SAND2014-15480PE

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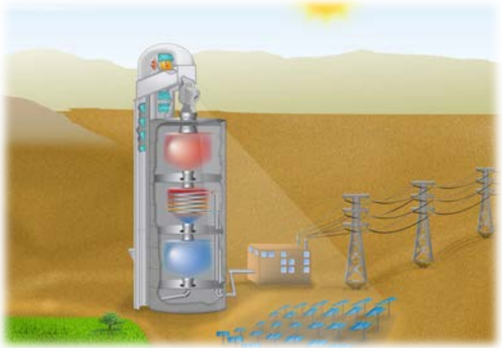

High-Temperature Receiver Designs for Supercritical CO_2 Closed-Loop Brayton Cycles

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Overview

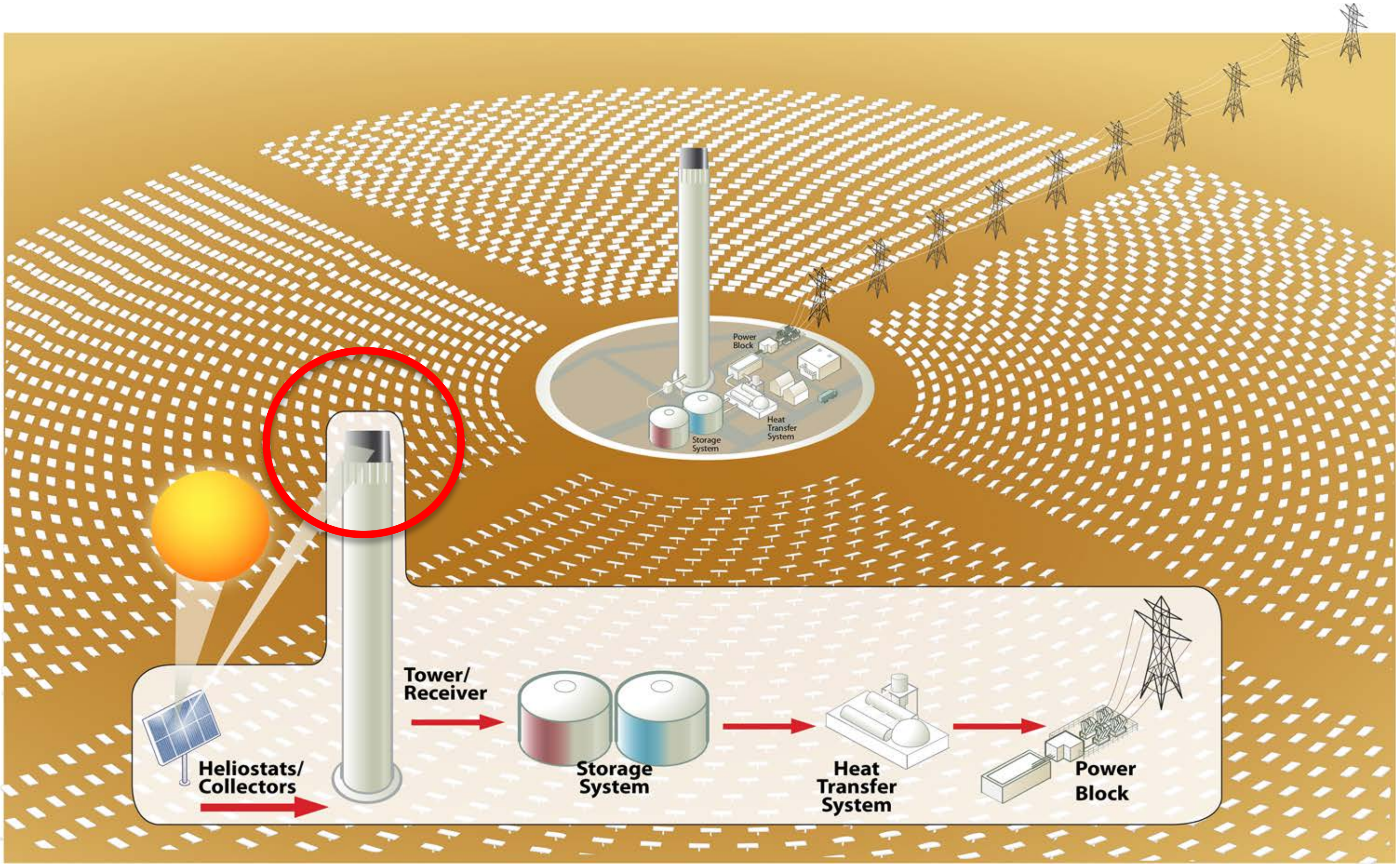
- Introduction and Objectives
- Direct Receiver Designs
- Indirect Receiver Designs
- Summary

SERIIUS – Solar Energy Research Institute for India and the U.S.

- Create disruptive technologies in PV and CSP
- Identify critical technical, economic, and policy issues for solar energy development in India
- Overcome technology barriers through bi-national collaboration between India and the U.S.

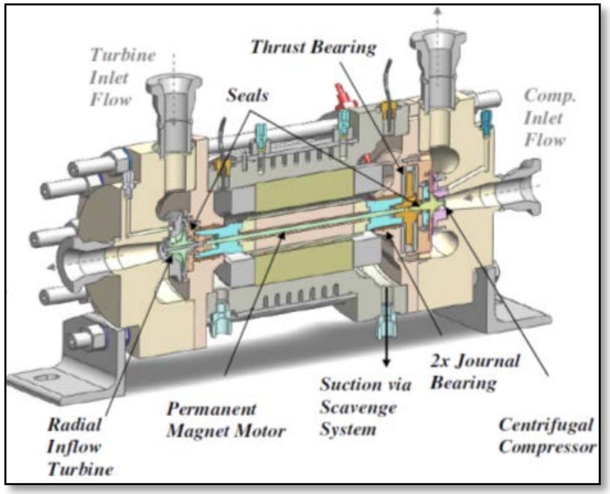
SERIIUS Task CSP-1

High-Temperature Receivers for sCO2 power cycles

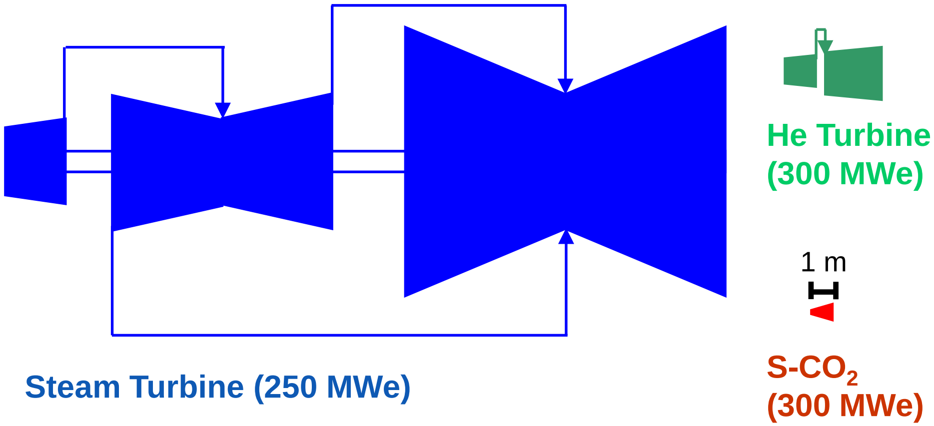


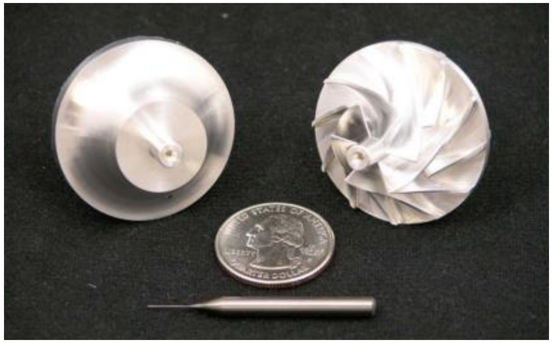
Supercritical CO_2 Brayton Cycle

- High potential efficiency
  - 50% thermal-to-electric
- Compact power conversion
  - Liquid-like densities with CO_2



Sandia sCO_2 turbo-alternator-compressor (Conboy et al., 2013)





Compressor wheel for 150 kW_e sCO_2 Brayton cycle (SAND2010-0172)

Project Objectives

- Identify high-temperature solar receiver designs compatible with sCO_2 power cycles
  - Direct CO_2 heating
  - Indirect CO_2 heating
- Desired capacity for SERIIUS program is 100 kW_e to 1 MW_e

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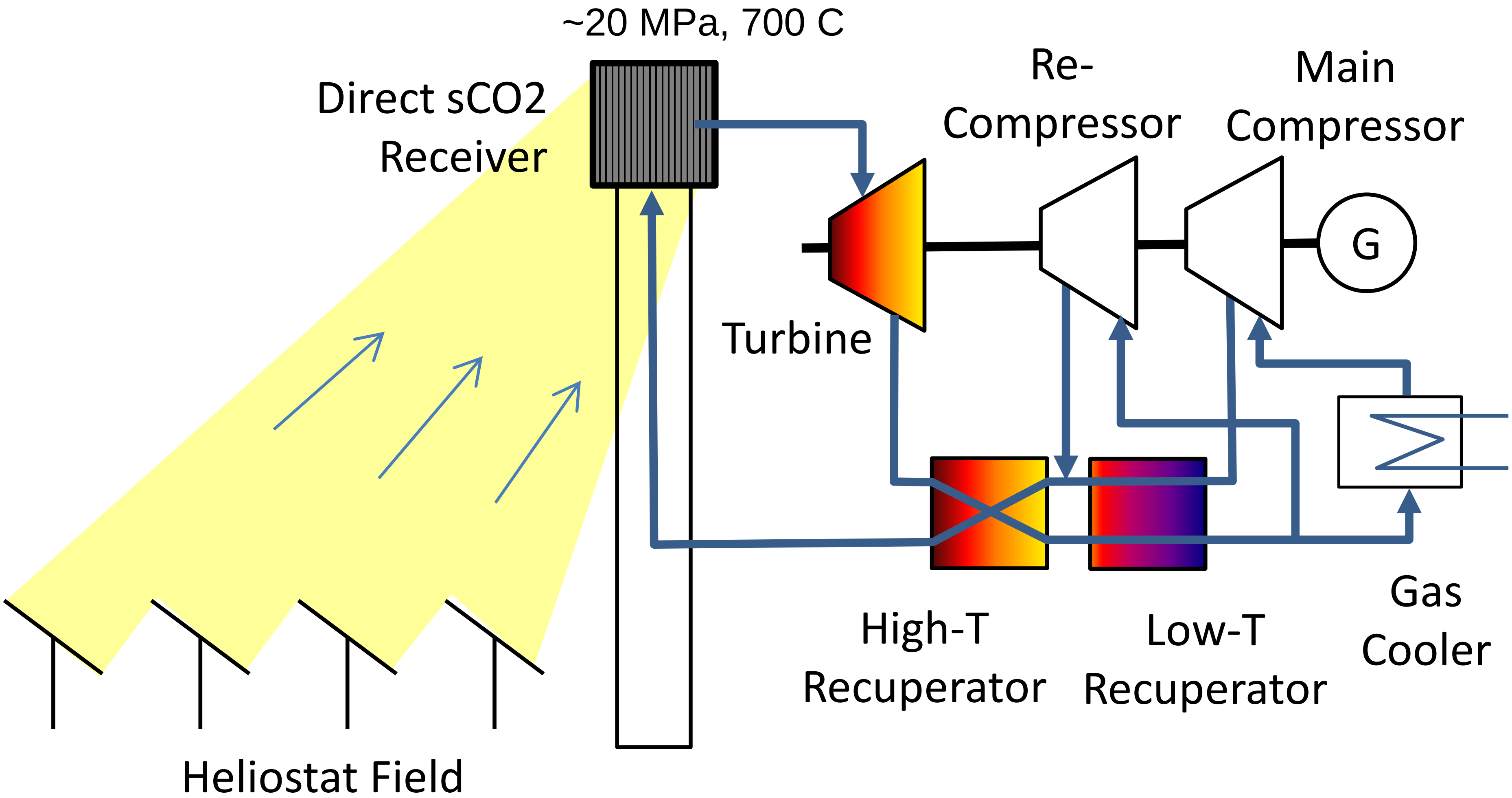
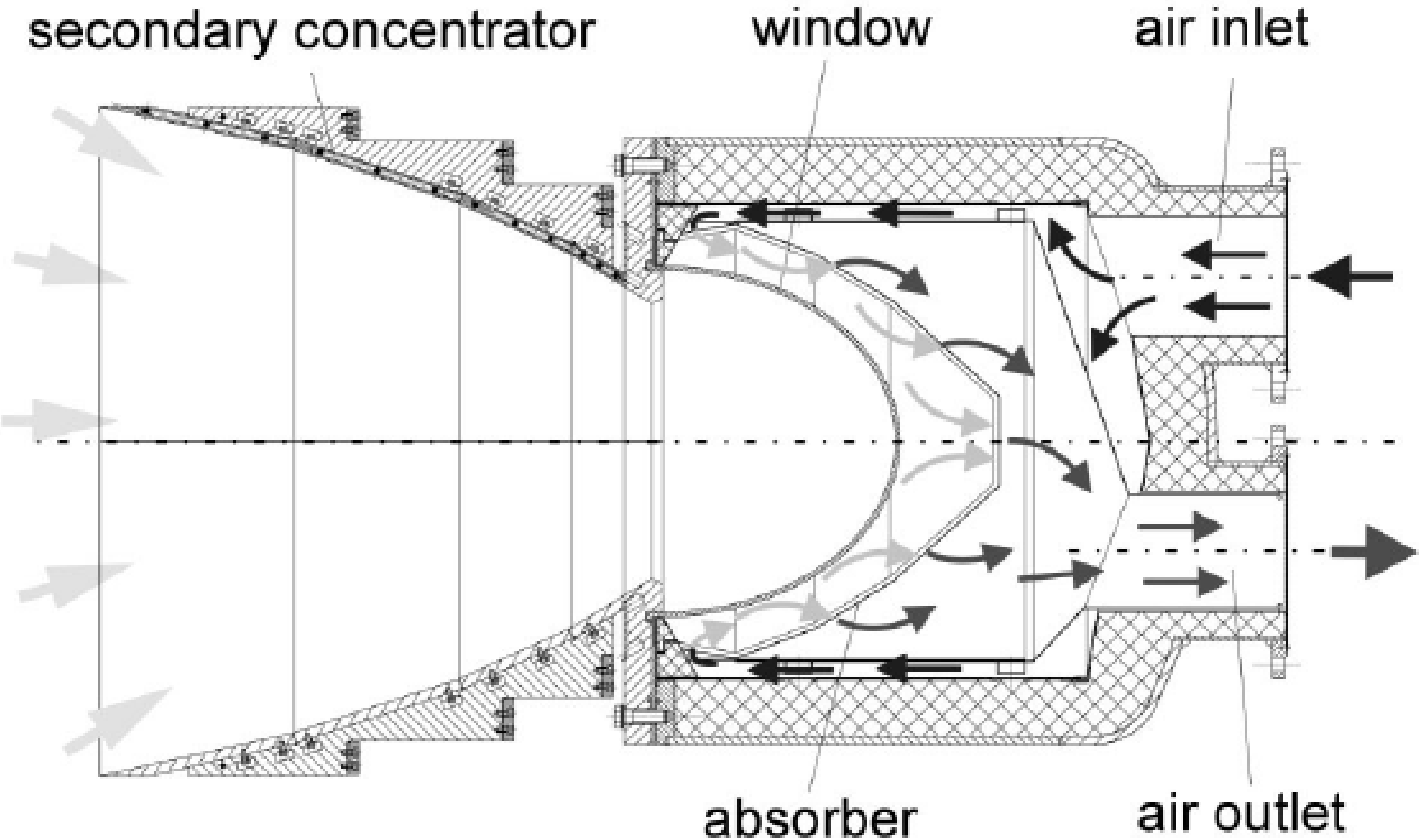
Direct sCO_2 Receiver Configuration



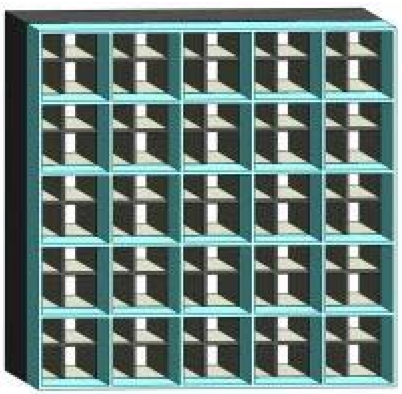
Direct Volumetric Receiver

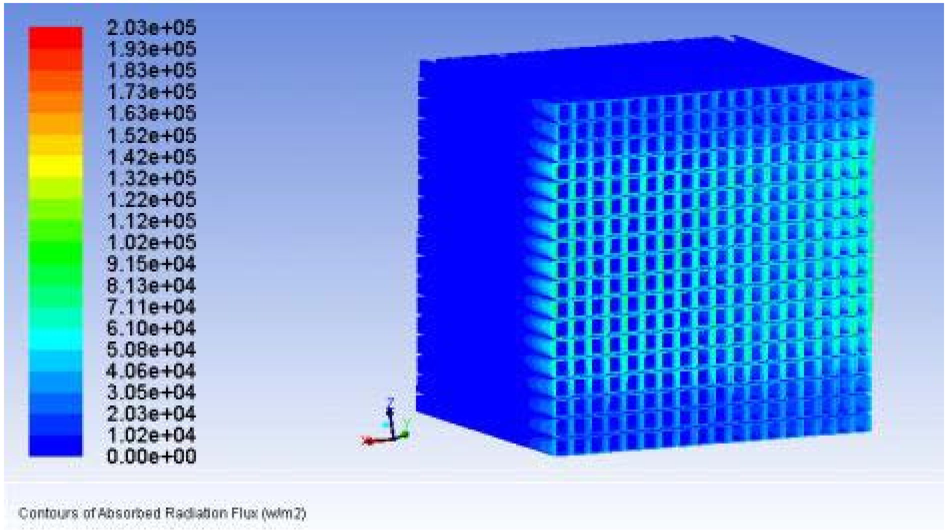
(Buck et al., 2002, JSEE)



Direct Volumetric Receiver

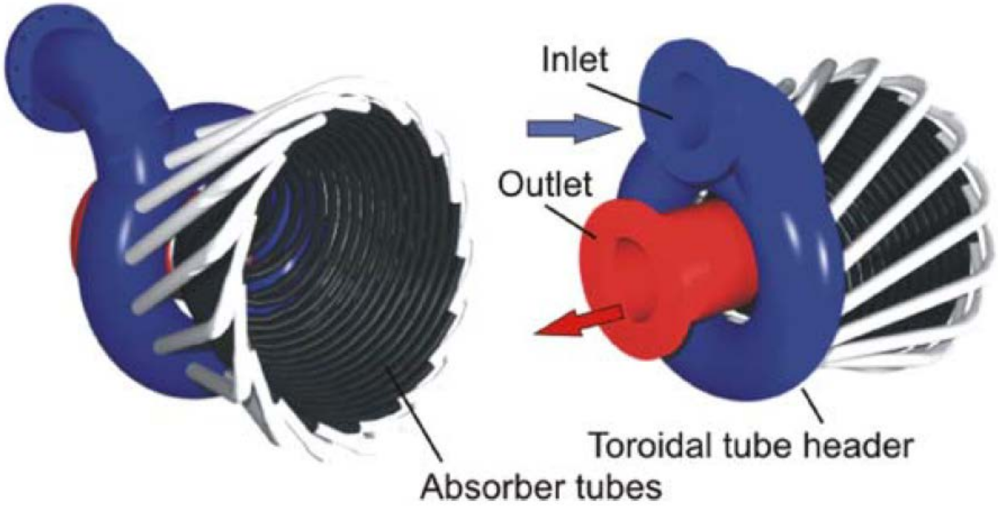
- Sagar Khivsara et al., ES-FuelCell2014-6482
  - "Development of a Ceramic Pressurized Volumetric Solar Receiver for Supercritical CO_2 Brayton Cycle"



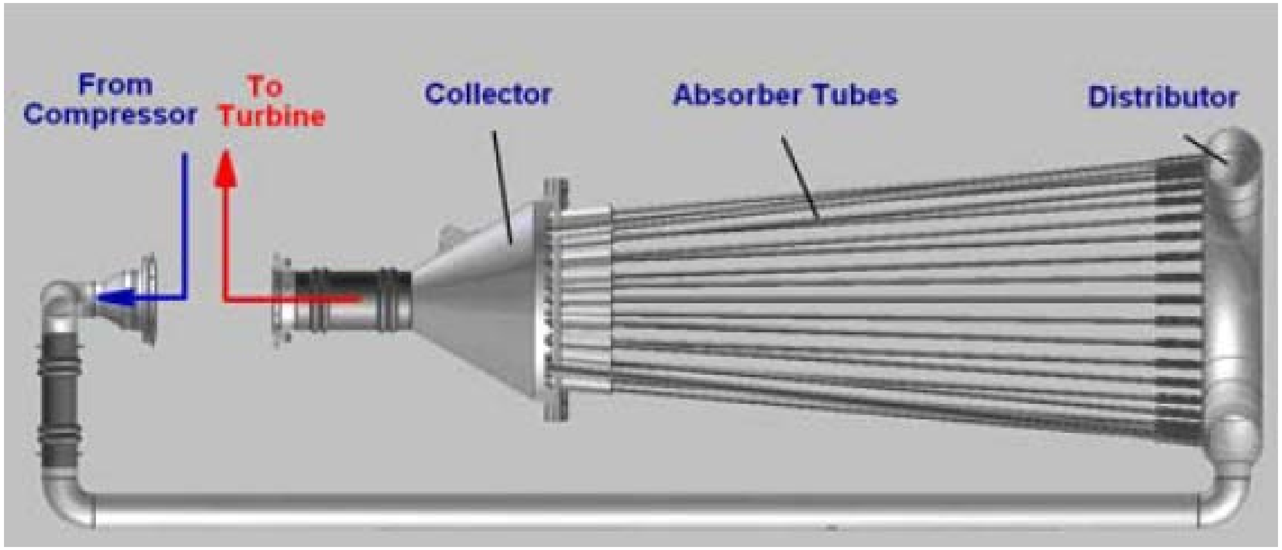


Josh Christian, SNL

Direct Tubular Receiver

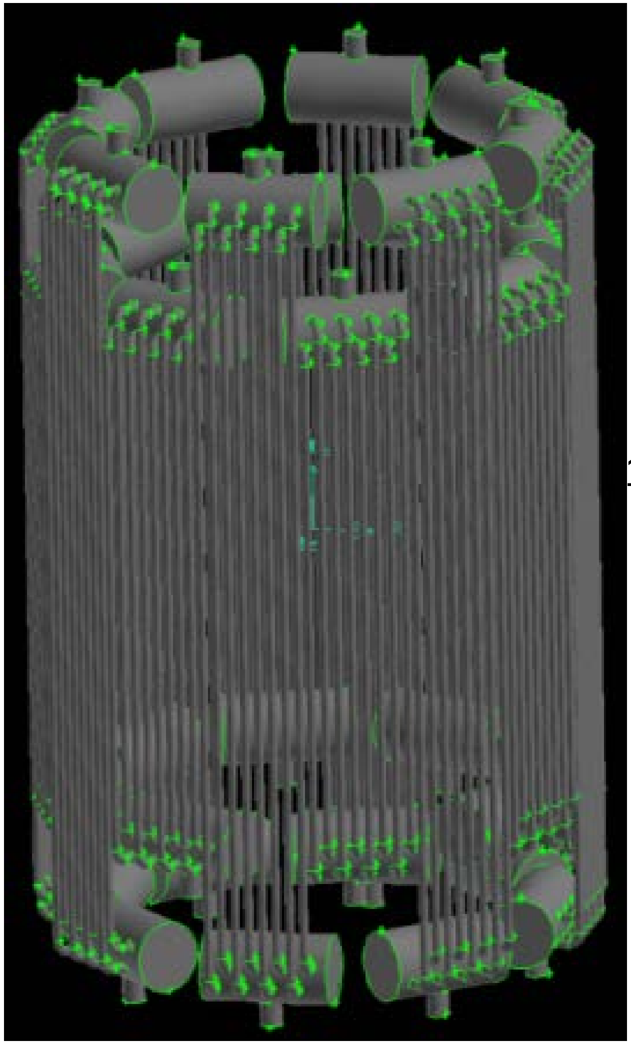


Heller et al. (2006, 2009)



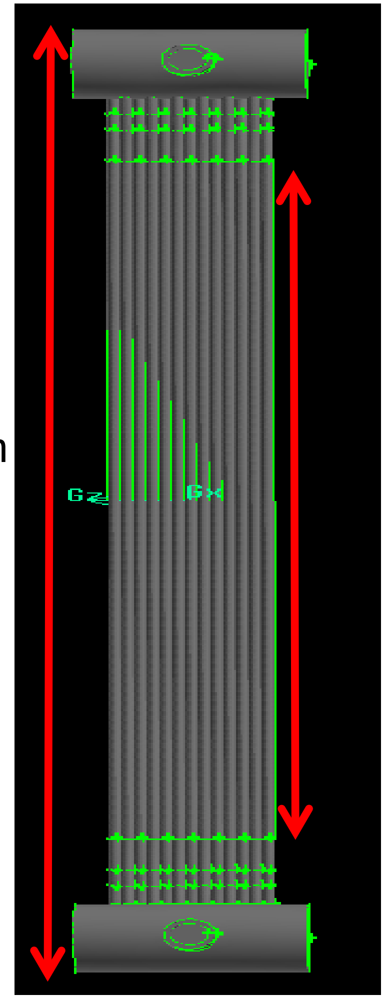
Direct Tubular Receiver Designs

(SERIIUS – Jesus Ortega, SNL; Samia Afrin, UTEP, ES-FuelCell2014-6376)

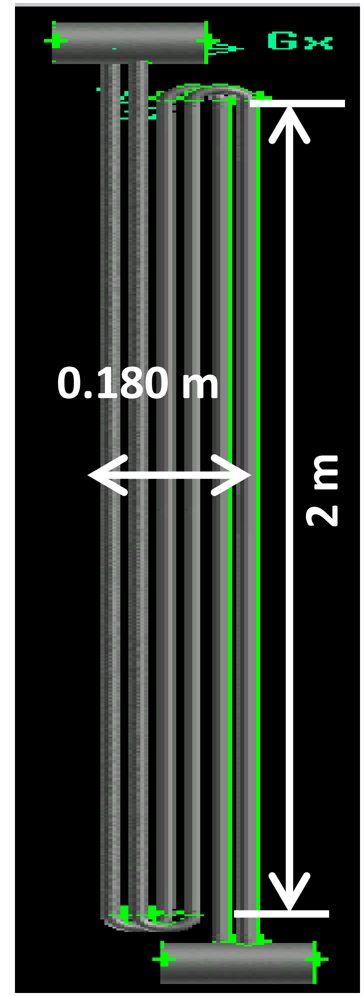


27.74 cm

1.8 m

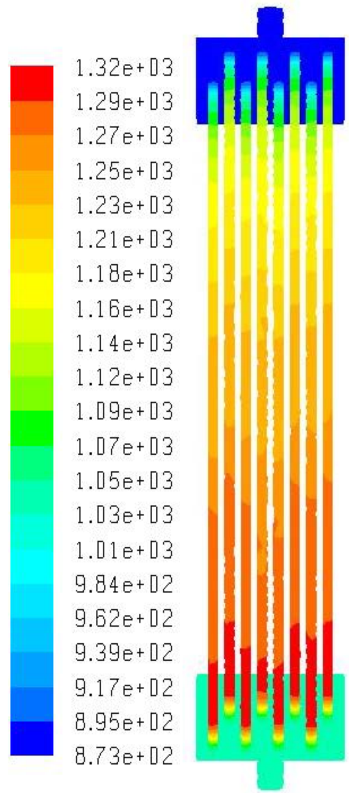


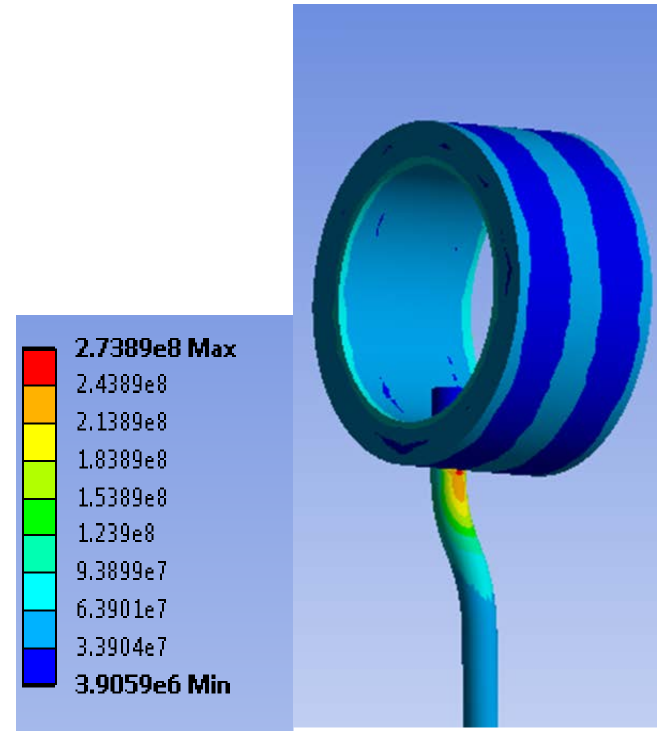
1 m



Thermal Structural Analyses

- Neises et al., ES-FuelCell2014-6603
  - "Structural Design Considerations for Tubular Power Tower Receivers Operating at 650 C"





Jesus Ortega, SNL

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Indirect sCO_2 Receiver Configuration

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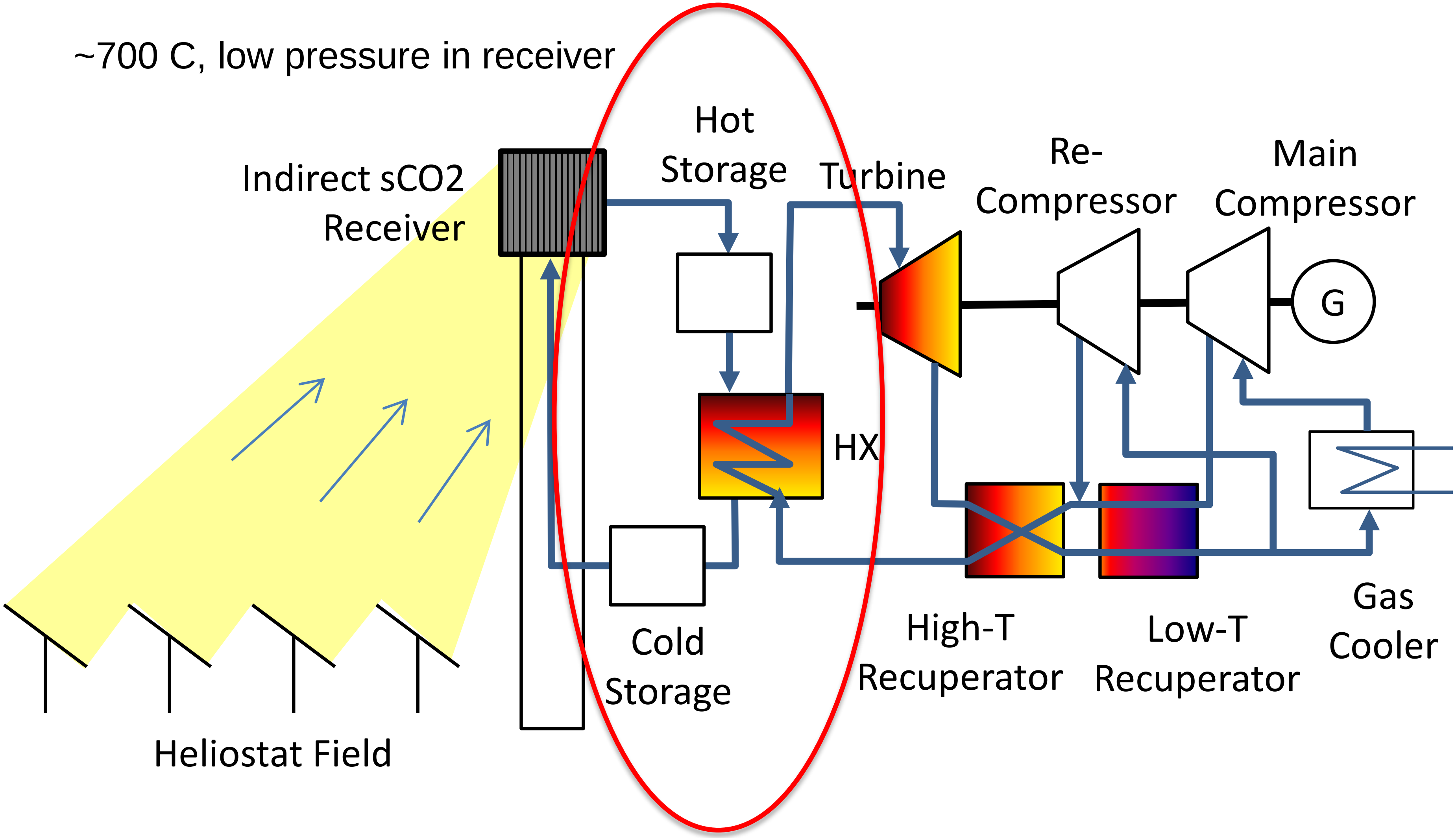
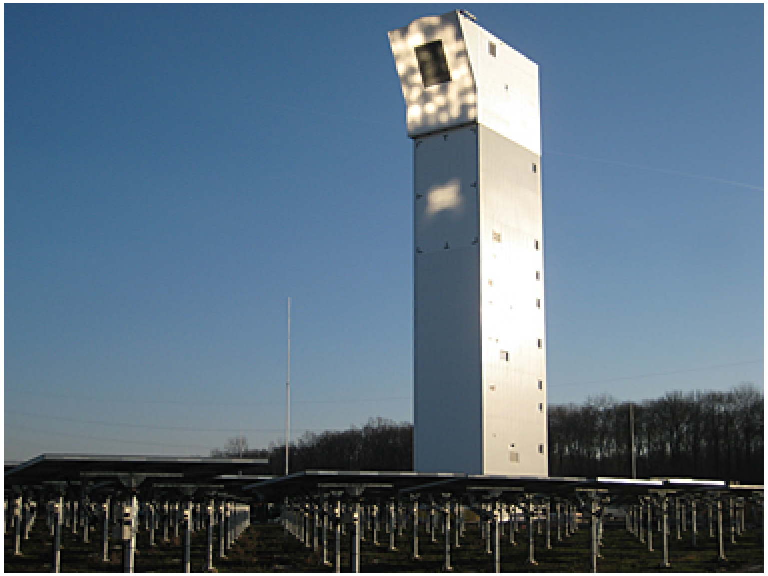
~700 C, low pressure in receiver



Indirect Receiver Designs

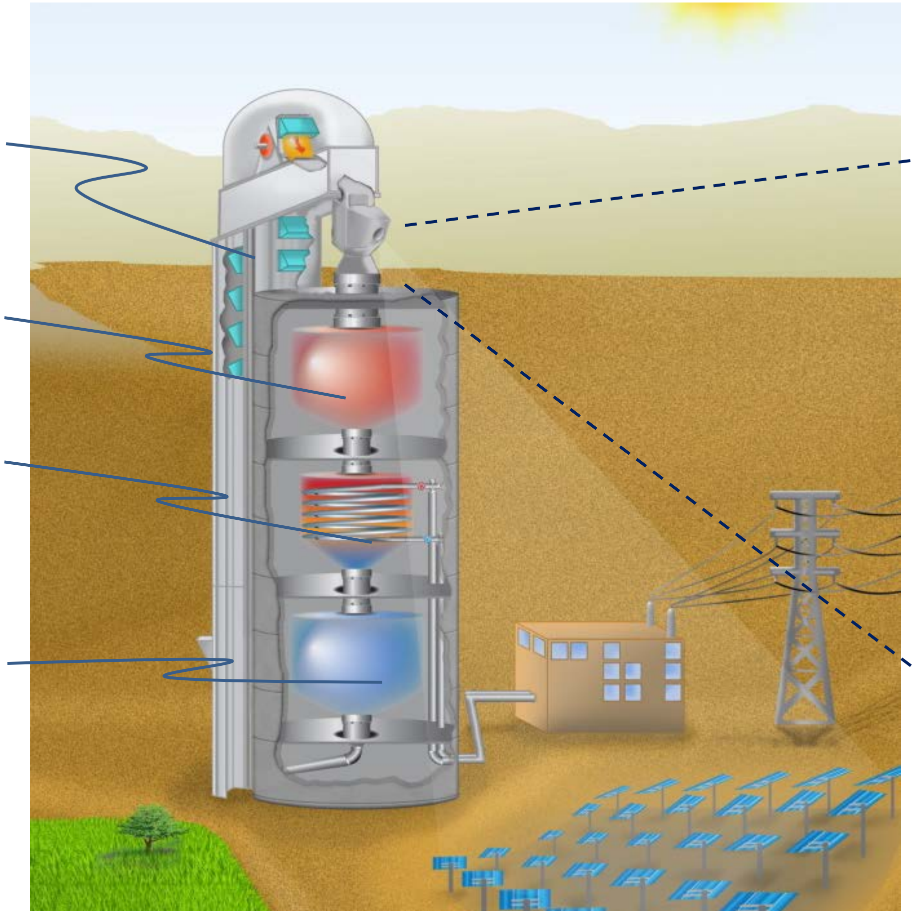
- Indirect Volumetric Receiver
- Indirect Tubular Receiver

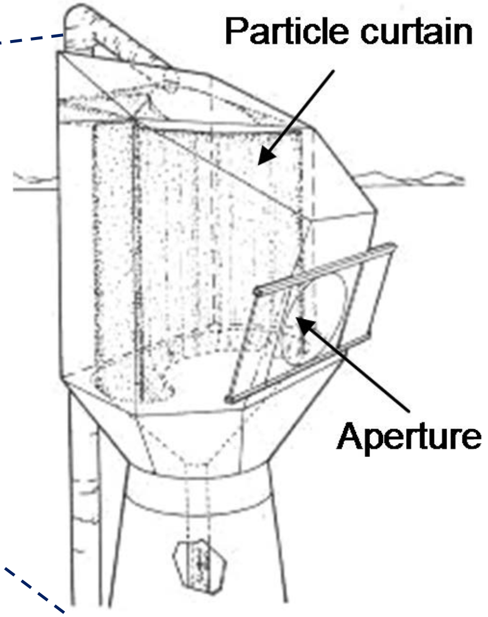


Julich Volumetric Receiver
(www.dlr.de)

Solar Two Tubular
Molten Salt Receiver

Falling Particle Receiver





Summary

Receiver Design	Benefits	Challenges / Research Needs
Direct Receivers		
Volumetric CO_2 Receiver	Capable of achieving high temperatures, simple and flexible construction, direct heating of CO_2	Window under high pressure, material durability, flow instability, hot spots, radiative heat loss, low thermal efficiency, storage, transients
Tubular CO_2 Receiver	Proven technology for direct steam and molten salt, direct heating of CO_2	Thermal cycling and fatigue of tubes, material compatibility, pressure limitations, flux limits, storage, transients
Indirect Receivers		
Volumetric Air Receiver	Capable of achieving high temperatures with air in open loop, simple and flexible construction	Material durability, flow instability, hot spots, radiative heat loss, low thermal efficiency, requires additional heat exchangers to store energy and to exchange heat with CO_2
Tubular Receiver (molten salt or liquid metal)	Proven technology for direct steam and molten salt, direct storage of heat transfer fluid	Thermal cycling and fatigue of tubes; material compatibility; pressure limitations; flux limits; requires fluid/CO_2 heat exchanger, reactivity
Falling Particle Receivers	Capable of achieving high temperatures, reduced flux limitations, direct storage of particles	Radiative and convective heat losses, particle attrition, requires particle/CO_2 heat exchanger

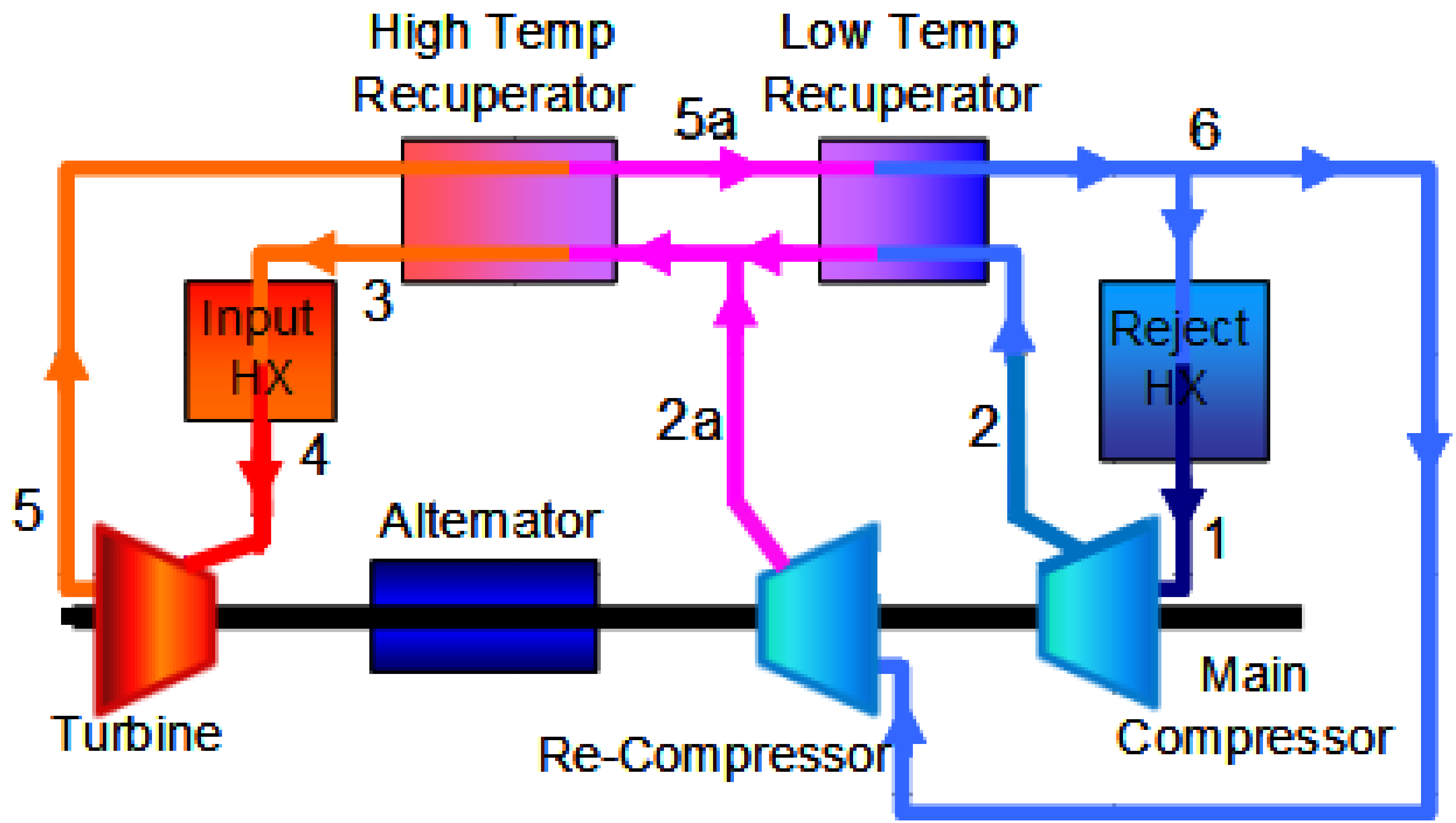
Acknowledgments

- SERIIUS (IIT Bombay, IISc Bangalore)
- U.S. DOE EERE

SERIIUS

Solar Energy Research Institute
for India and the United States

Backup Slides


High Temp Recuperator
Low Temp Recuperator
5a
6
Input HX
3
Reject HX
2a
2
4
5
Altemator
1
Turbine
Re-Compressor
Main Compressor