Dissemination workshop: Key elements for the new solar thermal energy plants

Competitive solar power towers – CAPTure project overview

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MSLOOP dissemination workshop
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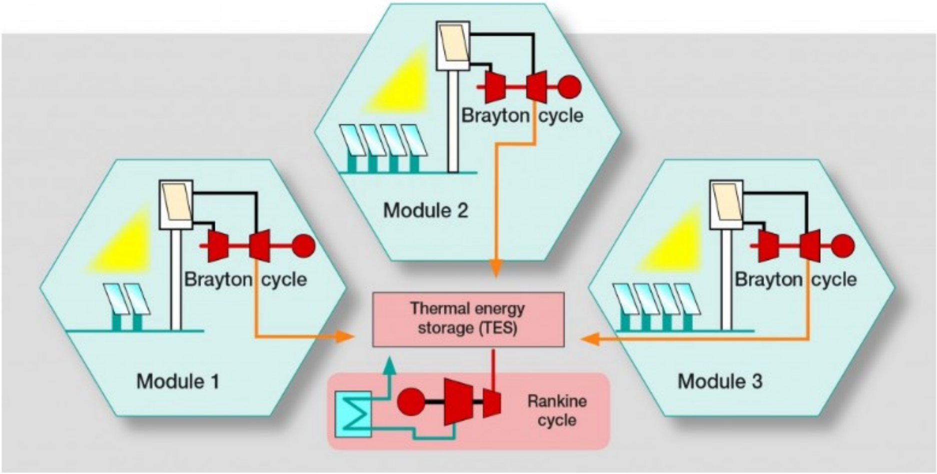
Summary Objectives



Decoupled solar combined cycle

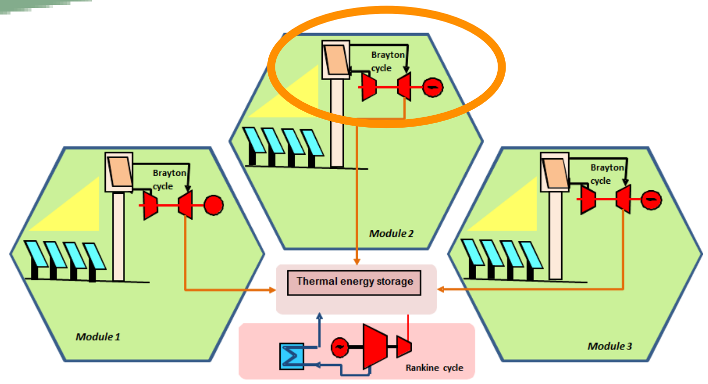
Small heliostat for mass production

Objectives of the project:

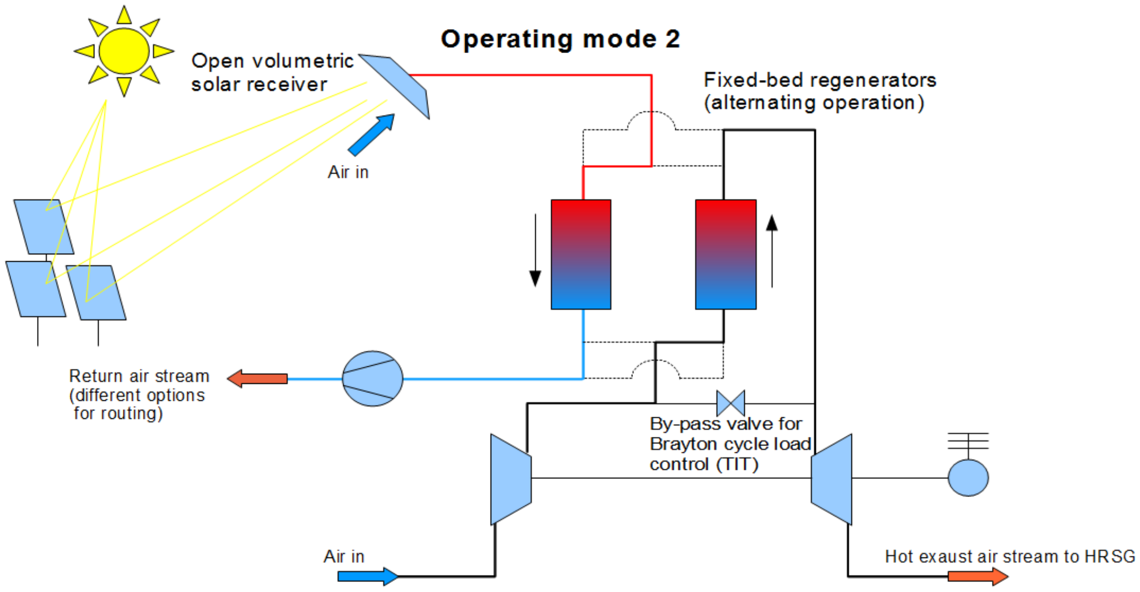
Increase plant efficiencies and reduce Levelized Cost of Electricity (LCOE) by:

- Proposing an innovative plant concept (solar combined cycle)
- Downsized heliostat for mass production + smart calibration system
- Validating the most critical components in the relevant environment

Summary Objectives



Decoupled solar combined cycle

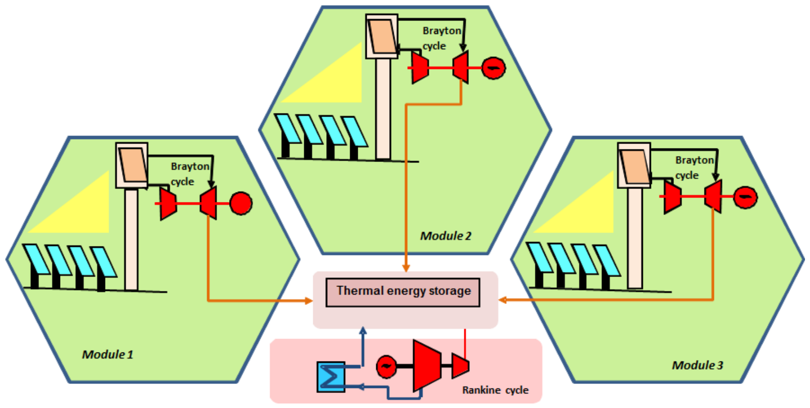


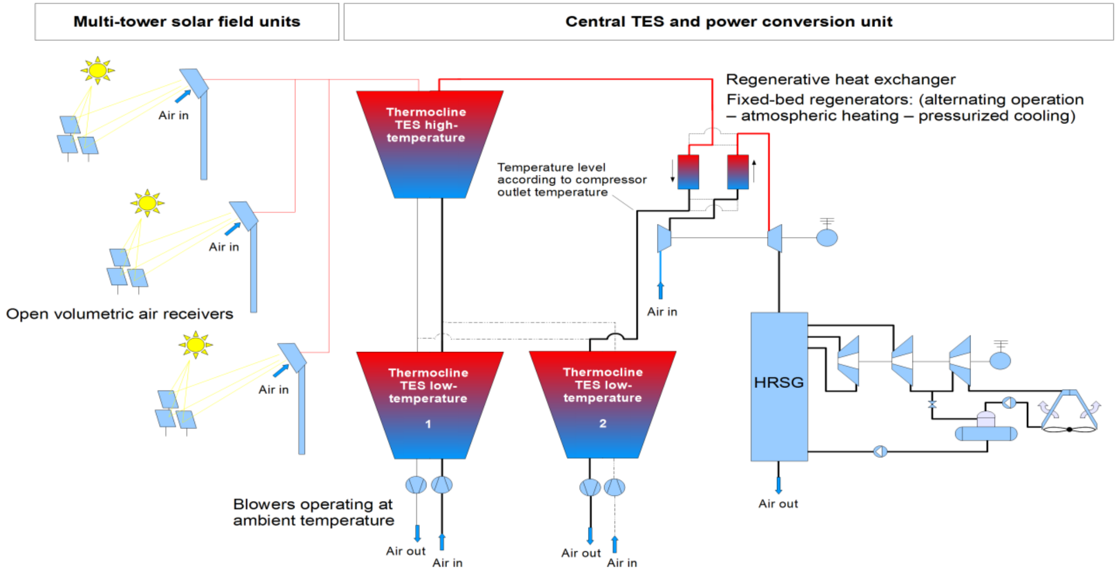
Objectives of the project:

Increase plant efficiencies and reduce Levelized Cost of Electricity (LCOE) by:

- Proposing an innovative plant concept (solar combined cycle)
- Development of a solar-driven hot air turbine prototype
- An open volumetric solar receiver charges a regenerator
- The regenerator is pressurized and discharged, driving the turbine

Summary Results



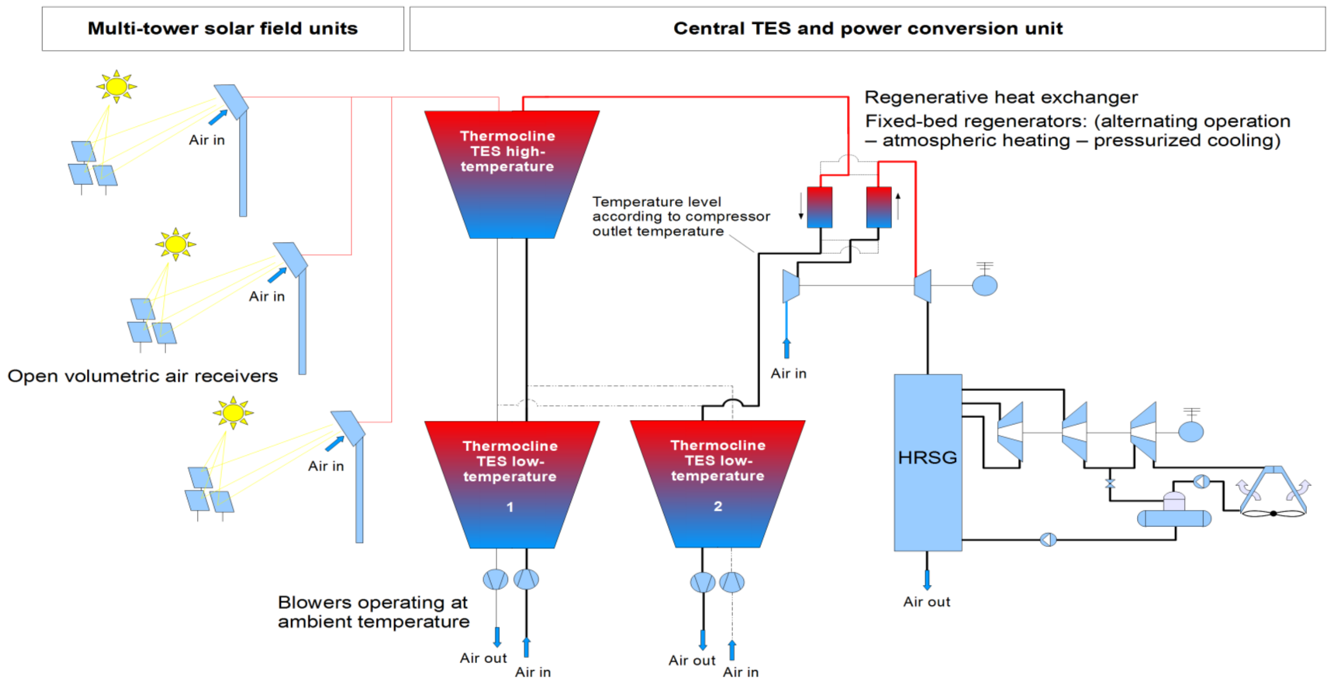


Decoupled solar combined cycle vs. a fully dispatchable solar combined cycle

The originally proposed solar combined cycle plant concept has some disadvantages:

- Solar powered gas turbine is not dispatchable -> Conflict with cheaper PV
- Molten salts cannot be used for the centralized thermal energy storage unit -> The air-to-molten salt heat exchanger's size is very large (heat transfer constraints of air) -> too expensive + pressure drop issues on air side -> limits gas turbine efficiency
- When applying a centralized TES, air-solid packed-bed thermocline storage needs to be used -> however, also here the pressure drop of the packed bed limits gas turbine efficiency

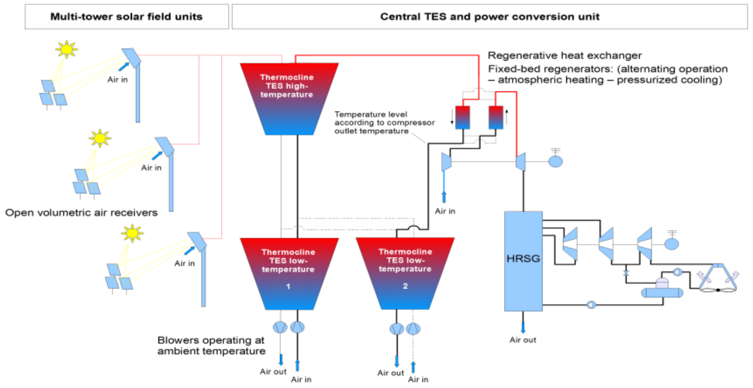
Summary Results



An alternative power plant layout has been proposed with TES upstream the combined cycle:

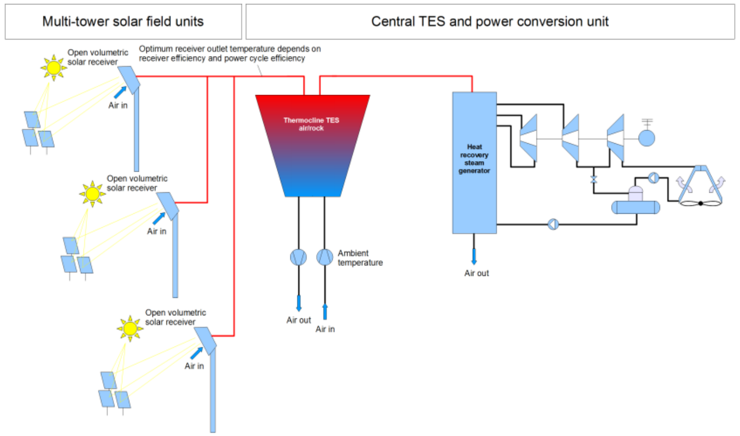
- This approach provides also dispatchable operation for the topping gas turbine
- A high-temperature air-solid packed-bed thermocline TES is used upstream the gas turbine
- Additionally, two low-temperature TES units make use of the return-air heat in regenerative manner
- The multi-tower approach allows good optical efficiencies due to compact heliostat fields

Summary Results



Solar combined cycle plant (GT + Rankine)

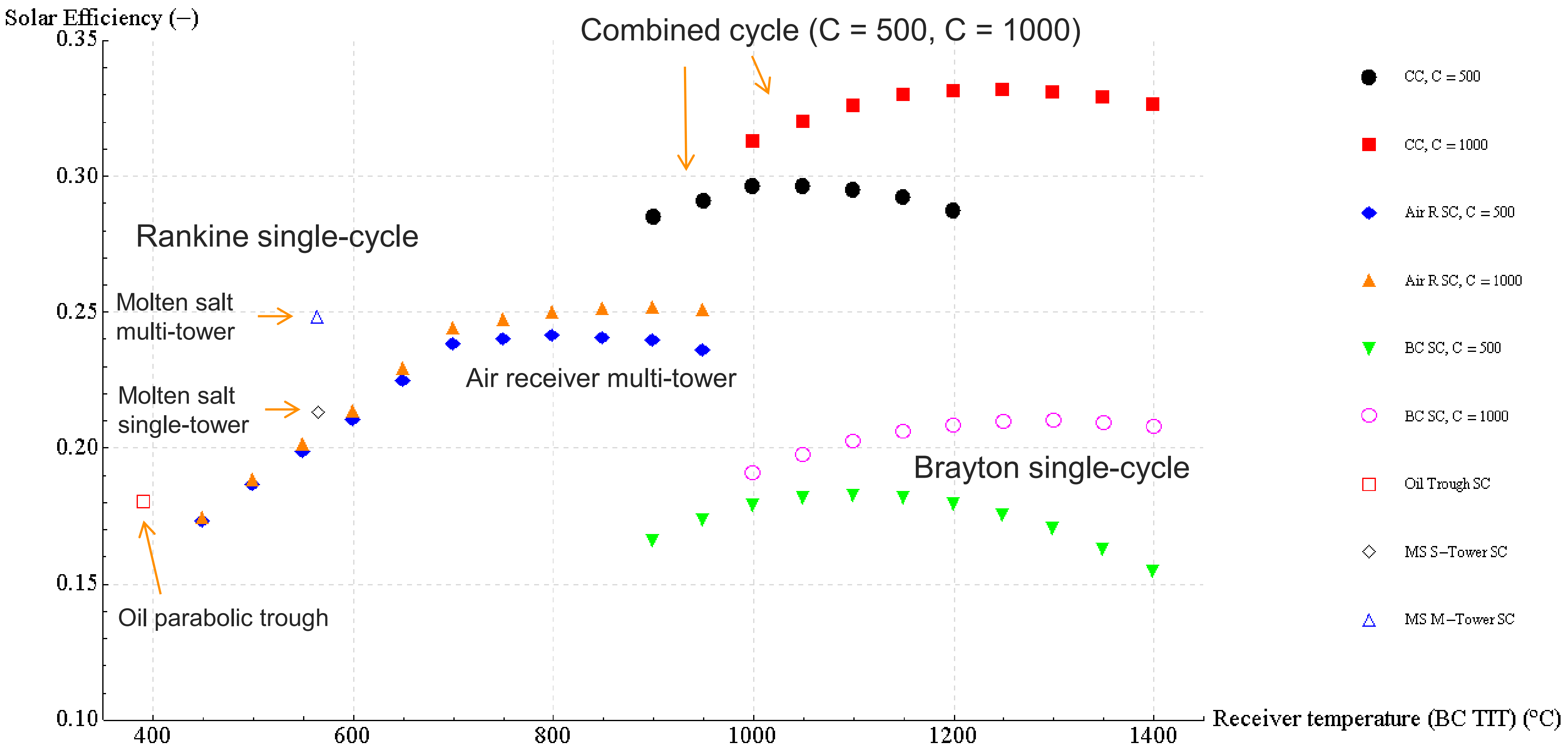
vs.



Solar single-cycle Rankine plant

- **The solar combined cycle has higher receiver operating temperature (1050 ºC)**
- **The solar combined cycle has thus a lower receiver efficiency -> however the power cycle efficiency increases (-> 50% thermal-to-electric efficiency for the best case scenario)**
- **The single-cycle Rankine plant has a lower receiver operating temperature (700-800 ºC)**
- **The single-cycle Rankine plant has thus a higher receiver efficiency, but lower power cycle efficiency (-> 38% thermal-to-electric efficiency)**

Summary Results



- **The solar combined cycle reaches a peak solar-to-electric efficiency of 29.6% (C=500)**

Summary Results

Preliminar techno-economic optimization results for Seville, Spain:

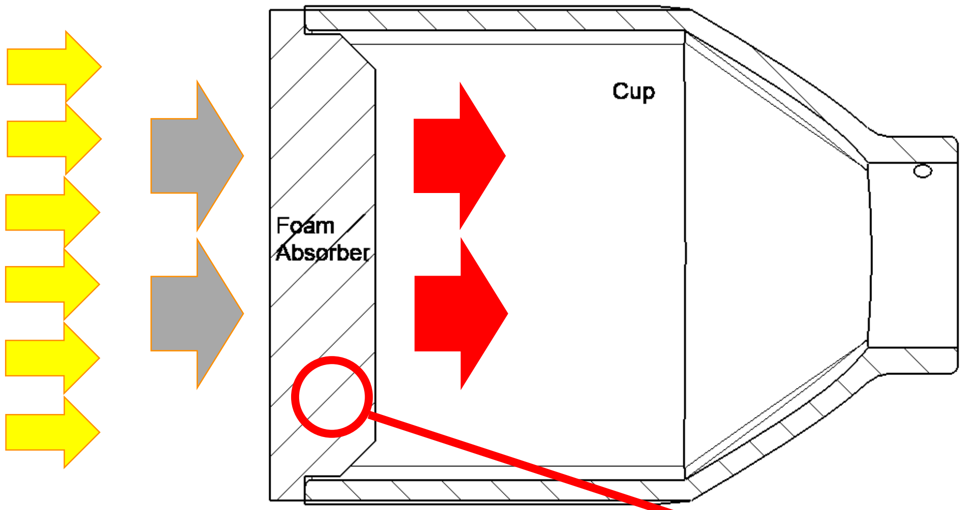
Parameter (Unit)	Preliminar CAPTure plant optimization results
Number of towers (-)	6
Nominal solar power per tower (MW)	51
Total nominal solar power (MW)	306
Receiver thermal efficiency at 1050°C outlet temperature (-)	0.76
Solar-to-thermal annual mean efficiency (-)	0.417
Solar-to-electric annual mean efficiency (-)	0.208
Solar multiple – SM (-)	2.3
Power cycle nominal power (MWe)	56
GT nominal power (MWe)	31
Rankine cycle nominal power (MWe)	25
Power cycle annual mean conversion efficiency: CC / GT / RC (-)	0.499 / 0.29 / 0.36
TES thermal capacity (MWh)	1,208
TES costs (M USD)	48.3
Yearly electricity yield (GWh)	194.5
Total plant cost (M USD)	208.43
Specific plant costs (USD / kWe)	3,722
Specific power cycle costs (USD / kWe)	933
LCOE (c$/kWh)	12.4

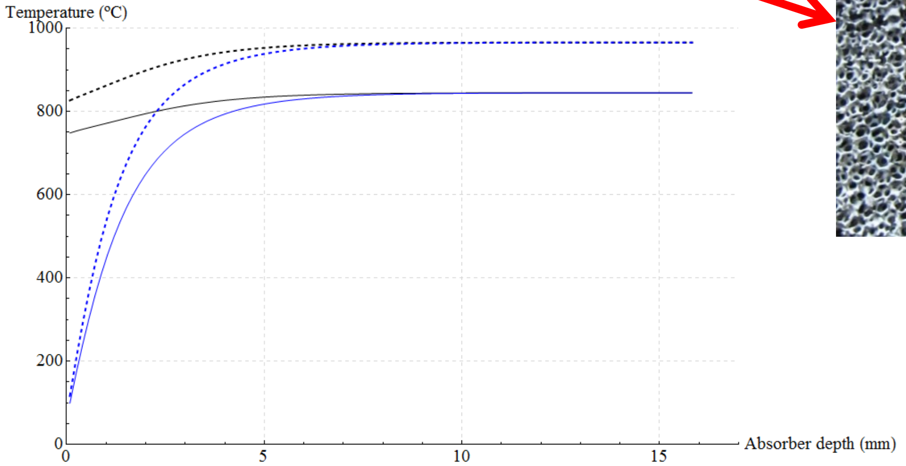
Summary Results
Receiver prototype

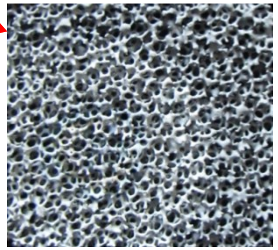
CAPTURE – COMPETITIVE SOLAR POWER TOWERS

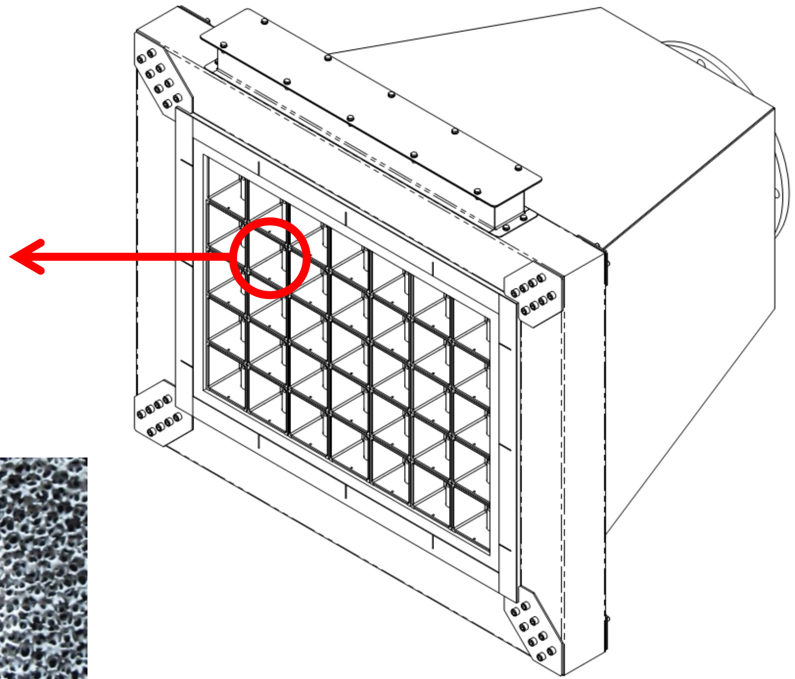
CENER | NATIONAL RENEWABLE ENERGY CENTRE

ADItech



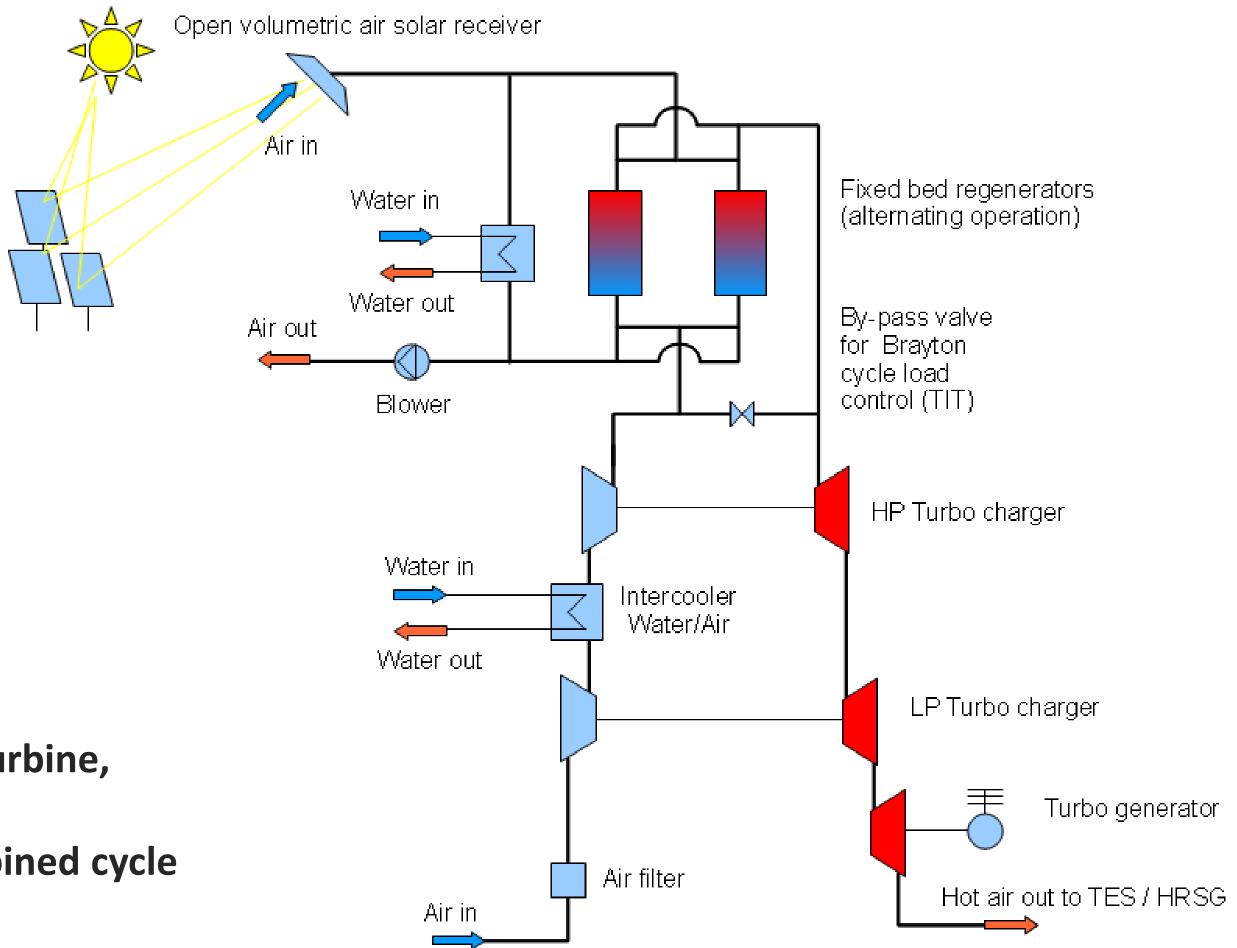






- Open volumetric air receiver
- SiC foam absorber
- ≈ 300 kW thermal
- 0.7 m2 aperture area

Summary Results
Capture prototype



CAPTure prototype:

- ≈ 300 kW thermal
- Currently being installed at CRS tower
- Solar testing operation until April 2020
- Should demonstrate the operation of a solar-driven gas turbine, powered by an open volumetric air receiver
- And consequently the feasibility of a solar-powered combined cycle

The techno-economic optimization of the combined cycle and its benchmarking will be presented at SolarPACES 2019

Main impacts

- How the project contributes to the future of the CSP:

  - Disruptive technology implemented:

  Solar powered combined cycle
  50 % cycle efficiency -> thermal to electric
  29.6 % peak solar-to-electric plant efficiency
  ≈ 21 % annual mean solar-to-electric plant efficiency
  -> still subject to optimization!

  - Cost reductions from project innovations (CAPEX, OPEX):

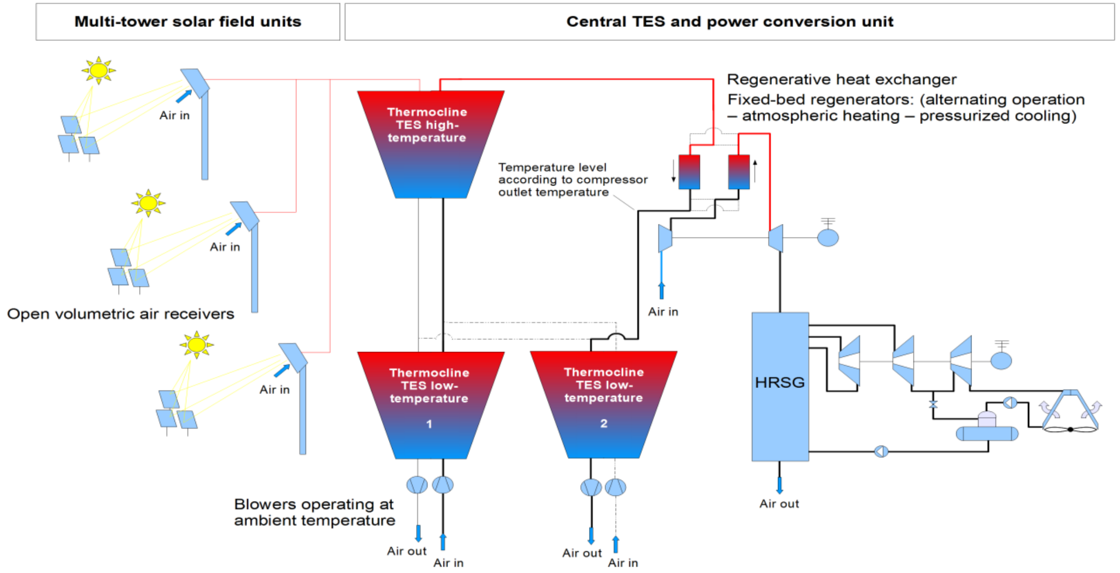
  Cost effective solar receiver – mass manufactured downsized heliostat –
  Cost effective thermocline air/solid packed-bed TES - Improved calibration of solar field

  Location Spain: **CAPTure LCOE: ≈ 12.4 c$/kWh vs. conventional molten salt tower: ≈ 17 c$/kWh**

  Note that for locations with better solar resource / financing conditions **≈ 7 c$/kWh** are given [1] (DEWA IV).

  - Environmental and safety improvements:

  Air as HTF -> no contamination issue, no heat tracing, simple operation



[1] J. Lilliestam, R. Pitz-Paal, Concentrating solar power for less than USD 0.07 per kWh: finally the breakthrough?, Renewable Energy Focus, 26 (2018) 17-21

THANK YOU FOR YOUR ATTENTION

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