

Materials for CSP receivers

State-of-the-art, R&D requirements and future options

Thomas Fend, German Aerospace Center

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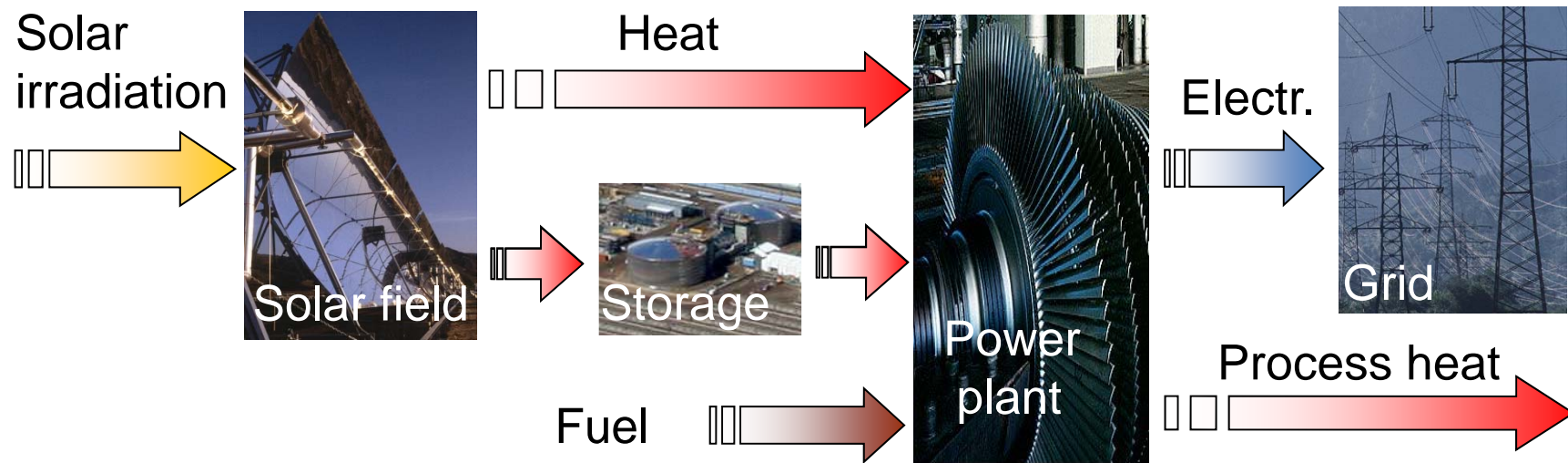


Outline

- Introduction to CSP
- Parabolic Trough technology
 - Indirect HTF loop (oil)
 - Direct steam
 - Indirect HTF loop (liquid salt)
- Tower technology
 - Direct steam
 - Molten salt steam
 - Volumetric air
 - Solar gas turbine



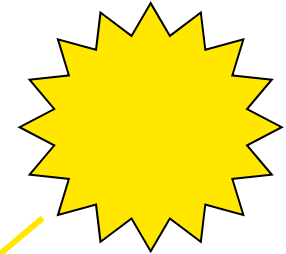
CSP: Concentrated Solar Power



- optional ***thermal storage***
- ***hybrid*** operation
- heat extraction for ***process heat, cooling, desalination***



CSP: Concentrated Solar Power



Solar tower (SNL)



Up to 1000° C Gas turbines

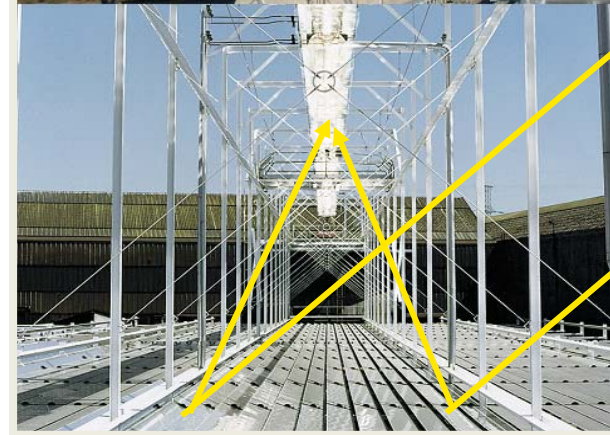


Dish-Stirling (SBP)

Parabolic trough (PSA)

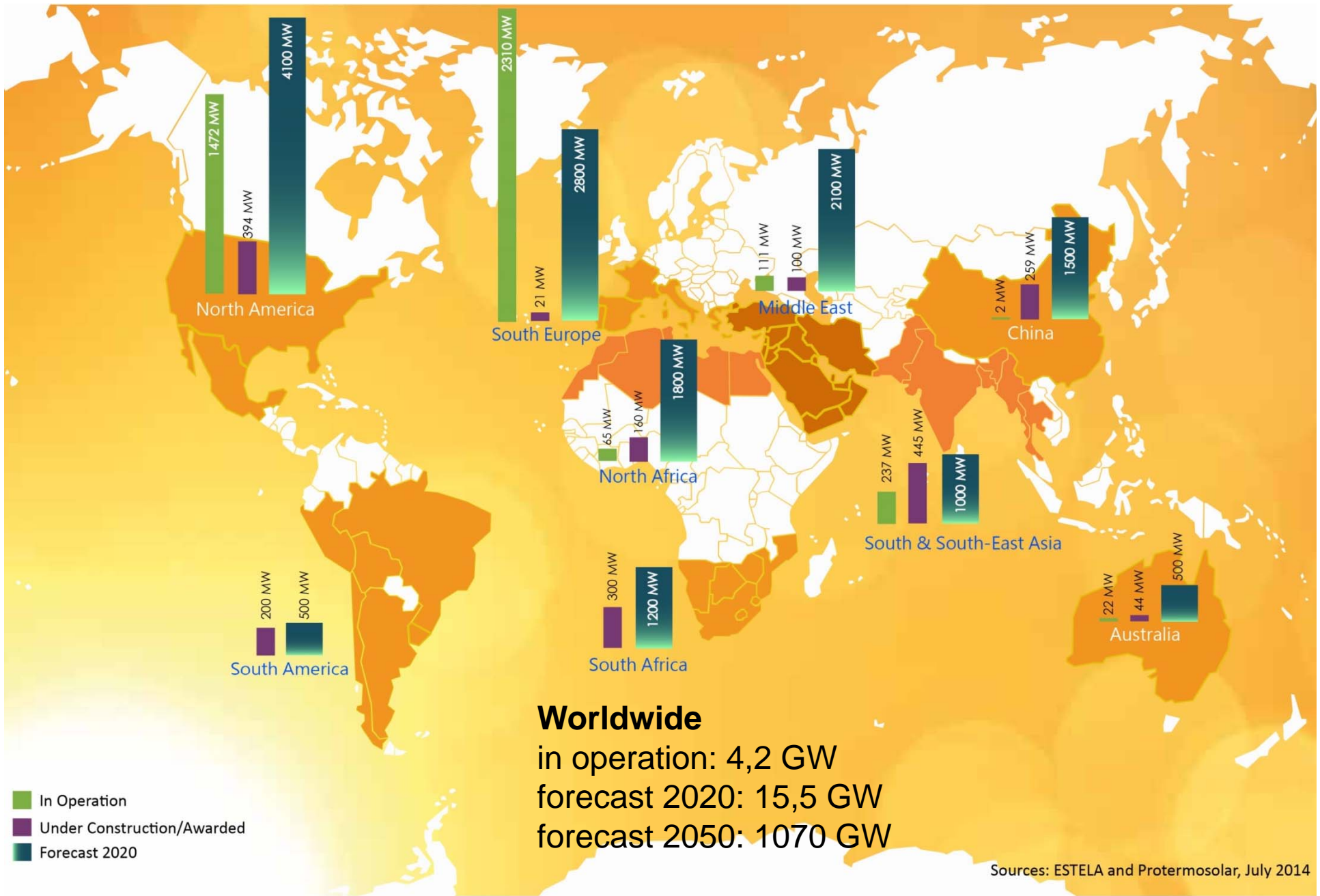


Up to 550° C steam turbines

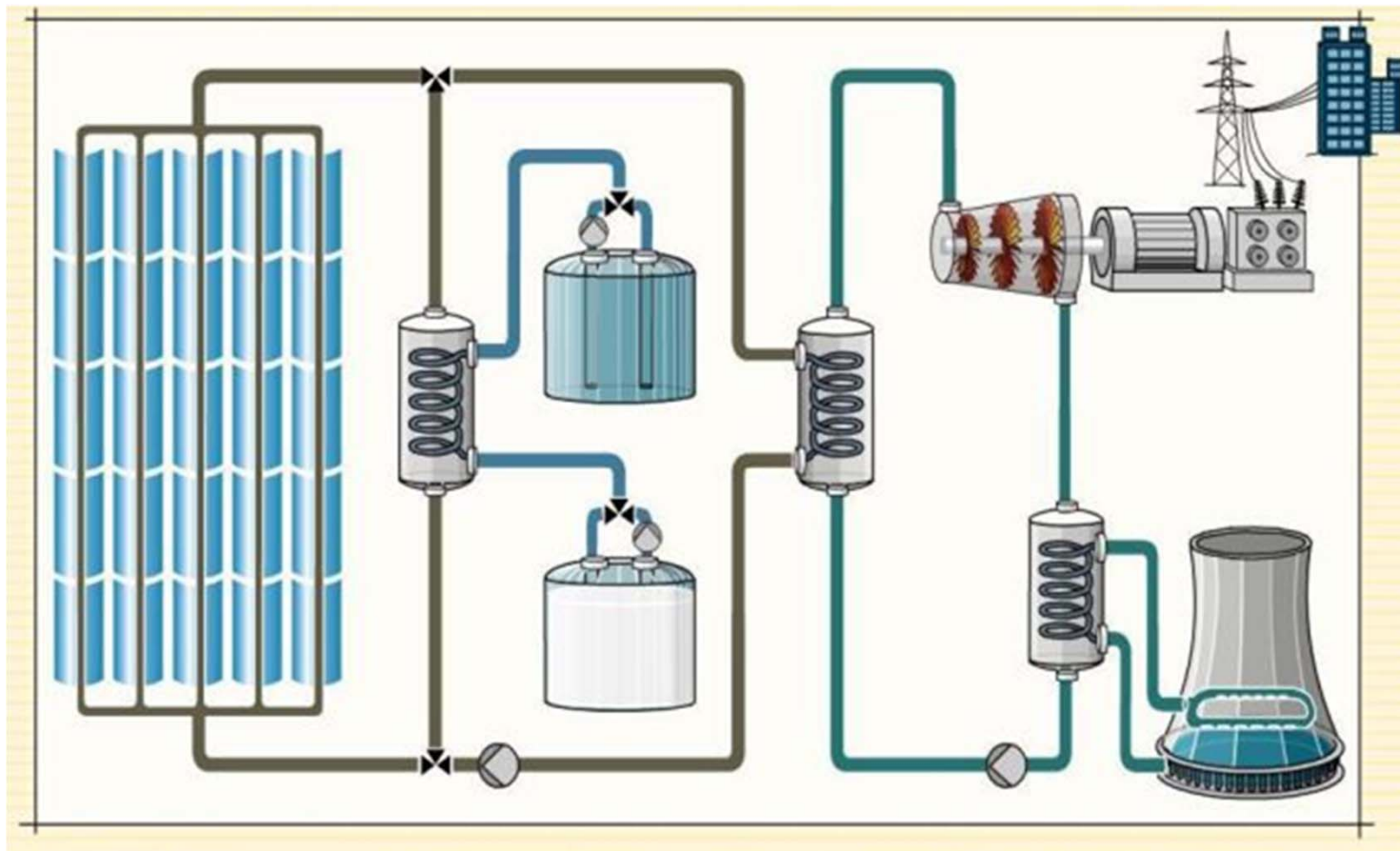


Linear Fresnel (MAN/SPG)





Parabolic Trough Technology: Indirect with Heat Transfer Fluid (HTF)



Source: Solar Millennium AG



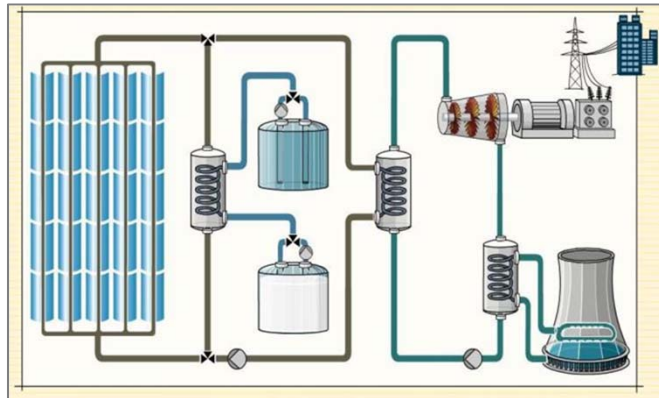
Parabolic Trough Technology indirect HTF: Absorber Tube



Source: Schott Solar



Parabolic Trough Technology indirect HTF: Status Quo



Technology Readiness Level (TRL):

high, >25 plants commercially operated

Suppliers: Schott, Archimede, Solel...

Temperatures: $T < 400^{\circ}\text{C}$

Materials: Iron based standard alloys

Further developments:

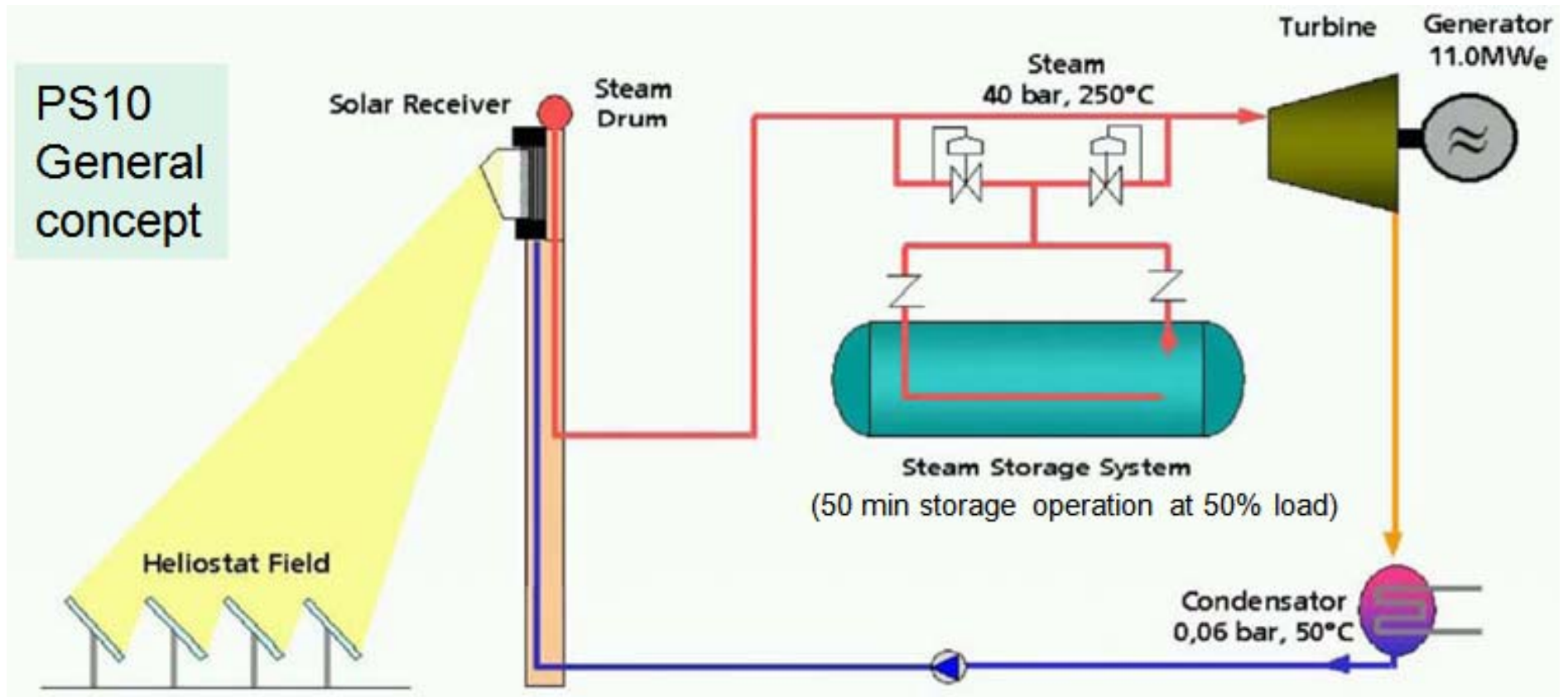
- Direct Steam Generation ($T < 550^{\circ}\text{C}$)
- Liquid salt as HTF ($T < 550^{\circ}\text{C}$)

Required research action:

- Qualification
- Lifetime prediction

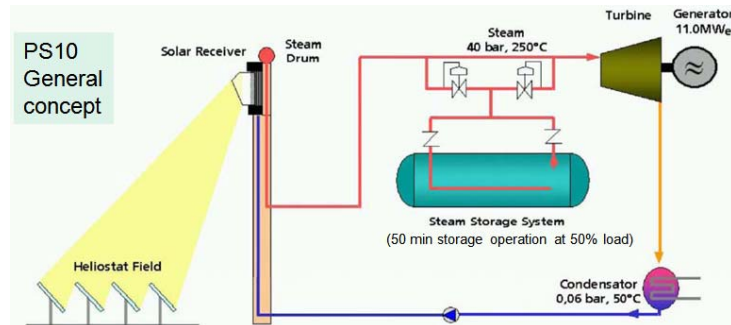


Tower Technology: Direct Steam Generation





Tower Technology: Direct Steam Generation



TRL:

high: 2 plants commercially operating

Suppliers:

Abengoa

Steam Temp.:

$T = 280^{\circ}\text{C}$

Materials:

Iron based alloys

Further developments:

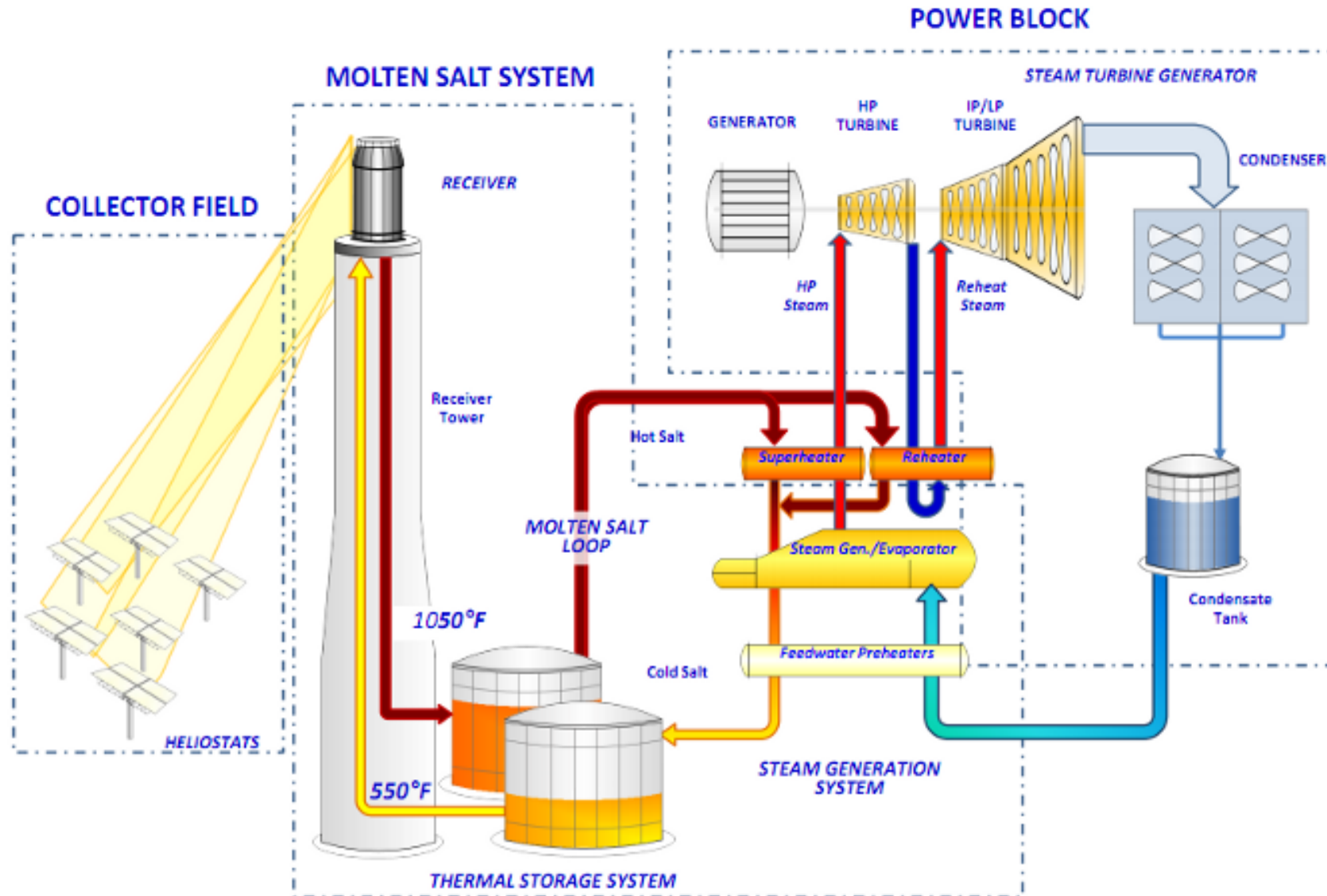
- Larger plants (Khi Solar one, 50 MW)
- Higher temperatures (superheated steam)
- Increase storage capacity

Required research action:

- Improved absorber tubes (thermal conductivity, heat transfer)



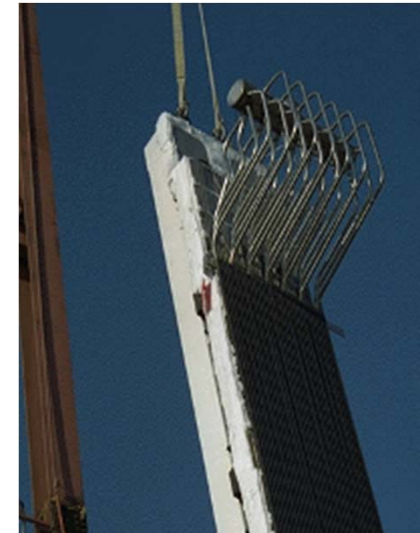
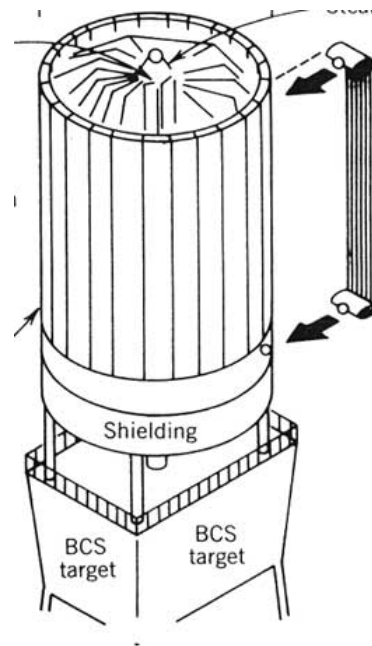
Tower Technology: Molten Salt System



Tower Technology: Molten Salt System



Foto: Torresol



material load parameters:

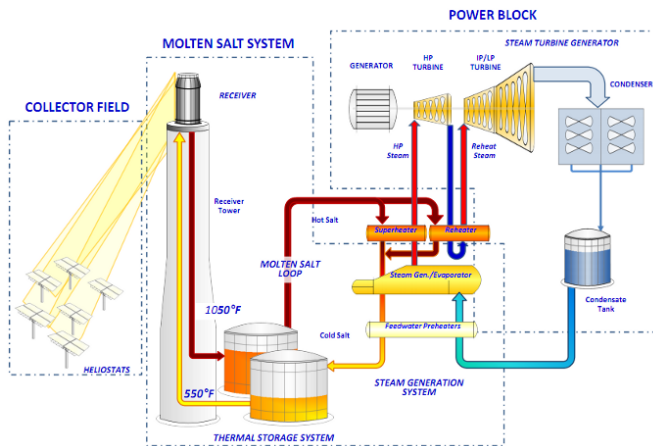
- pressure: ambient
- max. temp.: ~ 620C (film)
- max. heat load: ~ 800kW/m²

dynamic operation:

- wall temp.: 2.8K/sec



Tower Technology: Molten Salt System



TRL: high, 1 plant commercially operating

Suppliers: Fine Tubes, Sener,

Temperatures: $T < 620^{\circ}\text{C}$

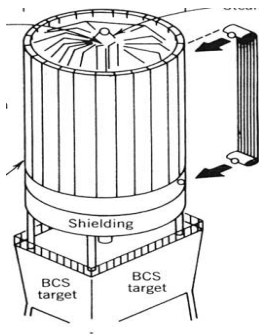
Materials: Iron based alloys

Further developments:

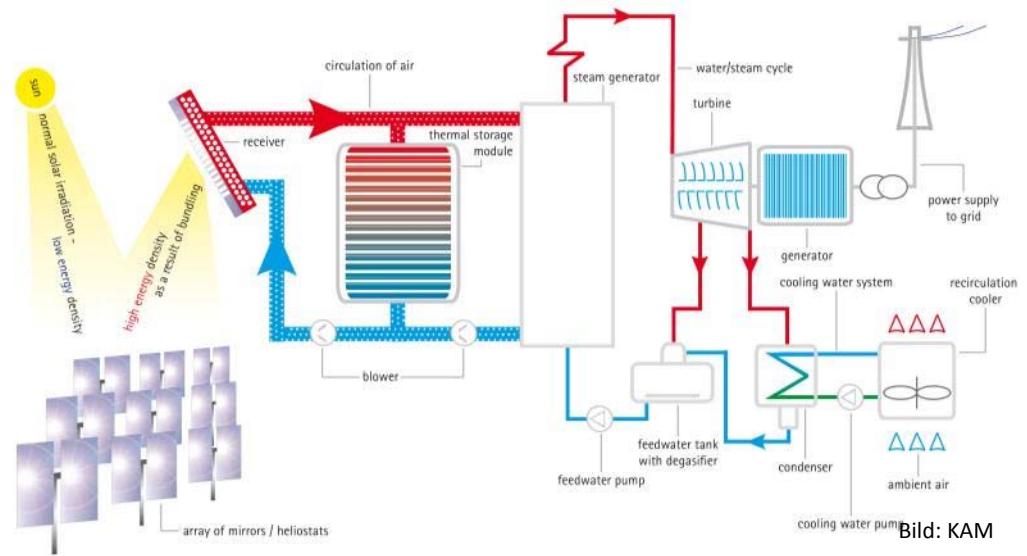
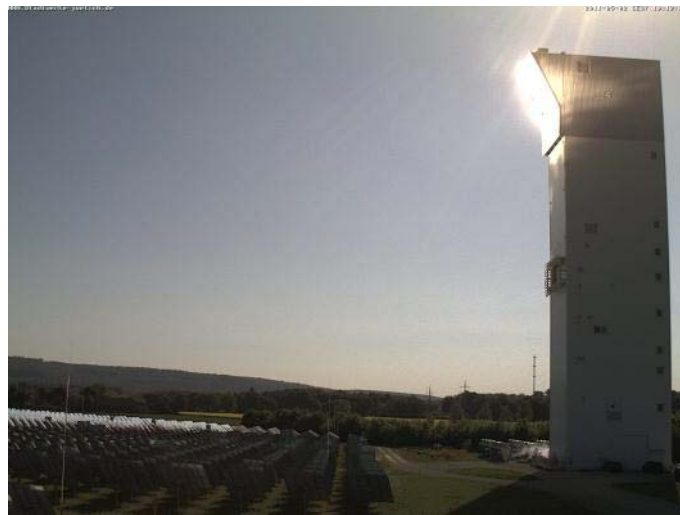
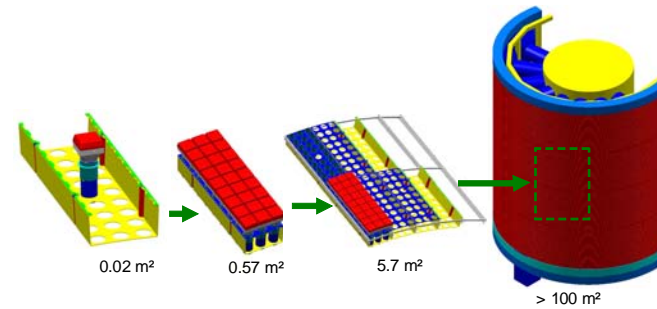
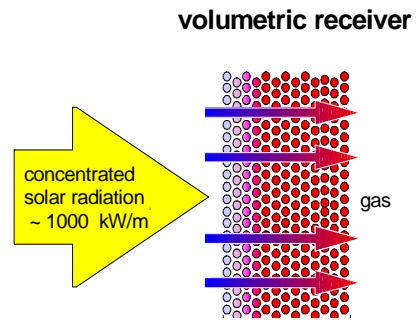
- Higher Temperatures

Required research action:

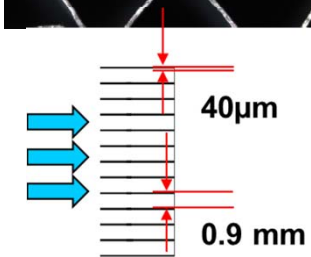
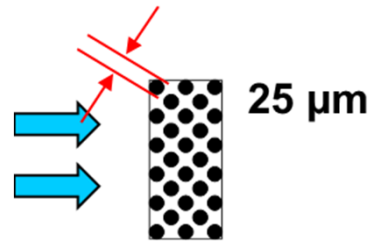
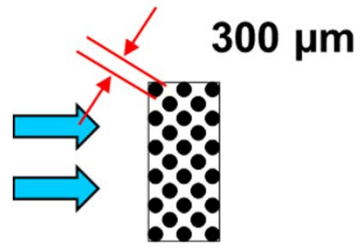
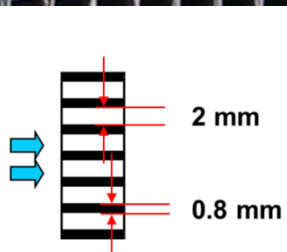
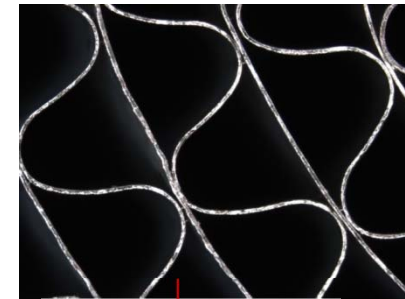
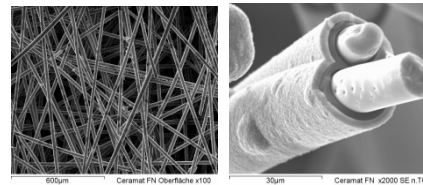
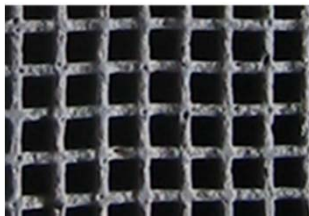
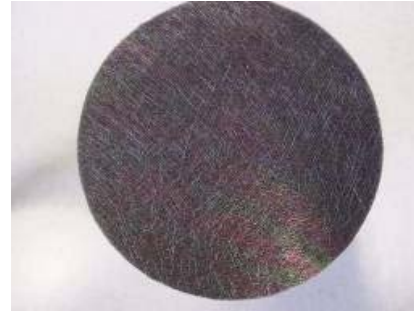
- Lifetime issues
- Innovative heat transfer fluids



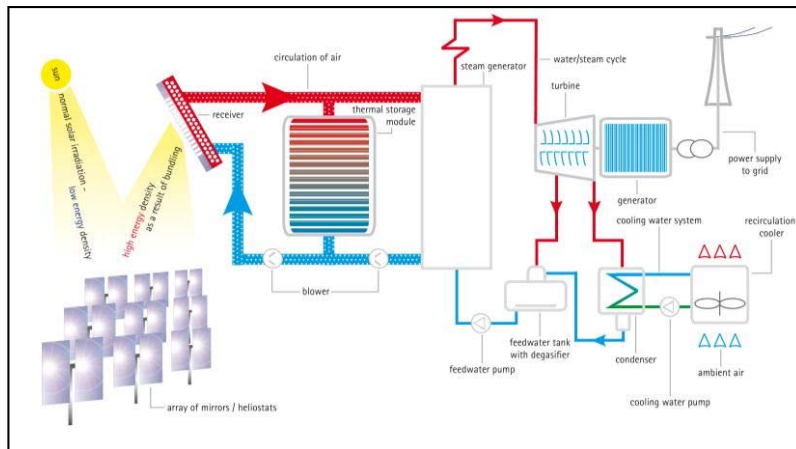
Tower Technology: Volumetric Air Receiver



Tower Technology: Volumetric Air Receiver: Improved Porous Receiver Materials



Tower Technology: Volumetric Air Receiver



TRL: middle, 1 experimental plant
Suppliers: SGIK, Kraftanlagen München
Temperatures: $600^{\circ}\text{C} < T < 1000^{\circ}\text{C}$
Materials: Porous Silicon Carbide, standard high temperature steel, nickel base alloys

Further developments:

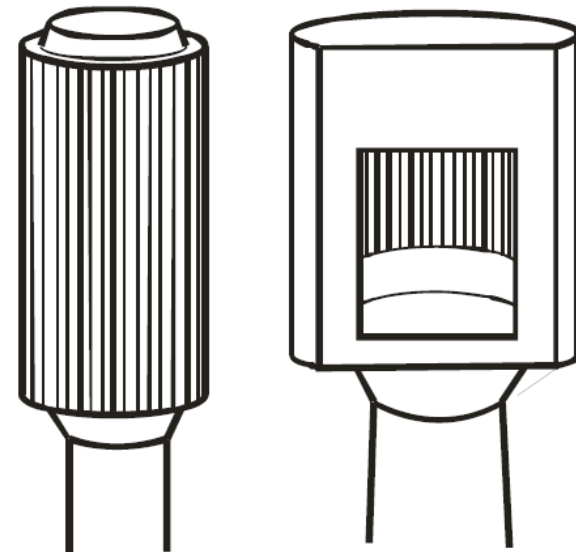
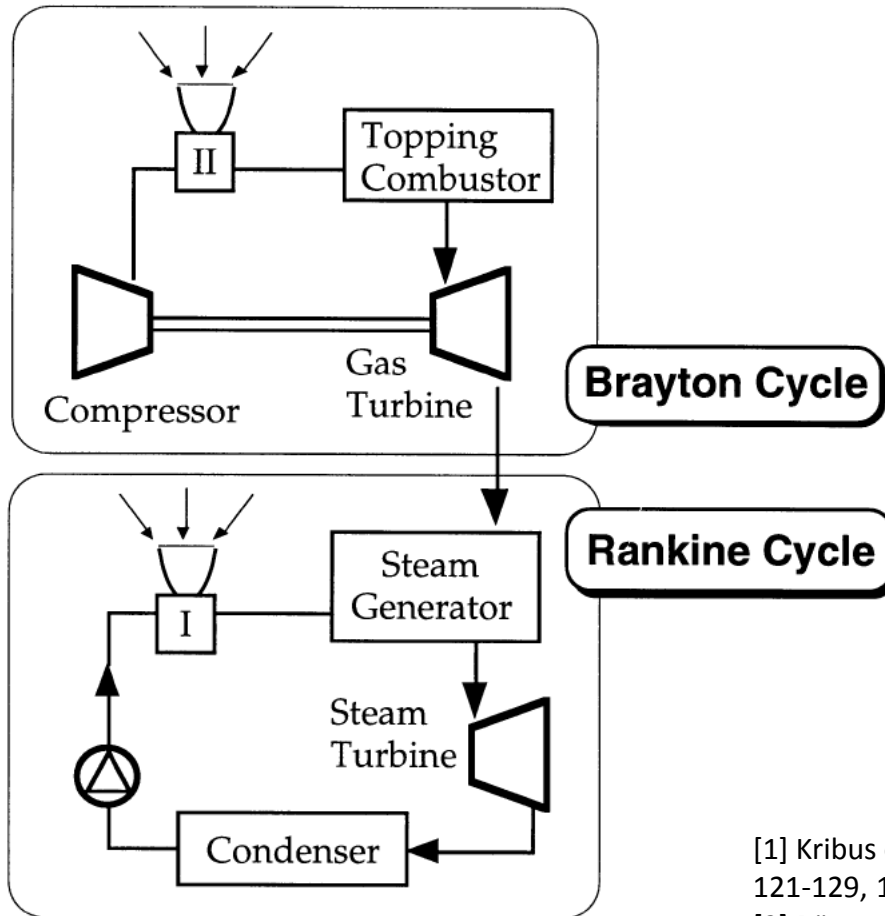
- Higher efficiencies, higher cell densities
- lower costs

Required research action:

- Improved receiver geometry
- Lifetime issues



Tower Technology: Solar Gas Turbine

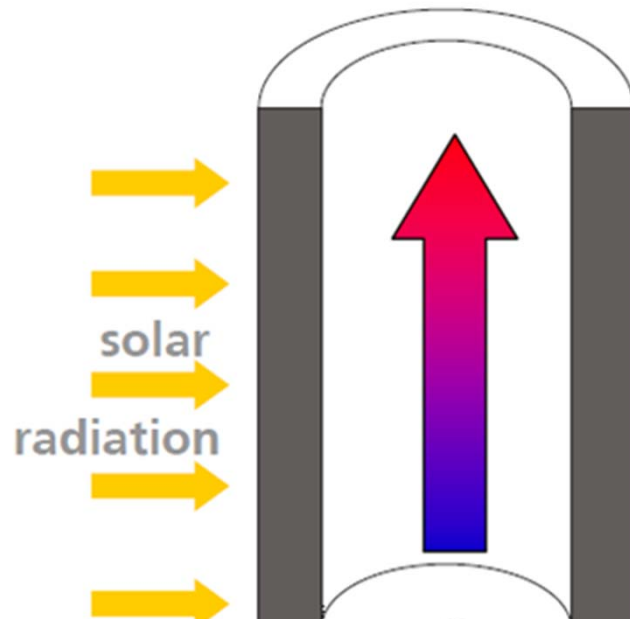


[1] Kribus et al., A solar driven cc power plant, Solar Energy 62, no 2, p 121-129, 1998

[2] Röger, Marc: EnerMENA Video Tutorials, Solar Tower Technology



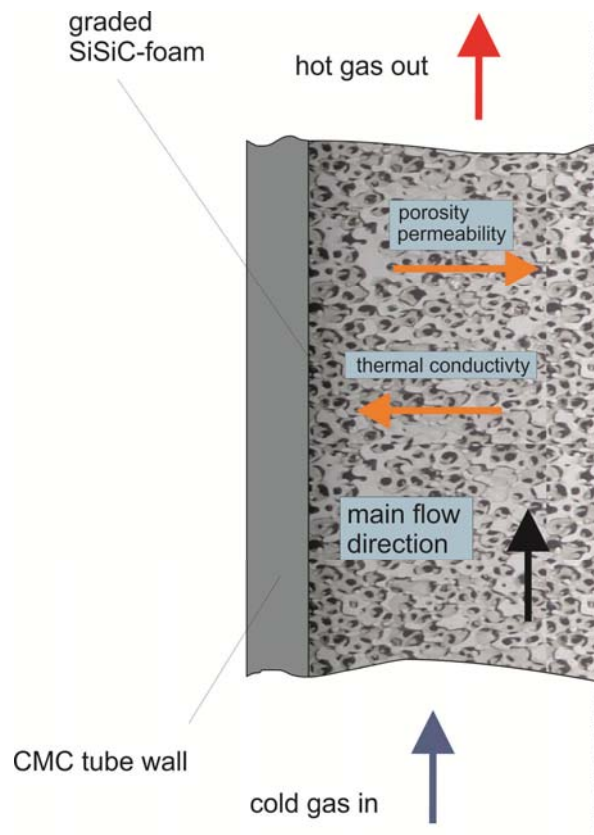
Tower Technology: Solar Gas Turbine



- Absorption
- Conductive thermal resistance in tube wall
- Convective thermal resistance



Tower Technology: Solar Gas Turbine



- Increased heat transfer surface
- Enhanced heat transfer by gradation in radial direction
- Thermal properties of porous material needed
- Proposed by Korean/Swiss/German consortium in the project **CMC4CSP**



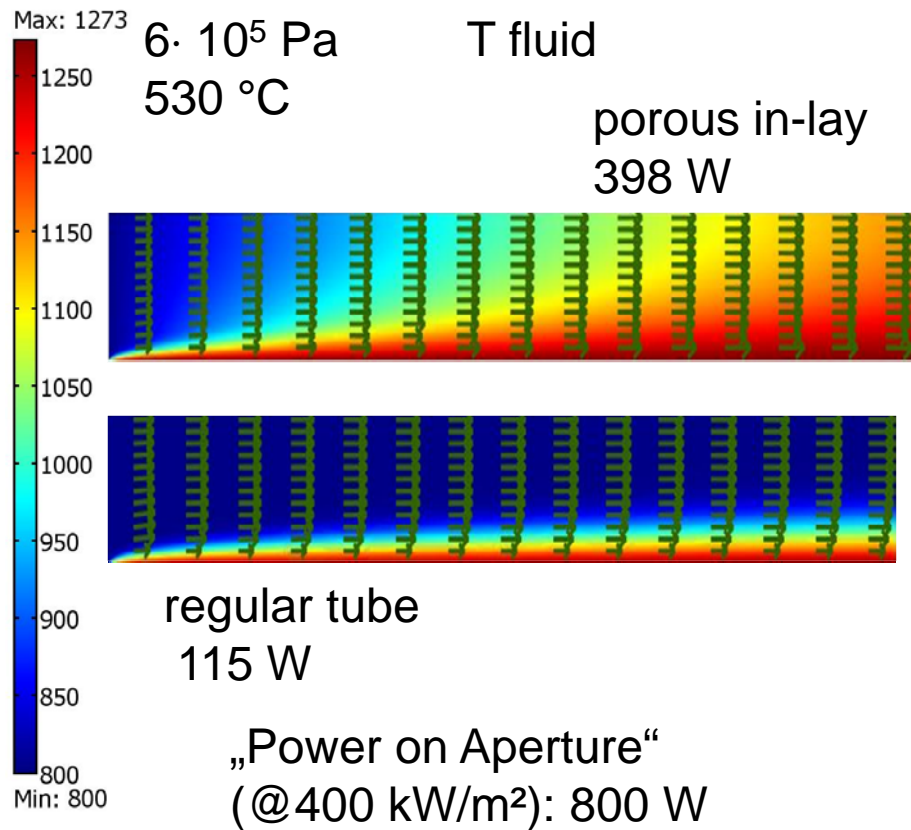
Tower Technology: Solar Gas Turbine



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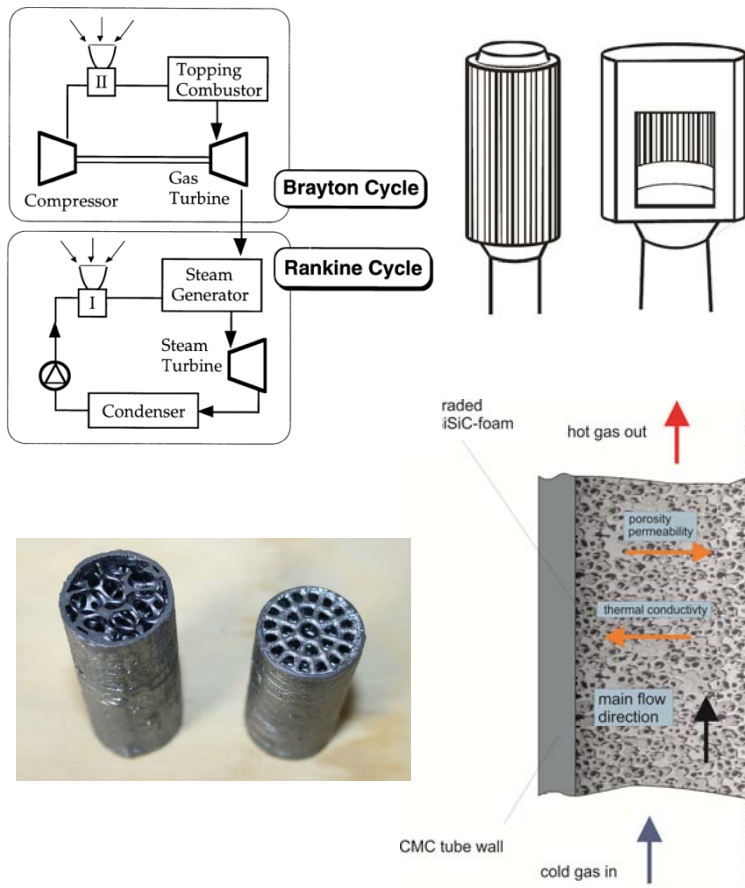
Tower Technology: Solar Gas Turbine



- Increased heat transfer surface
- Enhanced heat transfer by gradation in radial direction
- Thermal properties of porous material needed
- Proposed by Korean/Swiss/German consortium in the project **CMC4CSP**



Tower Technology: Solar Gas Turbine



TRL: low, technology demonstrated
Suppliers: EnginCer
Temperatures: $800^{\circ}\text{C} < T < 1300^{\circ}\text{C}$
Materials: Silicon Carbide Ceramics

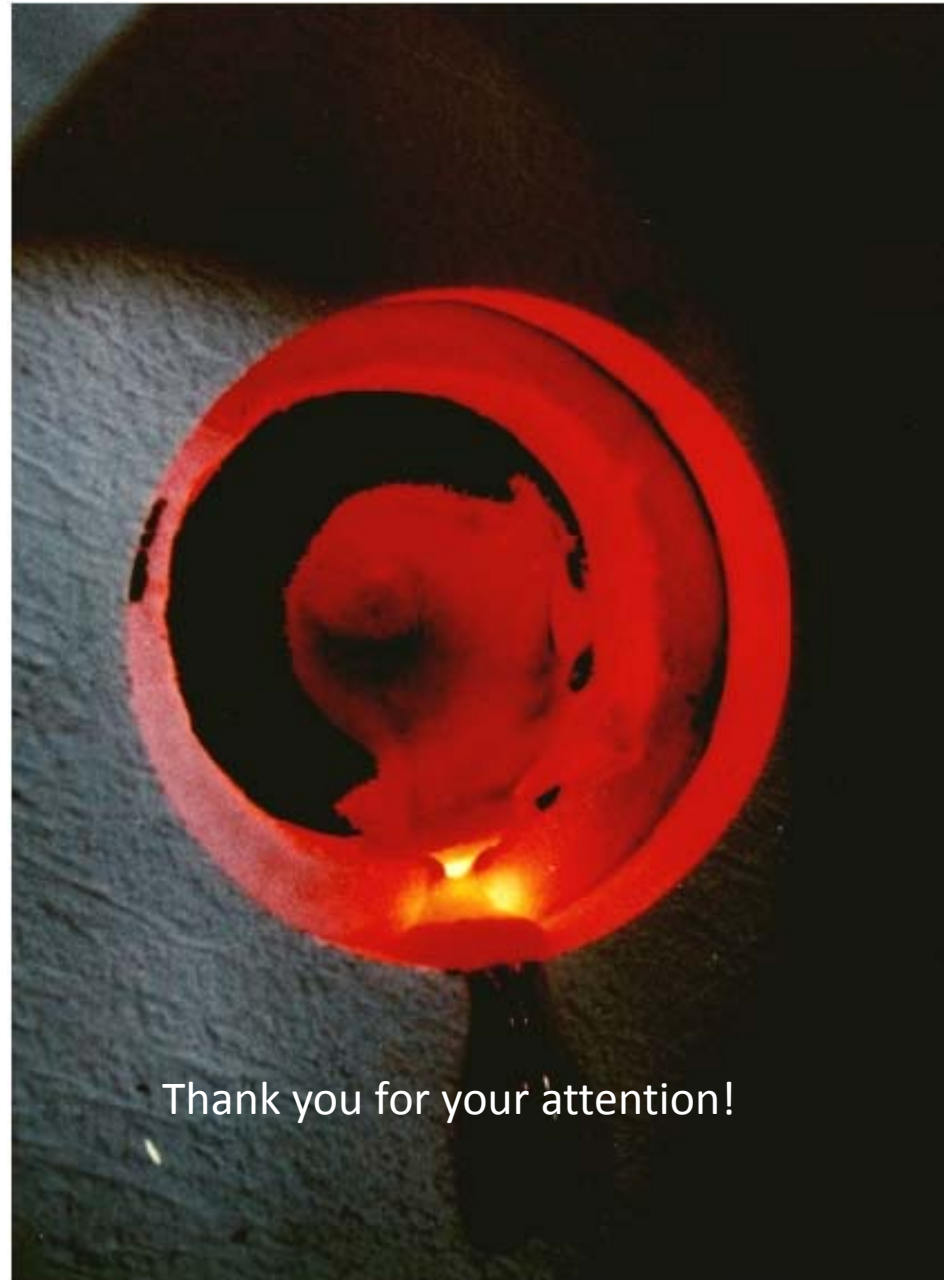
Further developments:

- Higher Temperatures
- Up-scaling , larger demonstration plants
- Solar only operation

Required research action:

- Improved receiver materials
- System integration





Thank you for your attention!

