Particle Solar Tower for High Temperature Process Heat

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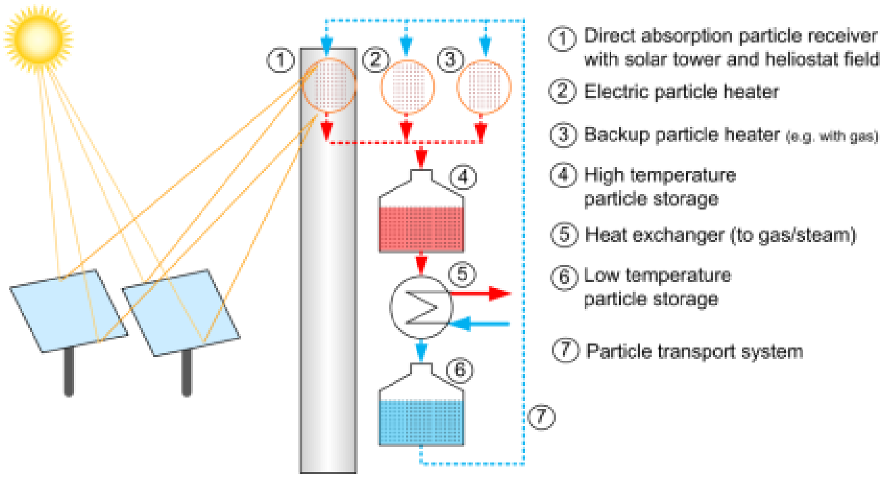
Ceramic particles as heat carrier and low-cost thermal storage



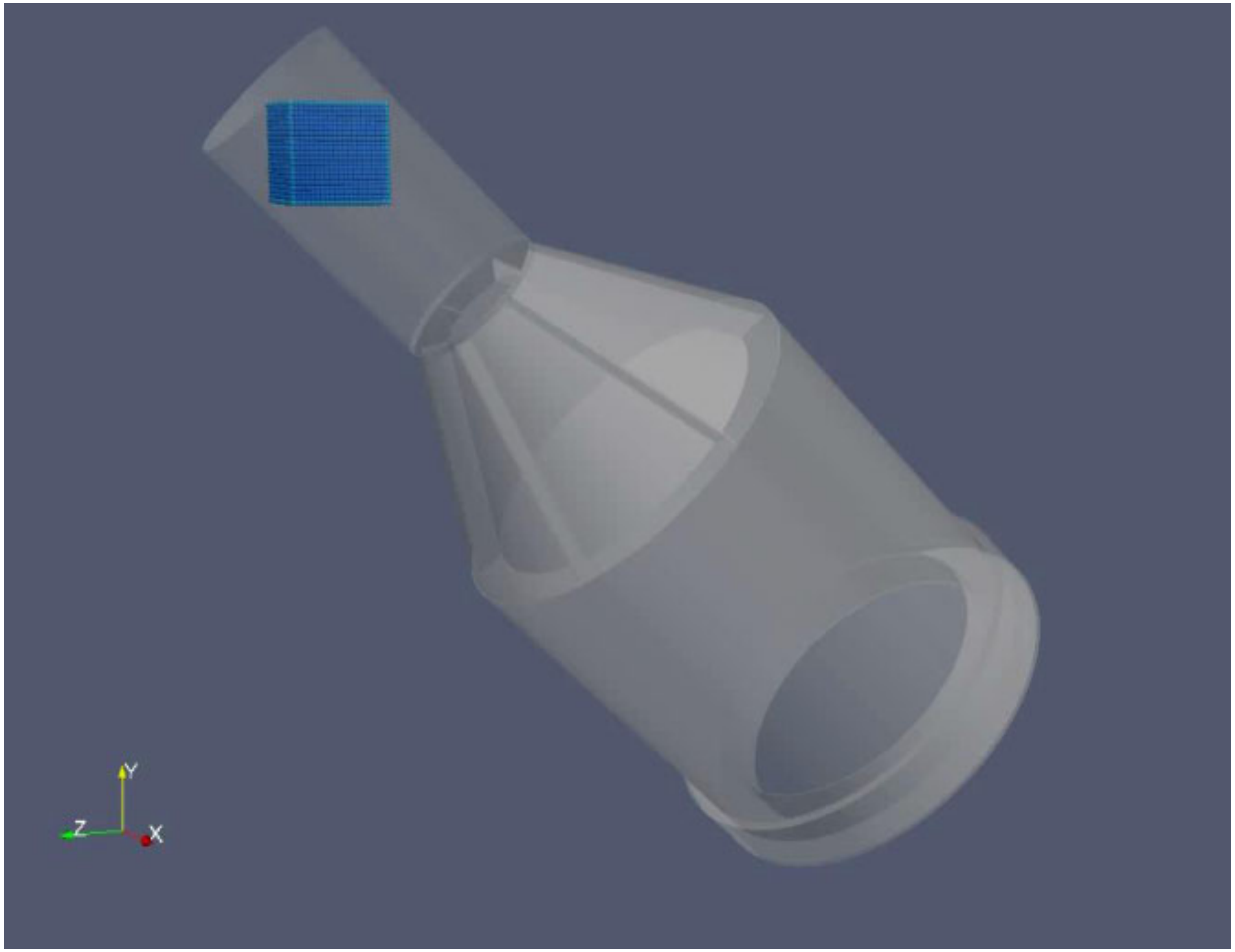
Ceramic particles enable:

- Temperatures **up to 1000°C and potentially above**
- Heat input from **concentrated solar and/or electricity** (wind and/or PV in a in a power to heat configuration)
- Easy hybridisation with e.g. biomass or gas for full **security of supply**
- Direct storage of heat for **24h operation**
- Heat supply as **hot air or steam** for
  - Electricity and cogeneration
  - Process heat

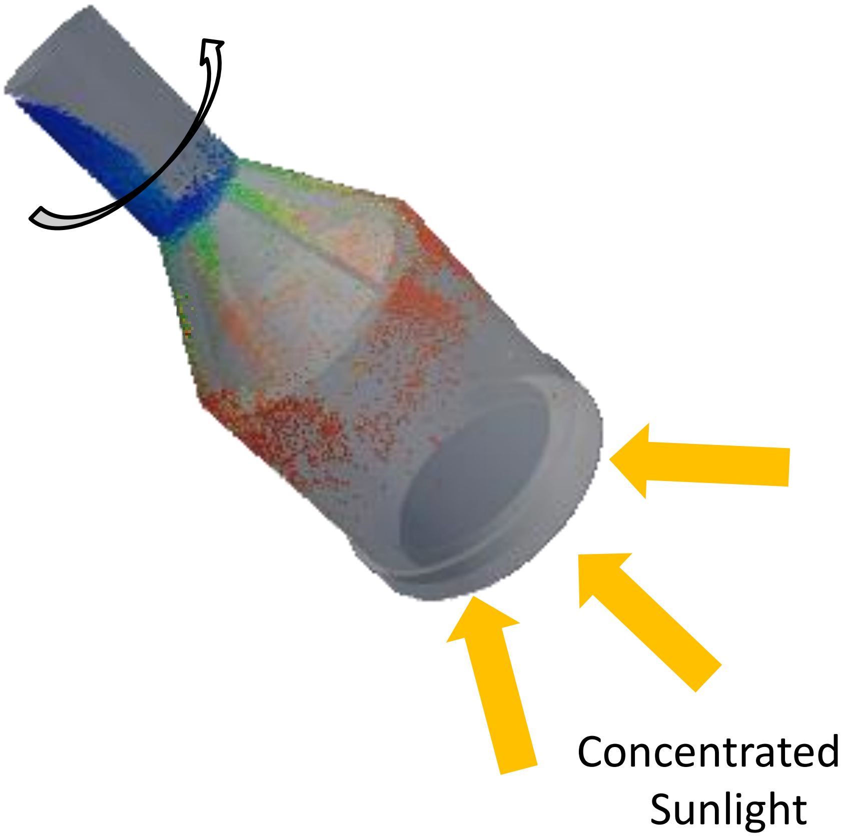
Comparison of storage capacities

	Specific heat [kJ/kg]	Mass per kWh [kg/kWh]	Volumetric storage capacity [kWh/m3]	Specific material costs at 1€/kg [€/kWh]
Solar Salt (60%$NaNO_3$,40%KNO_3) T = 288°C - 565°C	446	8.1	204	8.1
Sintered bauxite particles T = 288°C - 565°C	314	11.5	175	11.5
Sintered bauxite particles T = 400°C - 1000°C	735	4.9	408	4.9

Centrifugal particle receiver principle



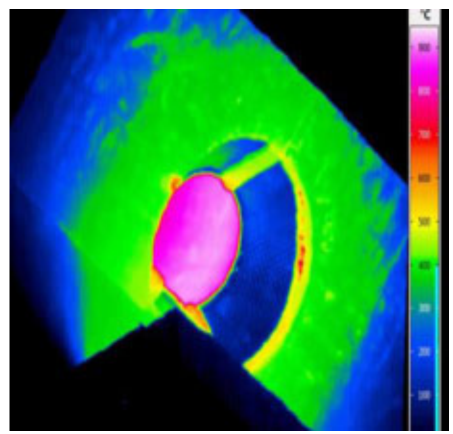
Centrifugal Particle Receiver ("CentRec®")



- Centrifugal forces form a particle film inside the rotating receiver drum
- Concentrated sunlight enters the receiver through the circular opening at the bottom and is absorbed directly by the particles on the inner walls
- Particle inlet at the top and outlet through the collection ring at the bottom
- Rotation allows control of retention time and therefore particle outlet temperature

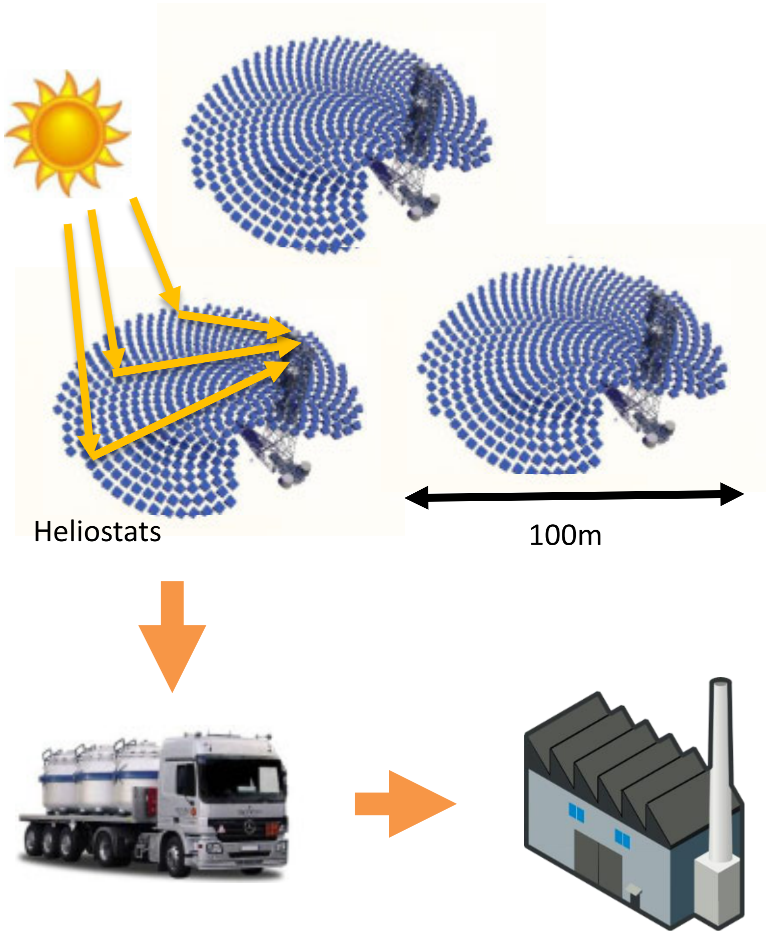
Development status

- **2.5 MW_{th} solar receiver prototype** achieved **965°C** outlet particle temperature at the Solar Tower Jülich, Germany
- Funding for project to scale receiver design to **50 MW_{th}** expected soon
- Spin-off company **HelioHeat GmbH** for commercialization of the receiver technology funded



Next step:
Demonstration plant

Multi-tower plant design

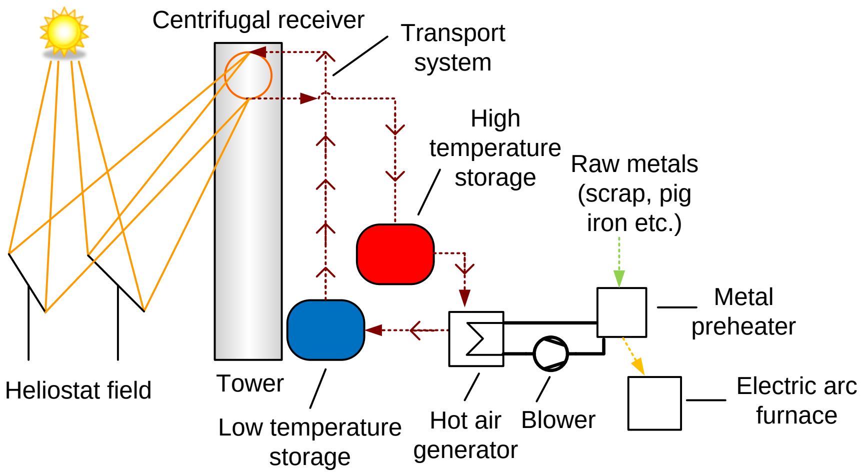


- **Multiple solar towers** can be combined, using particle transport similar to molten aluminium road transport, to **scale capacity to needs**
- Due to horizontal particle transport the plant can be built a few kilometers **away from the energy user** if:
  - Land is unavailable or expensive next to a manufacturing plant
  - Dust emissions from manufacturing plants are too high

Case study for a foundry in Brazil, State of Sao Paulo

- Melting capacity 22.5 t/h for cast iron with induction furnaces
  → ~12 MW_{el} baseload consumption
- Potential solar contribution by preheating scrap to 600°C:
  4 MW_{th} baseload
- Average annual DNI:
  2175 kWh/m^2a
- Corresponding solar plant using 2.5 $MW_{th,peak}$ receivers and 15 h of storage needs 5 towers
- **Payback time < 3 years due to replacement of electricity** at
  140 €/MW_{el} by solar generated heat

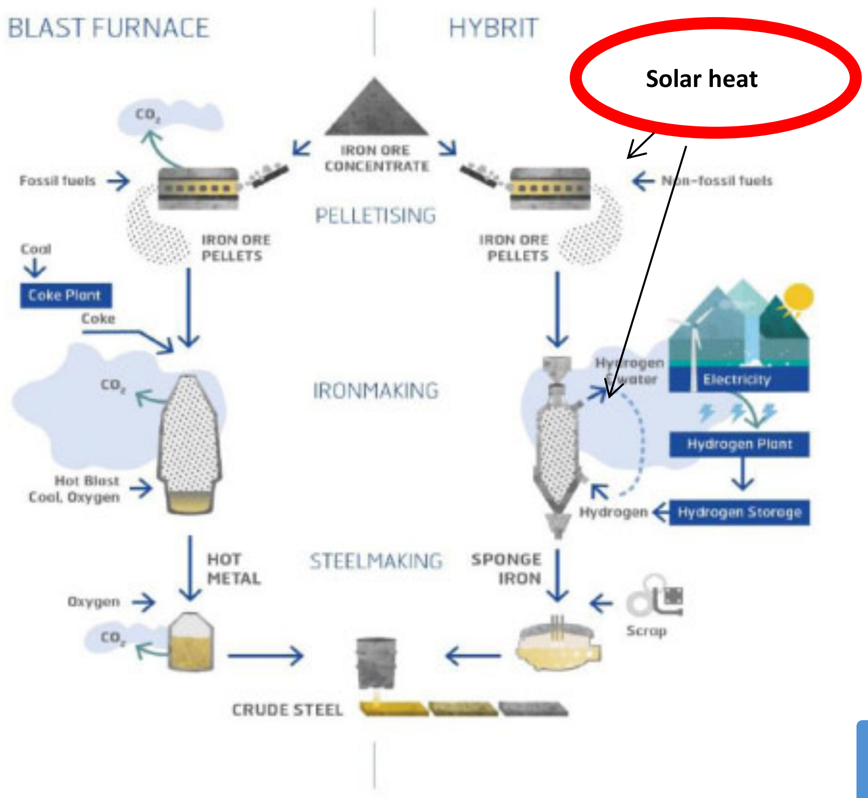
Application: Low GHG secondary steel by integration of solar heat in electric arc furnaces (EAF)



- **25% of world steel production** with EAFs, 50% by 2050 expected
- **~1/3 energy saving** is currently achieved by **preheating steel** to 600°C with furnace off-gases from co-firing of natural gas and coal, but rarely deployed due to problems with dust in the off-gas
- **Pre-heating** can be done **with solar heat**
- An inert gas loop enables higher pre-heating than 600°C without oxidation problems, saving more energy than current methods

Good financials due to substitution of electricity by solar heat (no turbine loss)

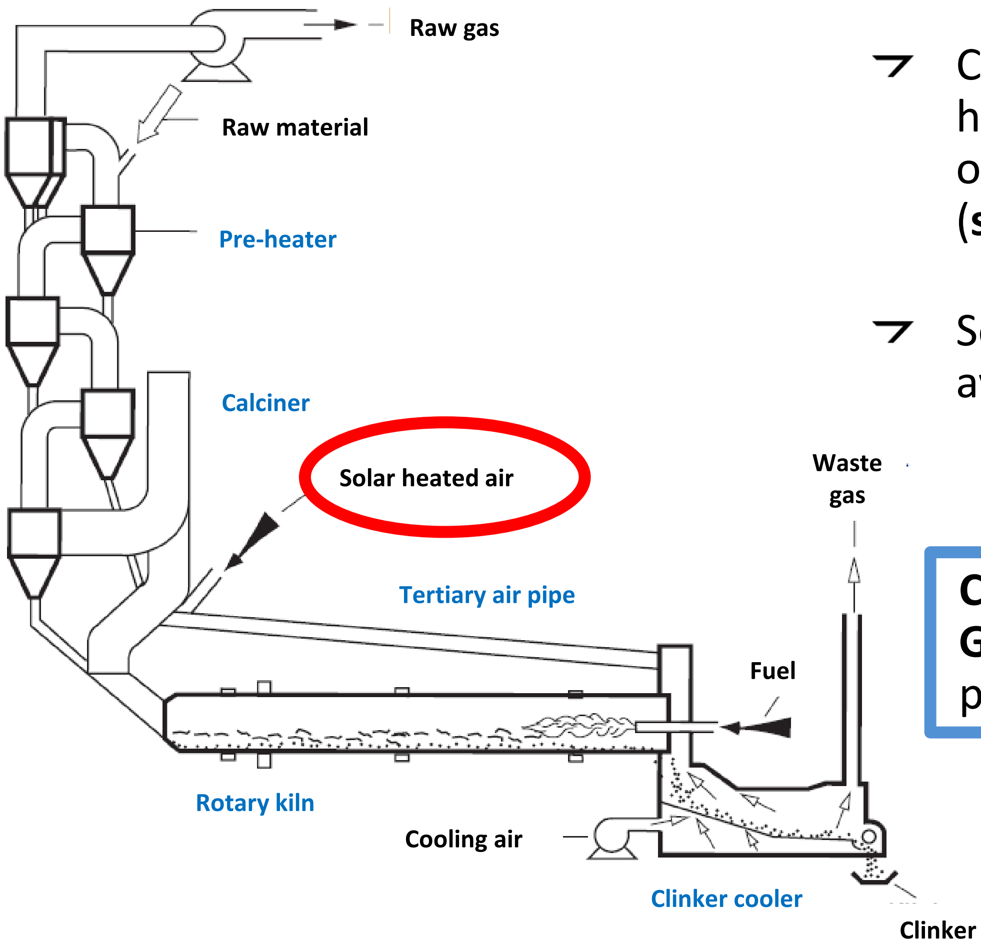
Application: Low GHG primary steel by integration of solar heat in direct reduced iron (DRI) production



- **75% of world steel production** from ore today, 50% by 2050 expected
- A consortium in Sweden is building the first demo plant for **green steel based on** direct reduced iron (DRI) with **green H_2** instead of CH_4 [HYBRIT]
- Using **solar high temperature process heat** in this project could save a lot of CH_4 today or green H_2 in the future and make it **much more competitive**

Good financials due to substitution of CH_4 today or green H_2 in the future

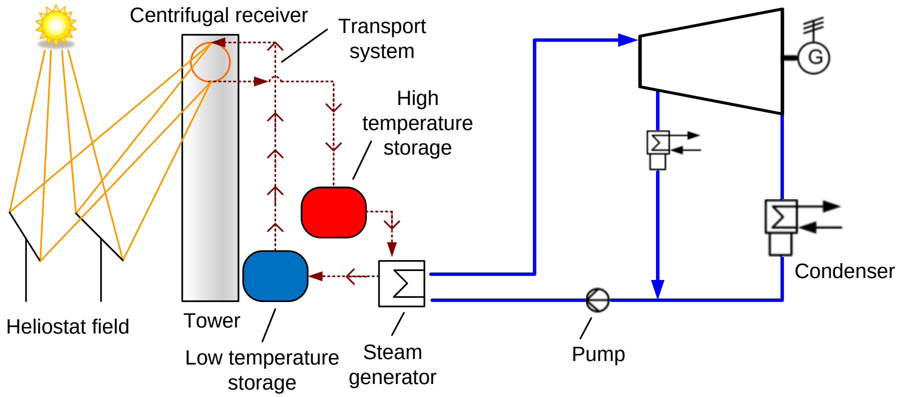
Application: Low GHG cement with solar heat



- Ceramic particles at 900°C can produce hot air to replace the fuel in the calciner of a cement plant (**saves ~60% of the energy** needed)
- Solar thermal cement production could avoid ~0.7 Gt/a CO_2 in China alone

Cement production is the largest single GHG producing process of all industrial processes

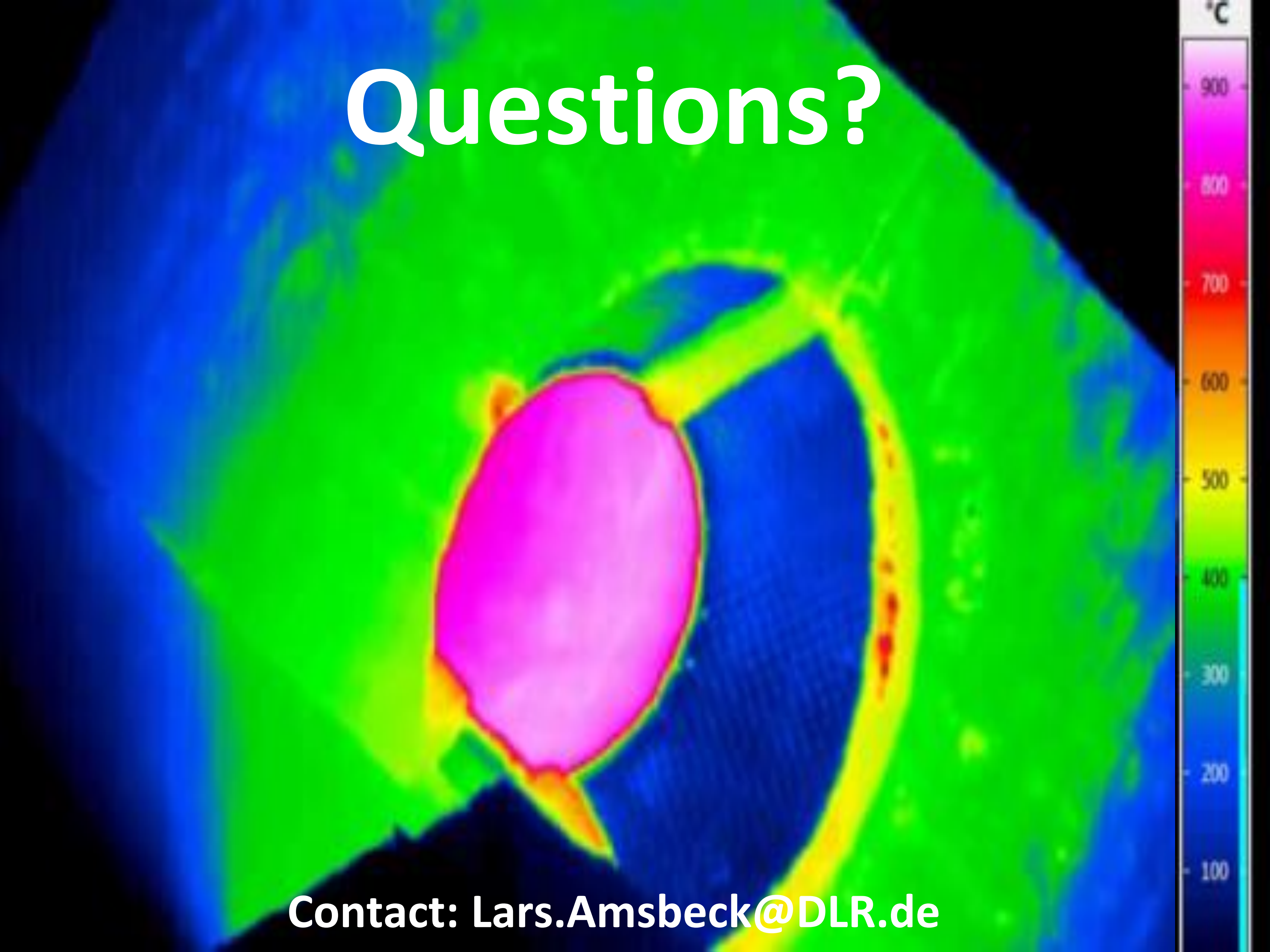
Application: Electricity generation and Combined Heat & Power (CHP)



- The high temperature of the particles allow power production through steam turbines, sCO_2 turbines and potentially also gas turbines
- Cogeneration of heat enhances the economics (worldwide capacity ~ 300 GW_{el}) [IEA]

Solar CHP with particles achieves **lower heat costs through** partial production of **higher value electricity** while providing **low cost storage for 24h operation**

Questions?



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