Multi-Tower Systems with Centrifugal Particle Receiver

Particle Receiver Panel, August 25, 2021

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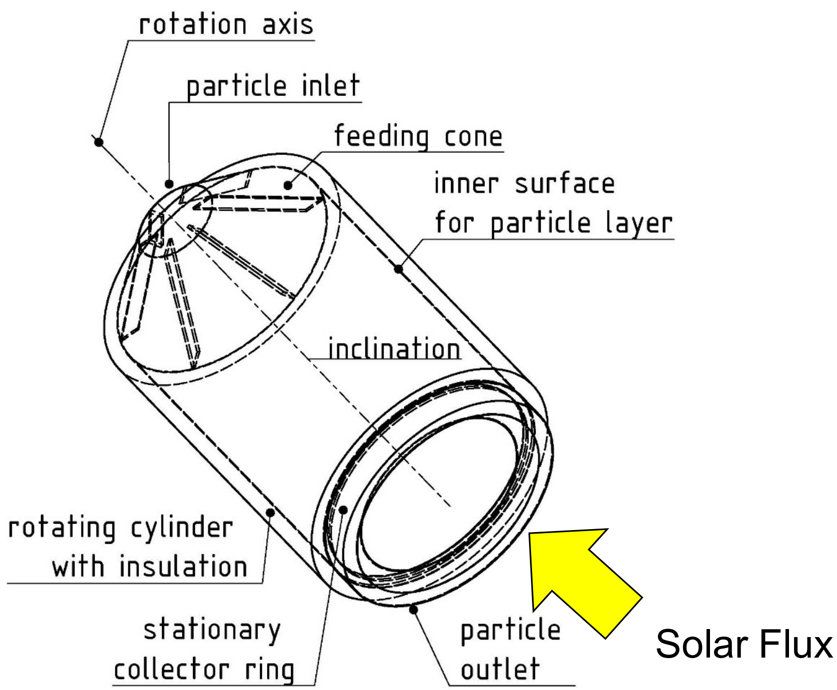
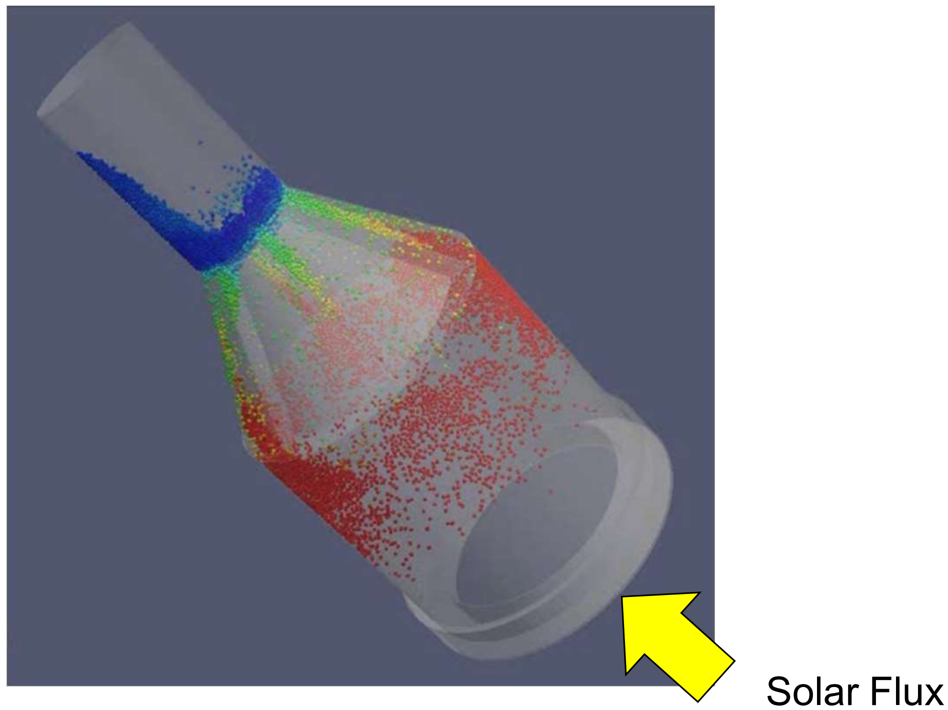
DLR

Introduction Centrifugal Particle Receiver „CentRec®“

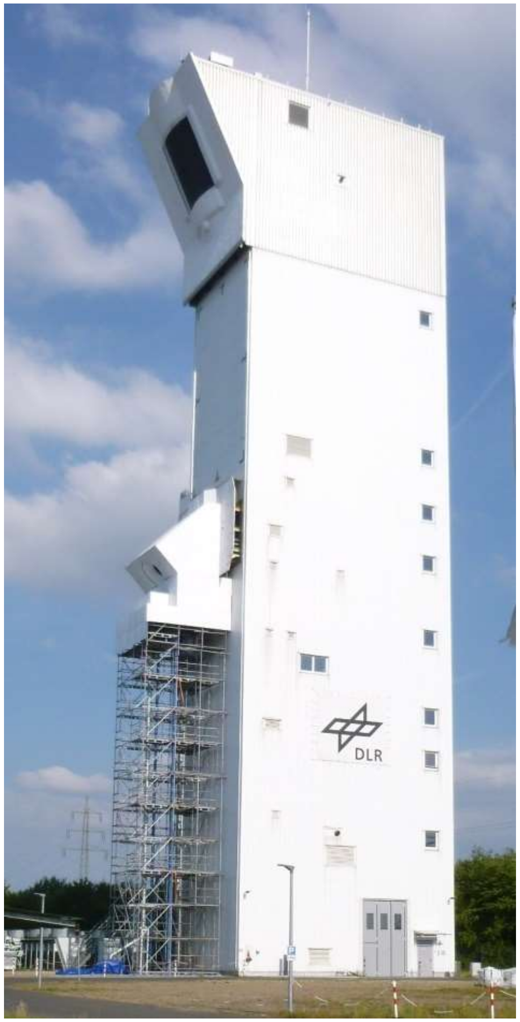


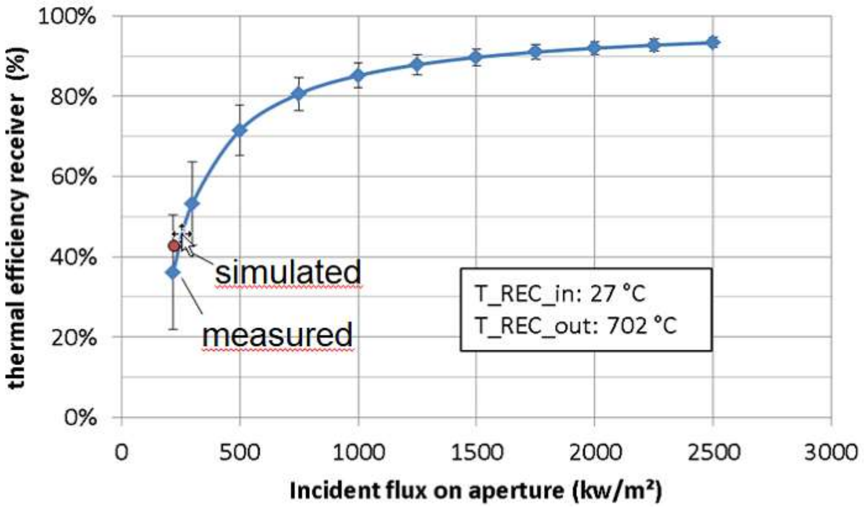


- Particle residence time / receiver outlet temperature controlled by adjusting rotational speed
- Thin, optical dense layer for all load conditions

CentRec500 – Test Campaign

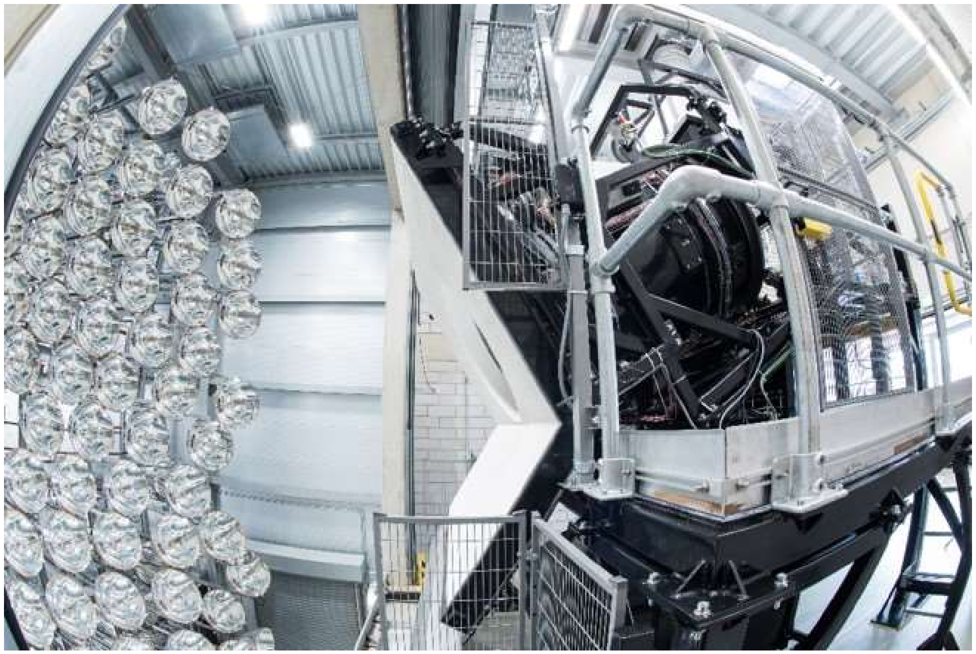
- Jülich Test Campaign 2017 – 2018:
- first on-sun test of CentRec® receiver
- validation only possible on < 500 kW input from solar field (Hence, the receiver titled CentRec500)
- T_{out} = 965°C (at < 10 % part load) achieved
- only one suitable steady-state point acquired at Tout =702°C permitting permitting validation of simulation models



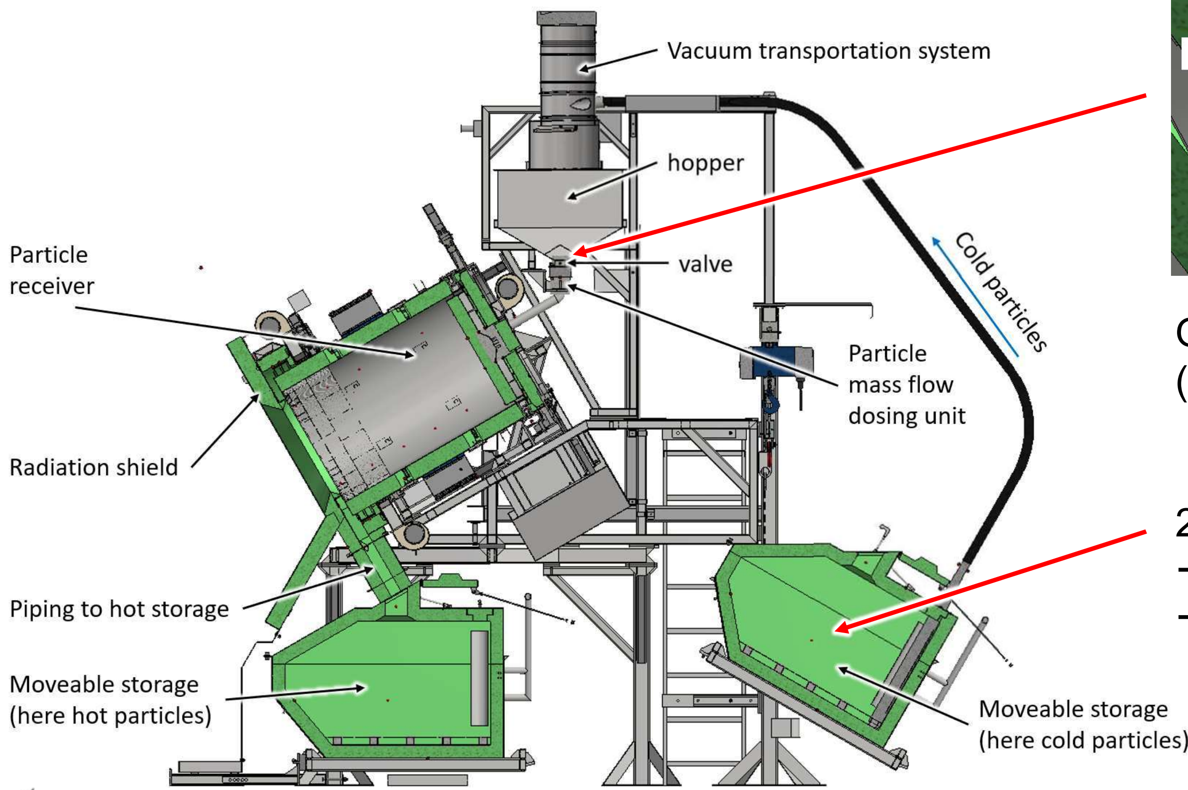


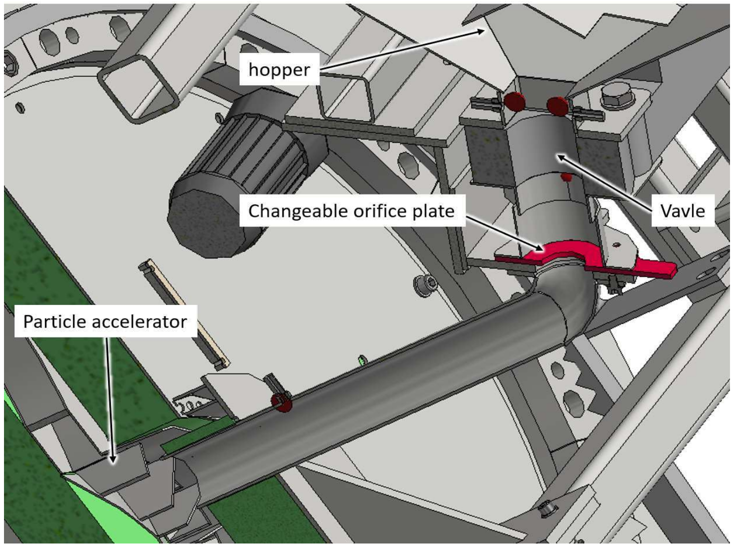
Recent Testing of 300kW Centrifugal Receiver

- Part of EU project “PEGASUS”: use of particle technology for solar-driven sulfur cycle
- Receiver aperture diameter: 60cm
- Tests in DLR sun simulator “Synlight” in Jülich



PEGASUS Test Setup
in Synlight Sun Simulator





Operation with fixed particle mass flow (changable orifice plates)

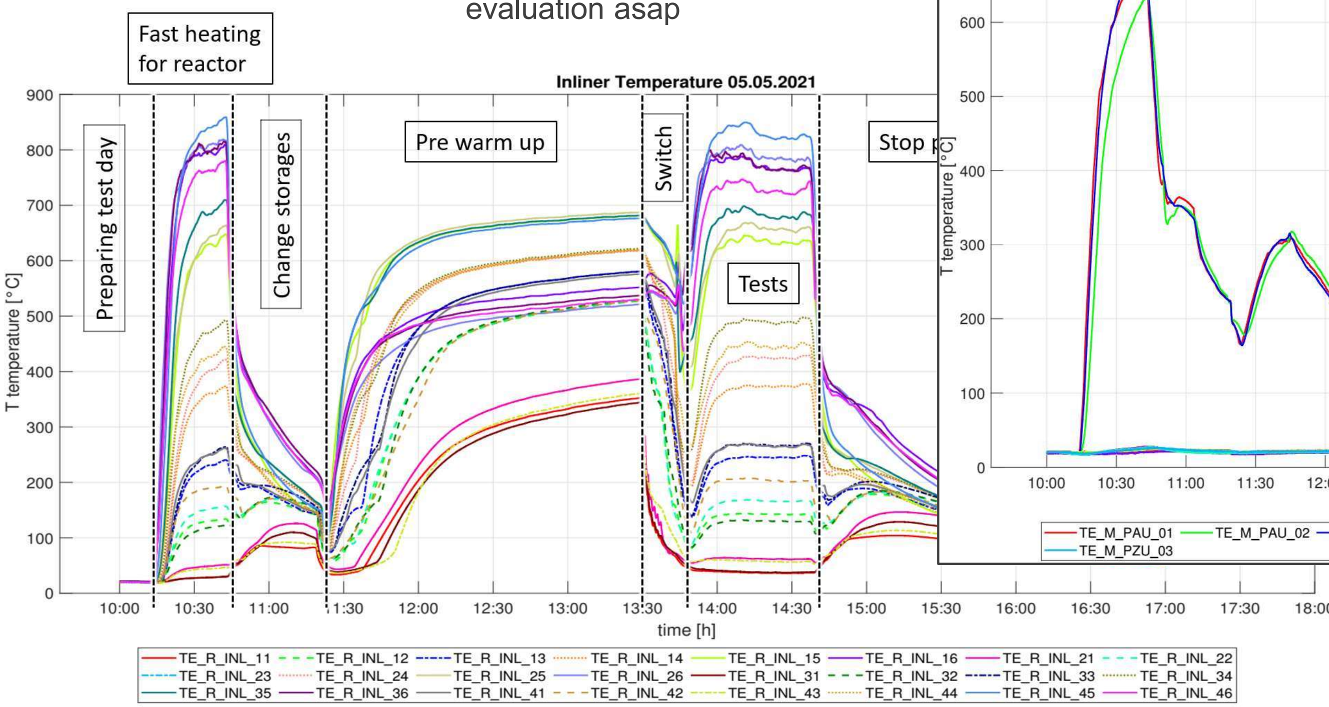
2 containers à 1 t particles
→ Batch mode operation
→ Particles cooled down at night with air

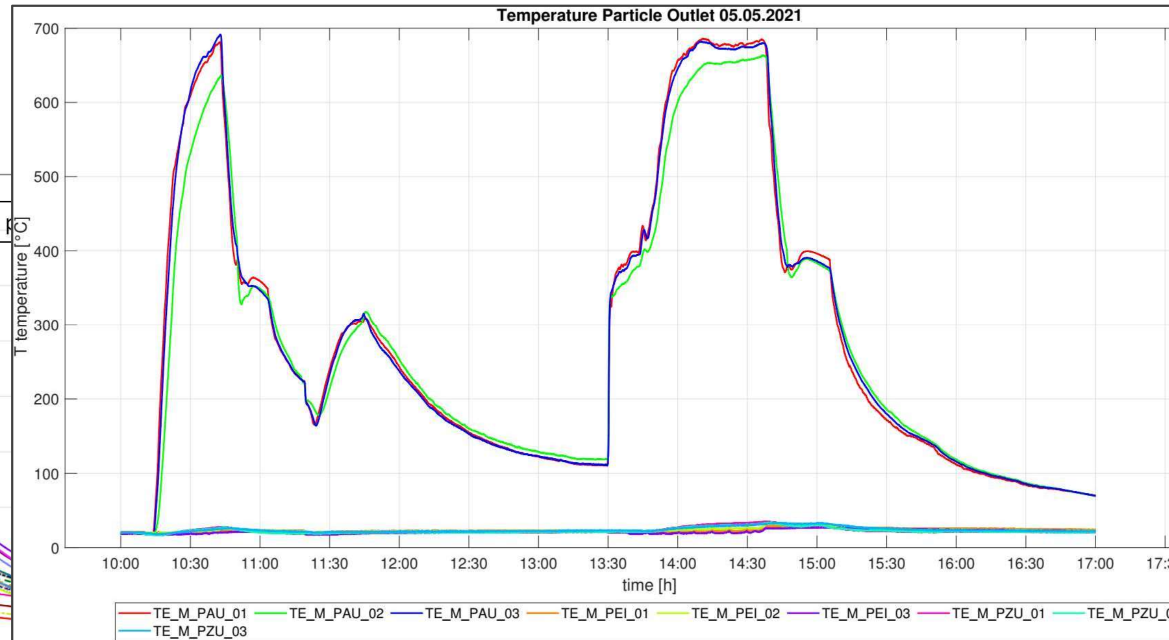
Test 05.05.2021 – Typical test run

Operation time per test limited by infrastructure (batch mode, particle transport capacity)

Test 1: fast heating to provide hot particles to consecutive sulfur cycle

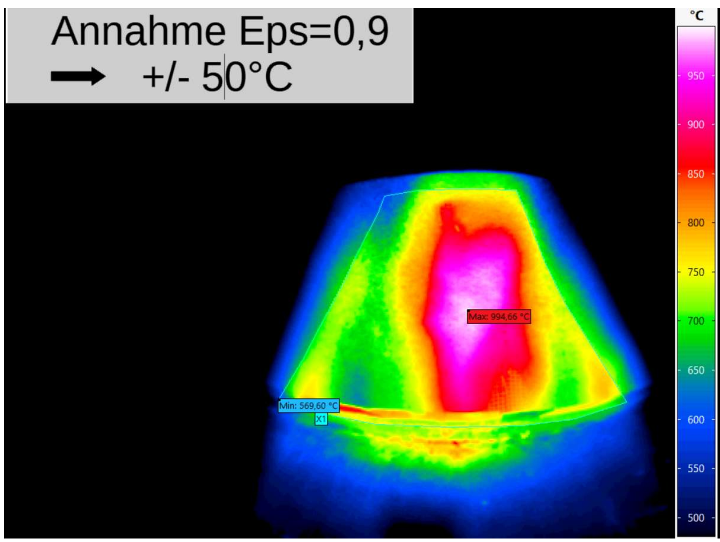
Test 2: pre-heating without particle flow to achieve steady-state test conditions for evaluation asap

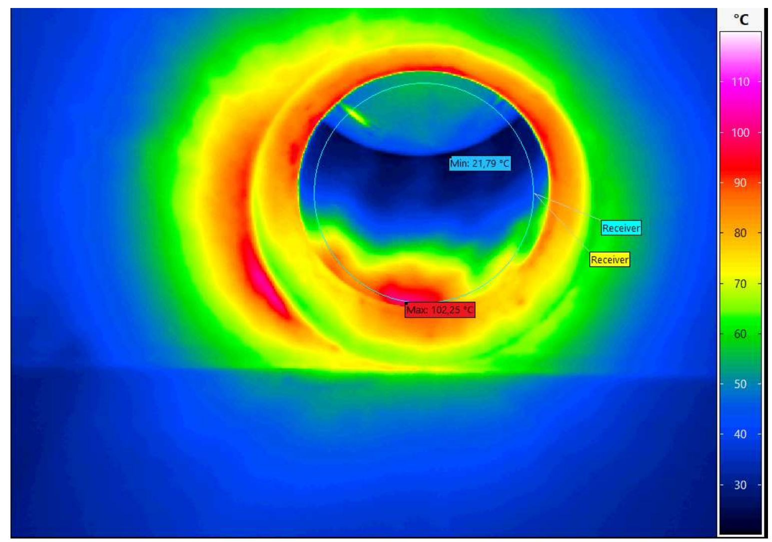




PEGASUS Test Results

- 22 test days with „solar“ operation, 25 h regular test time at various temperature levels
- Inhomogeneous mass flow distribution over circumference
  ⇒ Hot spots limit the maximum achievable temperature
- Max. measured outlet temperature: 720°C
- Errors in measured outlet temperature
  - Measured particle outlet temperature < particle temperature in storage (by about 50K)
- Currently analysis of reason for hot spots: particle distributor, cylinder tolerances, grid structure, …

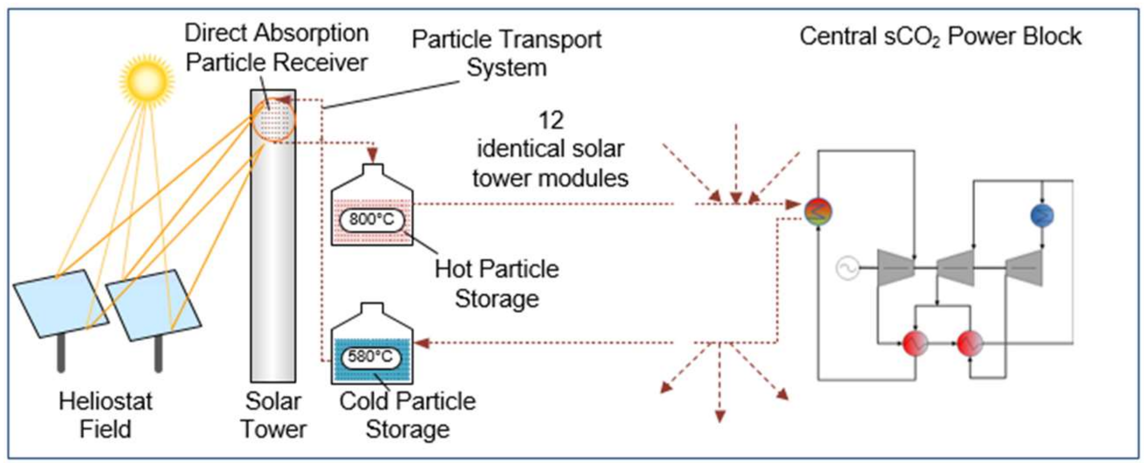




Results of Improved System Analysis
(in cooperation with Jeremy Sment, SNL)

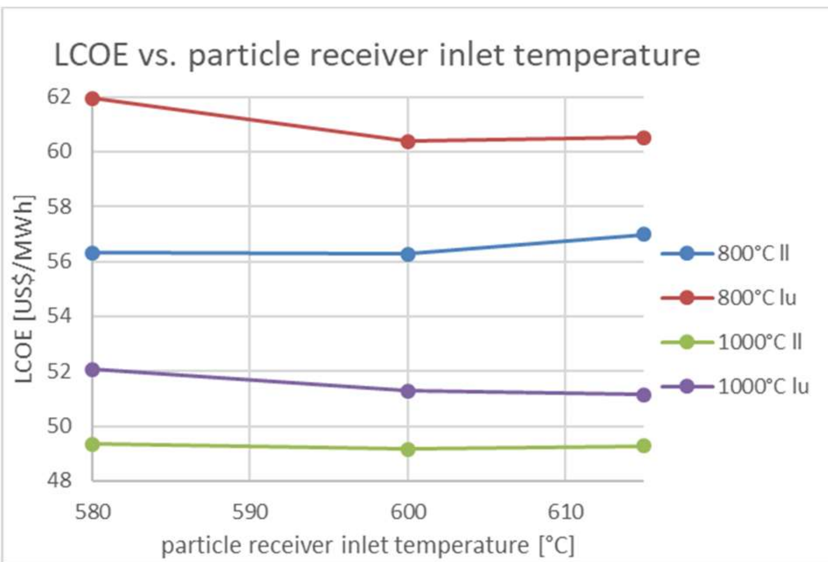
- Main assumptions according to Gen3 specifications
- Multi-tower system, 12 modules, each with $42MW_{th}$ centrifugal receiver and 14h tower-integrated storage
- Particle transport between modules and central power block: insulated containers, autonomous trucks
- sCO_2 power cycle 565°C / 700°C, η = 48%
- Lower/upper boundary cost correlation for tower (1st marker “l” or “u”)
- Lower/upper boundary cost correlation for primary HX (2nd marker “l” or “u”)

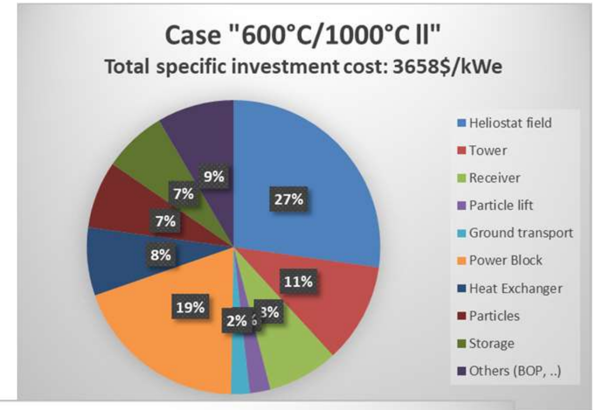
Parametric study for particle temperature selection
- Lower particle temperature: 580 / 600 / 615°C
- Upper particle temperature: 800 / 1000°C

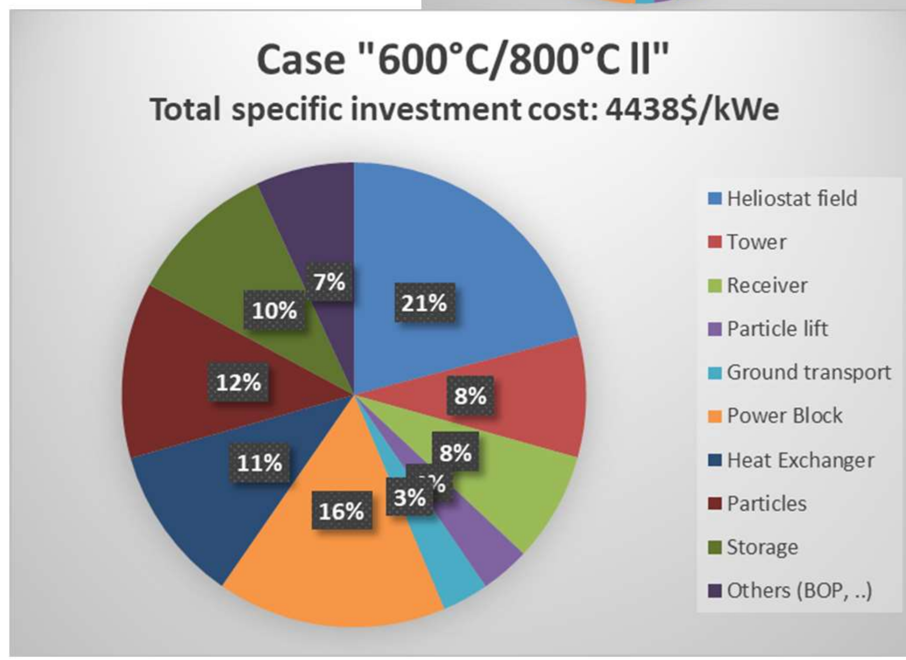


Results of Improved System Analysis
(in cooperation with Jeremy Sment, SNL)

- LCOE range from 49$/MWh to 66$/MWh
- Strong impact of assumptions for tower and HX cost correlation
- Strong impact of upper particle temperature
- Little impact of lower particle temperature







(no price escalation for DoE Gen3 parameters and other values considered)

Risks and Mitigation Measures

- **Particle loss**
  - Small chance for particle entrainment under high wind conditions
  - Preparation of lab tests for validation
- **Performance**
  - Too few “good” test data available yet
  - Further tests with improved sensors and longer test time required
- **Particle film characteristics**
  - Inhomogeneous particle flow creates hot spots
    - Ongoing lab tests to evaluate impact of potential sources
  - Thermal conductivity of particle film
    - Mixing effect in flowing particle film?
    - PhD work to evaluate this effect near completion
- **Cost**
  - Cost predictions need to be validated for
    - Receiver
    - (Particle ground transport)
- **Potential for further cost reduction**: hybrid CST/CPV receiver, multi-receiver tower, aim point switching, …

Ongoing Activities

- HIFLEX
  - EC project to install and tests a complete particle demonstration system in Italy; 2.5MW$_{th}$ receiver, ~ 10MWh storage, 620°C steam generator
- HEHTRES
  - DLR particle test infrastructure @ Solar Tower Jülich, 1MW$_{th}$ receiver
- PreMa
  - EC project for manganese production, includes particle-to-air heat exchanger development
- KOSTPAR
  - BMWi project; receiver upscaling, steam generator development
- TCF / NoLimits
  - DoE/BMWi project: Full load demonstration of particle receiver @ SNL/NSTTF, 600kW$_{th}$ receiver

Under preparation

- SpiCoPV (BMWi):
  - Integration of CPV into particle receiver aperture (to capture spillage)
- KOSTPAR-2 (BMWi):
  - Further receiver improvement, Steam generator demonstration

Thank you for your attention!

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