CSP Research on CSP cost reduction

Bernhard Hoffschmidt, DLR Institute of Solar Research

Outline

1. Strategy and Approach for Cost Reduction
2. Innovation to drive Cost reduction
   a. Near term: Advanced silicon Oil in parabolic troughs
   b. Mid term: Parabolic Trough with Molten Salt
   c. Long term: Particle Receiver Technology

5. Conclusions

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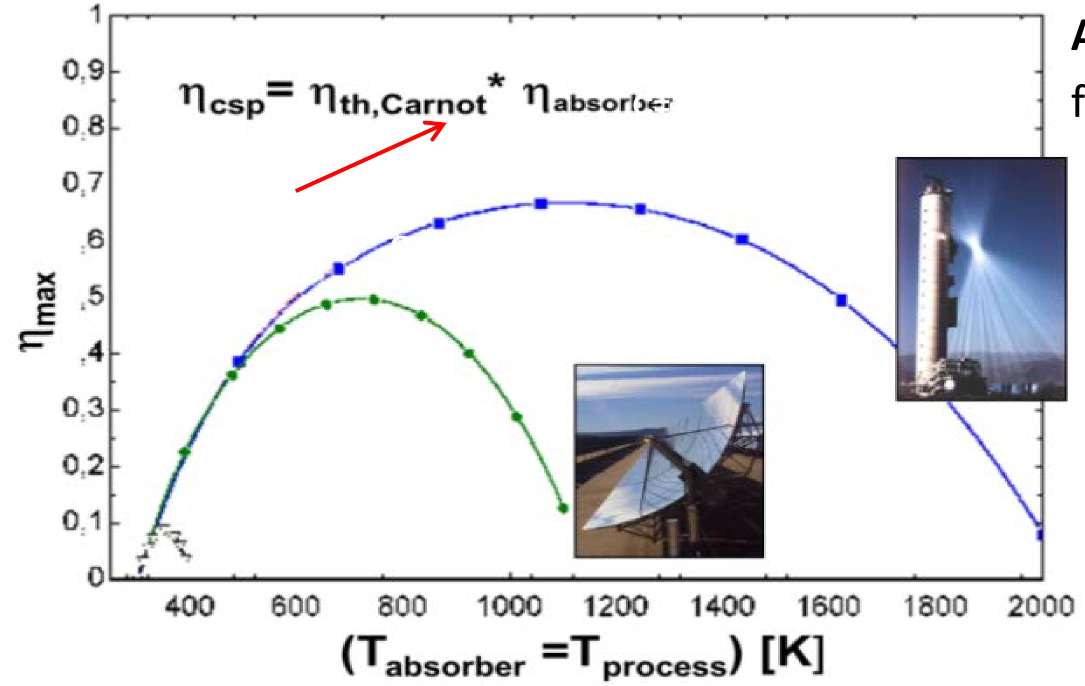
Strategy and Approach for Cost Reduction



Advanced heat transfer media needed for:

- high temperature operation
- efficient storage integration

to break todays temperature limit of 550°C

High Concentration + High Temperature = High Efficiency = Low Cost

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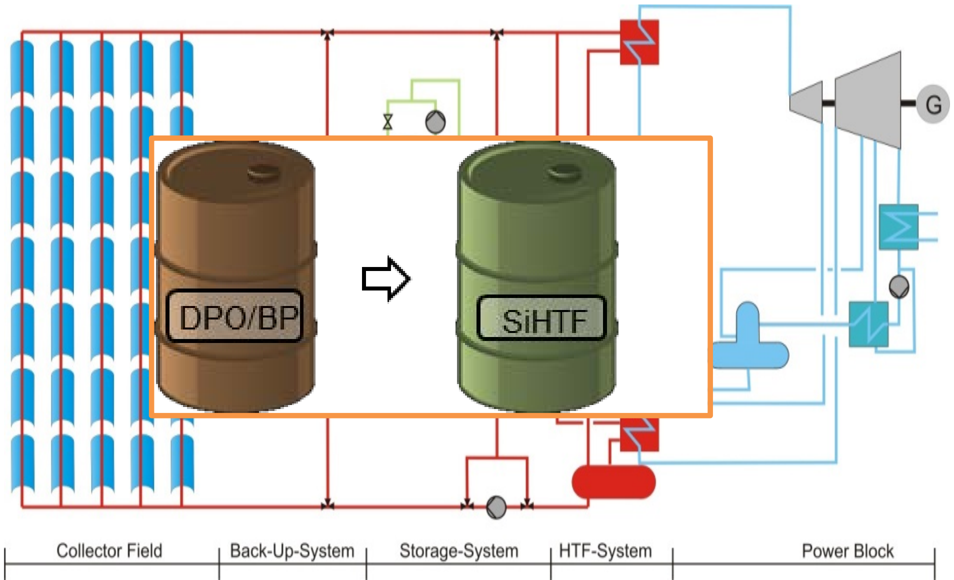
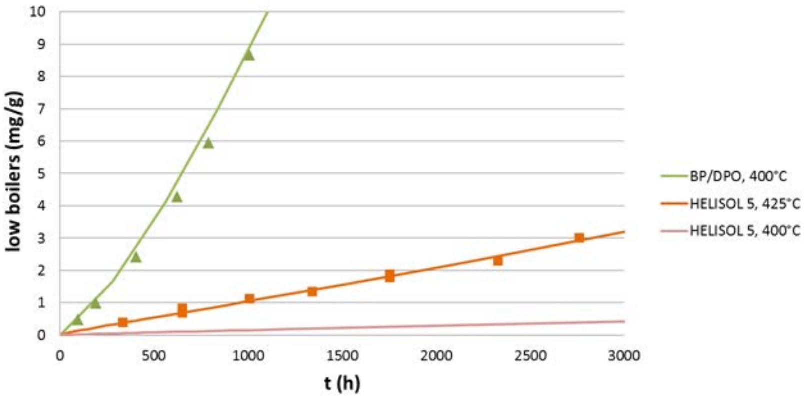
Advanced Silicon Oil in Parabolic Troughs

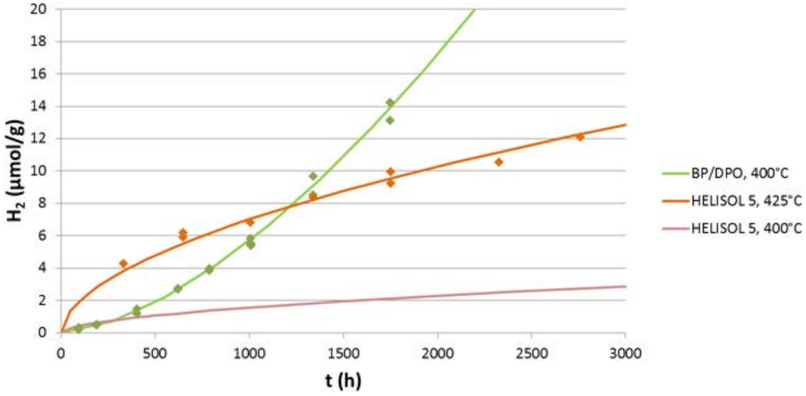


- **Environmental Safety**
- **Capacity / Performance**
  - **Reduction of auxiliary consumption** by lower pour point (-55°C)
  - **Higher 425°C** field **outlet temperature**
  - **Higher** possible **efficiency** of Rankine cycle
  - **Slower degradation**
  - **Smaller storage systems** at the same capacity

=> 5% cost reduction potential

Advanced Silicon Oil in Parabolic Troughs





Enhanced thermal stability

- **Comparison** of DPO/BP at only 400°C with HELISOL® 5A at 425°C
  - **Considerably slower formation** of low boiling degradation products
  - **Less hydrogen formation** (enhanced receiver lifetimes expected)

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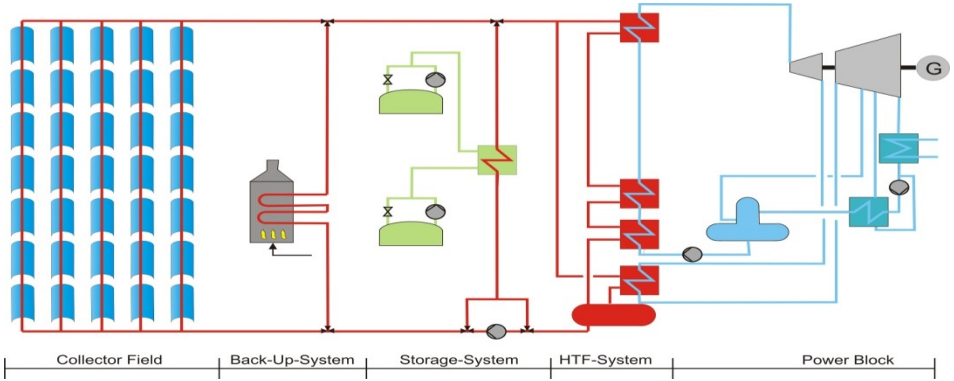
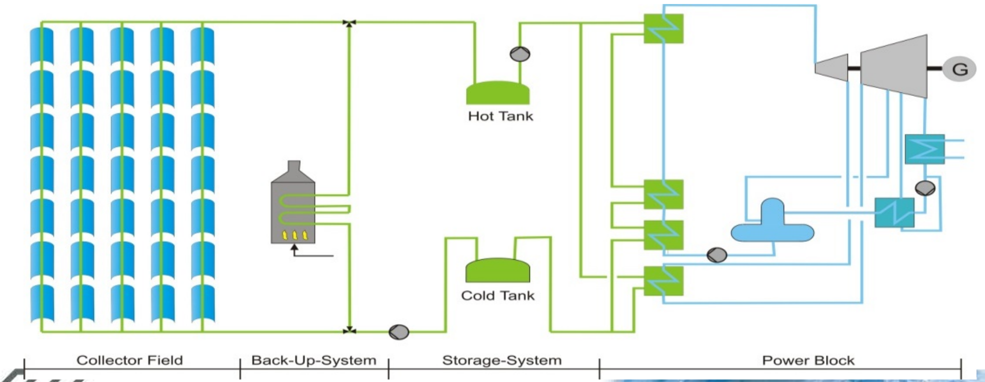
Molten Salt in Parabolic Trough Power Plants



Thermal oil (TO) based plant



Molten salt (MS) based plant

Advantages of the Molten Salt System

- **Higher overall system efficiencies** due to higher working parameters (**up to 565°C/150** bar instead of 400°C/100 bar)
- **Fully decoupled** Solar Field and power block
- **Lower price for heat transfer fluid** (HTF)
- **Environmentally friendly** heat transfer fluid vs. thermal oil

=> 20% cost reduction potential

DLR‘s objective in Évora, Portugal: to confute all concerns

Control Room

Once-Through
Steam Generating System

W/S-Cycle

Wind Fence

Solar Field Site

Thermal Energy Storage

Drainage Tank with
permanent Melting Unit

**HelioTrough loop
will be installed**

Project: HPS2 – High Performance Solar 2
Commissioning of the plant: January 2018

Supported by:

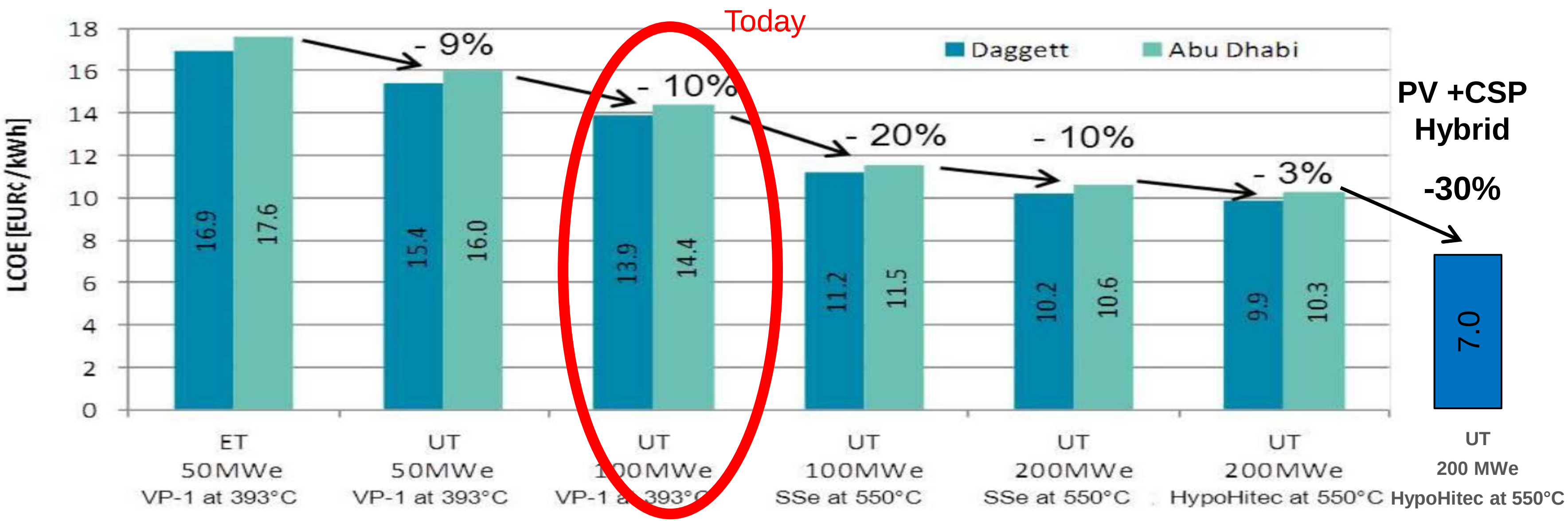
Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

See also: http://www.dlr.de/sf/en/desktopdefault.aspx/tabid-10436/20174_read-48143/

DLR

Road map of Cost reductions for molten salt parabolic trough plants



Rügamer, T., H. Kamp, et al. (2013). Molten Salt for Parabolic Trough Applications: System Simulation and Scale Effects. 19th SolarPACES Conference, Las Vegas.

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Long Term Perspective: Path to High Temperatures

Reference system: molten salt, steam cycle @540°C

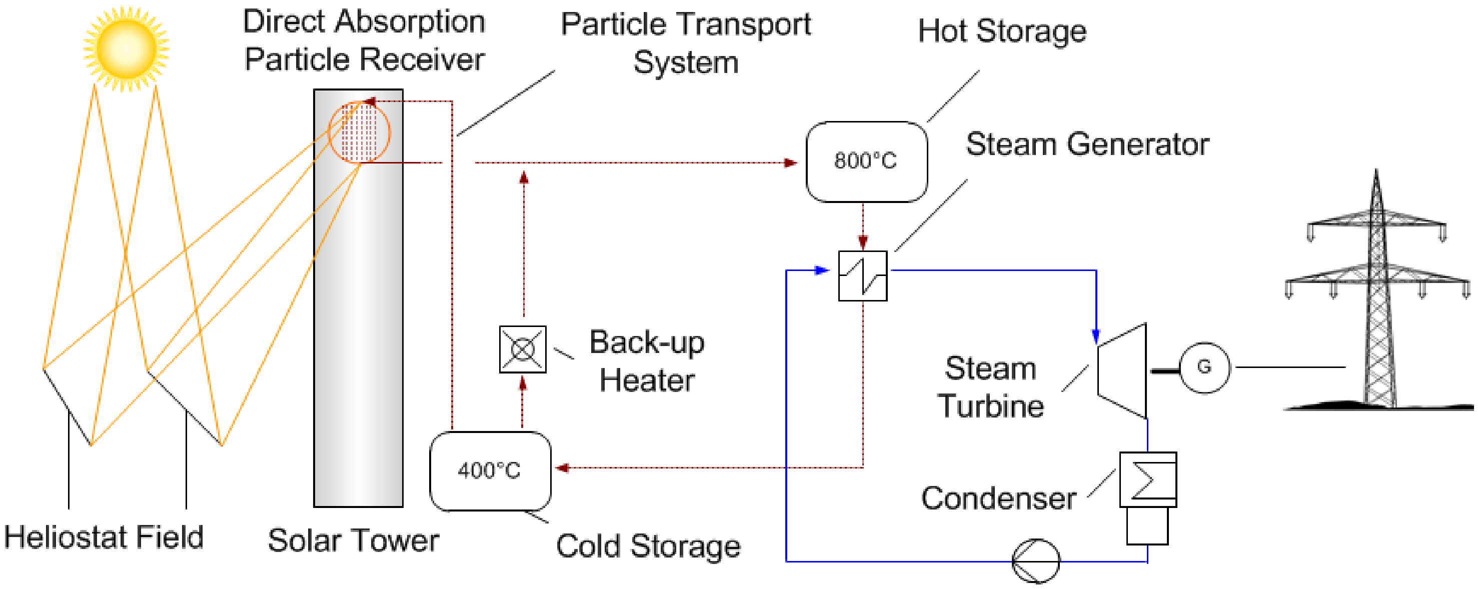
Target: higher system efficiency

- **Steam cycles of 620°C**: η_{cycle} up to 48%
- **Supercritical CO_2** cycles with up to 700°C: η_{cycle} > 50%?
- **Receiver temperature up to 1000°C**
- **Suitable heat transfer media**
  - New molten salt mixtures: cost, corrosion, degradation?
  - Liquid metals: cost, corrosion, safety?
  - **Solid particles?**

- Higher cycle efficiency ⇒ less heliostats required ⇒ **lower cost**

⇒ Bauxite particles

Principle of a Solar Particle System



Particle Direct Absorption Receiver: Falling Film Receiver

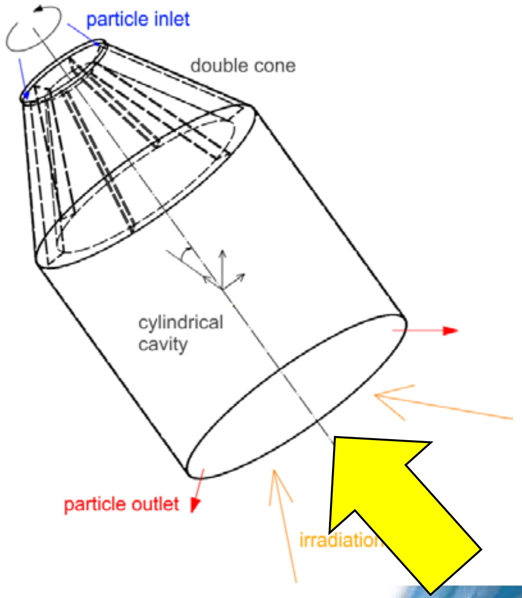
- Solar tests at temperatures > 700°C
- Particles: sintered bauxite (“proppants”)
- High particle velocities might be problematic (abrasion, attrition)

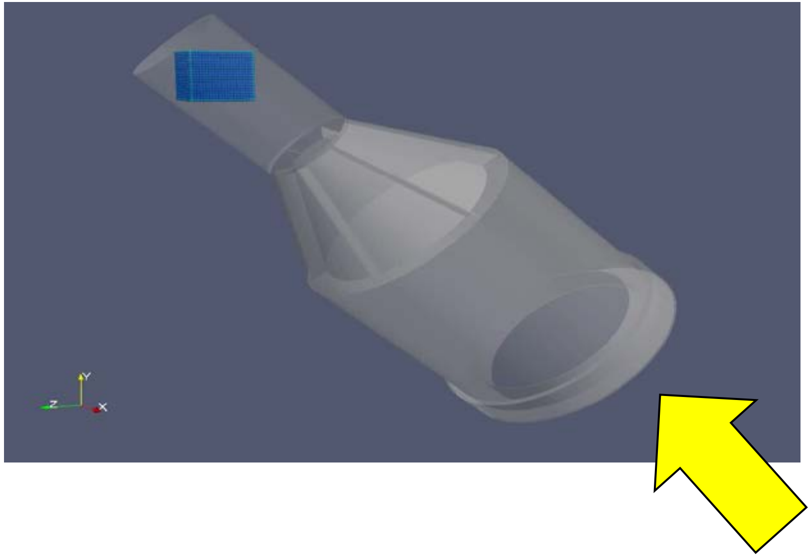


Particle receiver tests at Sandia Natl. Labs, USA

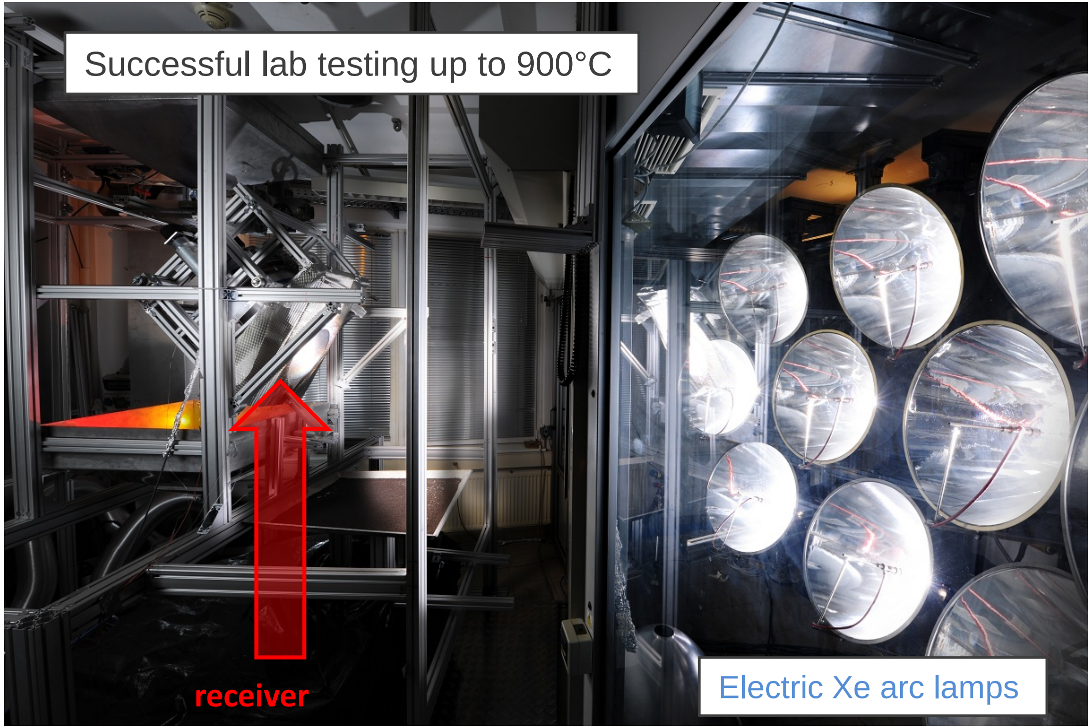
DLR Approach: Direct Absorption Receiver: Centrifugal Receiver

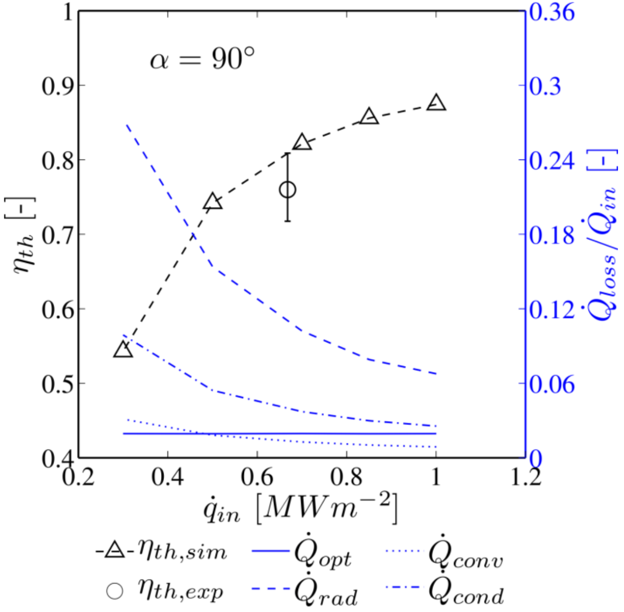
- Rotating receiver
- Centrifugal force keeps particles at the wall
- Residence time controlled by rotational speed
  - Good temperature control in all load situations





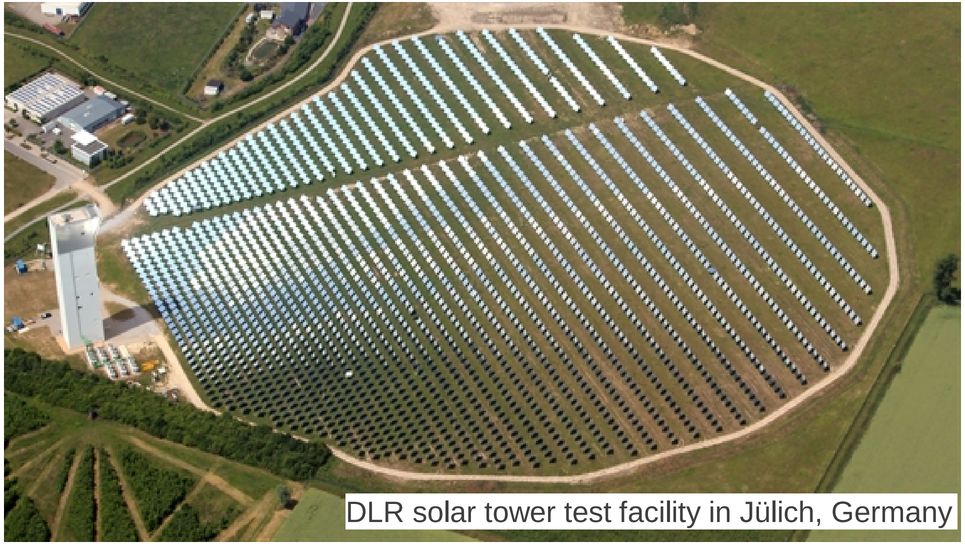
Centrifugal Particle Receiver: 10kW Test Receiver



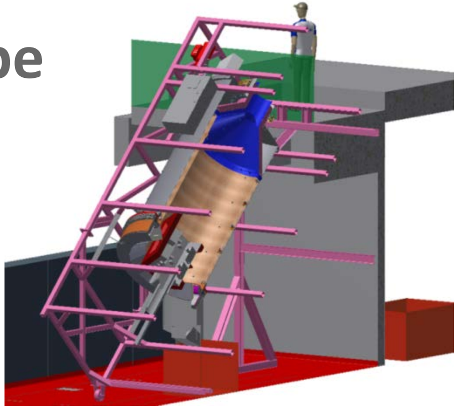


High receiver efficiency due to high flux capability

Centrifugal Particle Receiver: 500kW Prototype

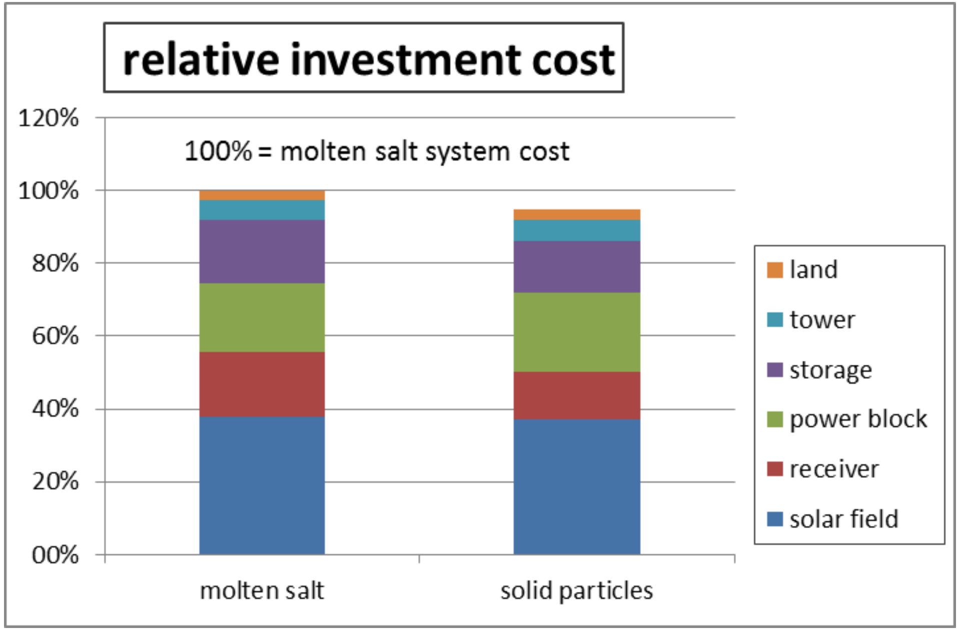


DLR solar tower test facility in Jülich, Germany



- 500 kW_{th} test prepared for summer 2017
- 900°C design particle outlet temperature

Economics of Solar Particle Systems vs. State of the Art Molten Salt Tower



⇒ LCoE reduction potential: about 16%

Conclusions

- **Cost reduction** requires **higher process temperature** to reach to higher solar-electric efficiency
- **New heat transfer fluids** needs to be integrated to reach higher process temperature
- **Advanced oil, molten salt or solid particles** are currently under large-scale testing to proof their feasibility
- **CSP + PV Hybrid Plants** has the potential to **meet price targets**

Thank you for your attention

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