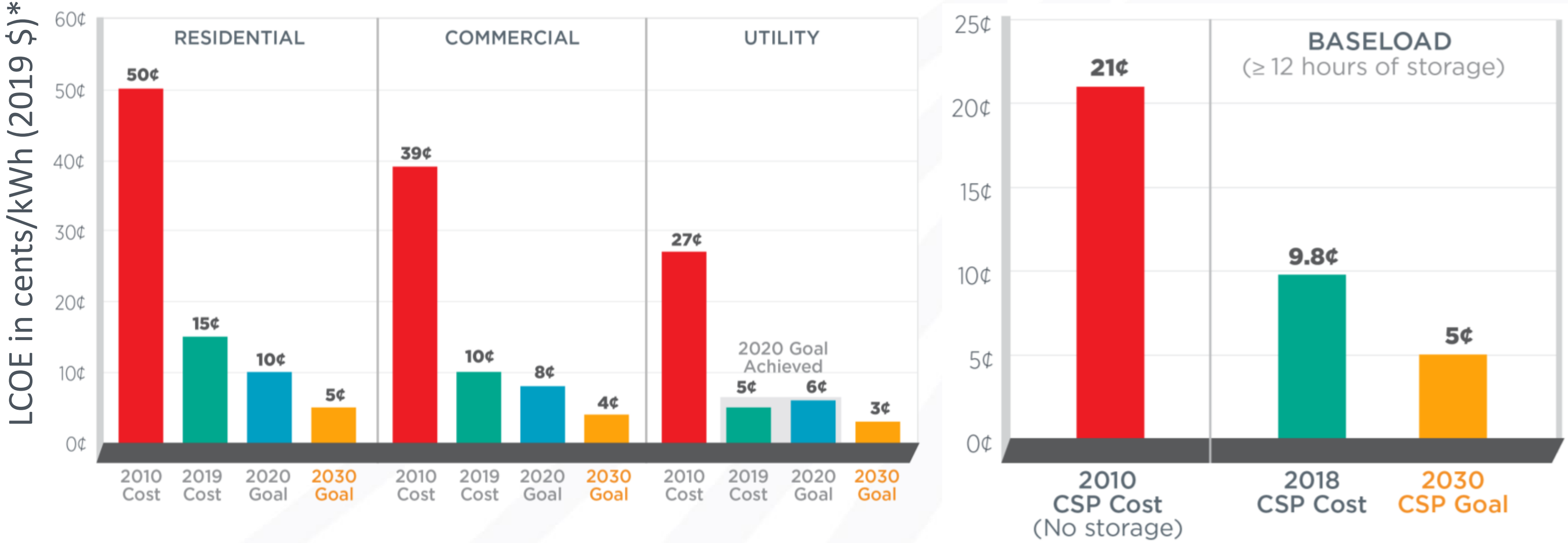
Overview of DOE-Supported R&D in Concentrating Solar-thermal Technologies

Dr. Avi Shultz, Program Manager, CSP
Solar Energy Technologies Office, US Department of Energy

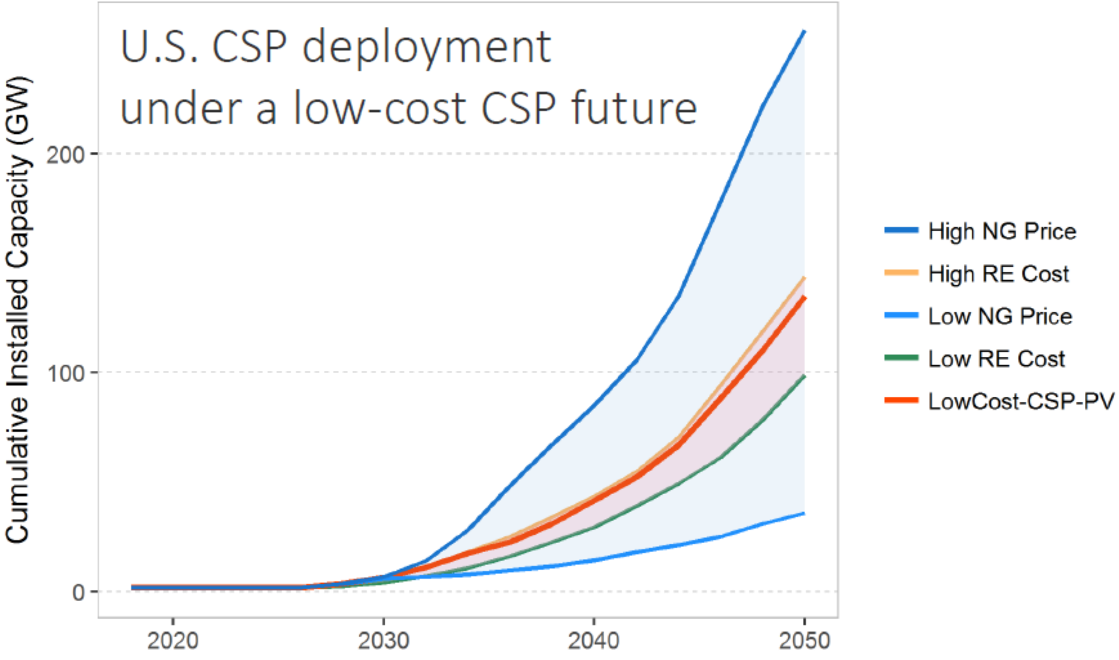
energy.gov/solar-office

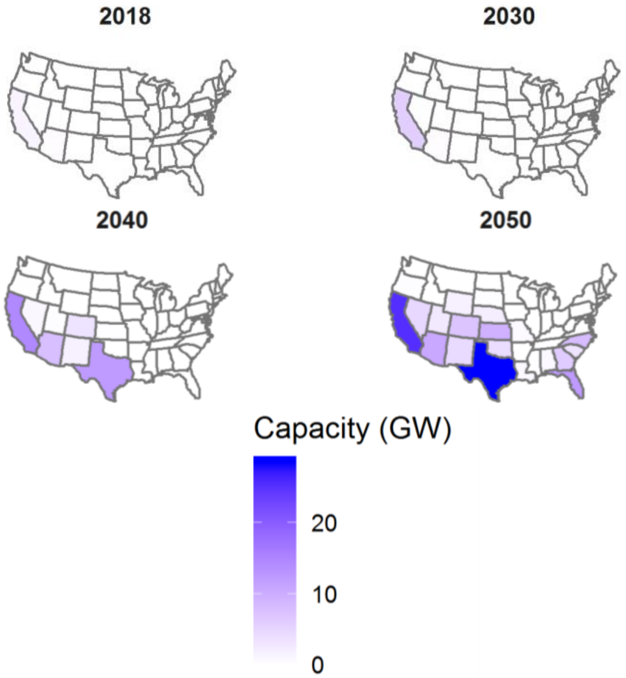
Progress and Goals: 2030 LCOE Goals



*Levelized cost of energy (LCOE) progress and targets are calculated based on average U.S. climate and without the ITC or state/local incentives. The residential and commercial goals have been adjusted for inflation from 2010-18.

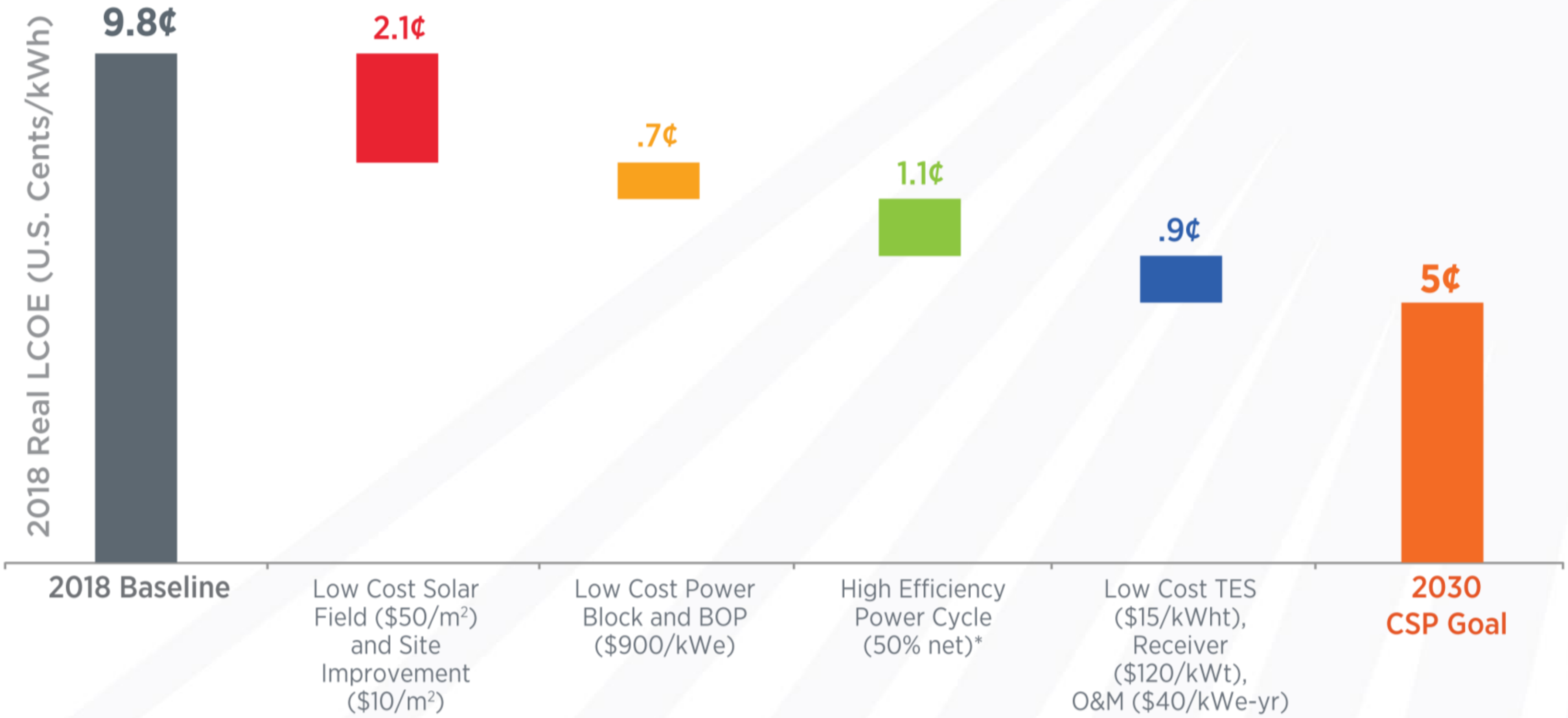
Potential CSP Deployment in the US if DOE CSP and PV 2030 Cost Targets are Achieved





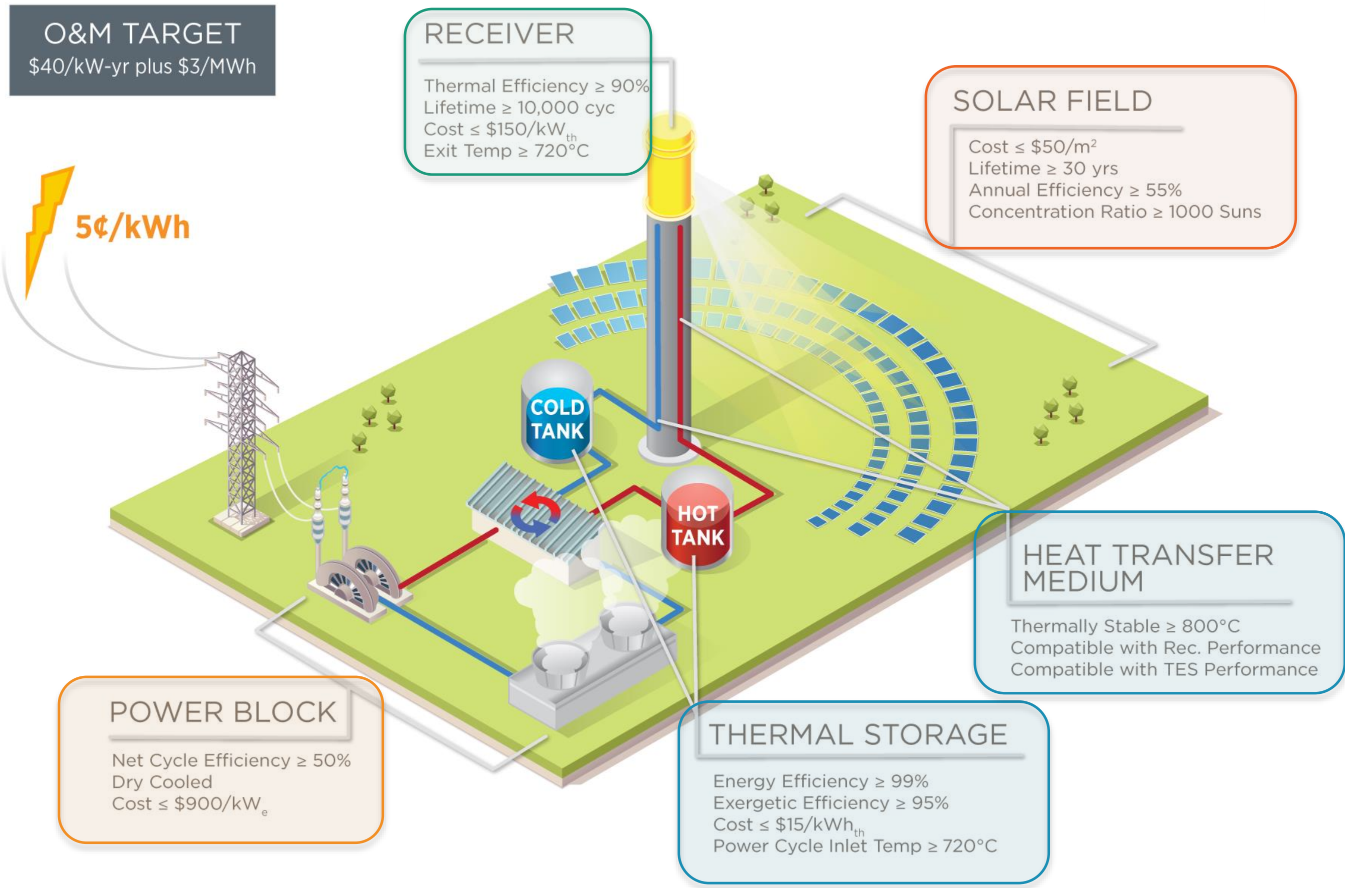
Murphy, et al. **2019**, NREL/TP-6A20-71912

A Pathway to 5 Cents per KWh for Baseload CSP



*Assumes a gross to net conversion factor of 0.9

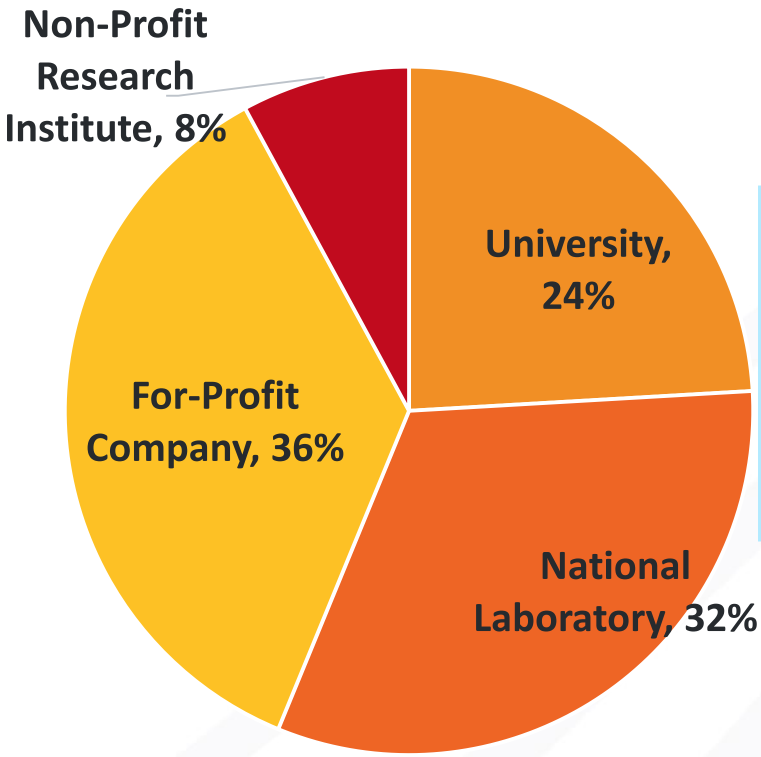
CSP Technical Targets



Competitive Programs

$43M	FY 2020 SETO FOA (2020)
$30M	FY 2019 SETO FOA (2019)
$22M	FY 2018 SETO FOA (2019)
$21M	Solar Desalination (2018)
$22M	FY19-21 National Lab Call (2018)
$70M	Gen3 CSP Systems (2018)
$15M	Gen3 CSP Lab Support (2018)
$9M	COLLECTS (2016)
$32M	CSP: APOLLO (2015)
$29M	CSP SuNLaMP (2015)
$1.4M	SolarMat II (2014)
$10M	CSP: ELEMENTS (2014)
$1.1M	SunShot Incubator (Recurring)
$4M	PREDICTS (2013)
$2M	SolarMat (2013)
$10M	CSP-HIBRED (2013)
$27M	National Lab R&D (2012)
$10M	SunShot MURI (2012)
$56M	CSP SunShot R&D (2012)
$0.5M	BRIDGE (2012)
$62M	CSP Baseload (2010)

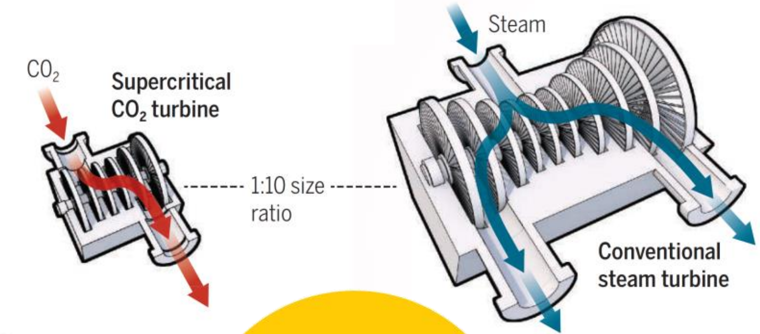
CSP Funding Portfolio



$185M over ~100 Active Projects

For full research portfolio, visit:
energy.gov/eere/solar/concentrating-solar-power

Next Generation CSP will Leverage Next Generation Power Cycles



Advantages of the sCO_2 Brayton Cycle:

- Higher Efficiency (50% at ~720 C)
- Compact Components
- Smaller Turbine Footprint (by a factor > 10)
- Reduced Power Block Costs
- Amenable to Dry Cooling
- **Scalability (< 100 MW) with high efficiency**
- Operational Simplicity

Ongoing Research Focus

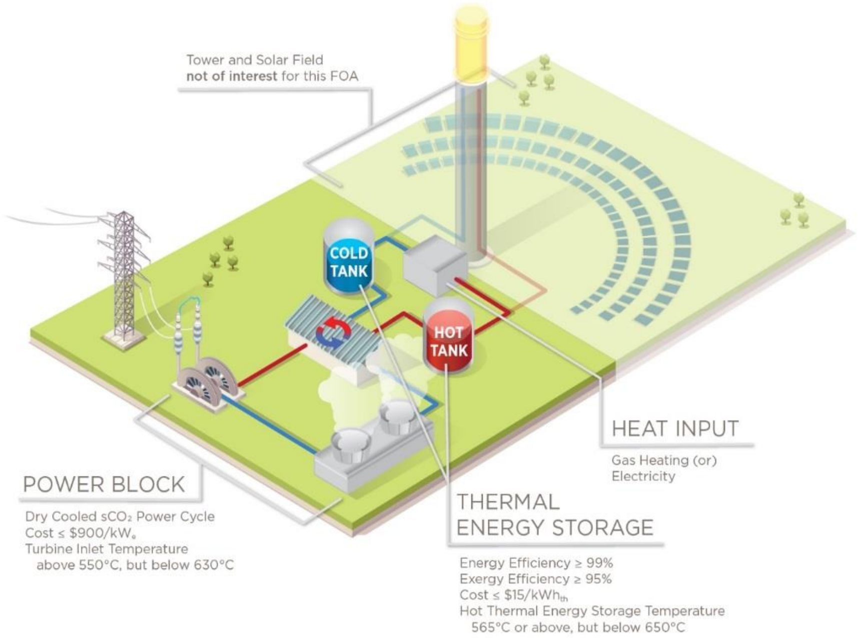
- Improvements in Expander Design – particularly dry gas seal performance
- Improvements in compressor efficiency and reduction in compression power – especially near dome
- Improvements in Manufacturing
  - Casting or novel manufacturing processes for casing
  - 3D printing or other Novel manufacturing for blades, rotor and bearings
- Integration of compressor and expander into one single casing, drive train; elimination of seals

FY 2020 SETO Funding Opportunity: Integrated Thermal Energy STorage and Brayton Cycle Equipment Demonstration **(Integrated TESTBED)**

Funding Objective

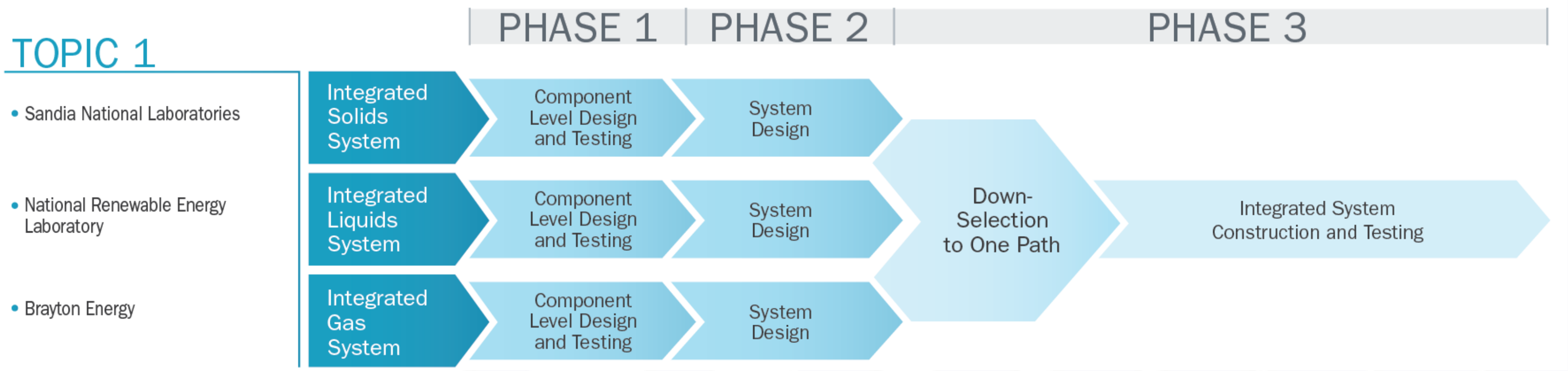
Applicants will address the following technical objectives:

- Integrated demonstration of a sCO_2 cycle power block heated by thermal energy storage at ~10 MWe scale in the range of 550-630°C
- Goal is to accelerate the commercialization of the sCO_2 Brayton cycle, which is critical to lowering CSP system costs, and provide operational experience for utilities, operators, and developers.
- **DOE expects to make 1-2 awards for $19.5 to $39 million per award**
- **Award(s) expected to be announced in October 2020**




Gen3CSP
Bringing together the people and the pieces for an INTEGRATED CSP SYSTEM

Gen3 CSP: Raising the Temperature of Solar Thermal Systems



- Phase 2 ends in January 2021
- $25M will be awarded to down-selected pathway to build MW-scale test facility

Gen3 CSP: Raising the Temperature of Solar Thermal Systems

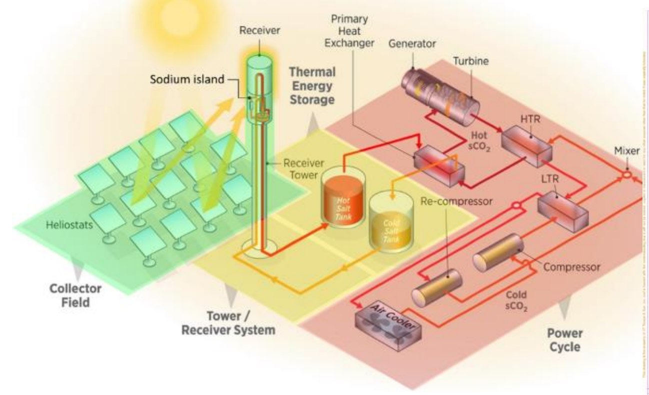
TOPIC 1

- National Renewable Energy Laboratory

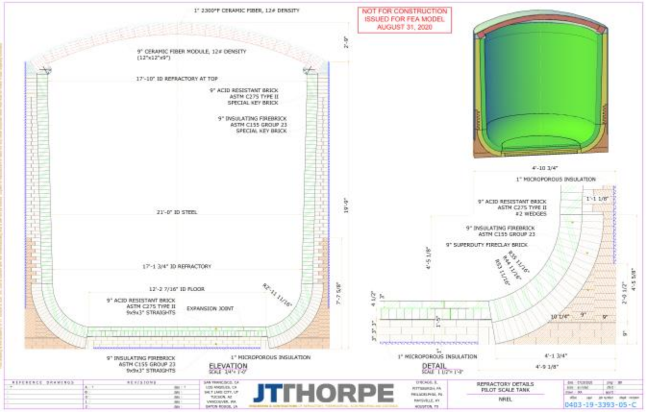
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

	PHASE 1	PHASE 2	PHASE 3	
Integrated Solids System	Component Level Design and Testing	System Design	Down-Selection to One Path	Integrated System Construction and Testing
Integrated Liquids System	Component Level Design and Testing	System Design		
Integrated Gas System	Component Level Design and Testing	System Design		

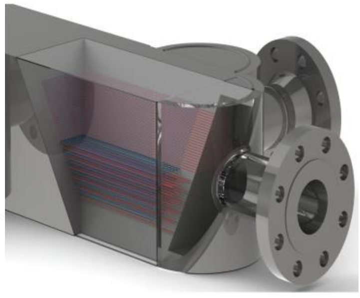
Integrated System Design



Molten Chloride Tank Design



Component Design and Prototyping

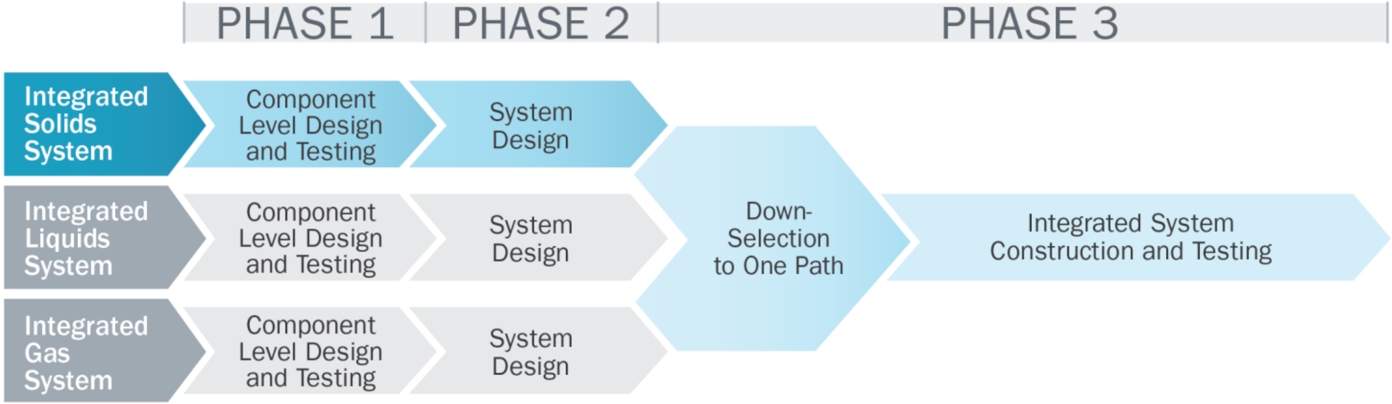


Gen3 CSP: Raising the Temperature of Solar Thermal Systems

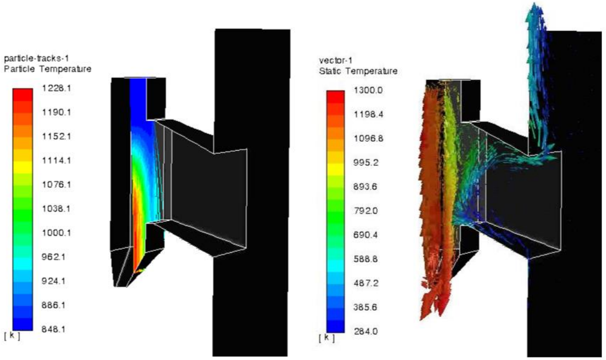
TOPIC 1

- Sandia National Laboratories

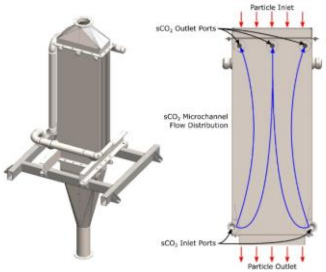
Sandia National Laboratories



Receiver Design and Modelling

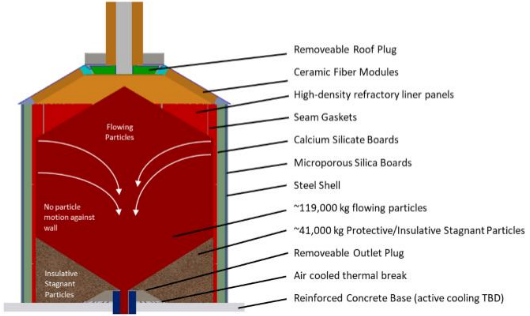


Particle – sCO2 Heat Exchanger



Contributors: VPE and Solex

Thermal Energy Storage (Particle Silo)



Contributors: Allied Mineral Products and Matrix PDM

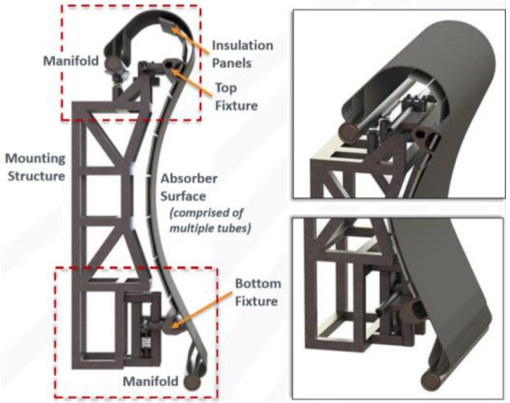
Gen3 CSP: Raising the Temperature of Solar Thermal Systems

TOPIC 1

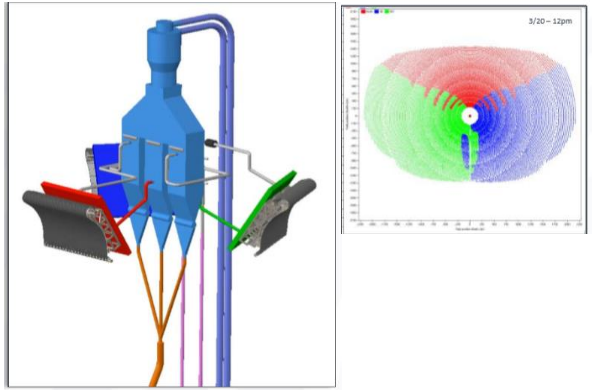
	PHASE 1	PHASE 2	PHASE 3	
Integrated Solids System	Component Level Design and Testing	System Design	Down-Selection to One Path	Integrated System Construction and Testing
Integrated Liquids System	Component Level Design and Testing	System Design		
Integrated Gas System	Component Level Design and Testing	System Design		

- Brayton Energy

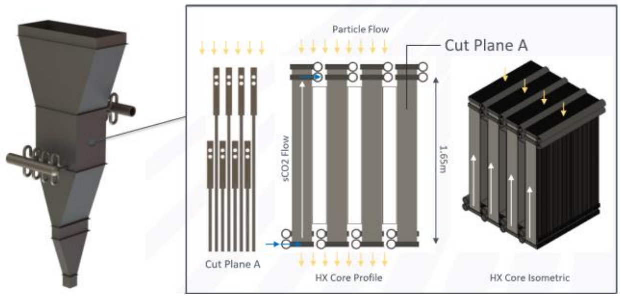
Receiver Design and Modelling



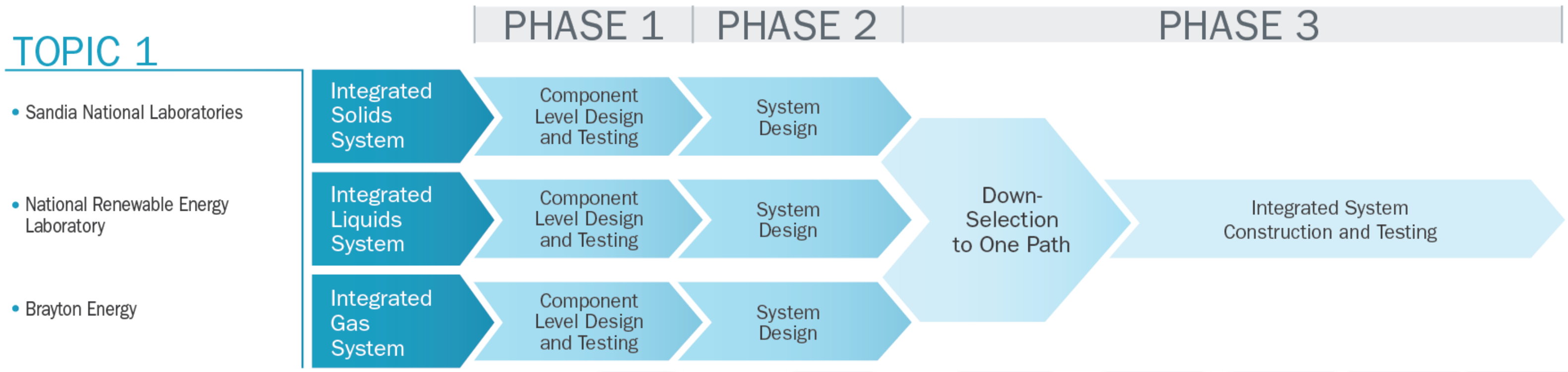
Tower and Solar Field Design



Particle TES and Heat Exchanger



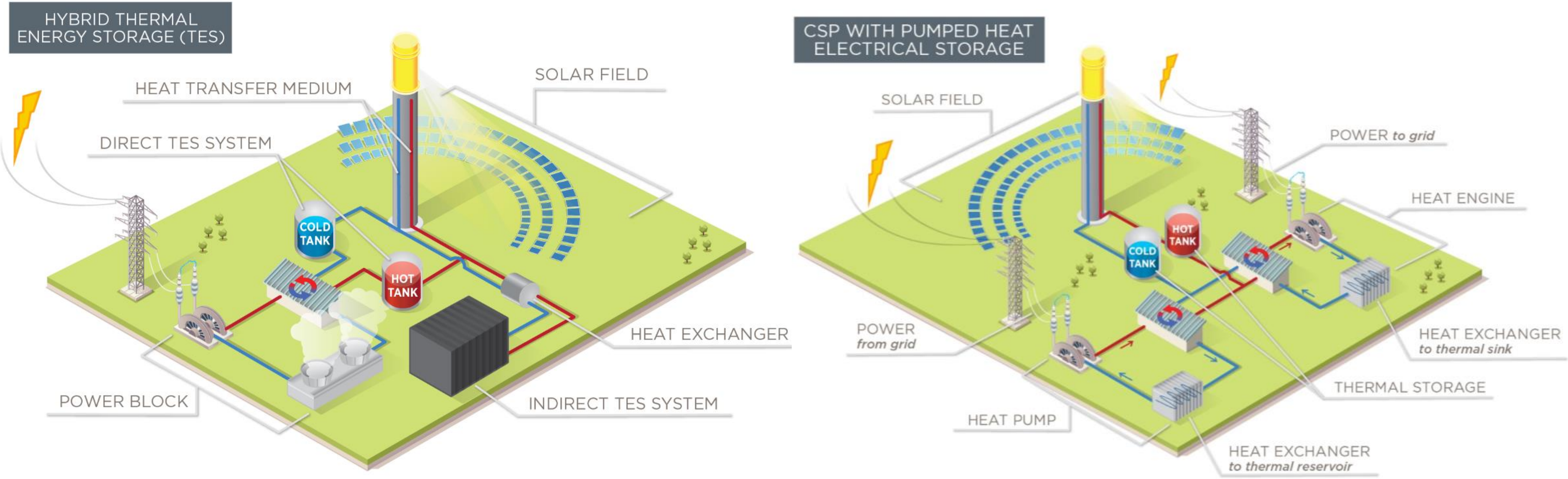
Gen3 CSP: Raising the Temperature of Solar Thermal Systems



Gen3 Technical Sessions (not comprehensive):

- Receivers and Heat Transfer Media and Transport: Point Focus
  - TUE-1A: Gen3 Liquid System
  - TUE-2A: Novel Particle Systems: Gen3
- Advanced Materials, Manufacturing, and Components
  - TUE-2B: Materials and Components for Molten Chloride Gen3 CSP
- Thermal Energy Storage Materials, Media, and Systems
  - TUE-2D: Particle-Based TES for Gen3 CSP
  - THU-2D: TES for Molten Chloride Gen3 CSP

Firm Thermal Energy Storage



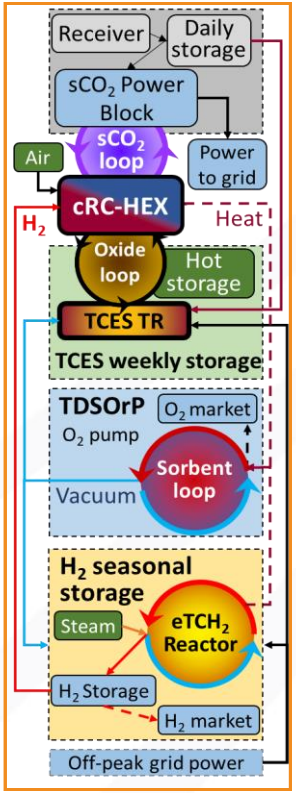
Existing power block at a CSP plant can be leveraged for high value ‘indirect’ TES:

- Long-duration thermochemical or (renewable) fuels
- ‘Pumped heat electrical storage’ for bi-directional grid value

Firm Thermal Energy Storage Projects

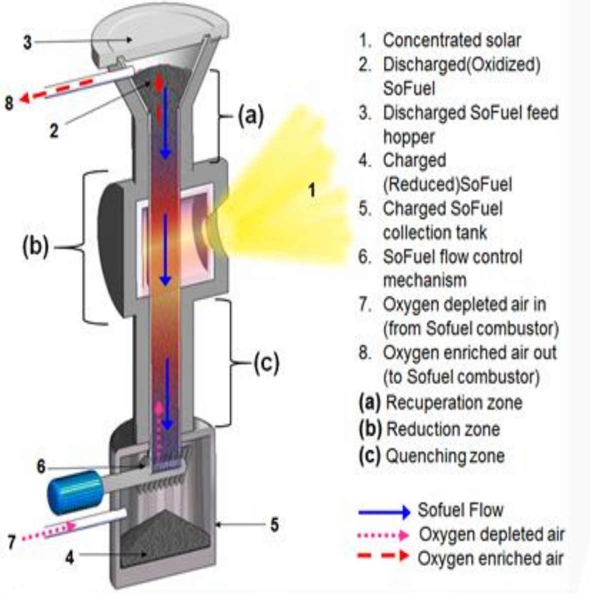
Arizona State University

Economic Weekly and Seasonal Thermochemical and Chemical Energy Storage for Advanced Power Cycles
PI: Ellen Stechel



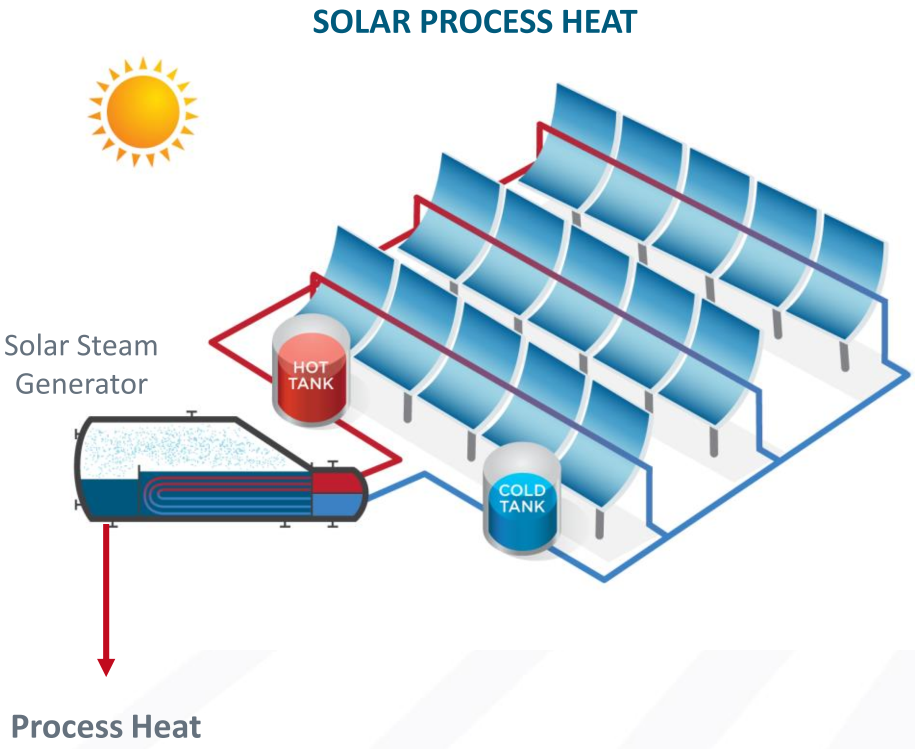
Solid State Solar Thermochemical Fuel (SoFuel) for Long Duration Storage
PI: James Klausner

Michigan State University



Layout of a SoFuel CSP production plant

Solar Thermal Industrial Process Heat



Priority Areas:

- Reduce the levelized cost of heat, **with thermal energy storage**, in temperature ranges of high priority to industrial processes
- Improve the **thermal efficiency** of solar-thermal-coupled processes
- Develop long-duration, thermochemical storage of solar energy (i.e. **solar fuels** and chemical commodities)

American Made Challenges: Solar Desalination Prize

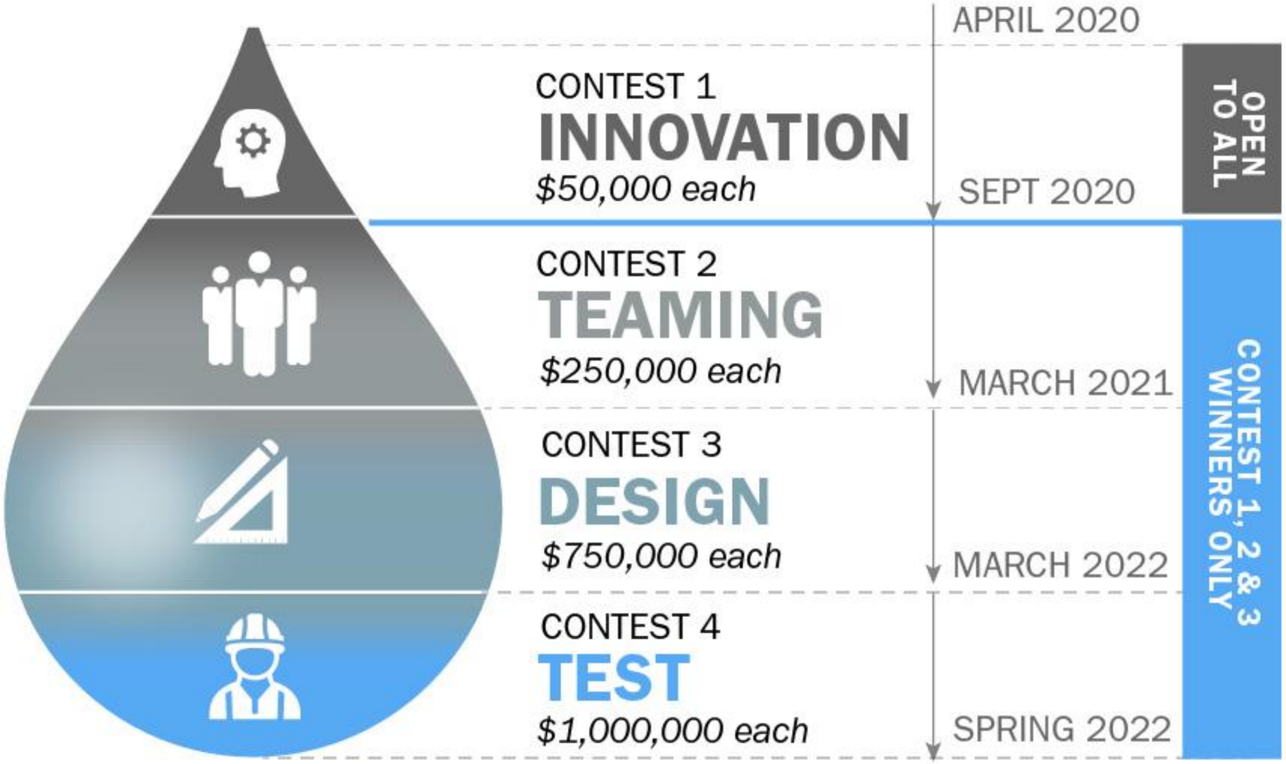
AMERICAN MADE CHALLENGES™

U.S. DEPARTMENT OF ENERGY

Incentivize the nation's entrepreneurs to strengthen American leadership in energy innovation

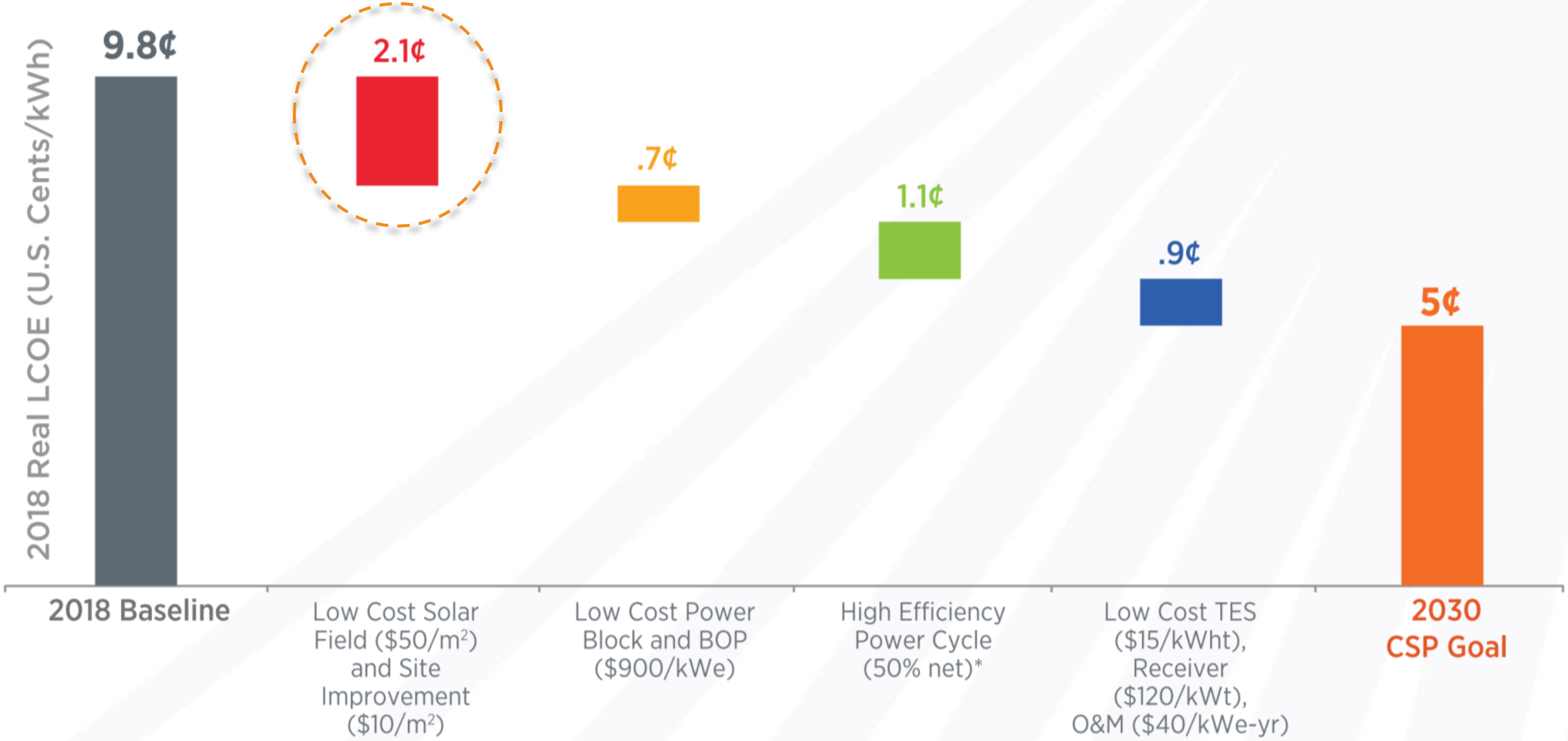
American Made Challenges: Solar Desalination Prize

AMERICAN MADE
SOLAR DESAL PRIZE
U.S. DEPARTMENT OF ENERGY



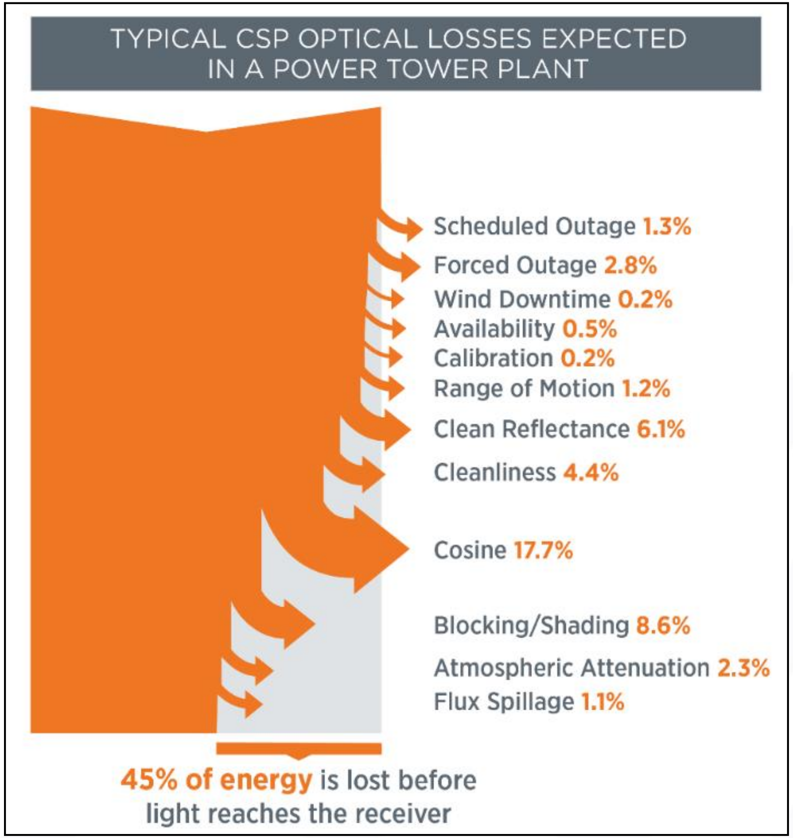
WATER SECURITY
GRAND CHALLENGE
Abundance Through Innovation

In one projected scenario, to achieve 5 Cents per KWh for a Baseload CSP in 2030, the solar field cost has to be reduced by ~2 cents/kWh



*Assumes a gross to net conversion factor of 0.9

Heliostat Development Challenges



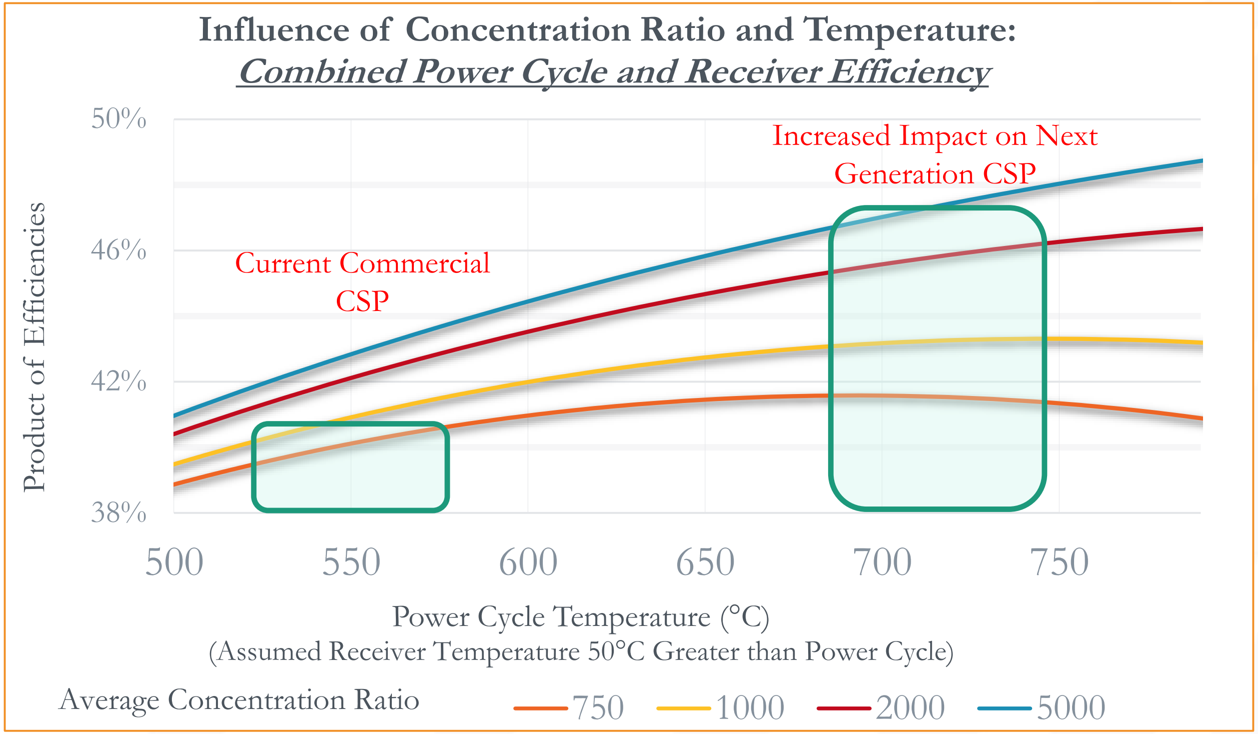
Challenges:

- Heliostat costs still > $100/m^2$
- Subcomponent major cost drivers are the support structure, azimuth drive, foundation, reflector and labor

Priority Areas for research:

- Reducing installed costs of heliostats and troughs through **simplified designs for manufacturing and installation**
- Reducing capital costs through **non-conventional materials** and components
- Improved performance through **autonomous operation, calibration, and optimization** of components and full systems

But more opportunities exist as we look towards 2030



Potential solutions include:

- Dedicated facilities for testing novel concepts at field scale
- Develop a core center of excellence in the US for heliostat technologies
- Accelerate the validation of novel designs and materials for heliostat components

SETO CSP R&D Virtual Workshop Series

- Autonomous, Integrated Heliostat Field & Components – **October 20th, 2020**
- Next Generation Receivers – **October 29th, 2020**
- Unlocking Solar Thermochemical Potential – **date tbd**
- Pumped Thermal Energy Storage Innovations – **date tbd**
- CSP Performance and Reliability Innovations – **date tbd**

*Topics and timing are tentative and currently being finalized – sign up for our mailing list to stay informed

QUESTIONS?

Avi Shultz

avi.shultz@ee.doe.gov

Program Manager, CSP