
Heliogen
sCO2 Power Cycles with
Sensible Heat Storage for
Industrial Decarbonization
sCO2 Symposium
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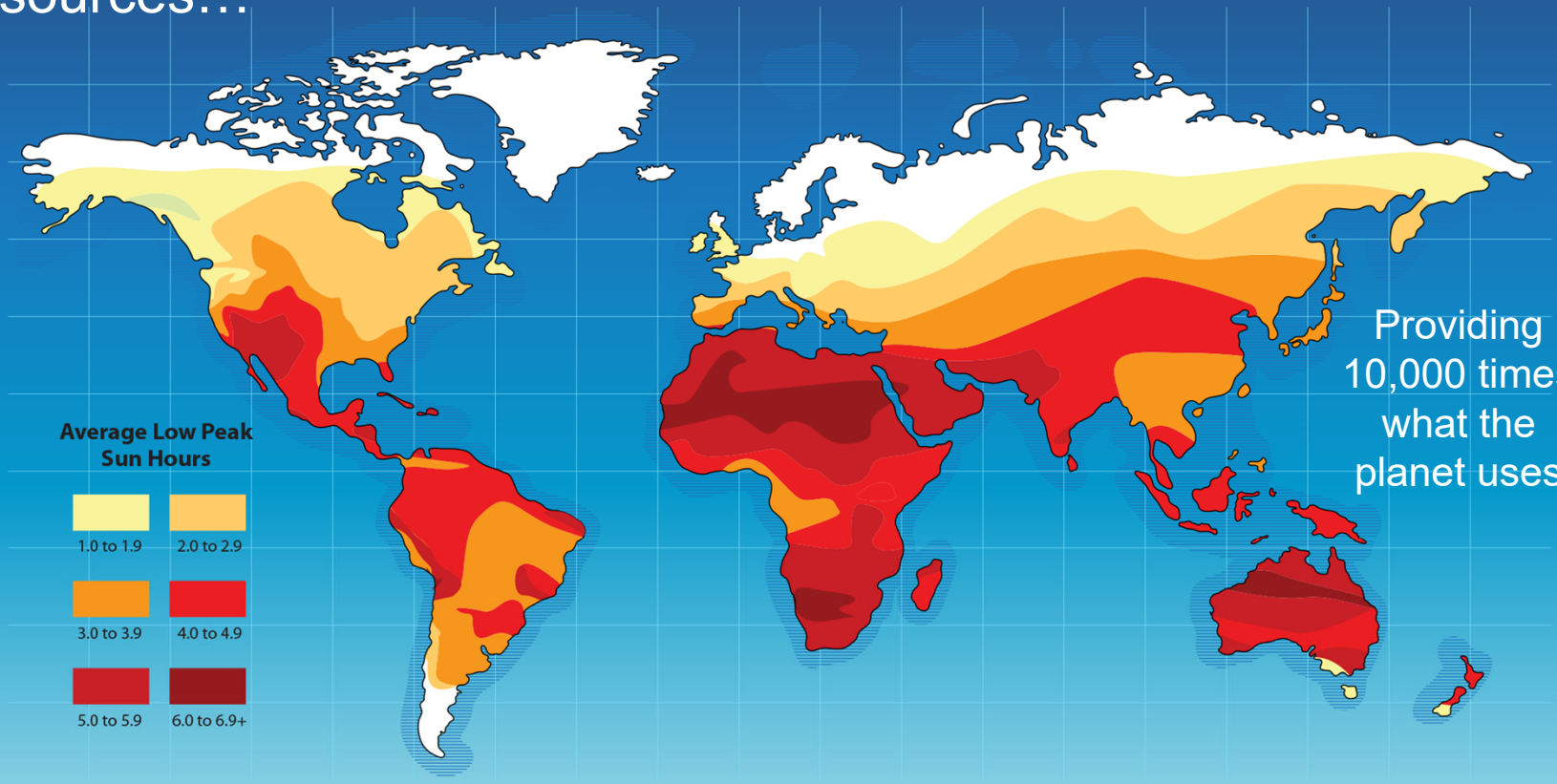
SVP Product Management
REPLACING FOSSIL FUELS WITH CONCENTRATED SUNLIGHT
Heliogen

Industry needs a new resource to power the energy transition including heat, power, and hydrogen

Solar energy is one of the most evenly distributed natural resources…



Providing 10,000 times what the planet uses

However, there are two problems:

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Heliogen

Heliogen's Sunlight Refinery™ will solve these two fundamental problems

Heliogen aims to produce near always-available and transportable renewable energy – cost-effectively

Insight:
Scale and modularity are key to driving down costs

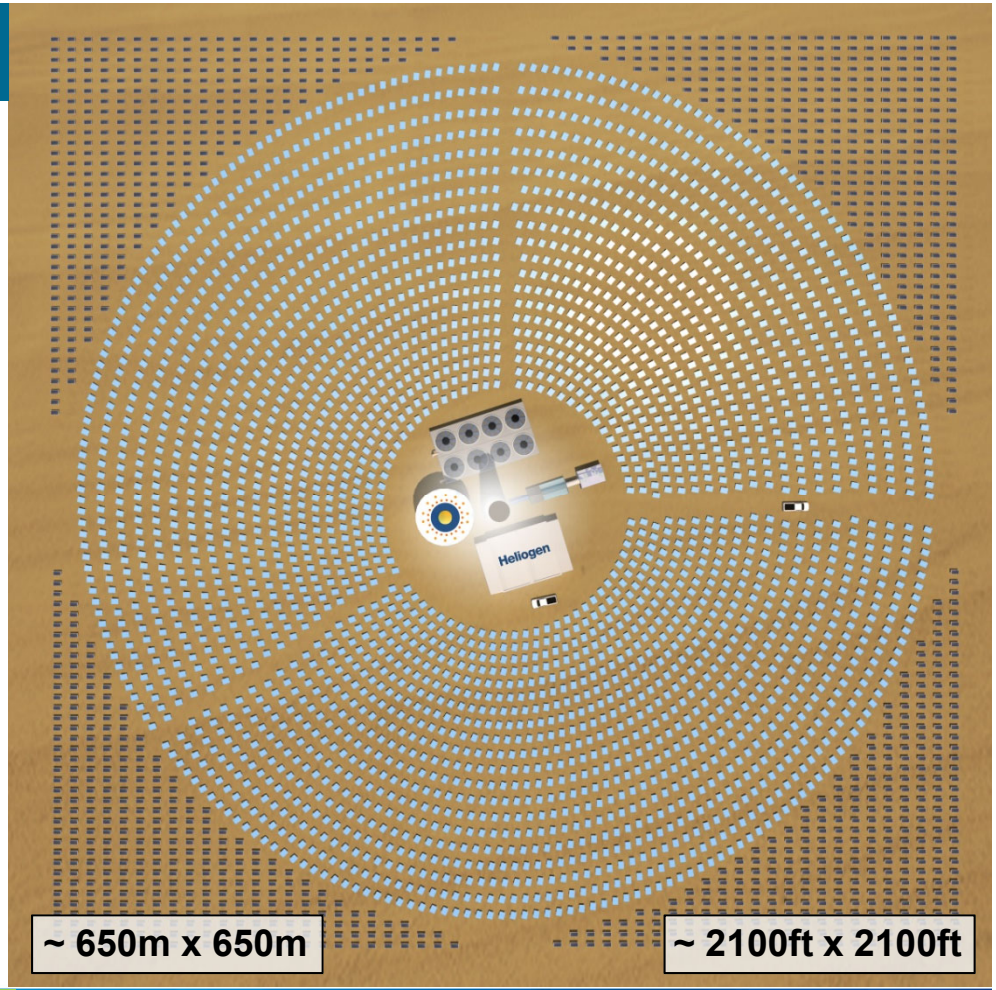
We Reinvented Concentrated Solar to be Modular & Scalable

We build ONE modular 5MW plant and replicate it to meet our customers' demand:

- ~100MW of electrical energy can be produced with ~20 modules
- Modular and easily scalable design will allow for growth to compete with large scale renewable projects

Plant estimated to produce:

- > 85% capacity factor renewable power
- < 5 cents per kW-hour power cost(1)
- < 1/6th square mile footprint (650m x 650m)
- > 850,000 kilograms of hydrogen/year



1. Heliogen estimates. Analysis assumes subsidized economics with 60% debt at 8% interest rate and 40% equity at 12% cost over 30 year projection period. Represents the estimated implied LCOE of Heliogen.

Heliogen

Heliogen

Heliogen's Sunlight Refinery™ designed to capture, concentrate and refine sunlight into cost-efficient energy on demand.

This near 24/7, low-carbon energy can be available as heat, power, or fuel in modular/scalable deployments.

HelioHeat

HelioHeat creates heat up to 800°C+ 24/7 to power industrial processes or mining.

~ 1 mile →

Delivery range of this product is approximately 1 mile.

HelioPower

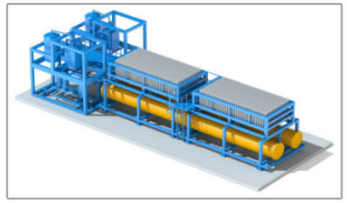
HelioPower delivers the HelioHeat solar thermal energy to a heat engine to produce electrical power 24/7.

~ 100 miles →

Delivery range of this product is approximately 100 miles.

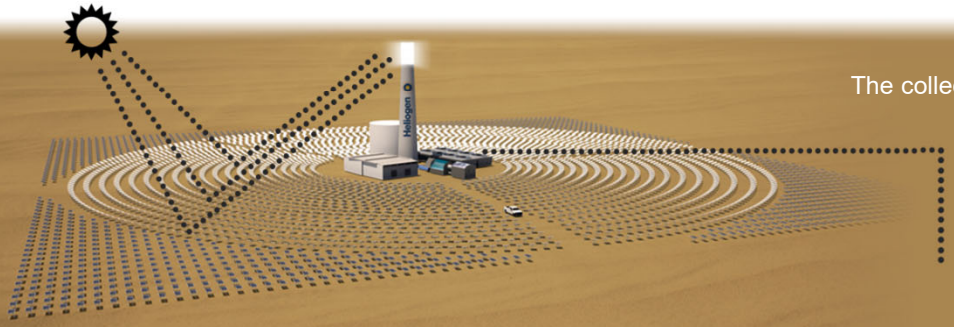
HelioFuel

HelioFuel systems couple a HelioPower plant with a large-scale water electrolyzer to produce green Hydrogen fuel.



> 10,000 miles →

Delivery range of this product is greater than 10,000 miles.



The collected sunlight is processed and converted to:

- HelioHeat
- HelioPower
- HelioFuel

To make green Hydrogen affordable, you need low-cost renewable energy **AND** high capacity-factor

(to leverage capex cost of electrolyzer)

20%
Fdsdflw|OIdfwru

Il{hg#Vrodu#Sdqhov

27.5%
Fdsdflw|OIdfwru

Wudfnhg#Vrodu#Sdqhov

46.5%
Fdsdflw|OIdfwru

Z bgg#Idup

50%
Fdsdflw|OIdfwru

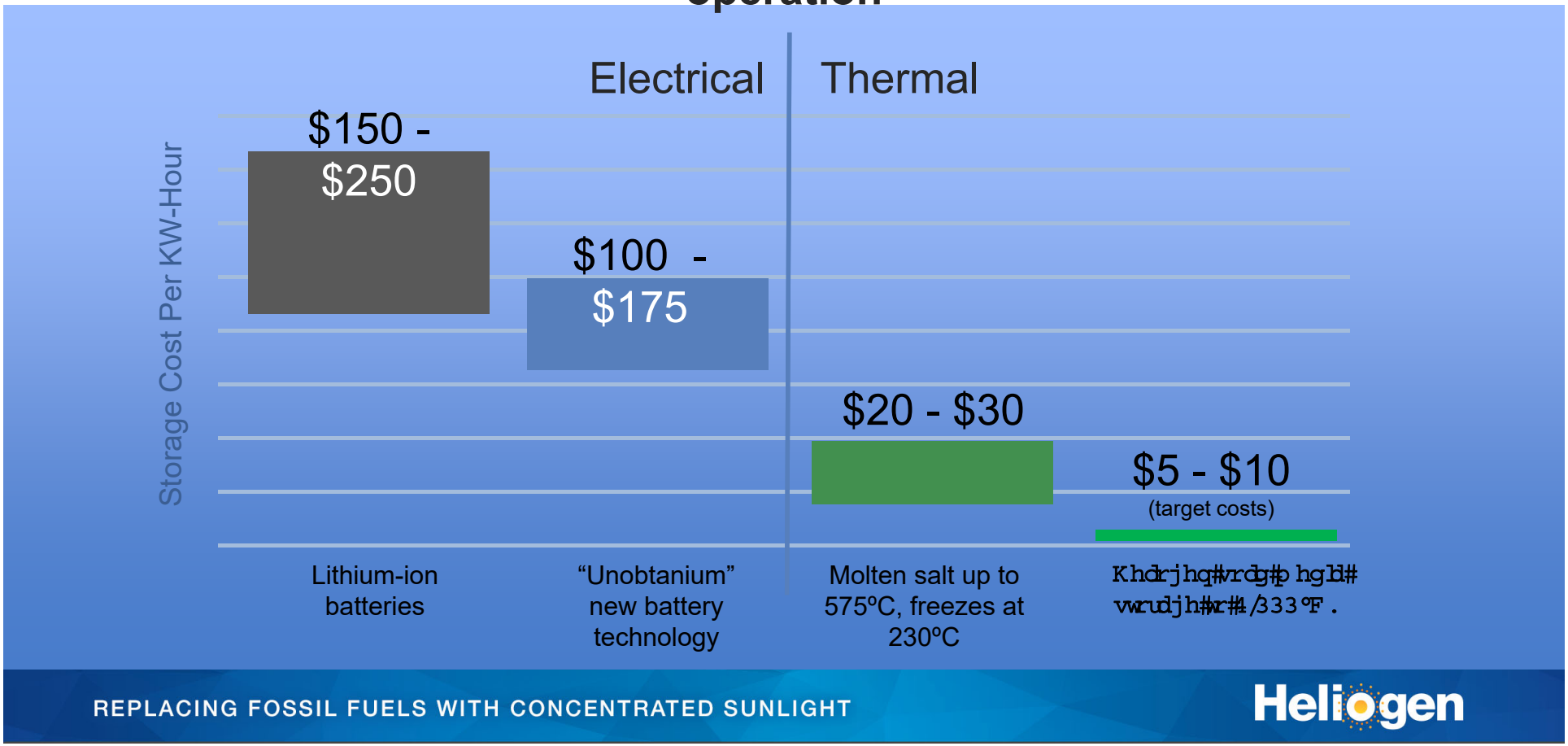
R iivkruh#Z bgg#Idup

~85+%
Fdsdflw|OIdfwru

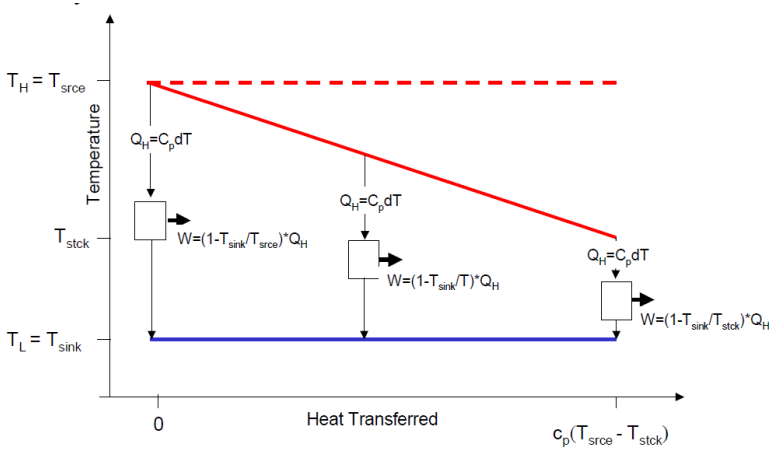
Khdrjhq

Source: Lazard 's Levelized cost of energy analysis 14.0 – Solar Panels = average of rooftop and C&I, Tracked = Utility-scale average, Wind Farm = Onshore Average, Offshore = Offshore Avg. Heliogen = estimate based on customer target

Heliogen's high-temp thermal storage enables economic 24/7 operation

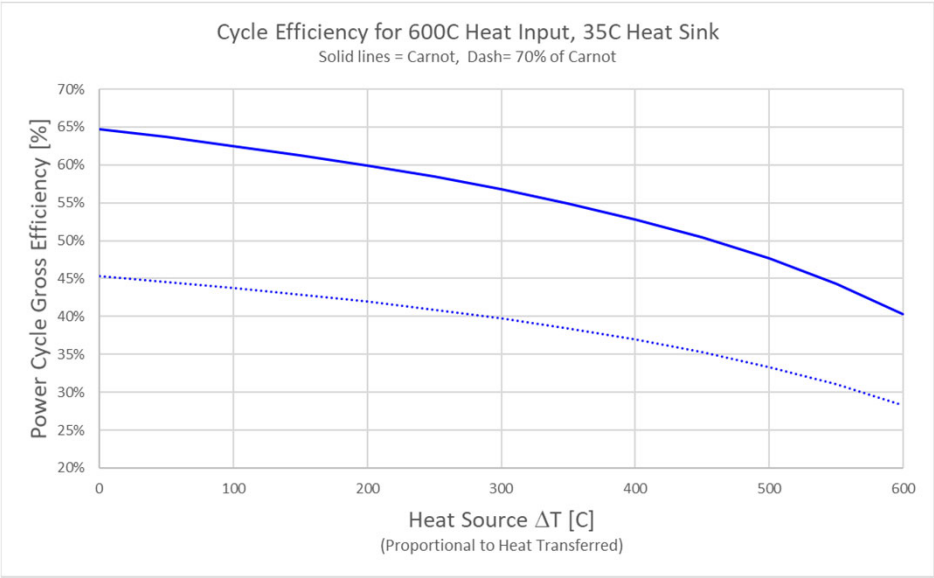


sCO2 Power Cycles integrated with Sensible Heat Storage



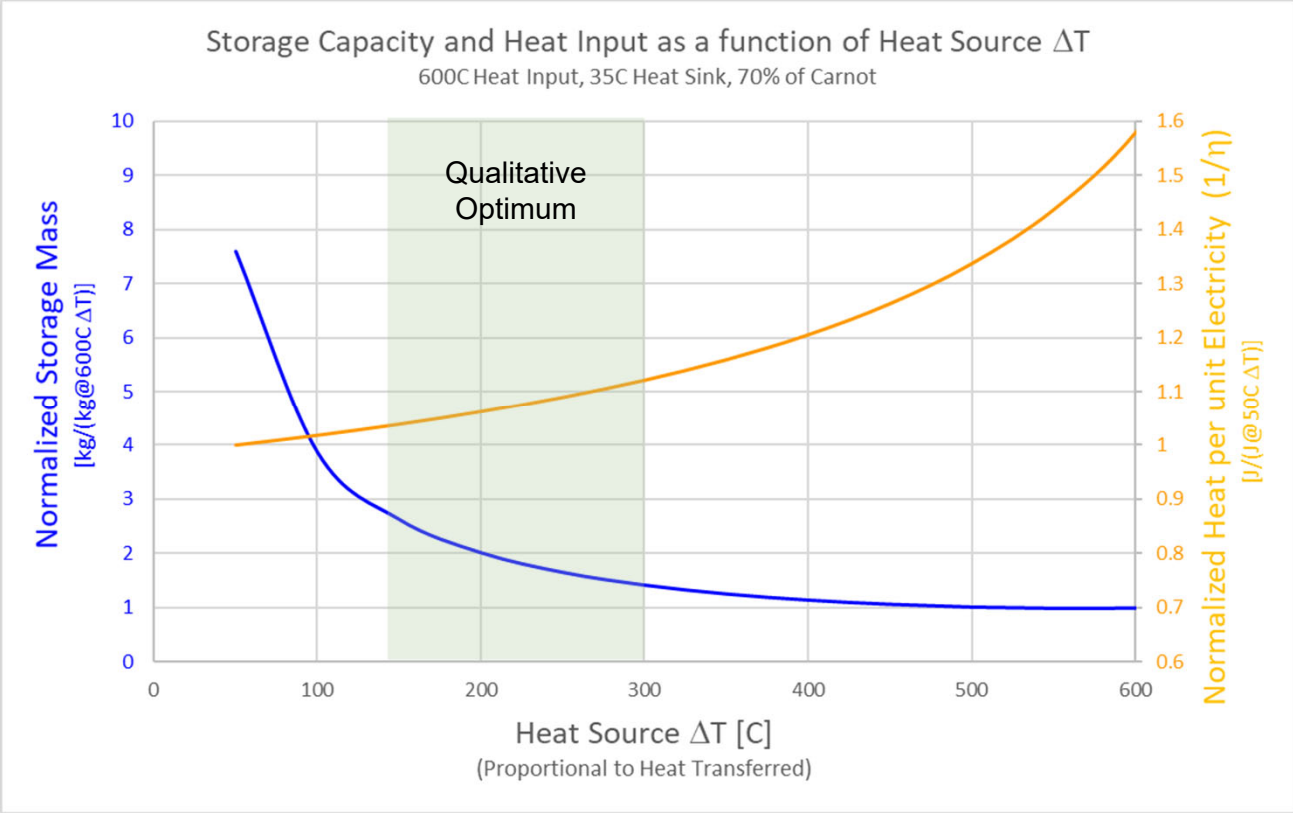
Common behavior between WHR cycles and Sensible Heat Storage:
Temperature of heat source drops as heat is transferred. Maximum efficiency drops with average heat addition temperature.

Impact on efficiency of increasing temperature drop in Sensible Heat Storage



GT2006-91213 Efficiency Entitlement for Bottoming Cycles, Hofer & Gulen

Sensible Heat Storage Optimal Temperature Difference

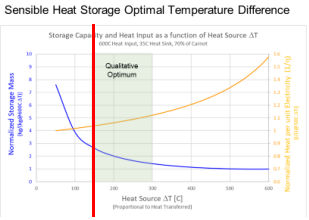


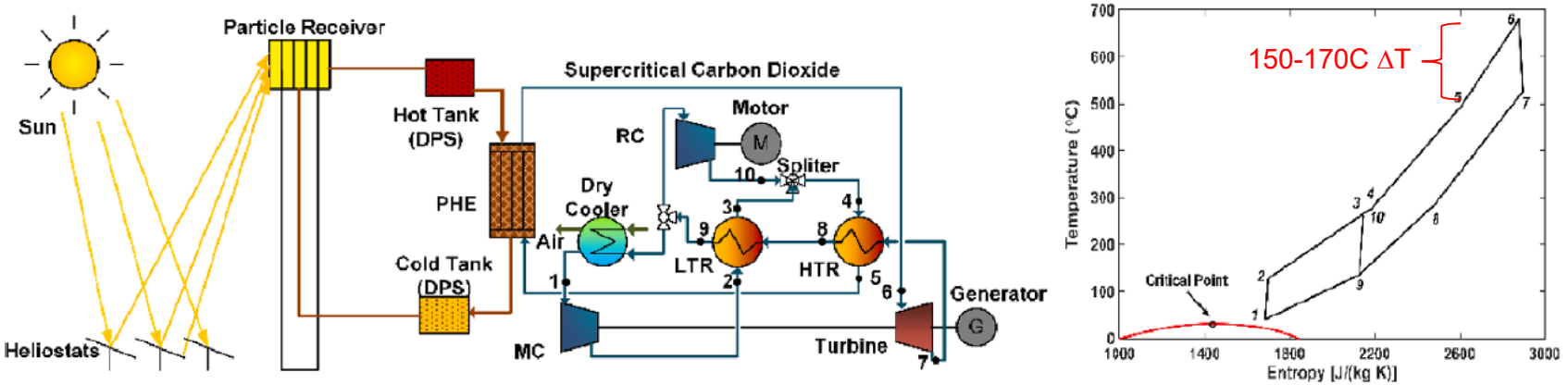
Minimizing storage mass favors large ΔT

Minimizing energy input (maximizing efficiency) favors small ΔT

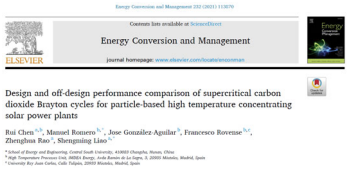
Precise optimum depends on detailed cost trades

Recompression Cycle





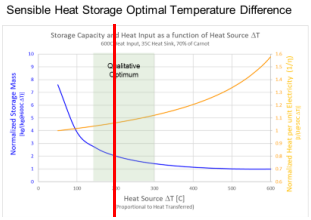
(b) Recompression S-CO_2 Brayton cycle and corresponding T-s diagram.

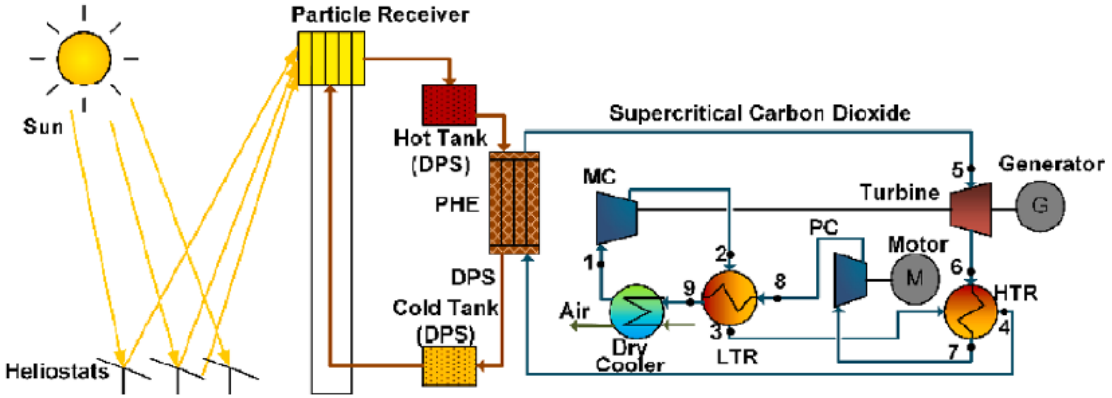


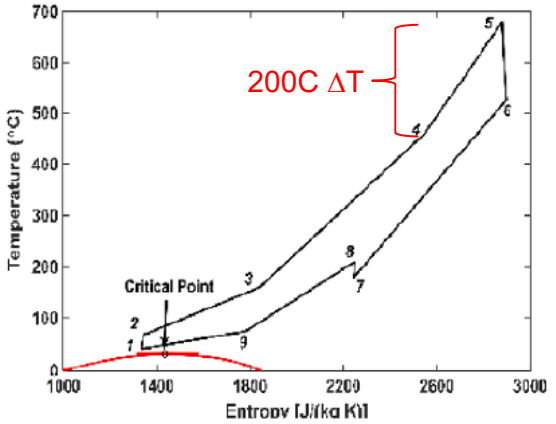
Energy Conversion and Management

Design and off-design performance comparison of supercritical carbon dioxide Brayton cycles for particle-based high temperature concentrating solar power plants

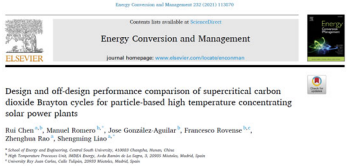
Pre-compression Cycle







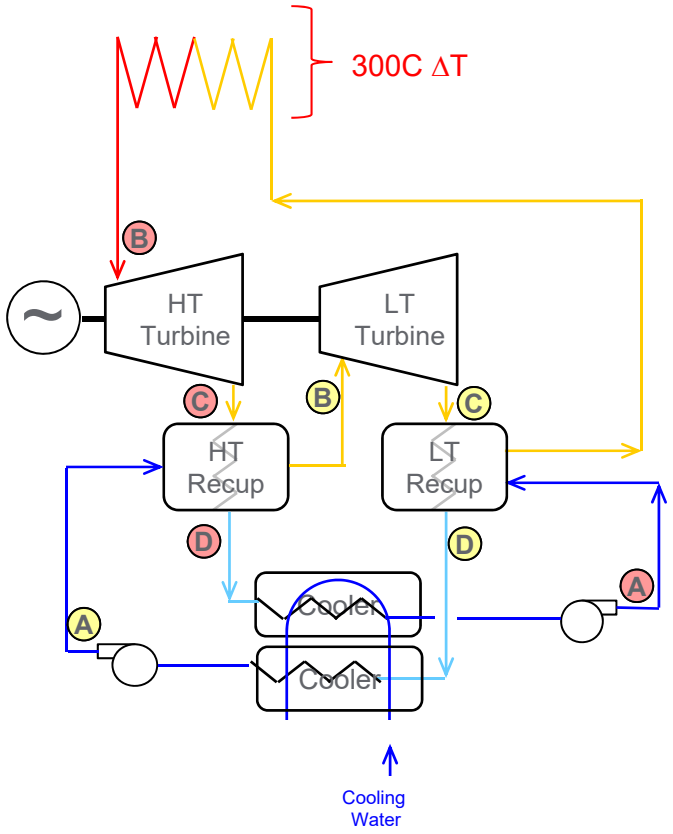
(c) Precompression S-CO_2 Brayton cycle and corresponding T-s diagram.



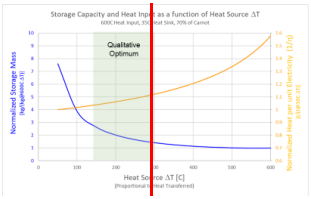
Energy Conversion and Management

Design and off-design performance comparison of supercritical carbon dioxide Brayton cycles for particle-based high temperature concentrating solar power plants

Cascaded Cycle



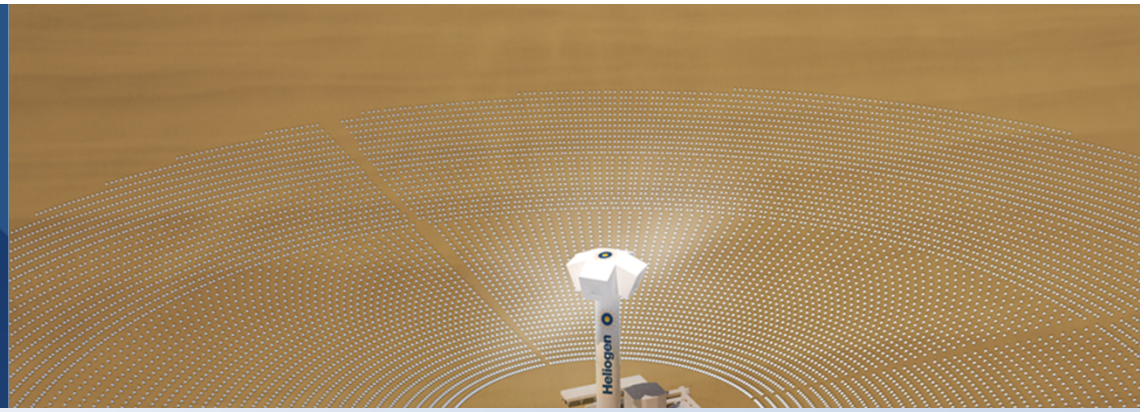
Sensible Heat Storage Optimal Temperature Difference



Conclusions

- Sensible Heat Storage is a low-cost thermal storage modality
- Power Cycles are more efficient with higher average heat input temps (lower ΔT)
- Storage is smaller (less expensive) with larger ΔT
- sCO_2 cycles can be devised to achieve the desired ΔT
- Current efforts focused on maximizing efficiency (low ΔT) with recompression cycles
- Economic optimum may drive to larger ΔT when storage size and cost are included

Heliogen



Thanks

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