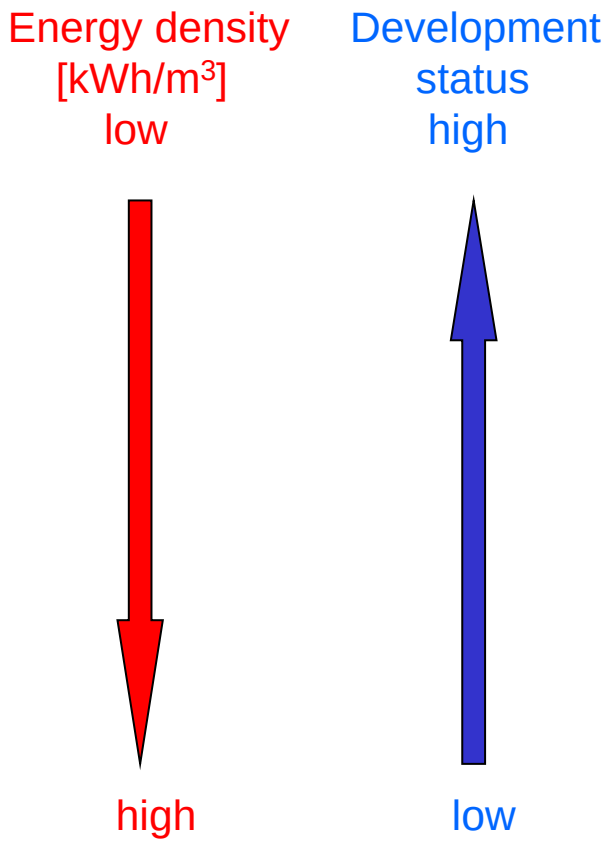
Sensible Heat Storage 20 – 200 kWh/m³
(depending on temperature difference)

Latent Heat

Latent Heat Storage 50 – 150 kWh/m³
(for small temperature difference)

Heat of Reaction

Thermo-chemical Storage 100 – 400 kWh/m³
(depending on driving gradient (temperature or pressure))



Sensible Heat Storage

Storage capacity $Q = m \bullet cp \bullet (T2 - T1)$

Preferred applications:
Single phase heat transfer fluids (water, oil, liquid salt, air, etc.)
Potential to use HTF as storage material (direct storage system)
Large ΔT between charging and discharging

Liquid materials
Water HTF+ storage
direct

Liquid materials
molten salt HTF+ storage
direct

HTF oil/steam
solid material/concrete
indirect

HTF air
Solid materials/
ceramics - direct

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Latent Heat Storage – PCM Storage

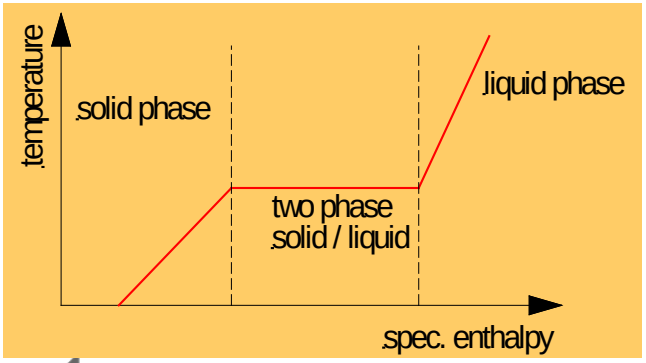
$$Q_{PCM} = m \cdot [cp_s \cdot (T_m - T_1) + \Delta H + cp_l \cdot (T_2 - T_m)]$$

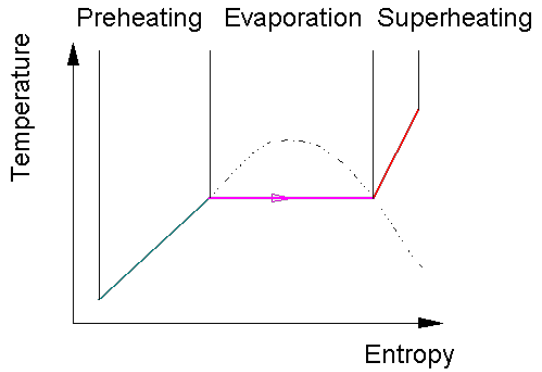
Features of PCM Storage

- Phase change temperature must fit to the specific application temperature
- Heat transfer of the TES is controlled by thermal conductivity of PCM
- Important PCM criteria: thermal conductivity, heat capacity, surface tension, thermal stability, material cost, corrosion

Preferred for:

- Small ΔT between charging and discharging
- 2-phase flow fluids (water/steam, organics)
  Process steam, steam turbines and ORC (140 to 550 ° C)





Thermo-chemical Heat Storage

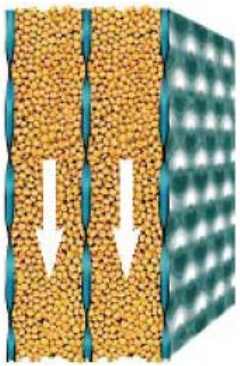
$$AB \underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}} A + B$$

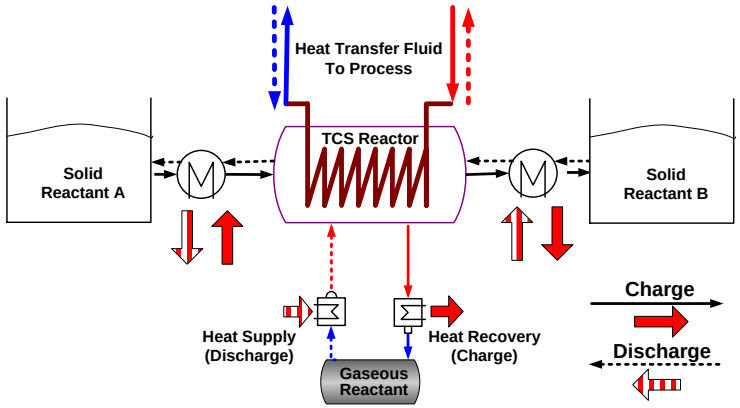
Using ΔH_R

Enthalpy of reaction/sorption of reversible processes reactions

Features of TCS

- High storage density
- Application in a wide temperature range (50 to above 1000° C)
- Loss-free and long-term storage
- Heat transport and heat transformation possible





Commercially available heat storage technologies (I)
Water Storage

The only predominant and multi million business is currently water storage for domestic heating systems

All further commercially available heat storage technologies currently cover only niche markets

- Pressurized water tank for distric heating (till 130/150 ° C
- Ruth´s – sliding pressure water/steam accumulator till 250 ° C
- Ice storage for cooling in combination with heat pumps

District heating storage Theiß, Austria

Sliding pressure storage for gas concrete manufacturing

Ice storage for energy management

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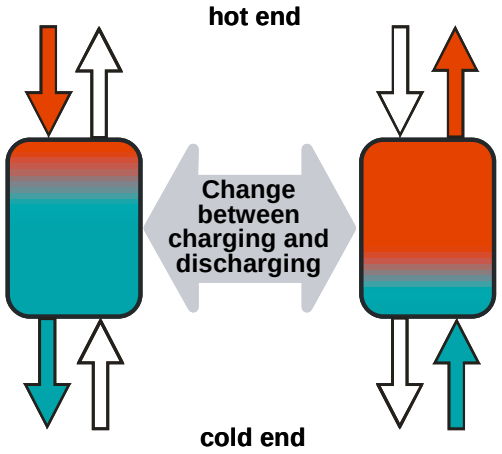
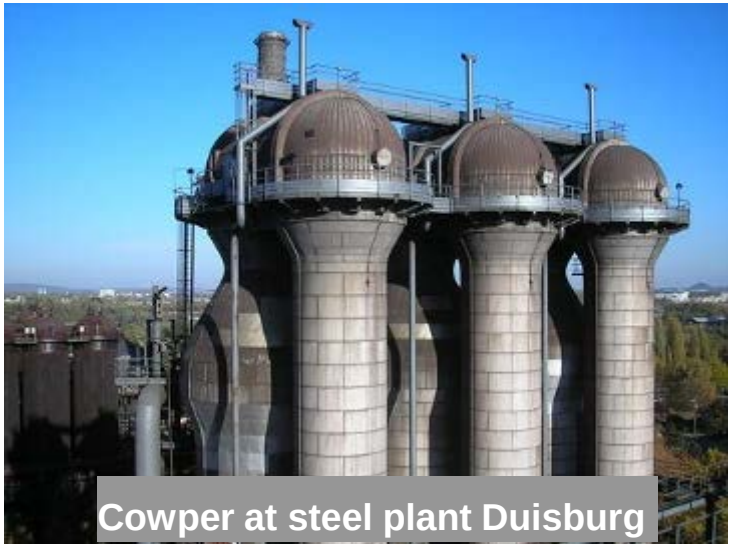
Commercially available heat storage technologies (II)
Cowper / Regenerator storage

High temperature heat storage for hot gas applications

- Cowper storage for steel making
- Regenerator for coke manufacturing
- Regenerator for glass manufacturing
- Regenerative thermal oxidation




Cowper at steel plant Duisburg


RTO at automotive paint shop Stuttgart

Commercially available heat storage technologies (III)
Molten Salt Storage for Solar Thermal Power Plants

1000 MWh Molten Salt Storage @ ANDASOL Plant

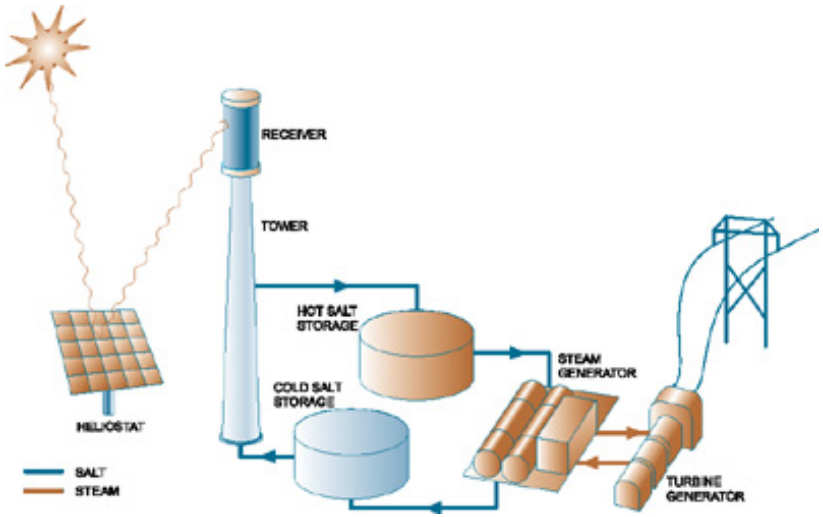
Salt inventory 28.000 t - Tank volume 14.000 m³

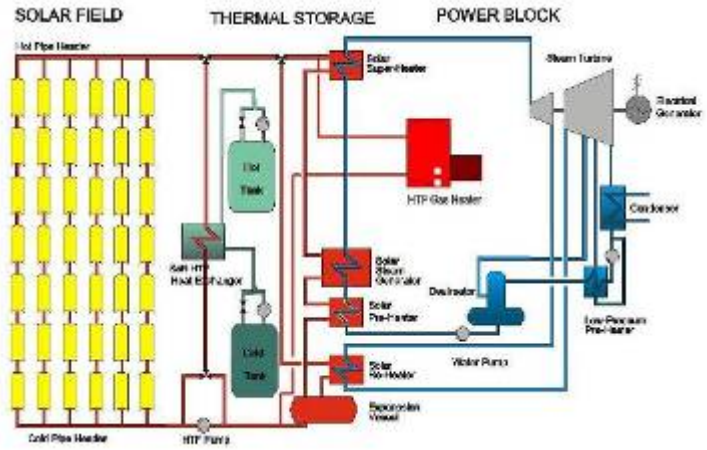
7.5 h storage capacity 1000 MWh

60% NaNO3 + 40% KNO3

Estimated investment cost 30-60 €/kWht

1000 MWh molten salt storage at Andasol plant





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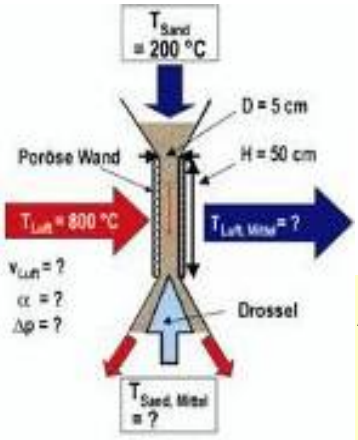
Limitations towards broad application

to realize a wide-spread use and market penetration of TES technologies in the domestic, industrial and power generation sector are:
to come down with investment cost and to increase reliability and efficiency of existing and new TES systems

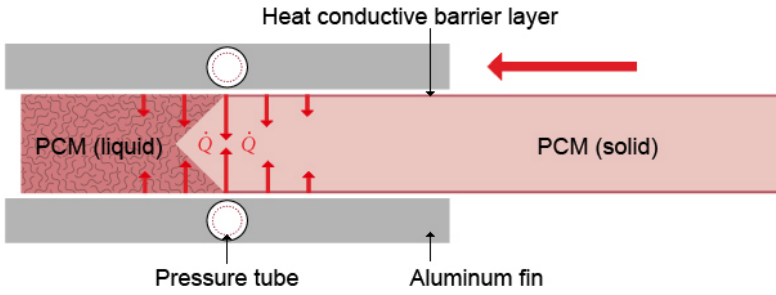
Scientific and technological objectives are:

- to develop storage materials with superior thermo-physical properties
- to develop advanced heat transfer fluids
- to identify advanced heat transfer mechanism for charging and discharging
- to reduce thermal energy losses
- to identify optimised method for system integration

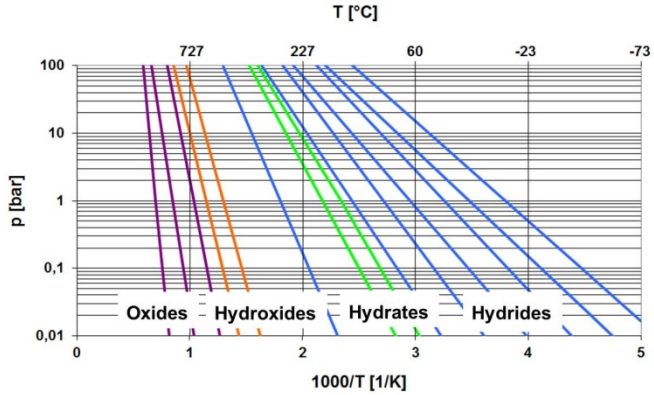
4 Examples of new and emerging approaches



Innovative PCM storage concept:
Separation of heat rate and capacity by moving PCM past the heat exchanger surface



Advanced heat transfer with moving bed heat exchanger & direct contact hot air/small particles



Thermo-chemical heat storage combining heat storage and heat transformation

Power to heat storage for storing excess electricity

Conclusions

Thermal energy storage is a key element of sustainable energy systems

Broad range of operation conditions require specific design solutions regarding capacity, power level, storage integration:

„One type fits all“ does not work

Besides hot water storage only few further TES systems are commercially available **... But still too expensive for large scale implementation**

1st niche applications in the area thermal management of industrial manufacturing processes and solar thermal power plants (10-100 MW range)

Key issues to achieve further cost reduction are:

- Materials with improved thermo-physical properties
- effective solutions for heat transfer and heat exchange
- cost efficient storage/reactor design concepts
- effective storage integration

Thank you for your attention!

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