Integration of Different Thermal Energy Storage Technologies into CSP Power Plants

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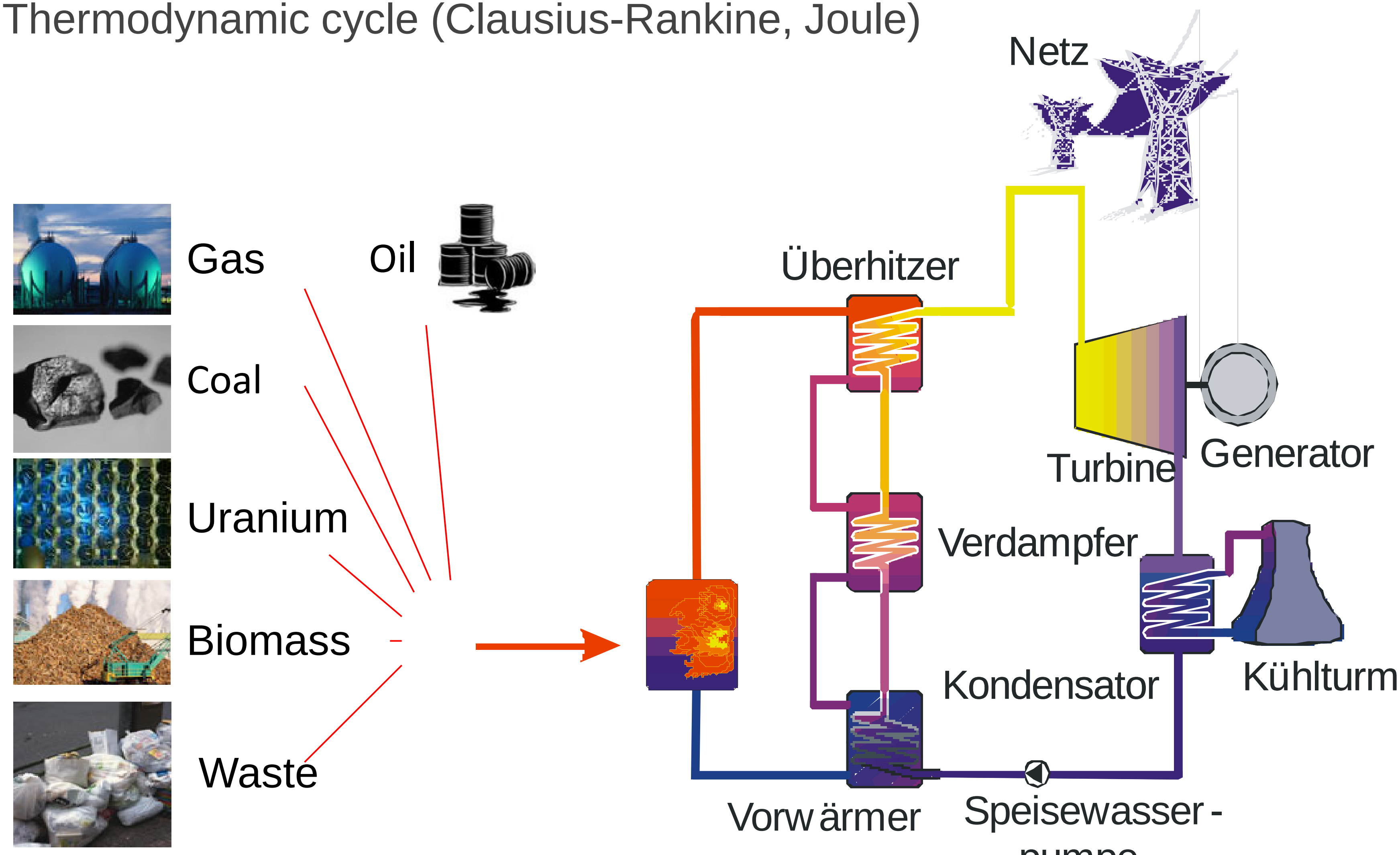
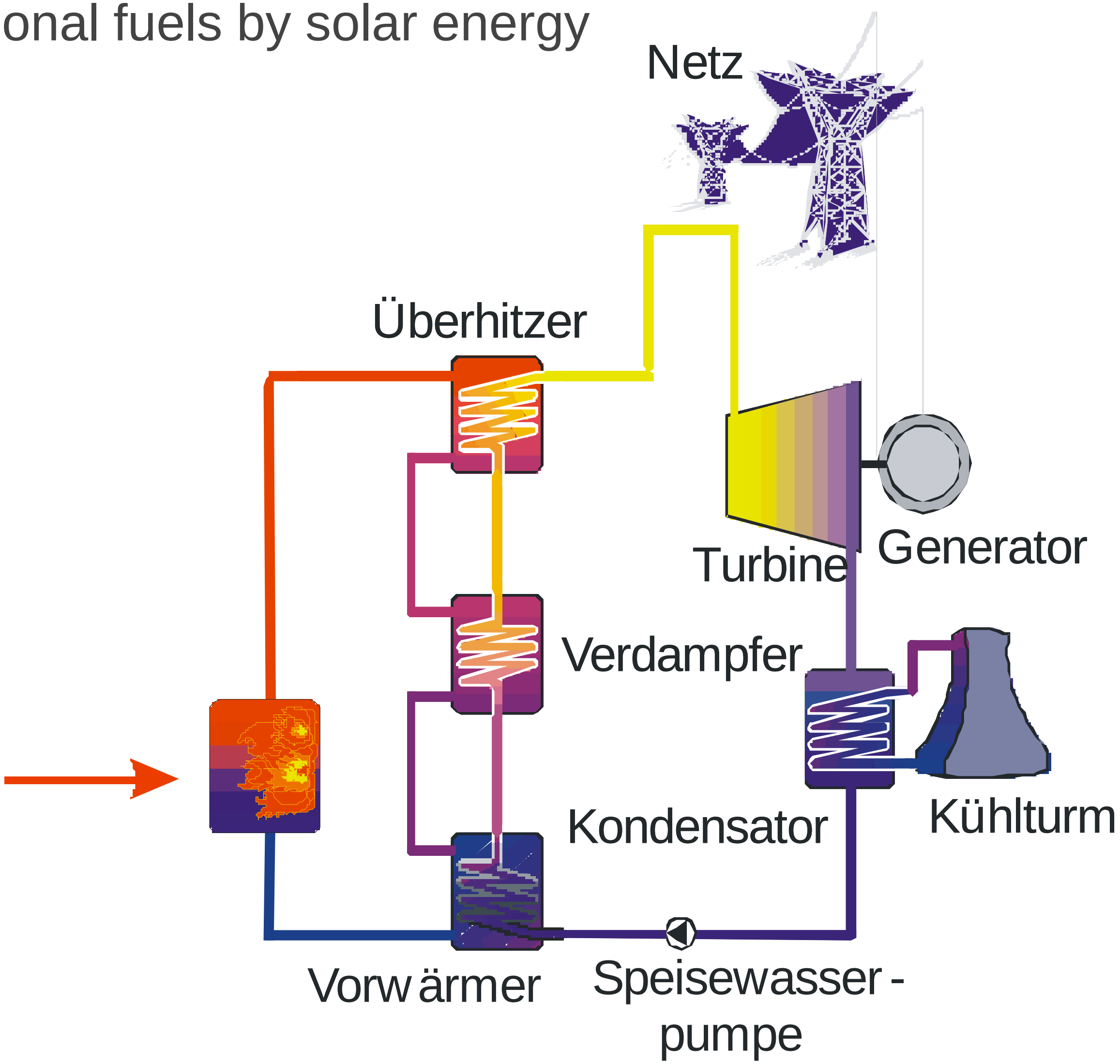
Principle of solarthermal power plants

Thermodynamic cycle (Clausius-Rankine, Joule)



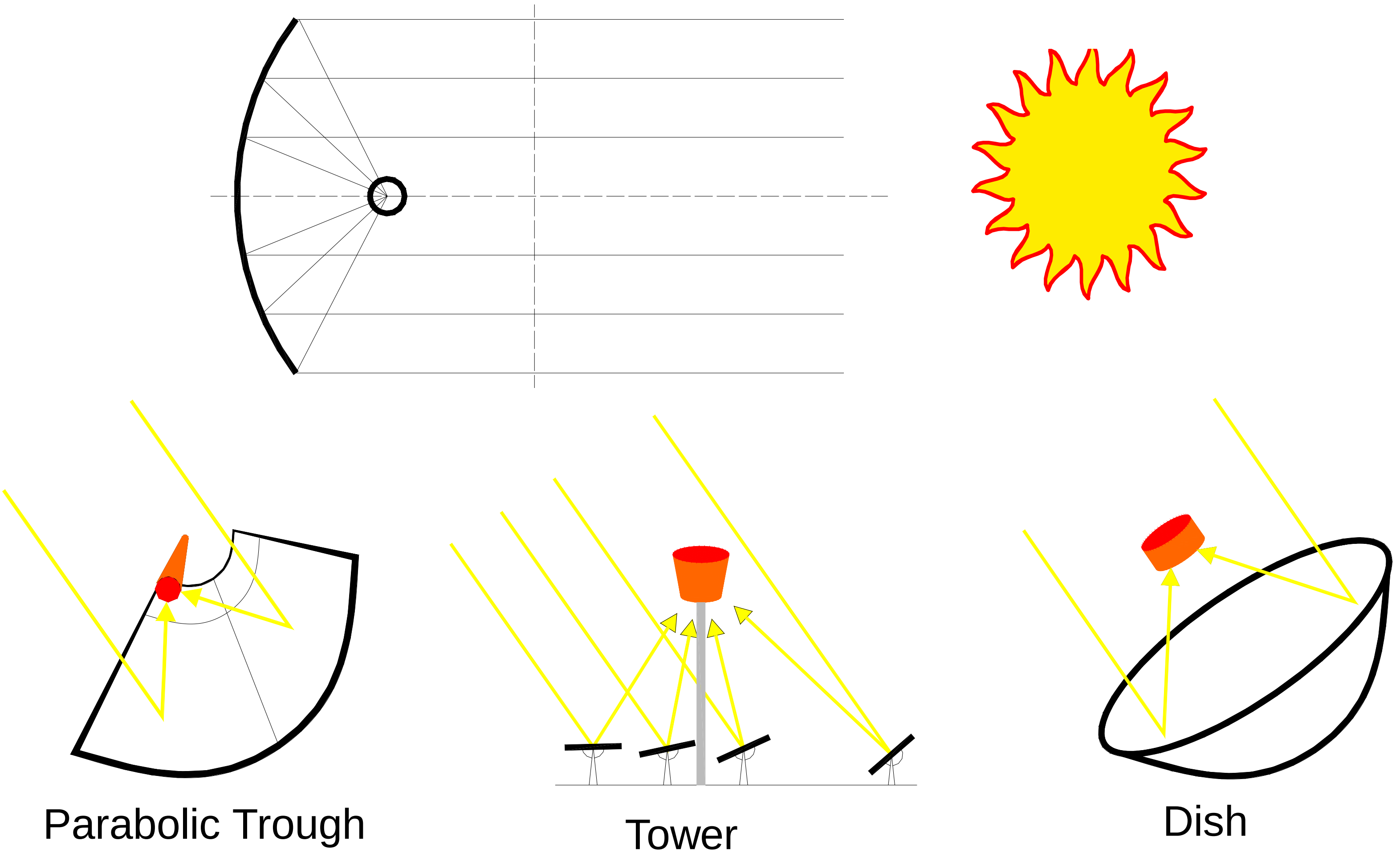
Principle of solarthermal power plants

Replacement of conventional fuels by solar energy

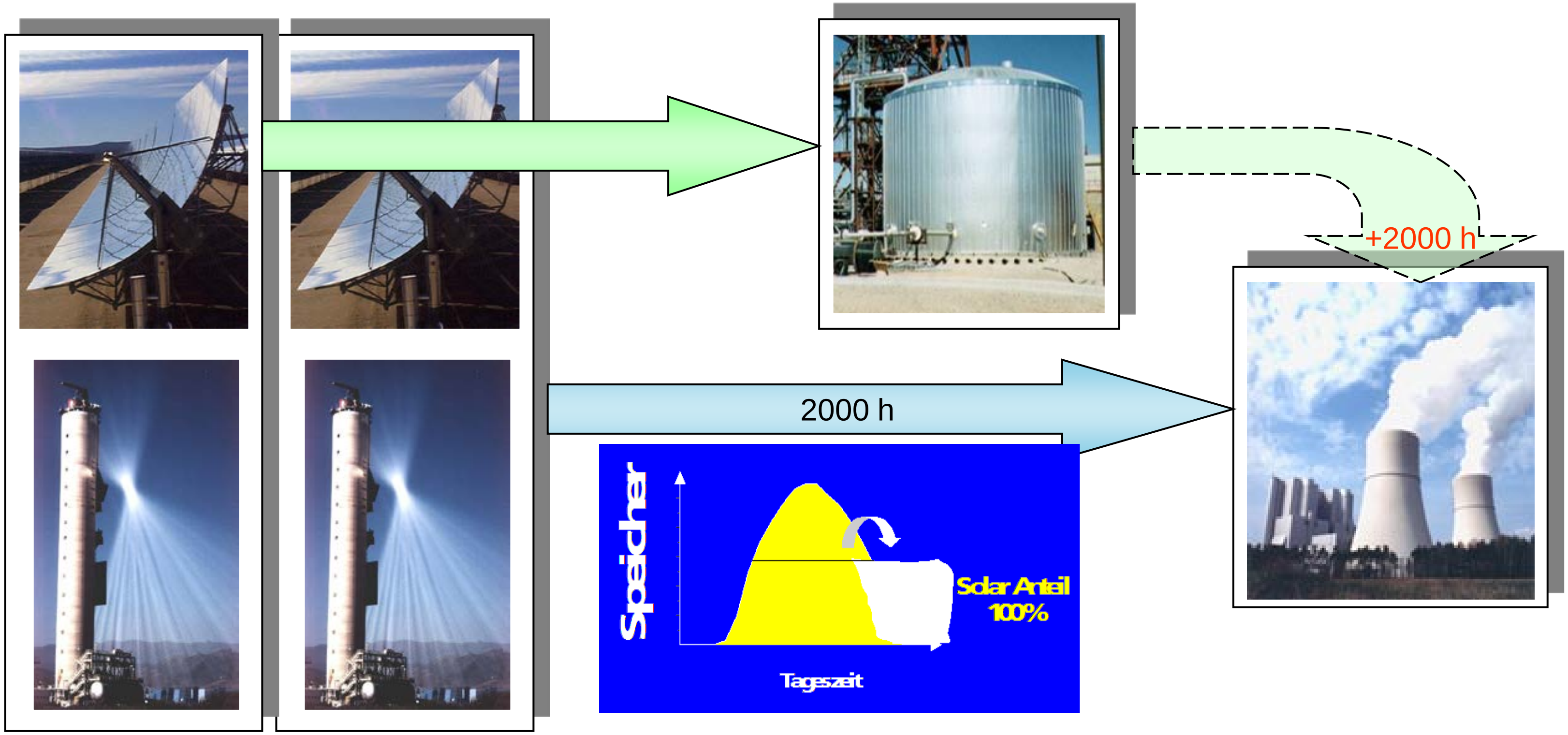


Principle of solarthermal power plants

High temperatures through concentration of solar radiation

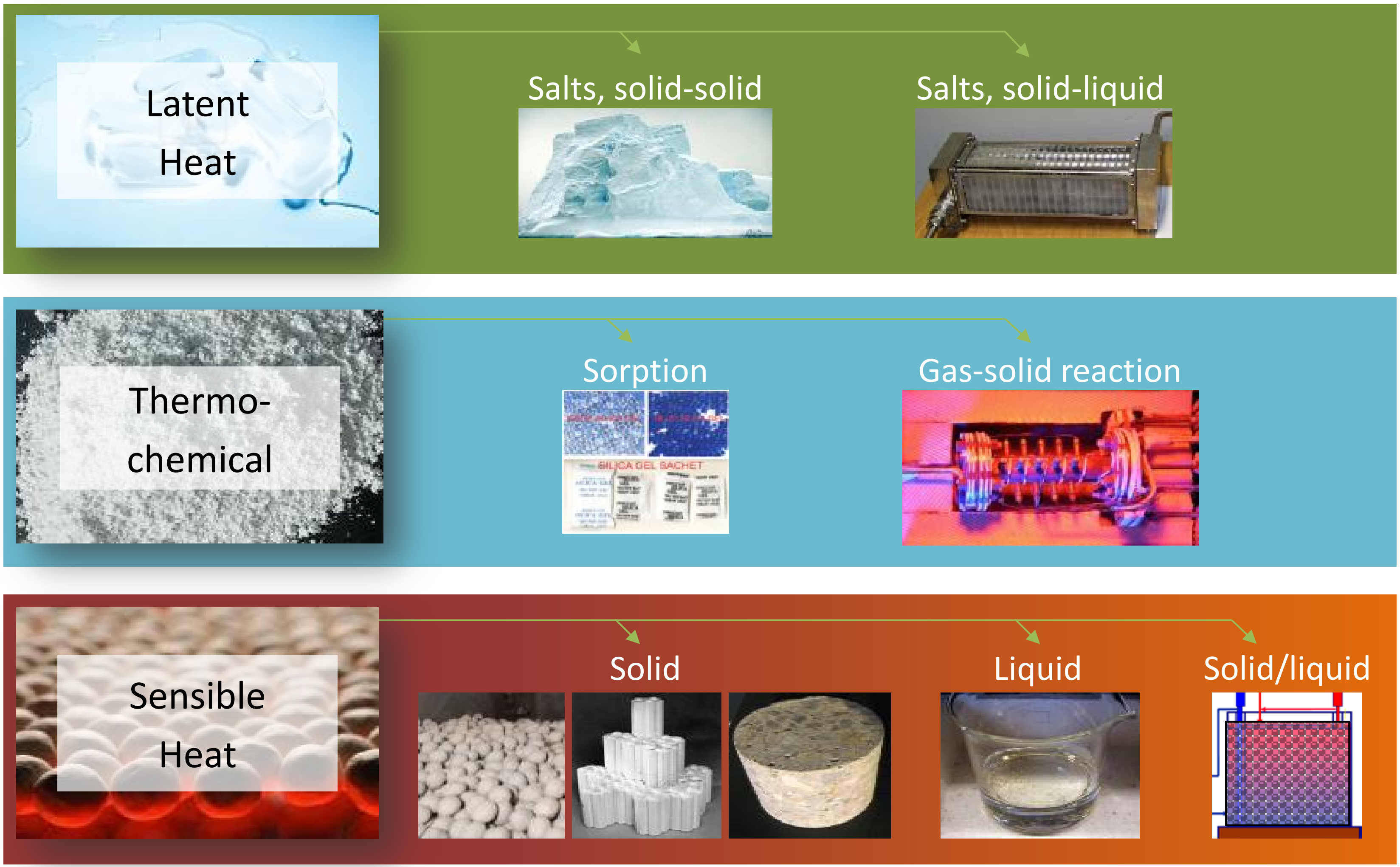


CSP Power Plants: Why Use Thermal Energy Storage?



Thermal energy storage → more operational hours → lower costs

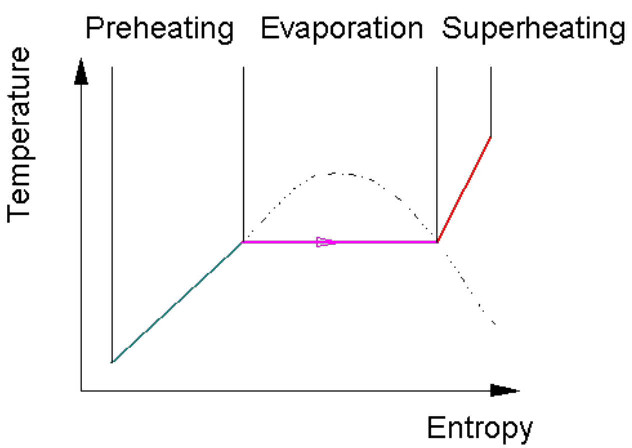
Storage concepts

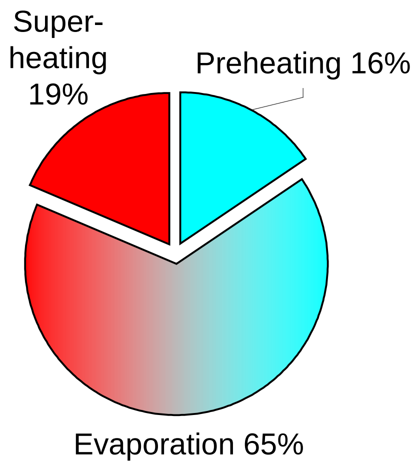


Storage Systems for DSG Plants
Latent Heat Storage

Latent Heat

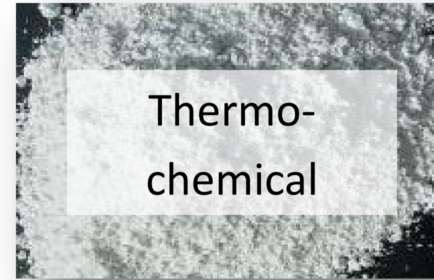
260 ºC – 400 ºC 107 bar





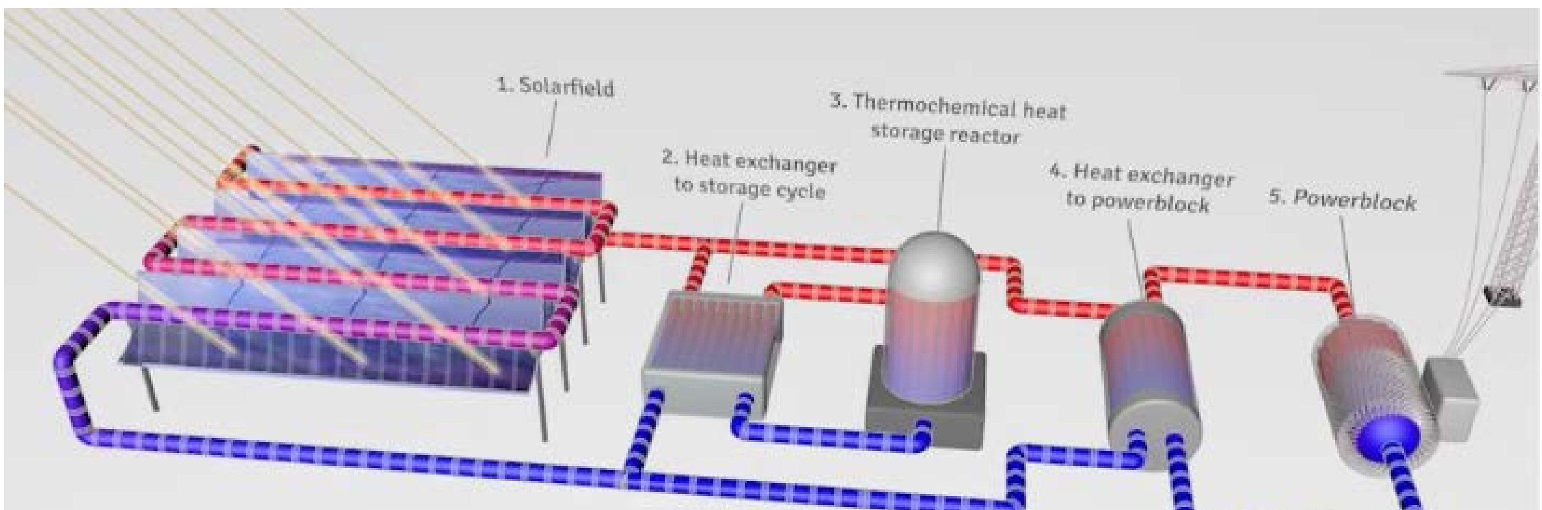
- → Operating temperature typ. ~300°C
- → Energy density: 50-150 kWh/m³
- → Constant Temperature

CSP Plant with Thermochemical Storage



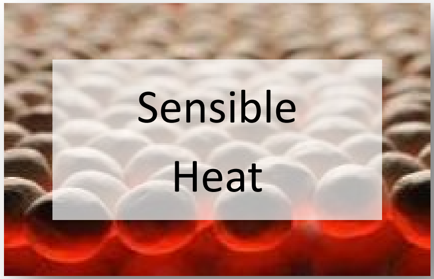
$$AB \underset{\text{exothermal}}{\overset{\text{endothermal}}{\rightleftharpoons}} A + B$$

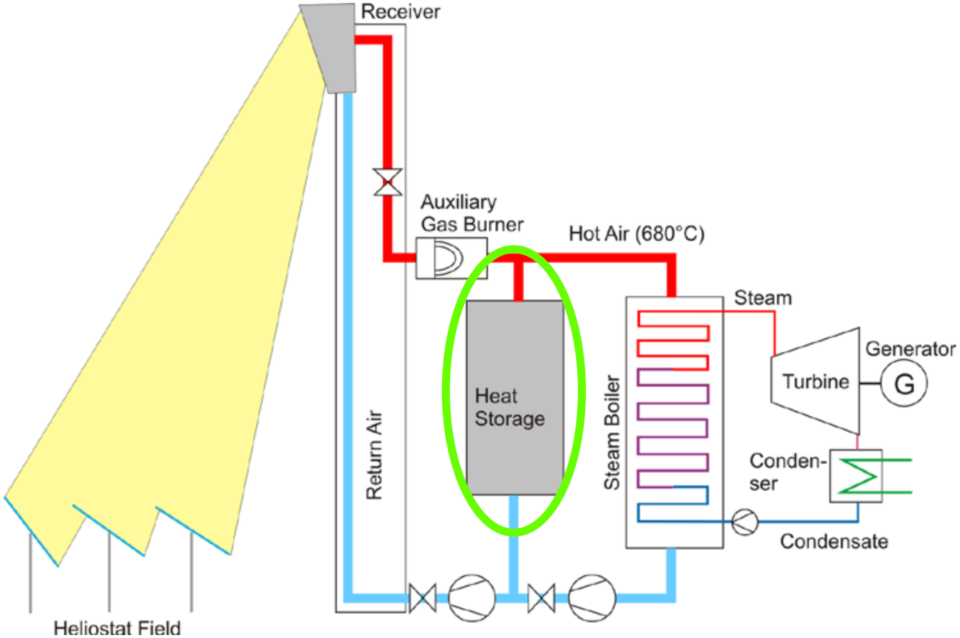
- → Operating temperature depending on pressure
- → Energy density: 100-400 kWh/m³
- → Long term storage possible



TCS-Power project:
Charging of thermochemical storage reactor

Example for Sensible Heat Storage: Solar Thermal Power Plant with Volumetric Air Receiver

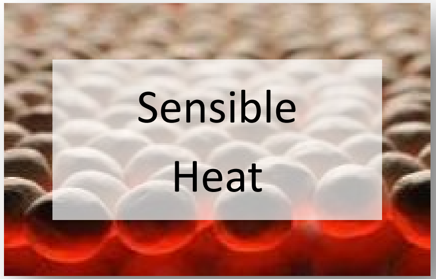




Solarturm Jülich (2009)

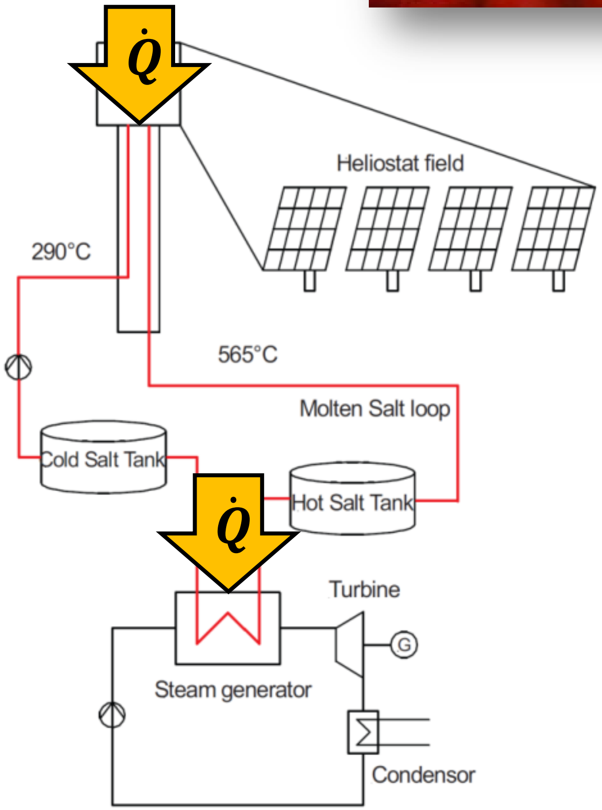
→ Operation temperatures 1000°C +
→ Energy density: 50-150 kWh/m³
→ Commercially available

Two-Tank Molten Salt Storage System: Solar Thermal Power Plant



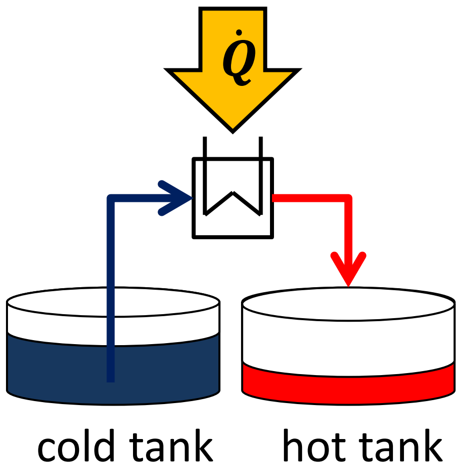
- Heat source: Solar irradiation is focussed at the receiver

- Heat sink: Conventional clausius-rankine cycle

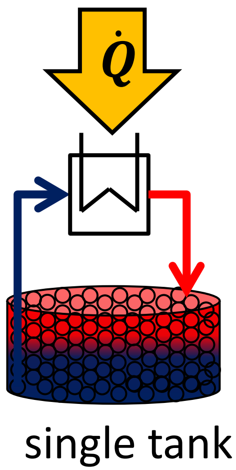


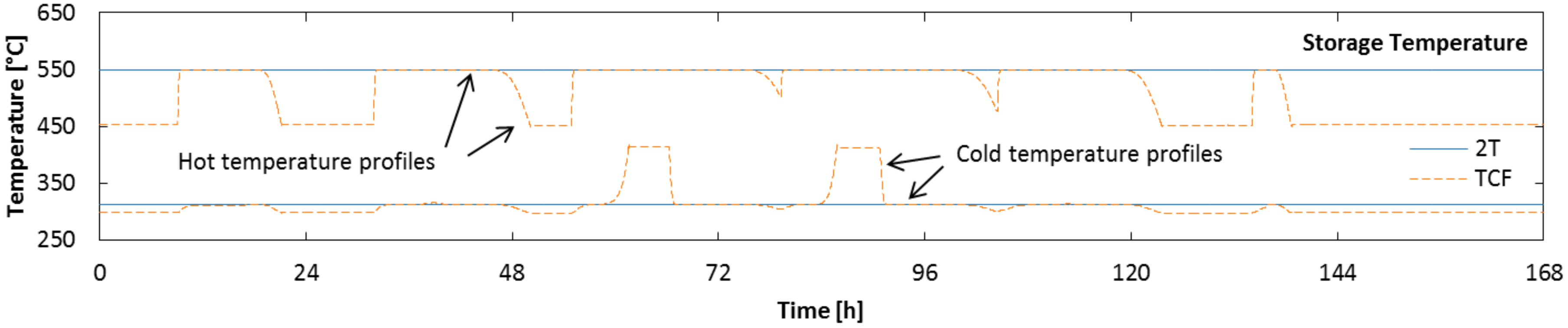
Overview of molten salt storage technology

2-Tank (state of the art)



Thermocline with filler (TCF)

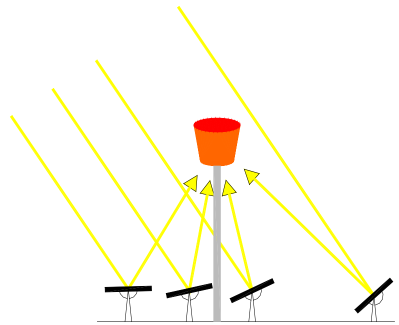




Comparison of 2-Tank and Thermocline System: Exergy

Energy Source:
(Solar field)

T_{in} =
290 °C



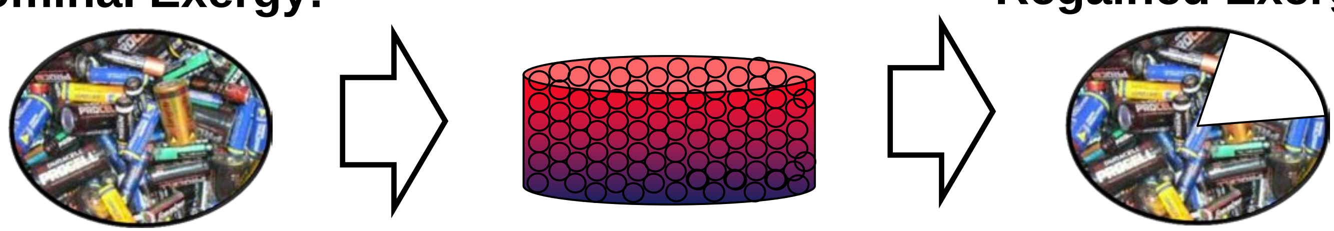
T_{out} =
560 °C

Scenario:

- 12 hours charging time
- 2.82 GWh thermal energy

Nominal Exergy:

Regained Exergy:



~1.59 GWh

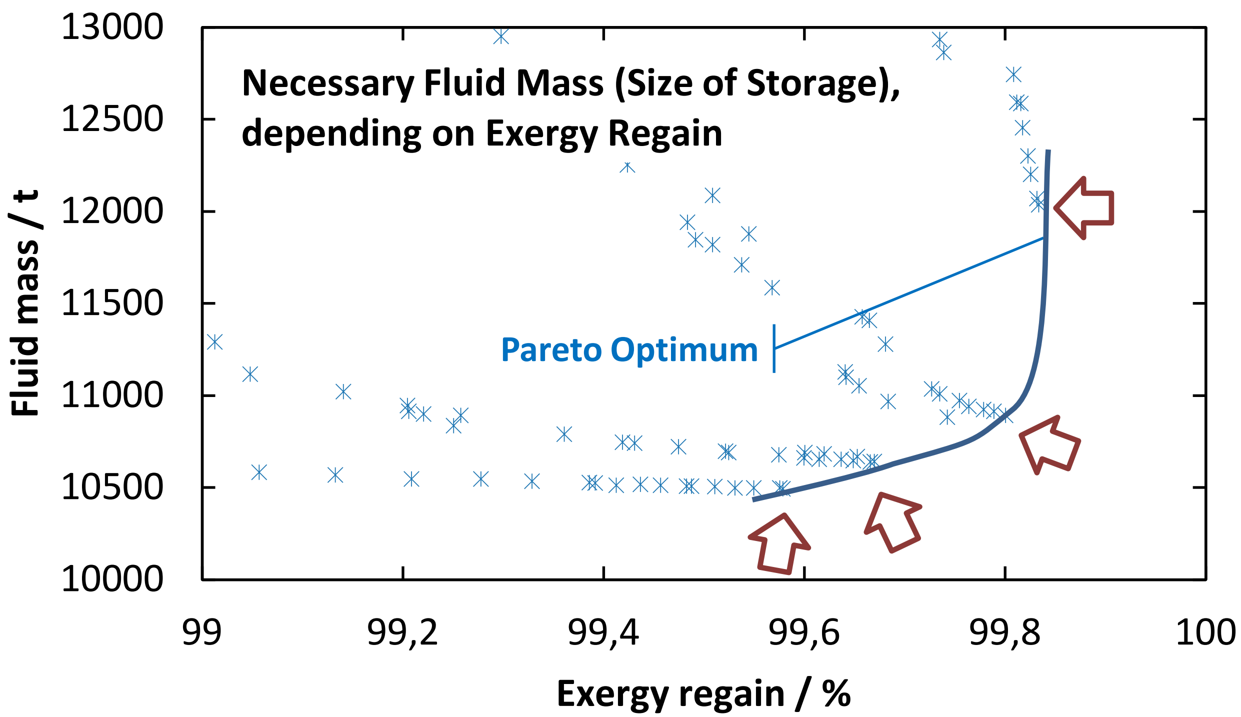
< 1.59 GWh

Parametric study:

Adapt length of storage volume for
- 12 hours charge time <u>and</u>
- permitted drop of exit temperature

Result of Parametric study

- 100s of possible storage configurations
- Every configuration fits into the scenario
- Difference: Regained exergy vs. molten salt holdup (storage size)



Selected Results of the Parametric Study

System	Thermocline, $\varepsilon = 40\%$				2-Tank	-
Permitted change in exit temperature (ΔT_e)	10	30	50	70	0	K
Exergy regain (Ξ)	99.8	99.8	99.7	99.6	100	%
Storage volume (V_{stor})	16.7	14.9	14.6	14.4	13.7	$10^3 m^3$
Fluid mass (m_f)	12.2	10.9	10.7	10.5	25.1	kt
Solid mass (m_s)	30.0	26.8	26.2	25.8	0.0	kt

Summary

What to consider for the integration of TES into a power plant:

- Which technology?
  → Utilising the specific advantages of each technology

- Which temperature level?
  → Each technology has limitations for the upper and lower limit

- What are the boundary conditions?
  → Constrictions of attached components and their operation affects utilization of storage technology

Thank you for your attention!

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