DLR Institute of Solar Research
Overview

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DLR

Research Fields

Solar thermal power plants

- Solar tower
- Parabolic trough
- Solar plant optimisation
- Plant control
- Qualification
- Energy Meteorology

Solar chemical engineering

- Processes for the generation of solar fuels, i.e. hydrogen
- Solar water treatment

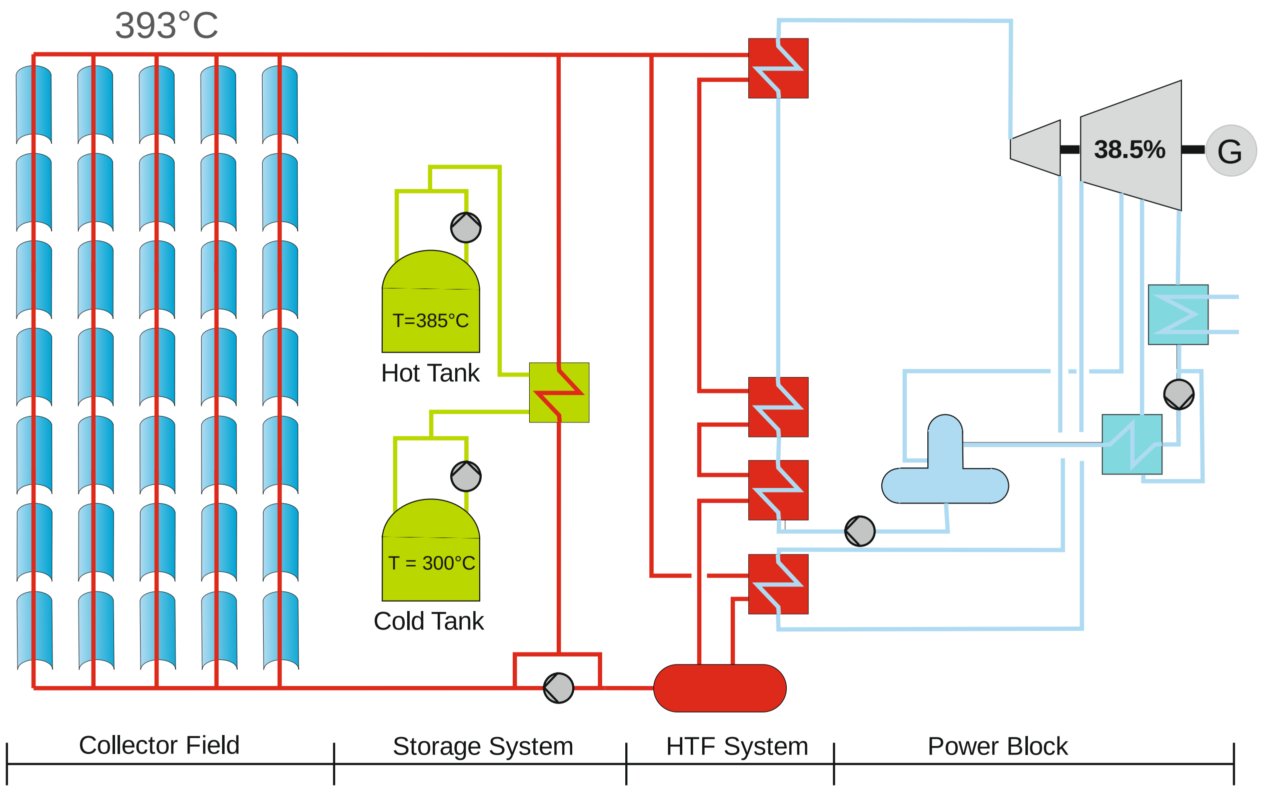
Thermal characterisation of building envelopes

- Using radar and infrared
- Measurements from outside
- Measurements from inside

The following slides show a selection of projects and work

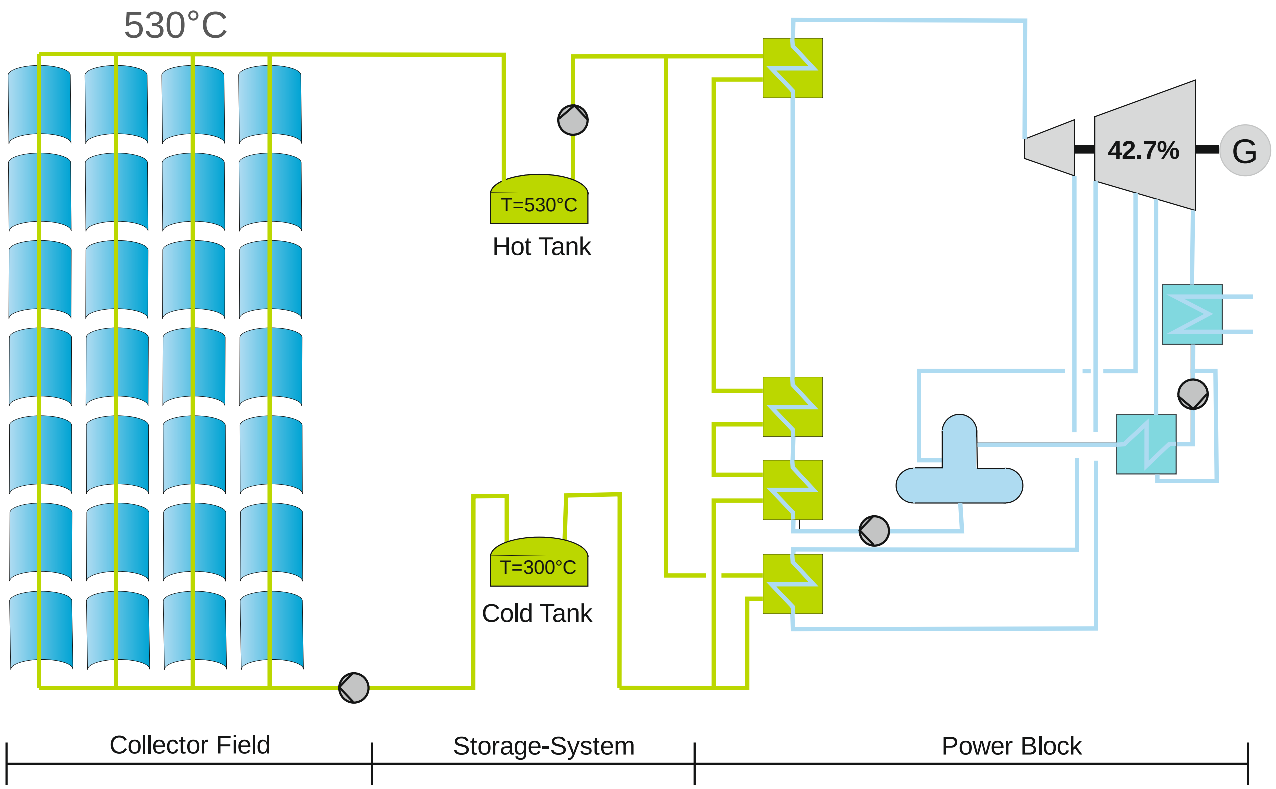
Molten Salt at Increased Temperatures

Approach for parabolic trough:
replace thermal oil by molten salt



Molten Salt at Increased Temperatures

Approach for parabolic trough: replace thermal oil by molten salt



Advantages:

- Increased HTF temperature (up to 565°C)
- Increased power block efficiency
- Increased storage density
- Reduced pumping losses
- Reduced system complexity
- Reduced investment cost

⇒ Significant reduction of LCOE

Molten Salt in Parabolic Troughs
Évora Molten Salt Platform (EMSP)

Challenges:

- Salt Freezing: filling and draining, losses in non-operation mode, freezing in normal operation mode
- Performance of the SCA / HCE
- Flexible connections
- Steam generating system

Demonstration in EMSP:

- Develop safe and efficient operation procedures
- Proof of performance and durability of components
- Achieve bankability

TSK FLAGSOL · YARA · Universidade de Évora · eltherm · steinmüller engineering · DLR · RIOGLASS · innogy · TSK · TSK FLAGSOL · SIEMENS

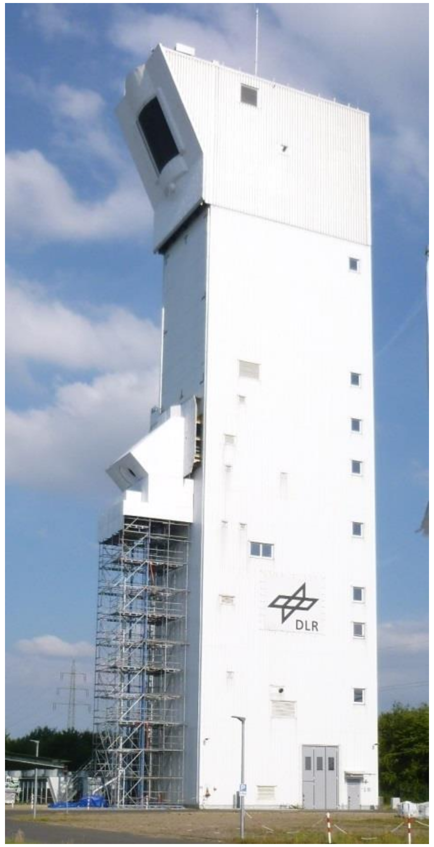
- 2.7 MW_{th} Heliotrough™ collector loop
- 1.6 MW_{th} once-through steam generator
- 2 hours thermal energy storage
- Maximum temperature 565 °C

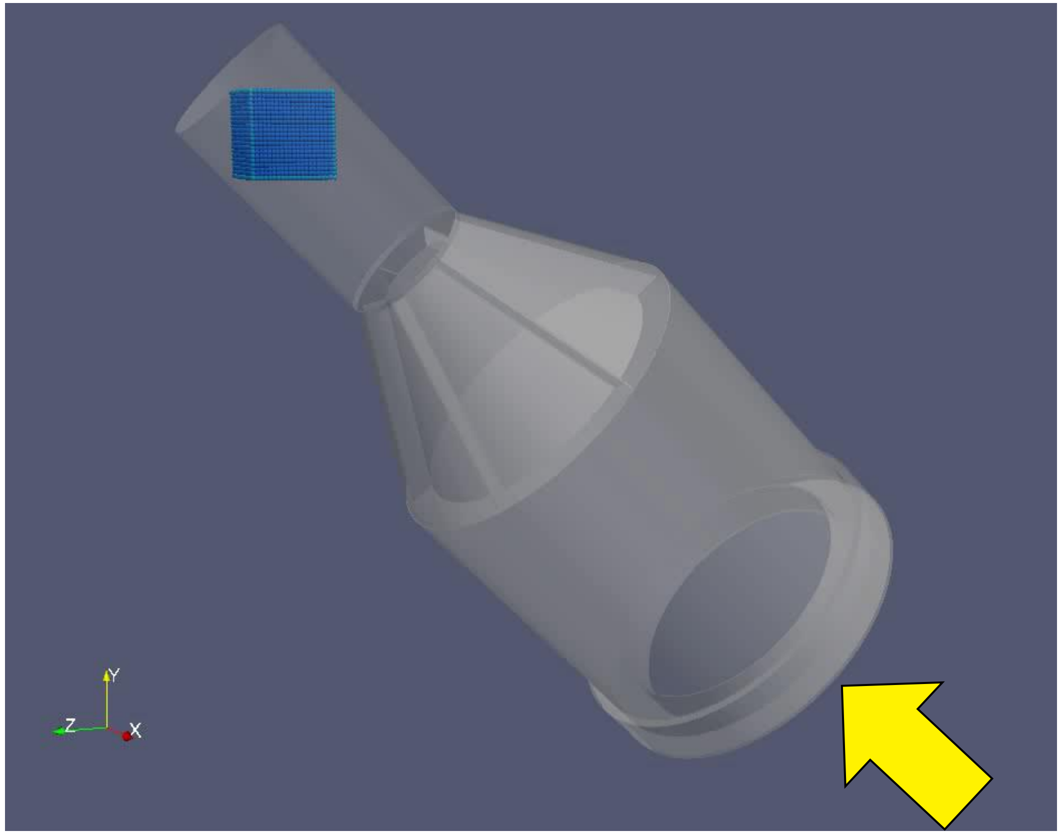
Particle Systems

Objective: Develop a high-efficiency receiver for high temperatures

⇒ Centrifugal particle receiver **CentRec** ® for 1000°C

- Bauxite particles
  - Cheap (500 – 1000 €/ton)
  - Stable >1000°C
- Direct absorption receiver
- Particles as heat transfer and storage medium

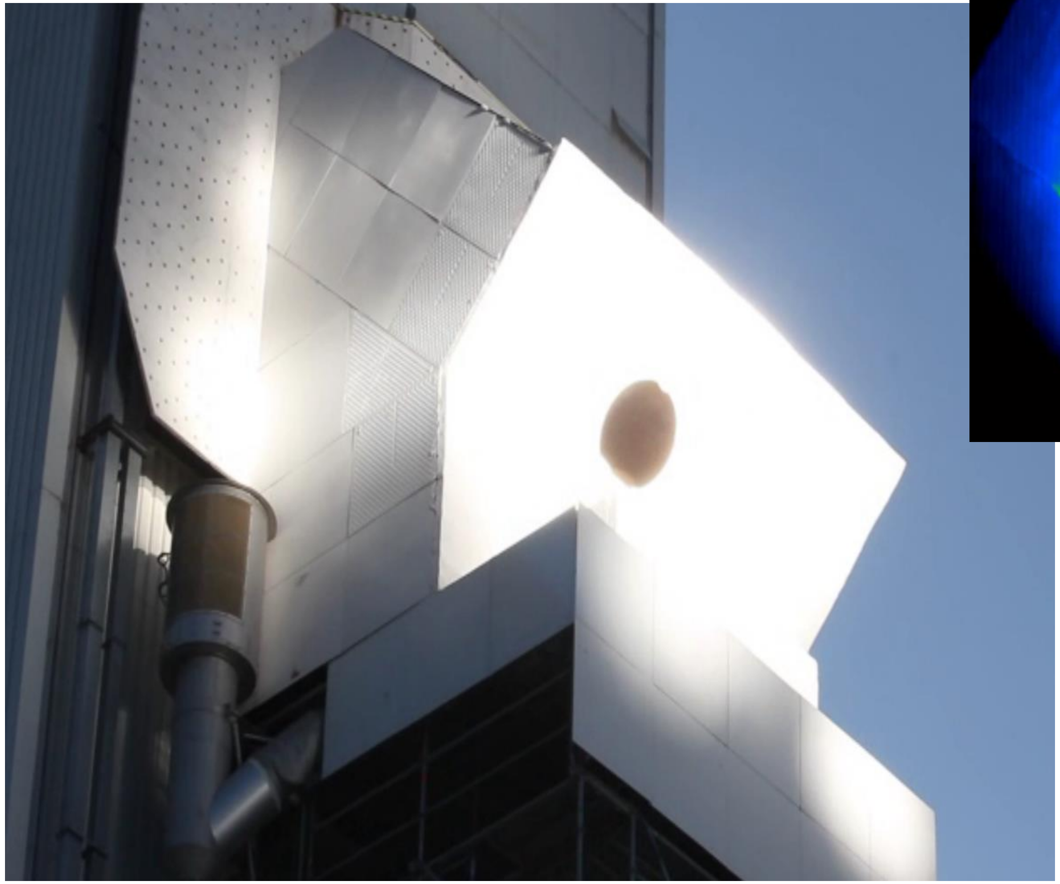


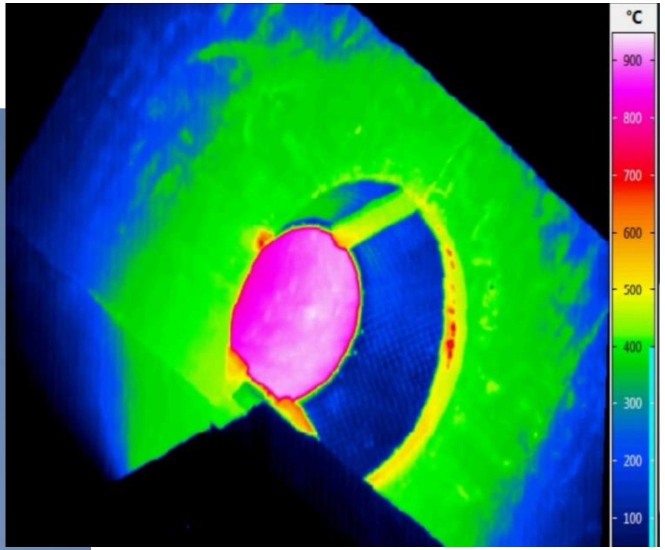


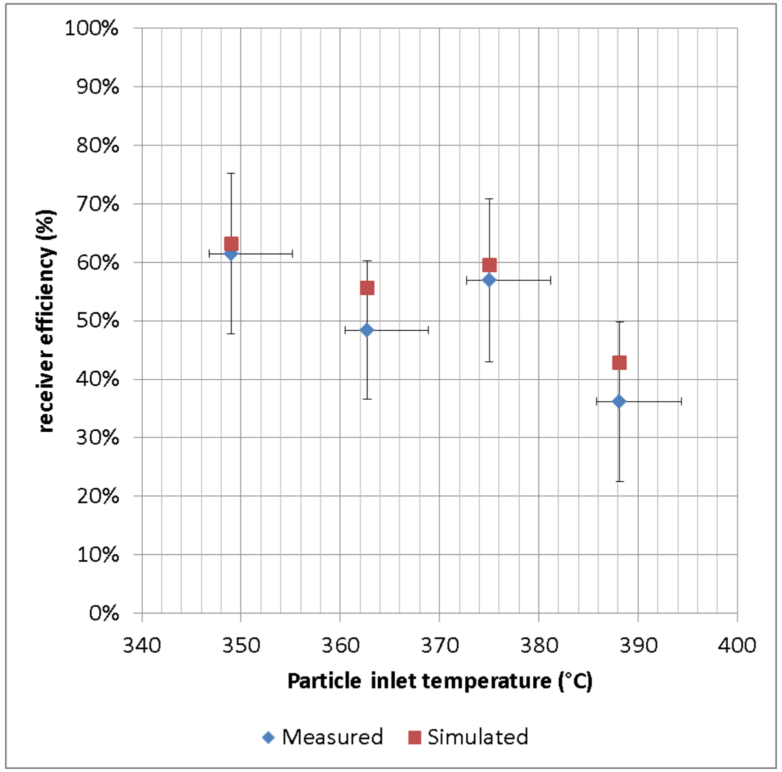
- Residence time controlled by rotational speed
- Cylinder walls isolated by particle layer

Particle Receiver Test

Solar tests in Jülich Solar Tower







Test results:

- About 70 hours of solar operation in 25 test days
- Receiver outlet temperature of 965°C achieved
- Homogeneous temperature over circumference
- Receiver efficiency corresponds to simulation model

Particle System Status

Power production: annual system efficiency > 20% predicted

- Assuming 620°C steam power block with 43% efficiency, further improvement possible
- With future sCO_2 cycles, even higher efficiencies are predicted

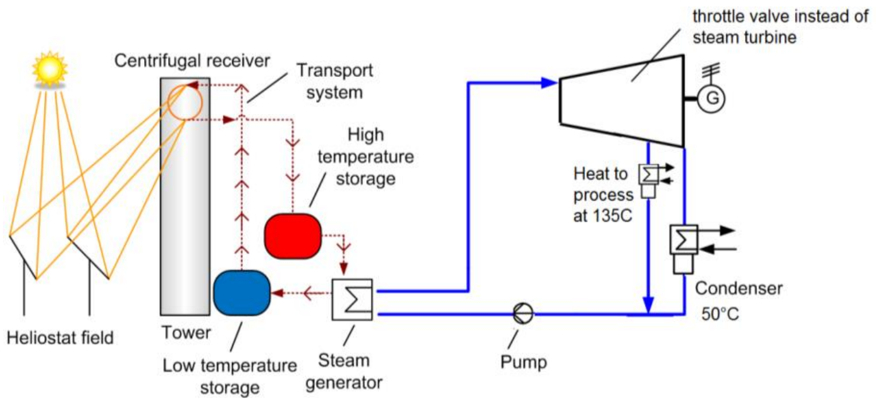
Process heat: focus for near-term applications, large variety of applications

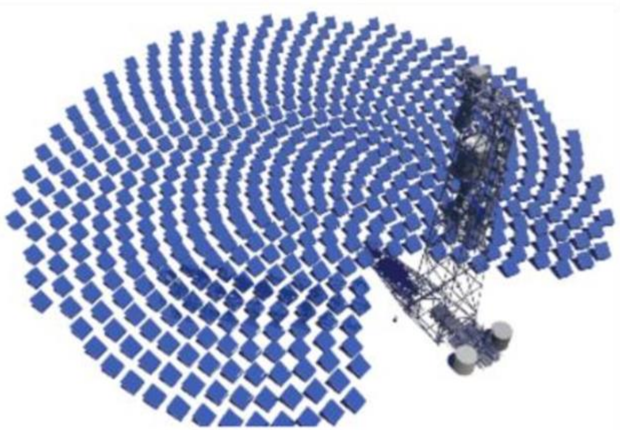
Foundation of spin-off company HELIOHEAT in 2017

- Marketing and production of CentRec® receiver technology (under license from DLR)

Lighthouse Project HIFLEX:

- EU project with 9 international partners, 18.4 M€
- complete particle system with 2.5MW$_{th}$ receiver, providing 800kW$_{th}$ for 24/7 using particle storage, produce steam at 620°C



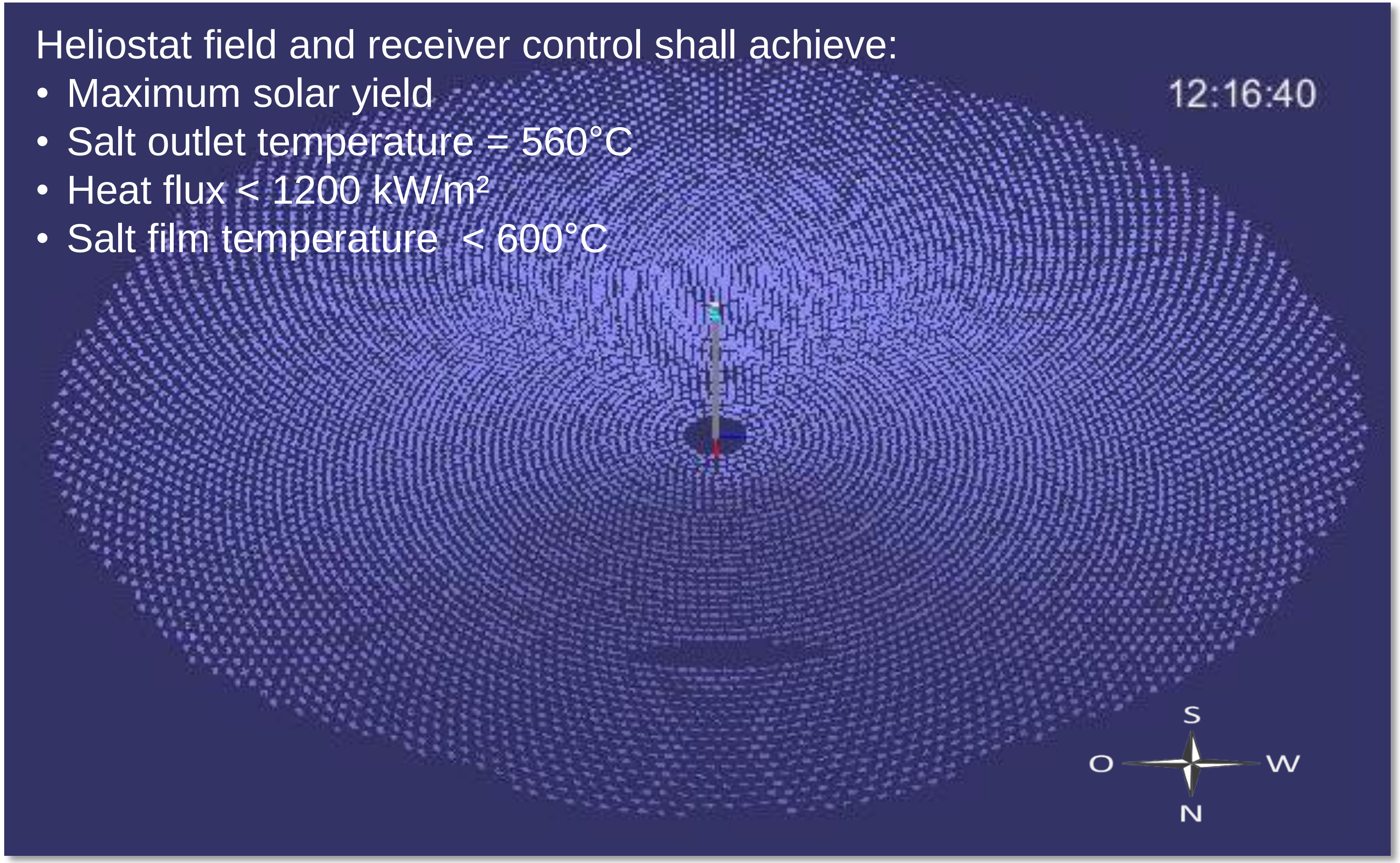


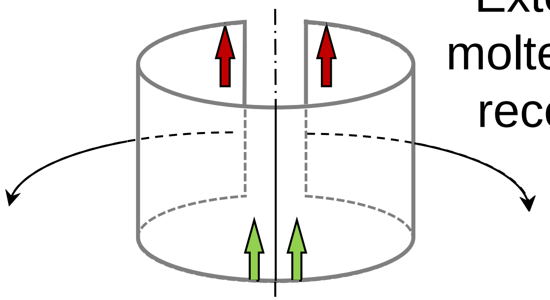
Autonomous Plant Control using Artificial Intelligence

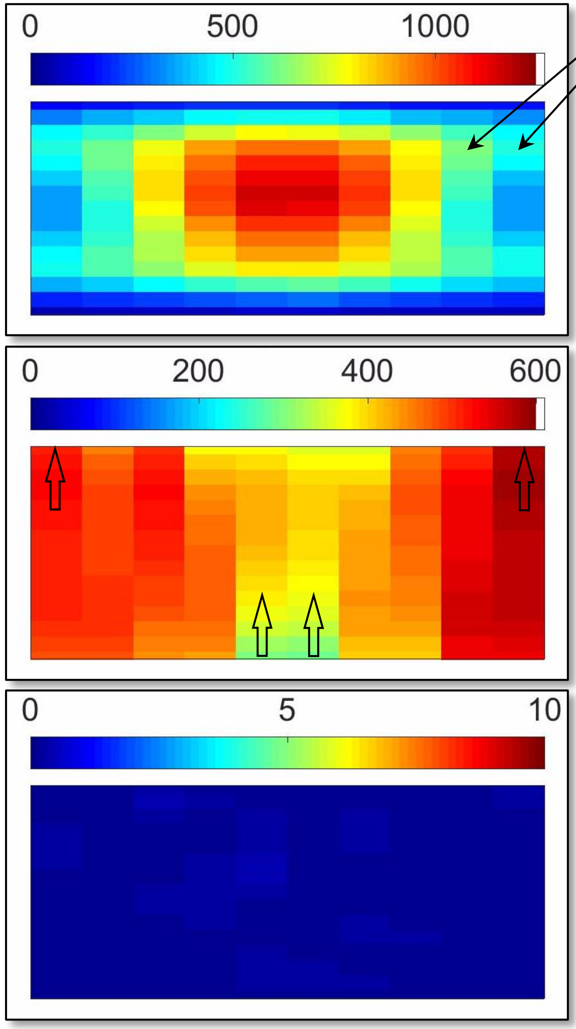
Operation Simulation using Ray-Tracing & Aim-Point Strategies

Heliostat field and receiver control shall achieve:

- Maximum solar yield
- Salt outlet temperature = 560°C
- Heat flux < 1200 kW/m²
- Salt film temperature < 600°C







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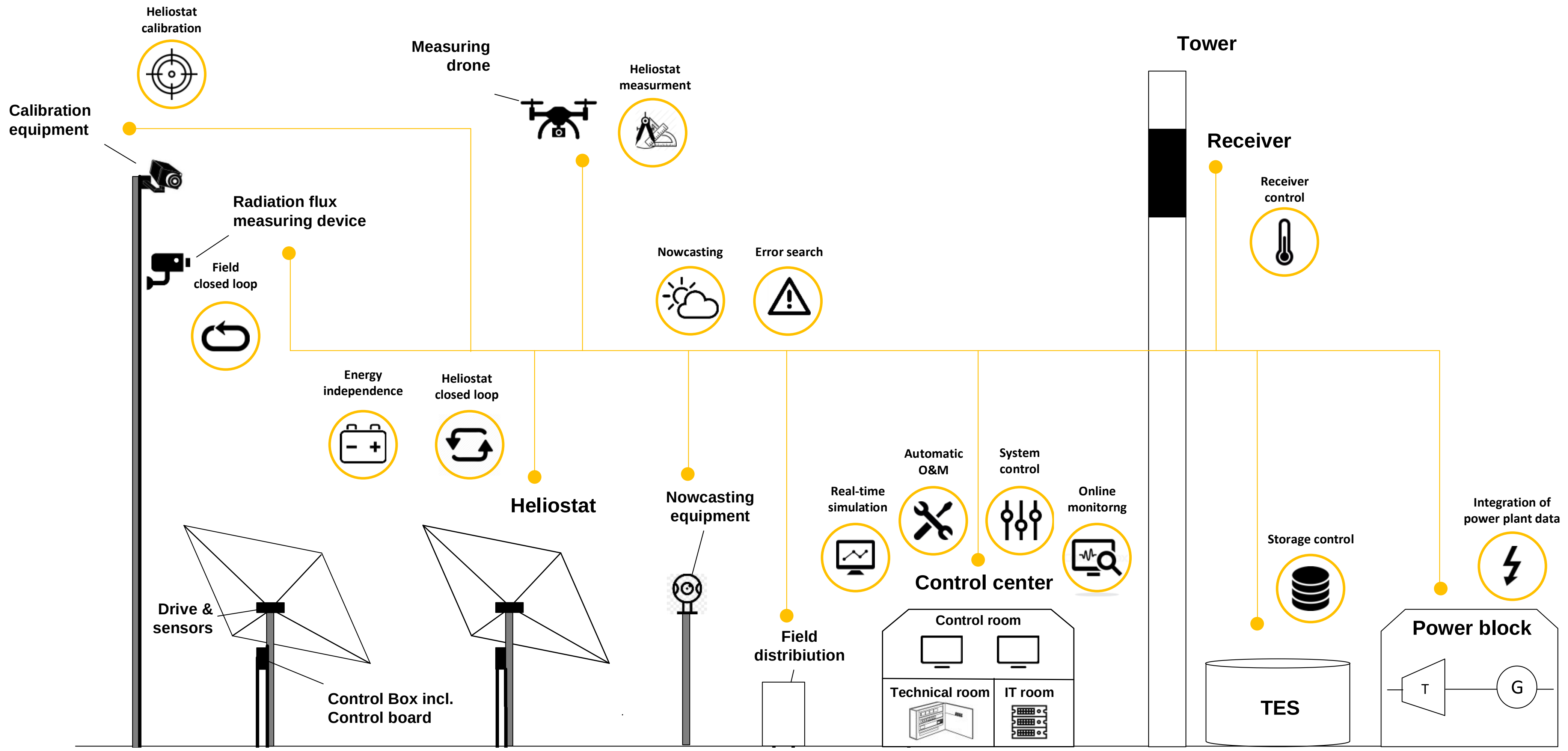
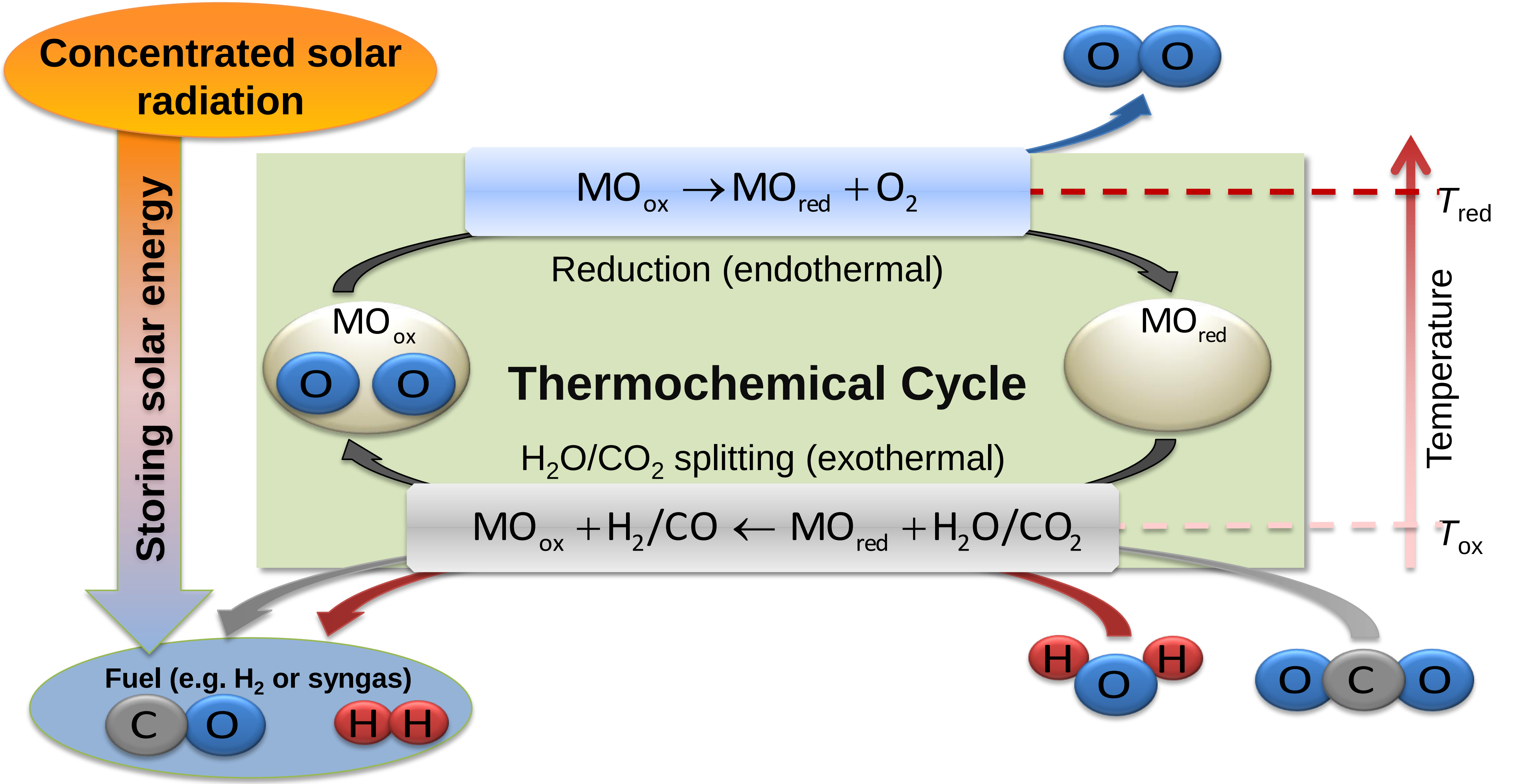


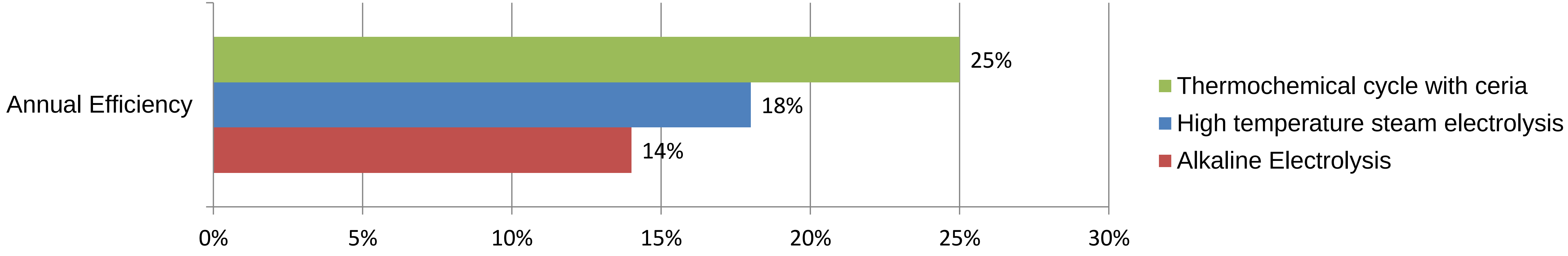
Demonstration in Jülich planned

Thermo-Chemical Cycles for Solar Fuels



Solar Hydrogen Production from Water – Theoretical Efficiencies

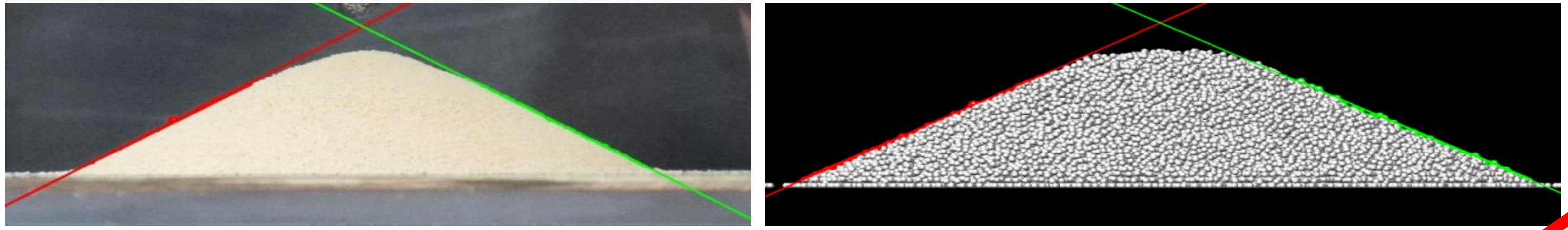
Process	Temperature	Solar interface
	of the chemical reaction	receiver temperature
Alkaline Electrolysis	25°C	Solar PV
High temperature steam electrolysis	850°C	Future solar tower 1200°C
Thermochemical cycle with ceria	1500 / 1150°C	Future solar dish 1500°C



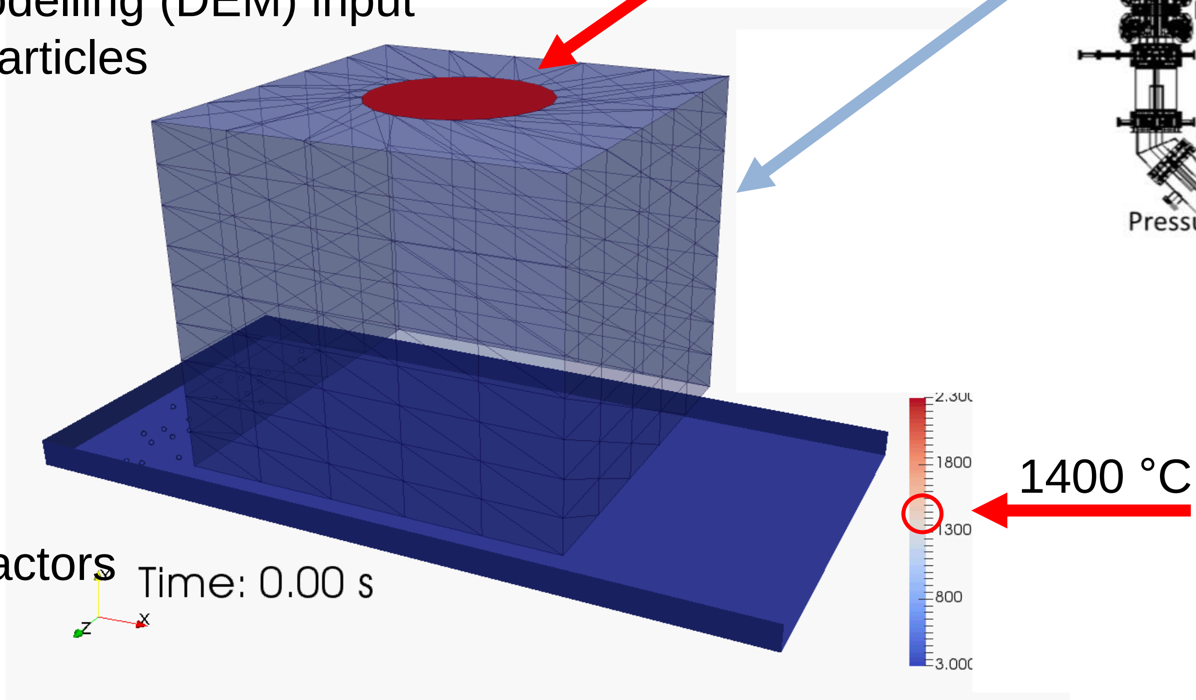
*G.J. Kolb, R.B. Diver SAND 2008-1900 / N. Siegel et al. I&EC Research May 2013

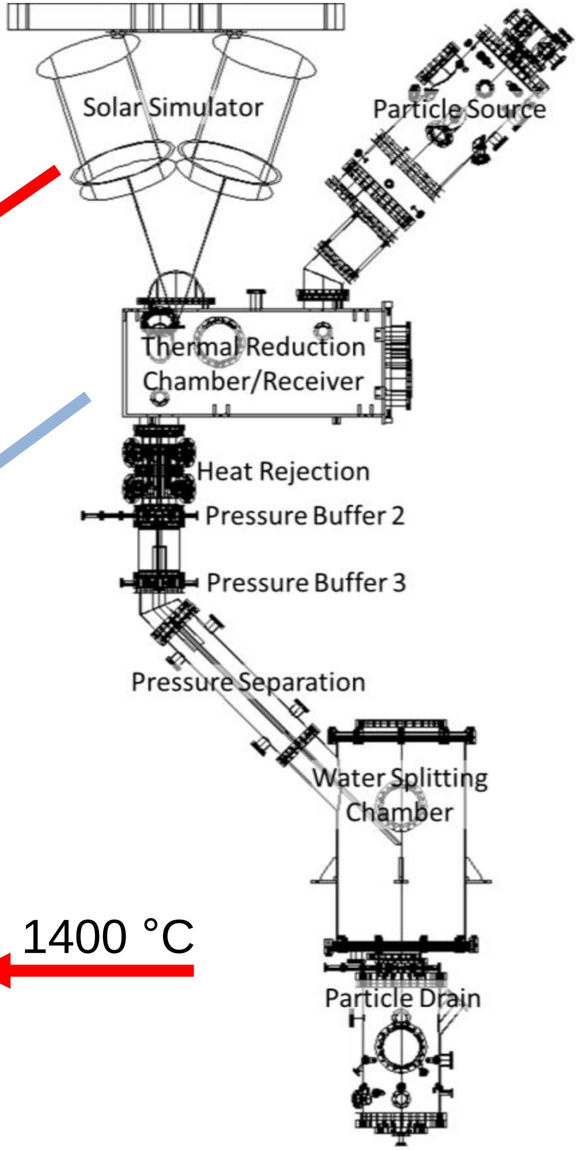
Development of New Reactors with Higher Efficiency

- Modelling Solar Vacuum Particle-Reactors



- Calibration of Discrete Element Modelling (DEM) input parameters for bauxite and ceria particles
- Heat transfer models for DEM
  - Chemical reaction
  - Inter-particle model
  - Radiation with Monte Carlo Ray Tracing
- Use for the design of advanced reactors





QFly: Airborne Condition Monitoring and Optimisation of Plants

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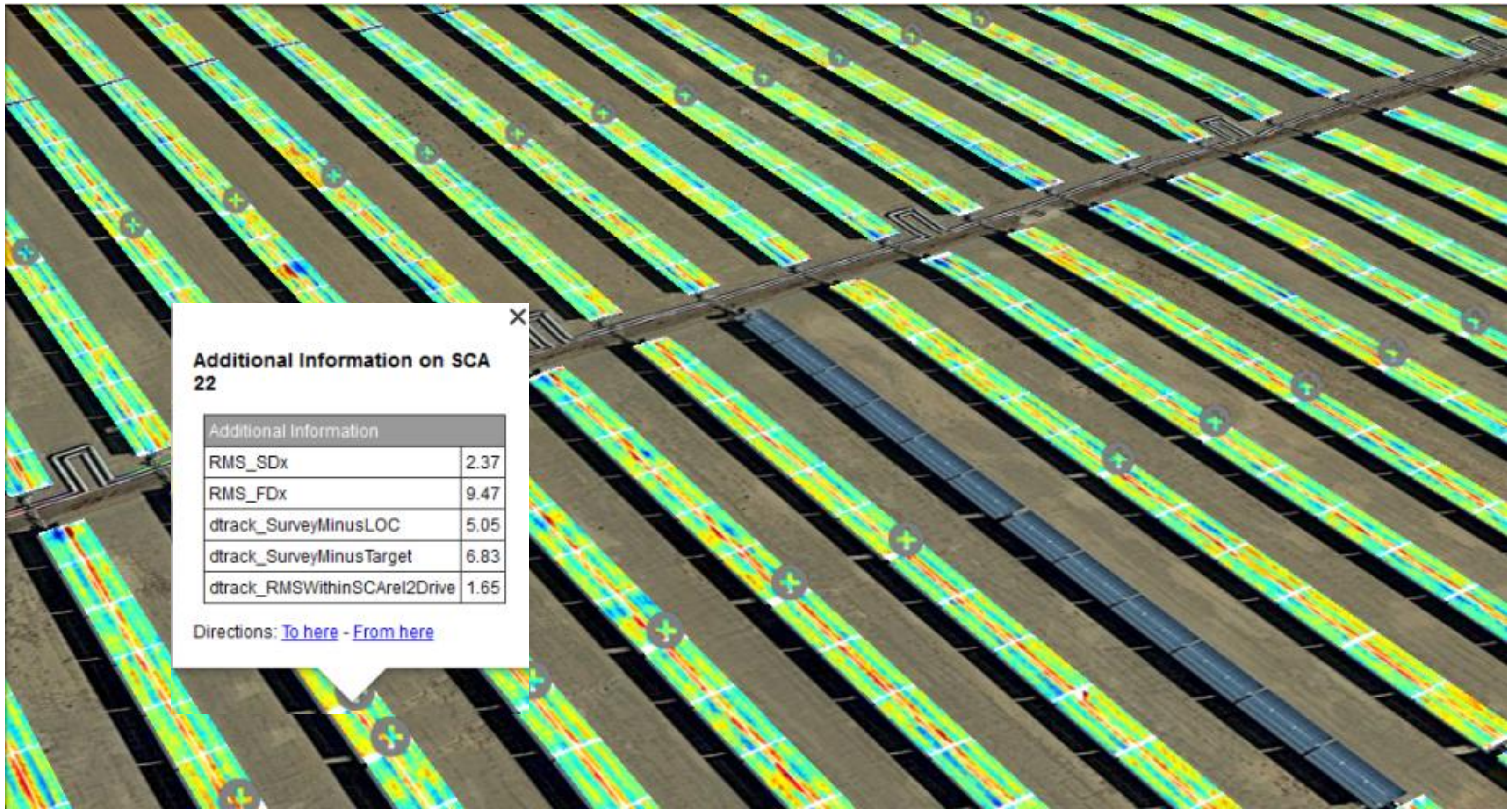
Scope: Reduce the cost for condition monitoring and provide data to optimise plant performance

- Measurement of optical performance of collectors (slope deviation of reflectors)
- 4 hours for 50 MW field
- Height <250m

Results:

- Localisation of misalignments and surface errors
- Commercially available by licence to CSP Services



Slope Deviation *SDx,eff* for the whole collector (SCA) in mrad

Condition Monitoring by Nowcasting of DNI

Sky images from 2 to 4 all sky imager

↓

Cloud detection

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Cloud modeling

↓

Shadow projection

↓

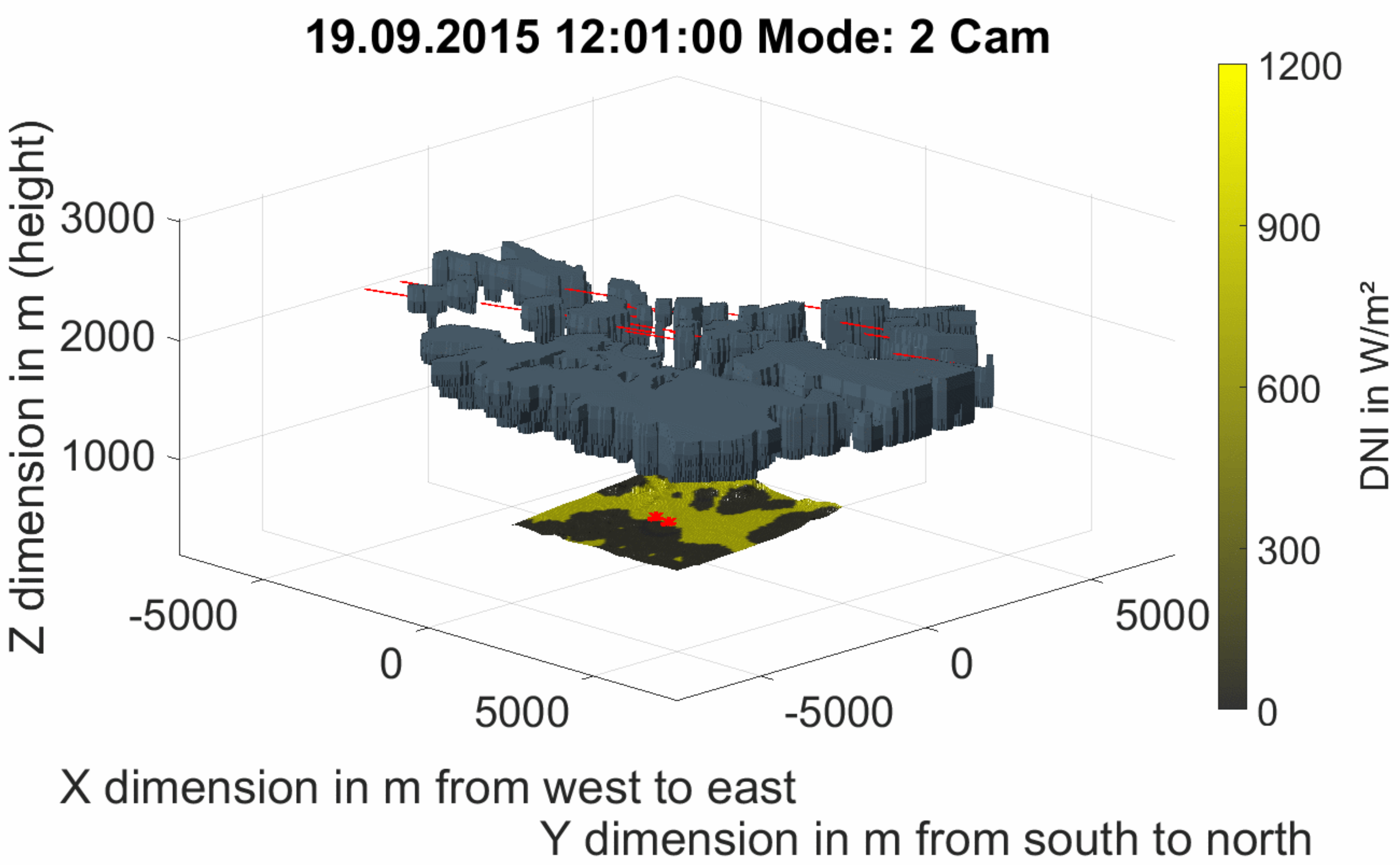
Allocation of cloud transmittance

↓

Cloud tracking

↓

Highly resolved DNI maps in space and time



Condition Monitoring by Nowcasting of DNI

Objective: Improved plant control

- During cloud transition improved control of outlet temperature desired
- Automised and optimised control strategy increases revenues using spatial DNI information
  - First analysis shows increased revenues of 2% (approx. 200 t€/yr) for a 50 MWe plant (La Africana)

Andasol Power Plants 3 x 50 MWe

Outlook:

- Increased revenues also expected at CSP towers → first works started
- Additional potential with longer prediction horizon (→ combination of satellite & model predictions)

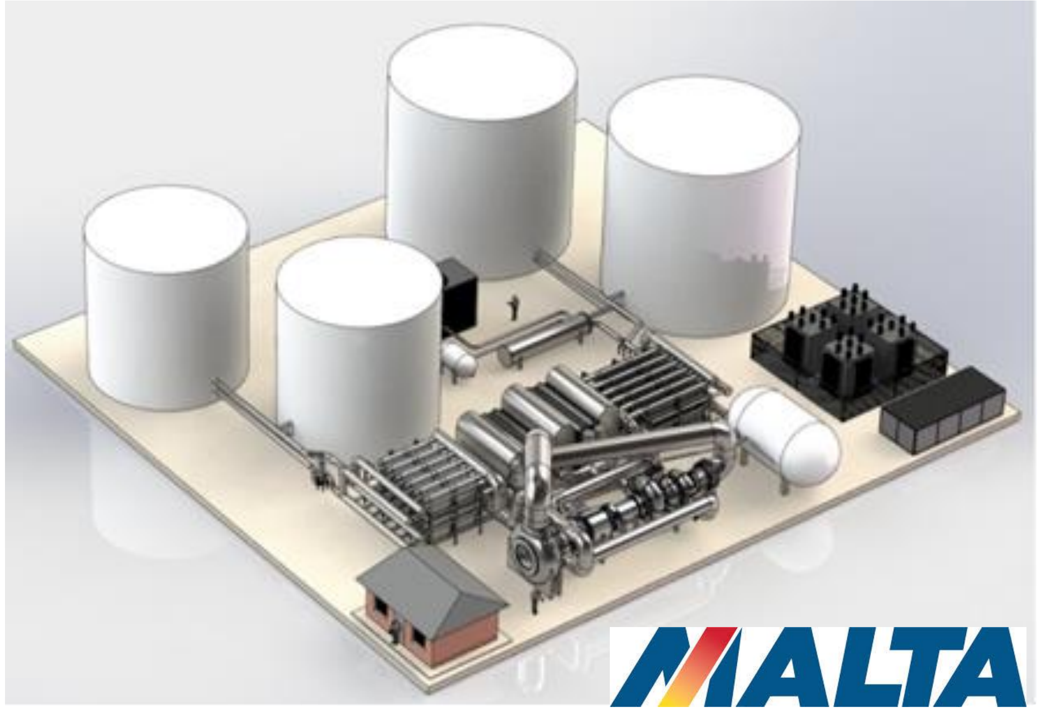
New R&D Efforts

Third Life of Coal Power Plants

- Replace combustion system with thermal storage heated by renewable energy
- System studies
- Demonstration in real power plant planned

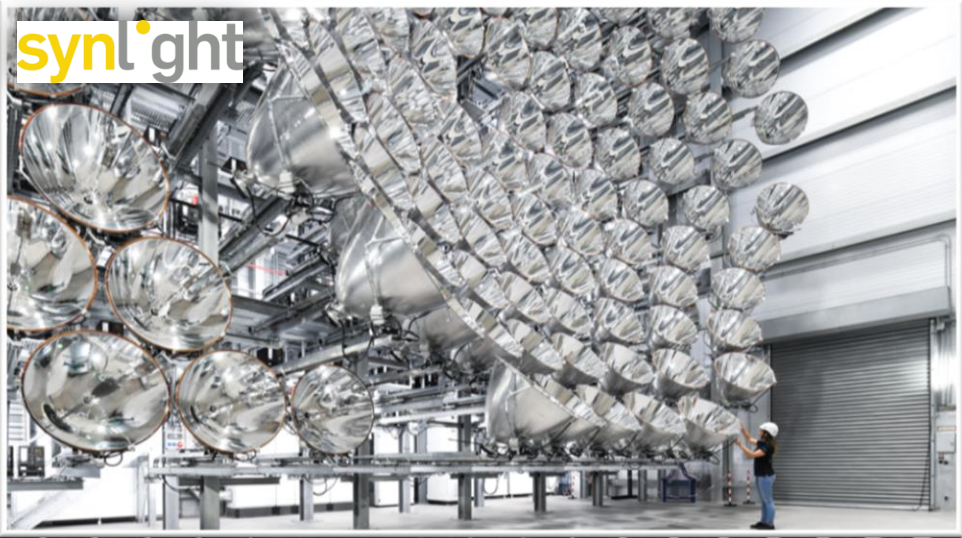
Malta (Carnot Battery)

- Gas-based cycle with thermal storage, used as power cycle and heat pump
- Round-trip efficiencies up to 70%
- Demonstration system planned in Jülich



Large Scale Facilities in Cologne and Jülich


Multifocal Tower

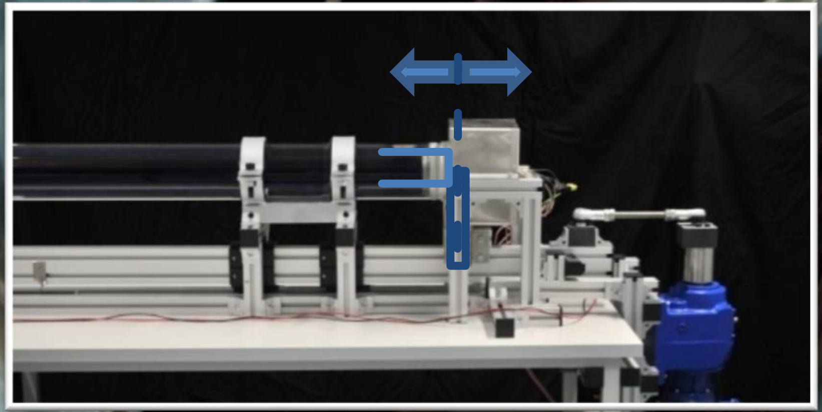


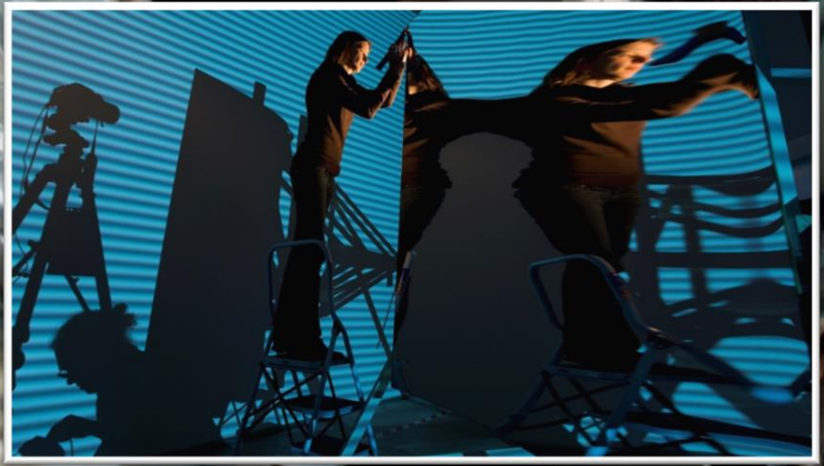

Heliostat Testplatform HELITEP


Solar Furnace

QUARZ®-Laboratory

for standardised testing of industrial of industrial CSP system components DLR-Cologne





Plataforma Solar de Almería

owned and operated by CIEMAT


Thank you for your attention!