Demonstrating Cost Effective Thermal Energy Storage in Molten Salts: DLR’s TESIS Test Facility

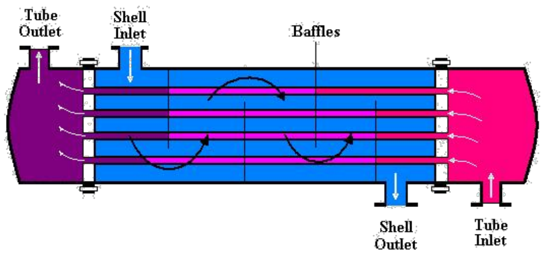
Christian Odenthal, Freerk Klasing and Thomas Bauer

German Aerospace Center (DLR)

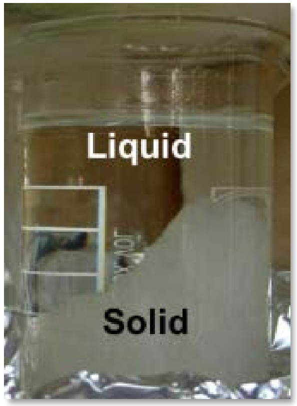
Institute of Engineering Thermodynamics (ITT)
Stuttgart / Cologne

Advantages of Molten Salt

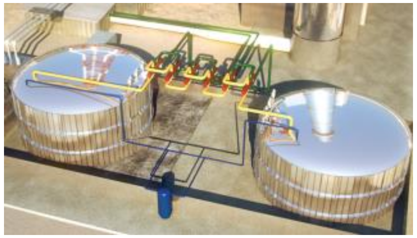
Molten Salt as Heat Transfer Fluid (HTF)



- Unpressurized (low vapor pressure)
- High heat transfer rates
- Low viscosity
- Operation temperature up to 560 °C
- Most common HTF in solar tower plants
- Trend for future parabolic trough plants



Molten Salt as Storage Material



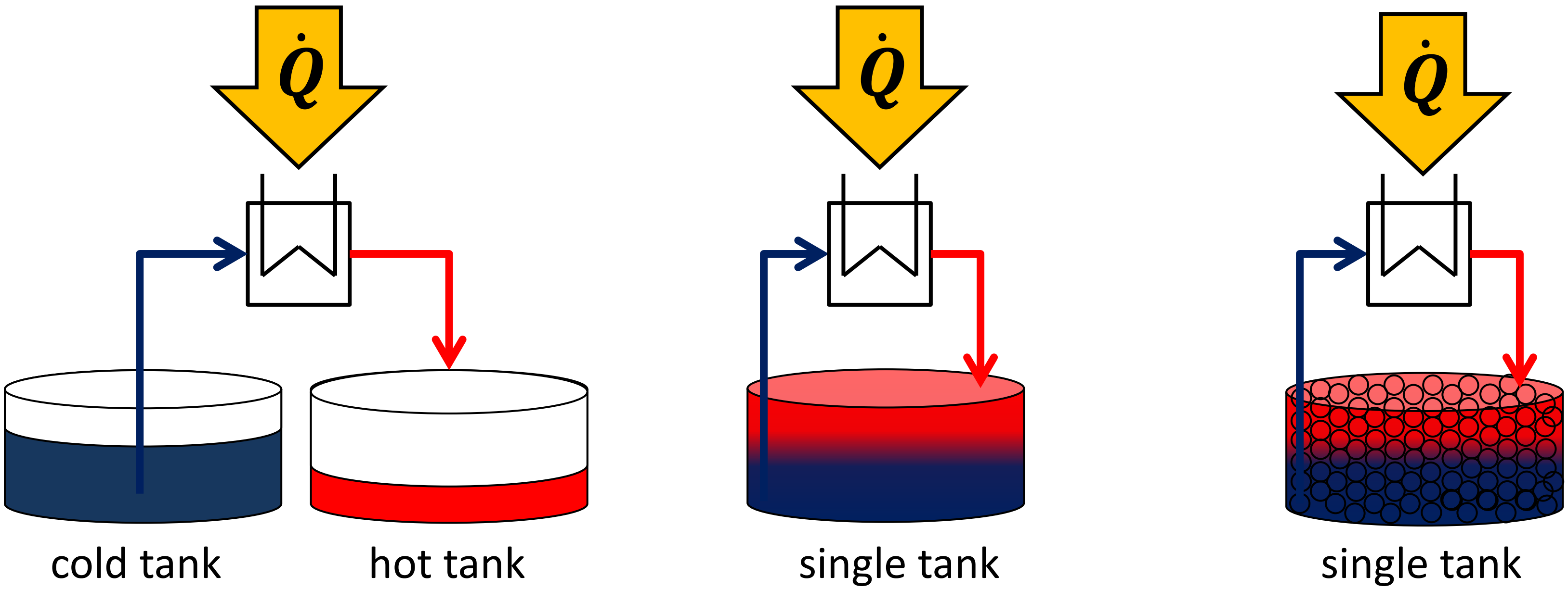
- Unpressurized
- Less expensive than synthetic oil
- No heat exchanger to HTF molten salt
- Nontoxic, nonflammable and no explosive phases
- Spec. heat capacity (liquid phase): about 1.5 kJ/(kgK)

Overview of molten salt storage technology

2-Tank (state of the art)

Thermocline

Thermocline with filler

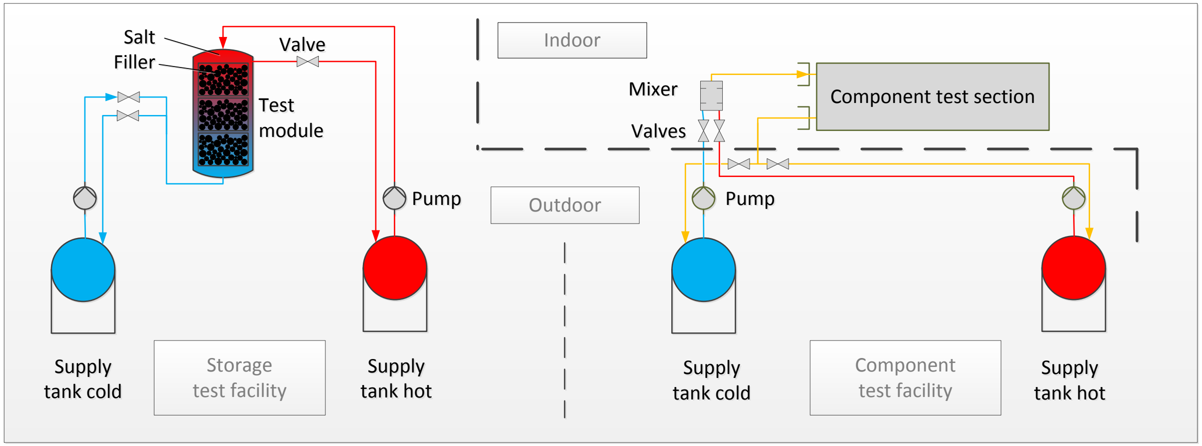


Research at DLR – TESIS Facility

Test facility for Thermal Energy Storage In Molten Salts

Test section for molten salt energy storage – TESIS:store

Test section for molten salt components – TESIS:com



- Flexible test section for alternative thermal energy storage concepts
- Long-term / permanent testing possible

- Flexible set-up for various components (e.g. valves, receiver tubes or instruments)
- Critical conditions possible

Research at DLR – TESIS Storage Test Section
TESIS:store

Molten salt medium	Nitrate - Nitrite salt mixtures
Min. operation temperature	150 °C
Max. operation temperature	560 °C
Max. mass flow rate	4 kg/s
Max. mass of filler material	**45 t**
Max. empty tank volume	22 m³

→ Behavior of storage system, model validation / refinement, molten salt chemistry on large scale

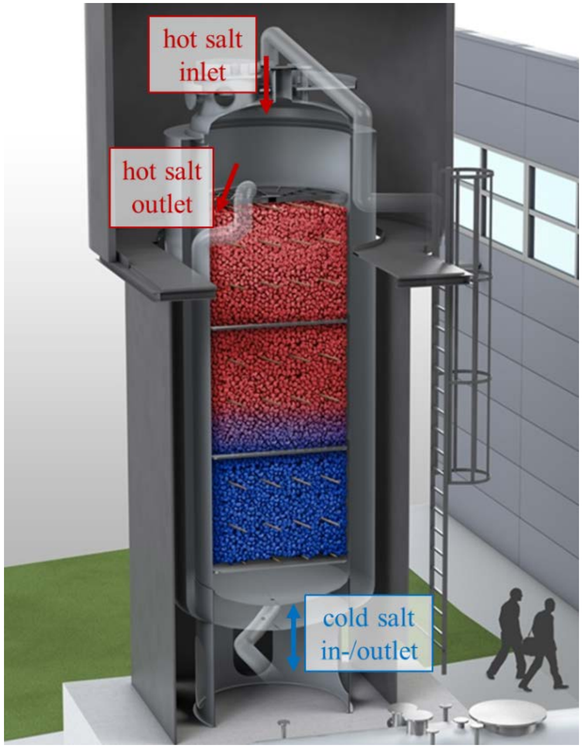
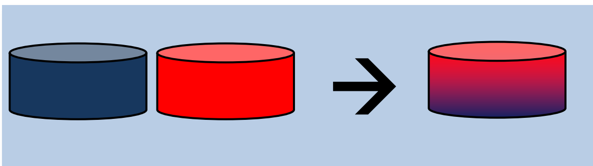


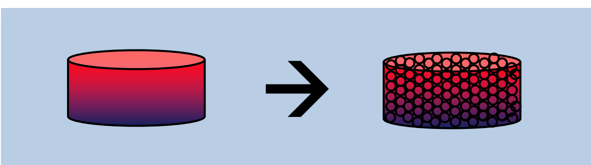
Photo of the TESIS Plant

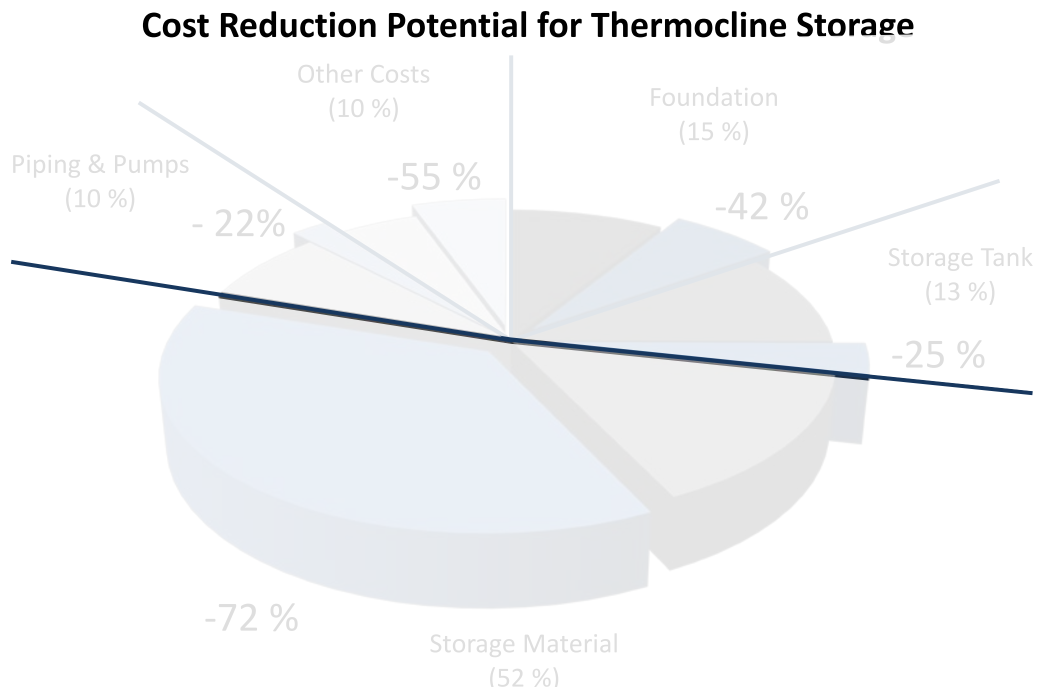
Potential for Cost-Reduction of Molten Salt Systems

Potential #1:



Potential #2:

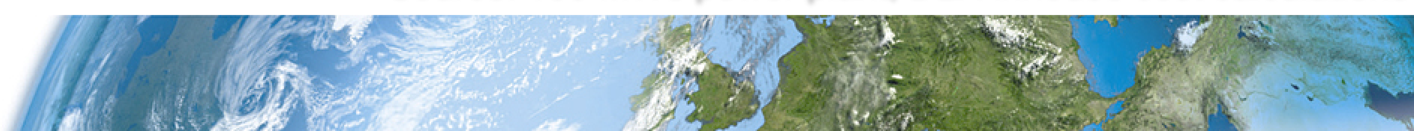




General potential:

- Limited operational experience
- Understanding of corrosion mechanisms
- Understanding of molten salt degradation / small ΔT

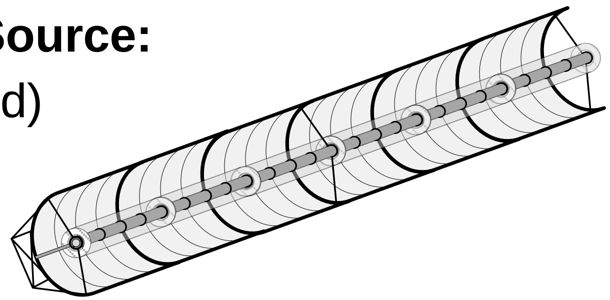
Source: 100 MWe power plant, DLR inhouse cost calculations



Example for Cost-Reduction: Exergy

Energy Source:
(Solar field)

T_{in} =
290 °C



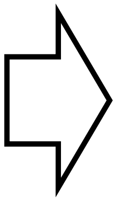
T_{out} =
560 °C

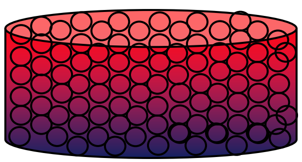
Scenario:

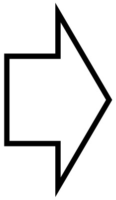
- 12 hours charging time
- 2.82 GWh thermal energy

Nominal Exergy:

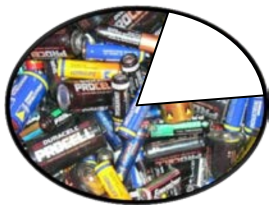
~1.59 GWh







Regained Exergy:



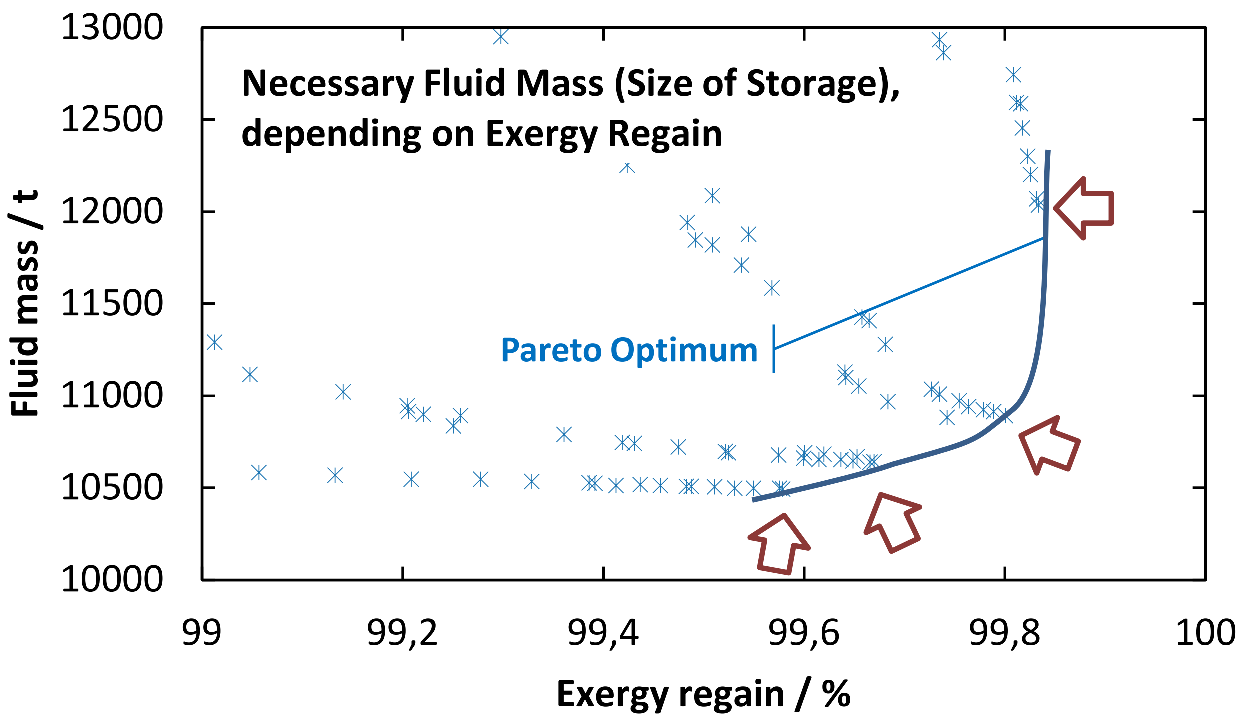
< 1.59 GWh

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

Molten salt thermal energy storage is proven technology with large cost reduction potential

→ DLR has built two test facilities TESIS:store and TESIS:com, which help understanding storage behavior, salt chemistry and testing components for faster market application

Example based on exergy has shown that thermocline storage with filler can achieve

→ high exergetic efficiency and
→ significant reduction of salt inventory (investment cost)

Thank you for your attention

Christian Odenthal

German Aerospace Center (DLR)
Institute of Engineering Thermodynamics (ITT)

christian.odenthal@dlr.de
www.dlr.de/tt/en