U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

Concentrating Solar-Thermal Power

Introduction

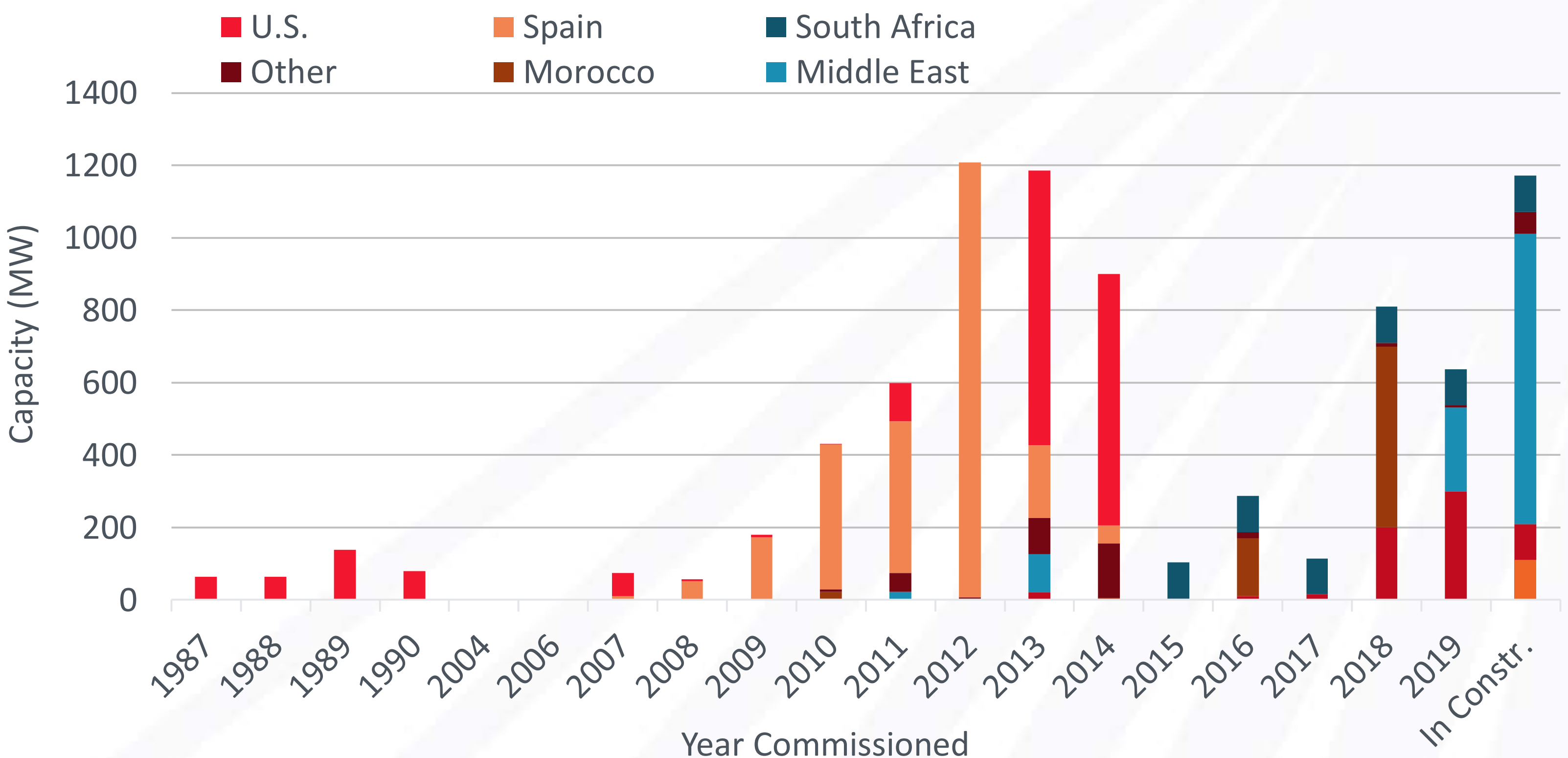
Avi Shultz

Program Manager

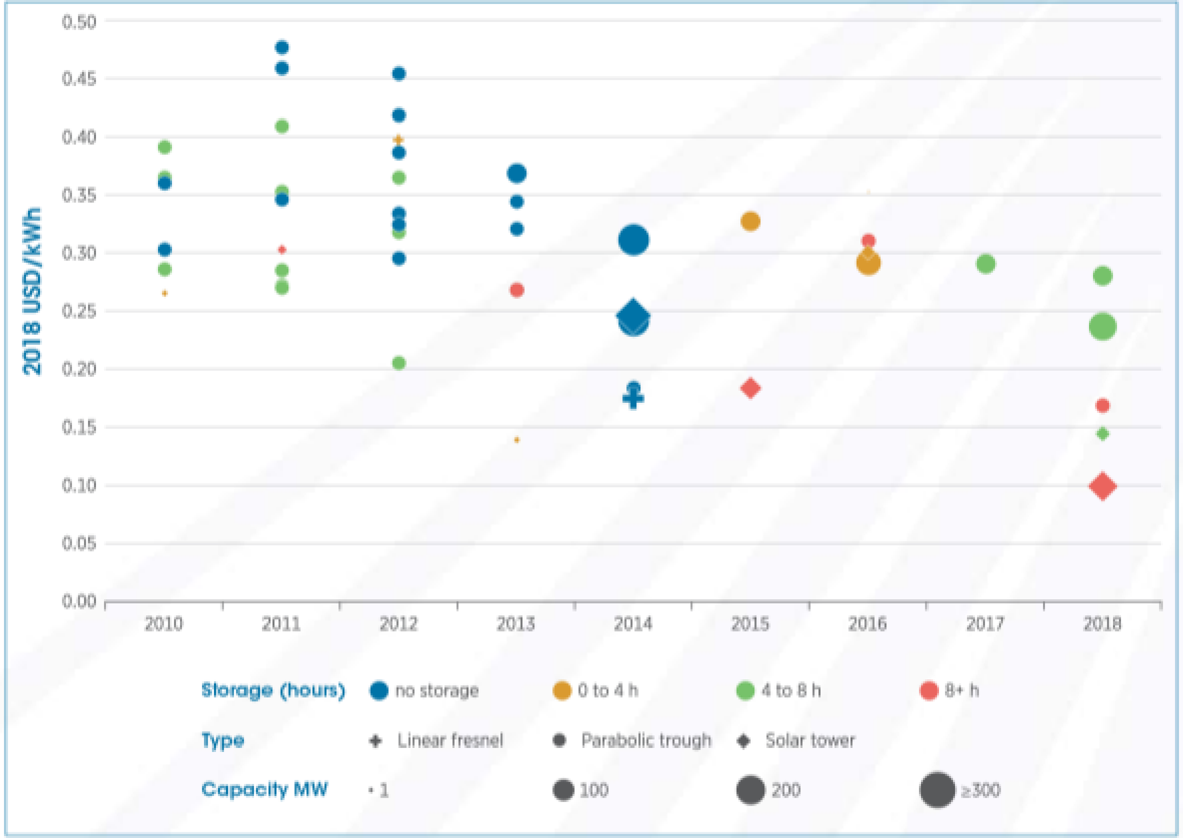
2020 SETO Peer Review

CSP Track

6.9 GW CSP Deployed Worldwide

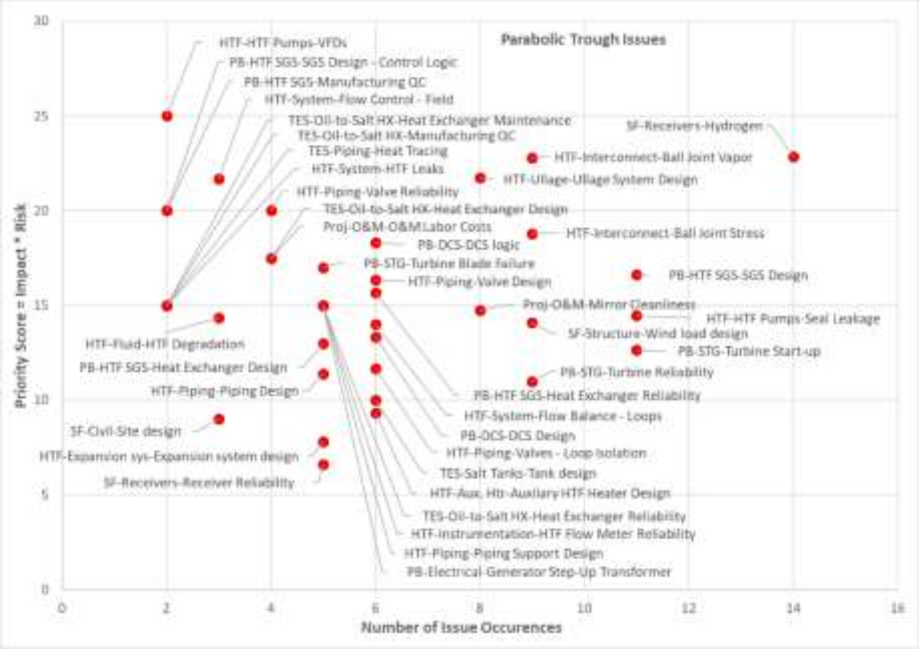


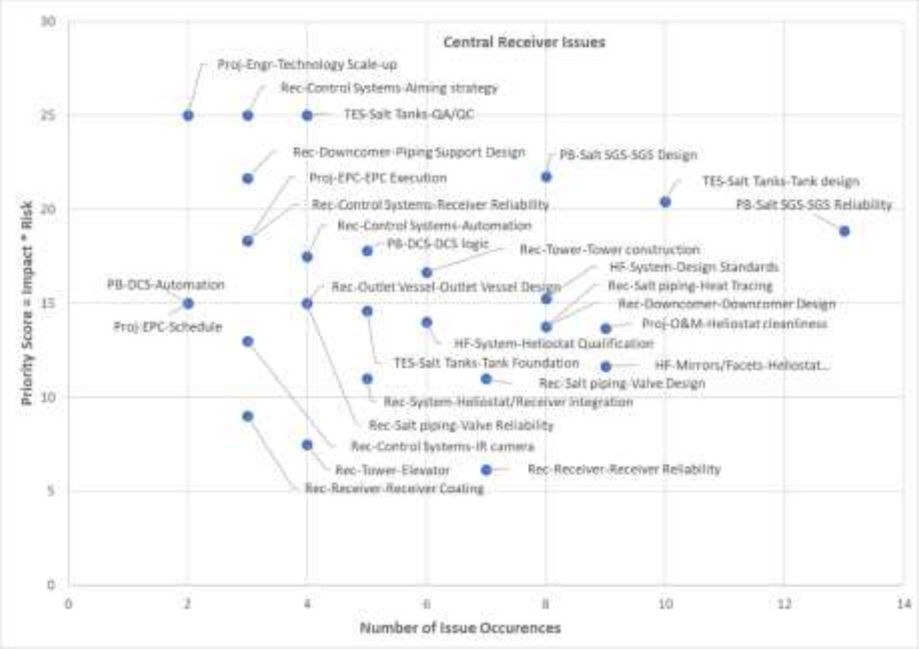
Global CSP LCOE



Source: IRENA, “Renewable Power Generation Costs in 2018.”

Documenting CSP Best Practices





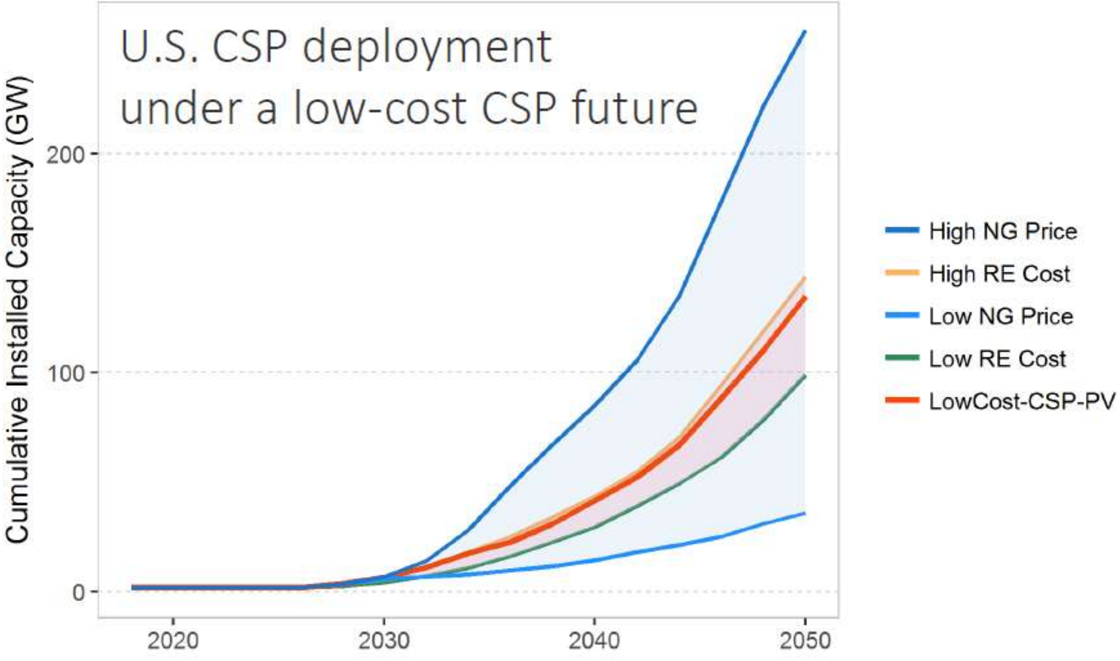
NREL; PI: Mark Mehos

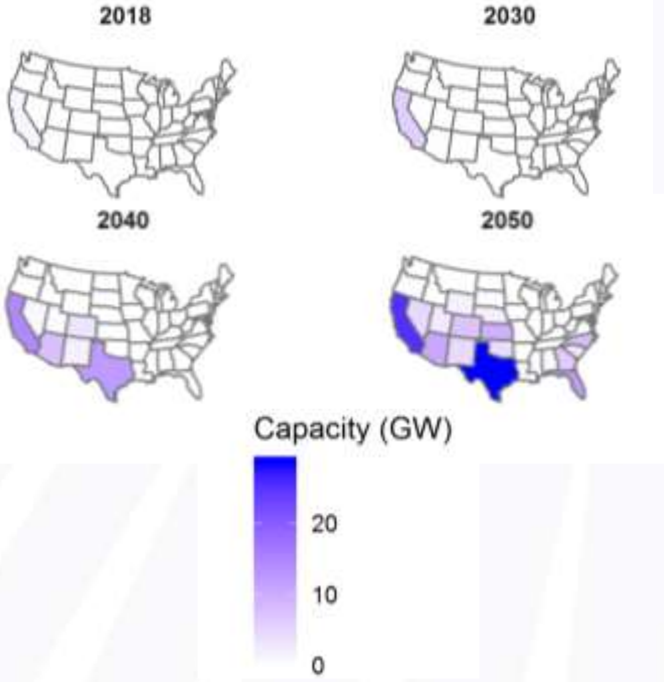
Report in preparation

Progress and Goals: 2030 CSP Goal

The office's 2030 cost targets for CSP baseload (≥12 hours of storage) plants will help make CSP competitive with other dispatchable generators.

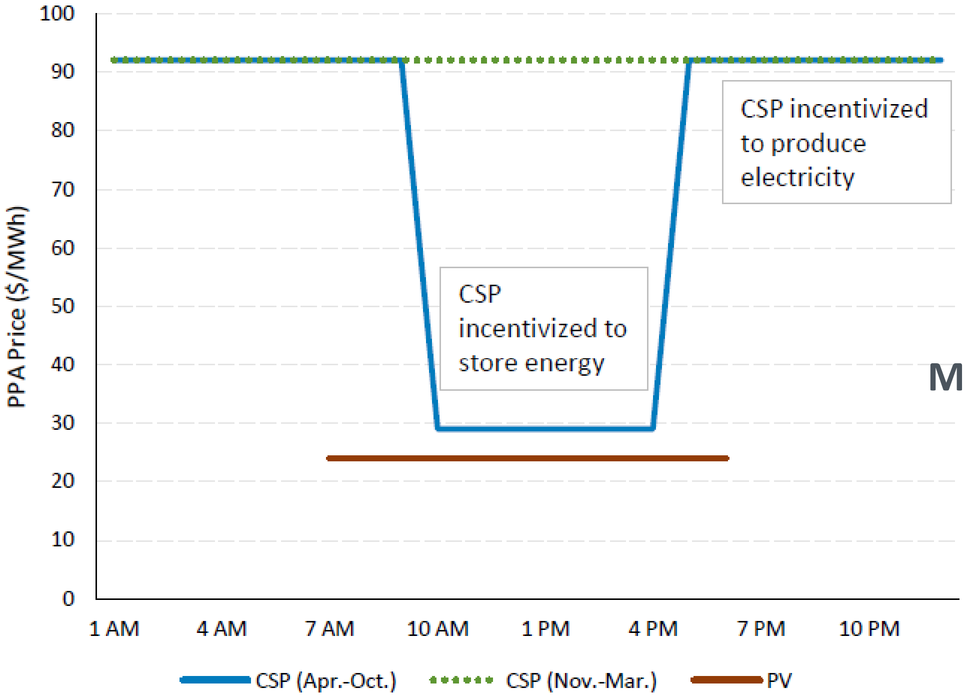
Potential CSP Deployment in the US if DOE CSP and PV 2030 Cost Targets are Achieved





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

Commercial Developers are Optimizing CSP/PV Hybridization



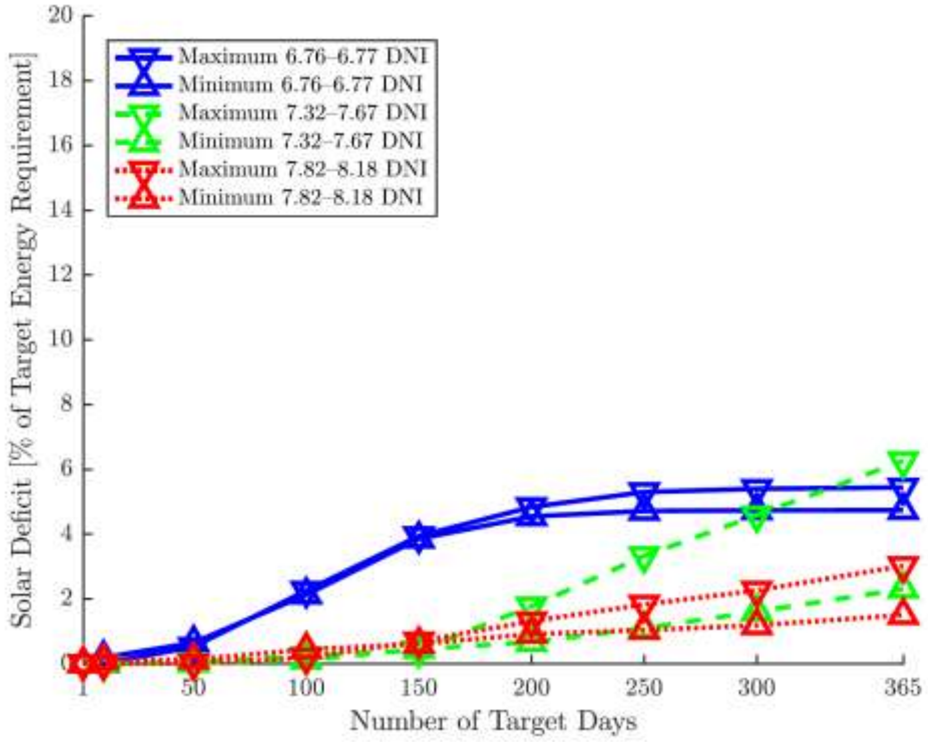
DEWA IV – Dubai

- Developer: ACWA Power
- PPA signed at $73/MWh
- 950 MW total capacity
  - 200 MW x3 Troughs with 10 hours TES
  - 100 MW Tower with 15 hours TES
  - 250 MW PV

Midelt 1 – Morocco

- Developer: EDF/MASDAR/Green of Africa
- PPA signed at $71/MWh
- 400 MW PV
- 400 MW Trough with 5 hours TES
- Excess PV electricity will be stored in molten salt TES

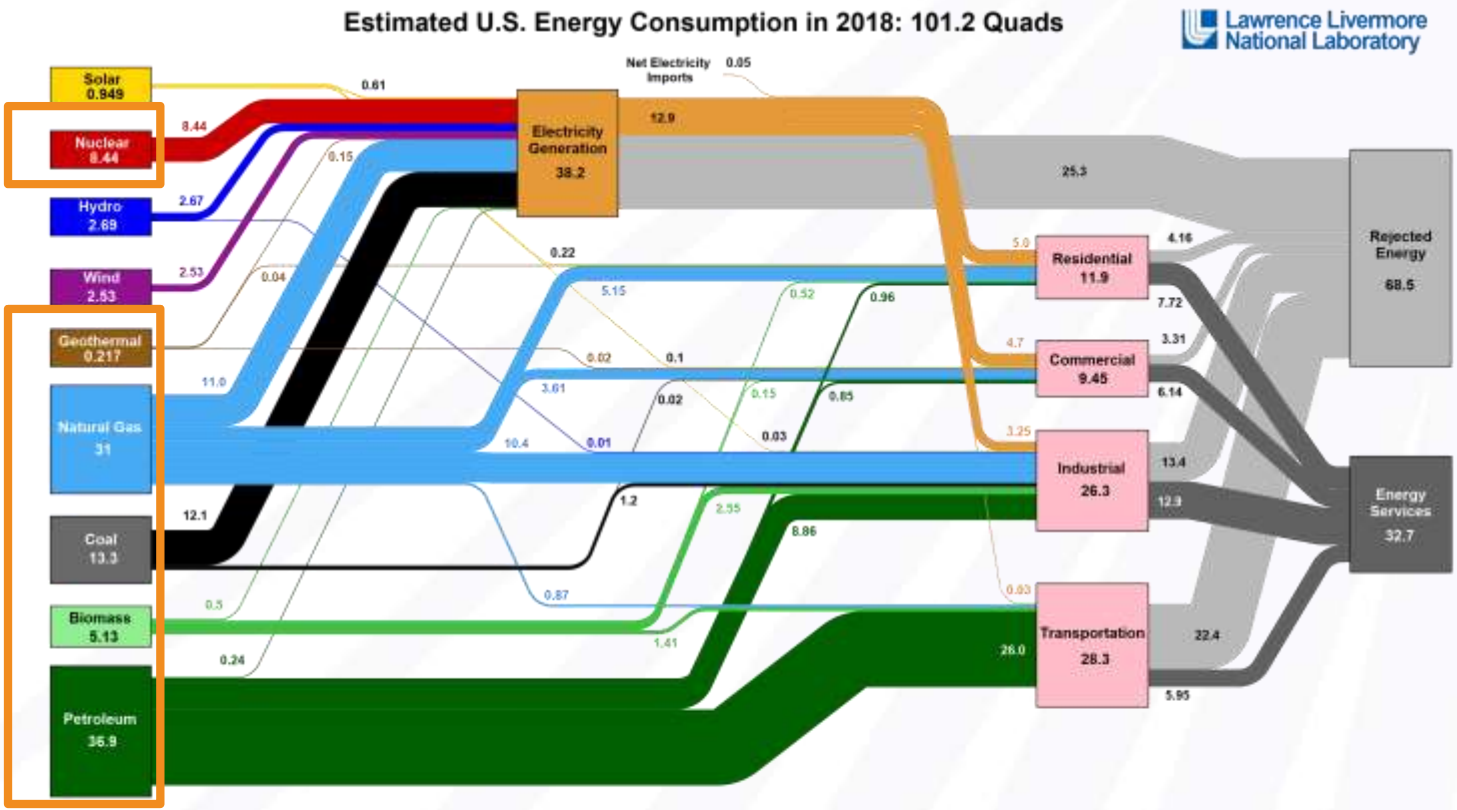
Value of CSP to the Grid



A CSP plant with 12 hours of storage can provide 365-day capacity with 2-5% of the fuel consumption of a natural gas plant

Yagi, Sioshansi, Denholm. *Solar Energy, 191*, **2019**, 686

Solar Thermal can Integrate with the Existing Energy System



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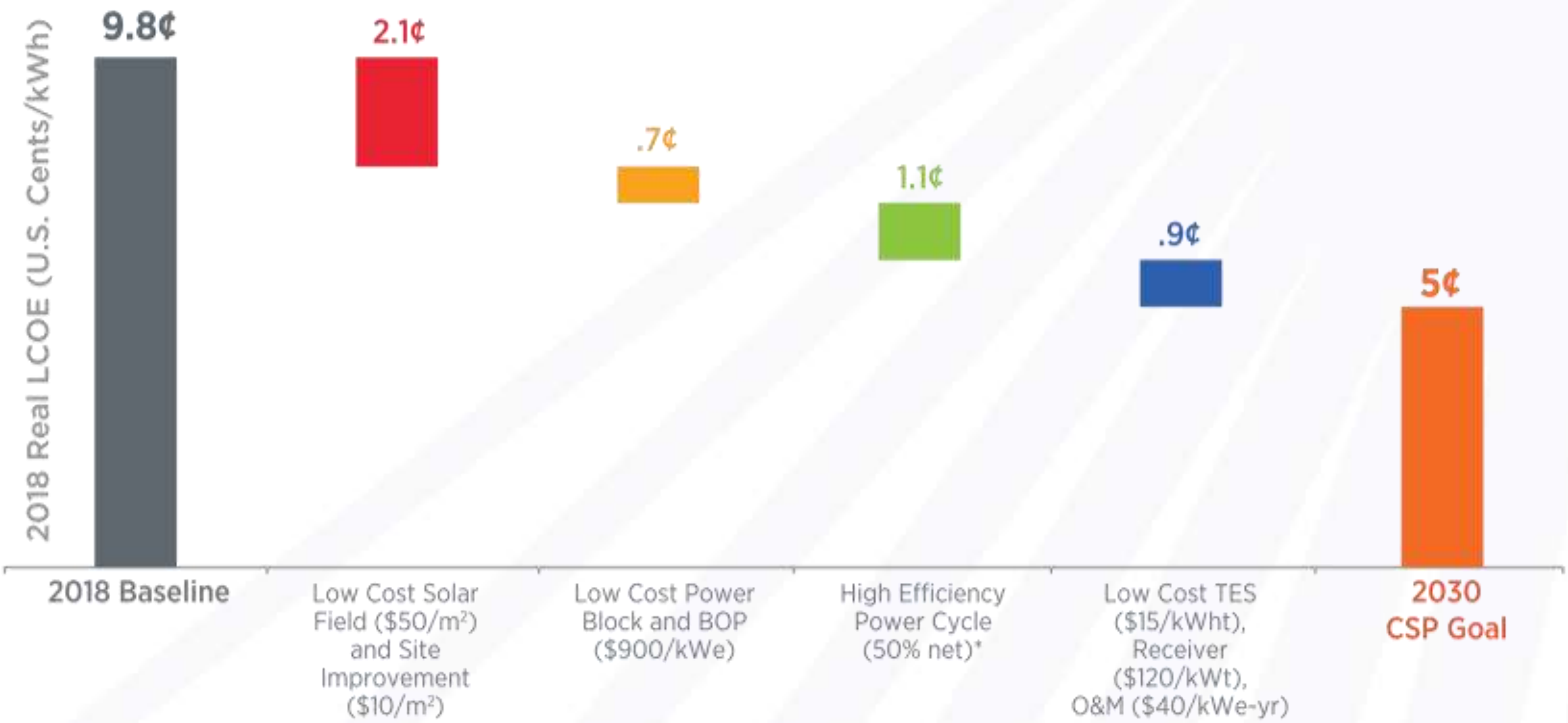
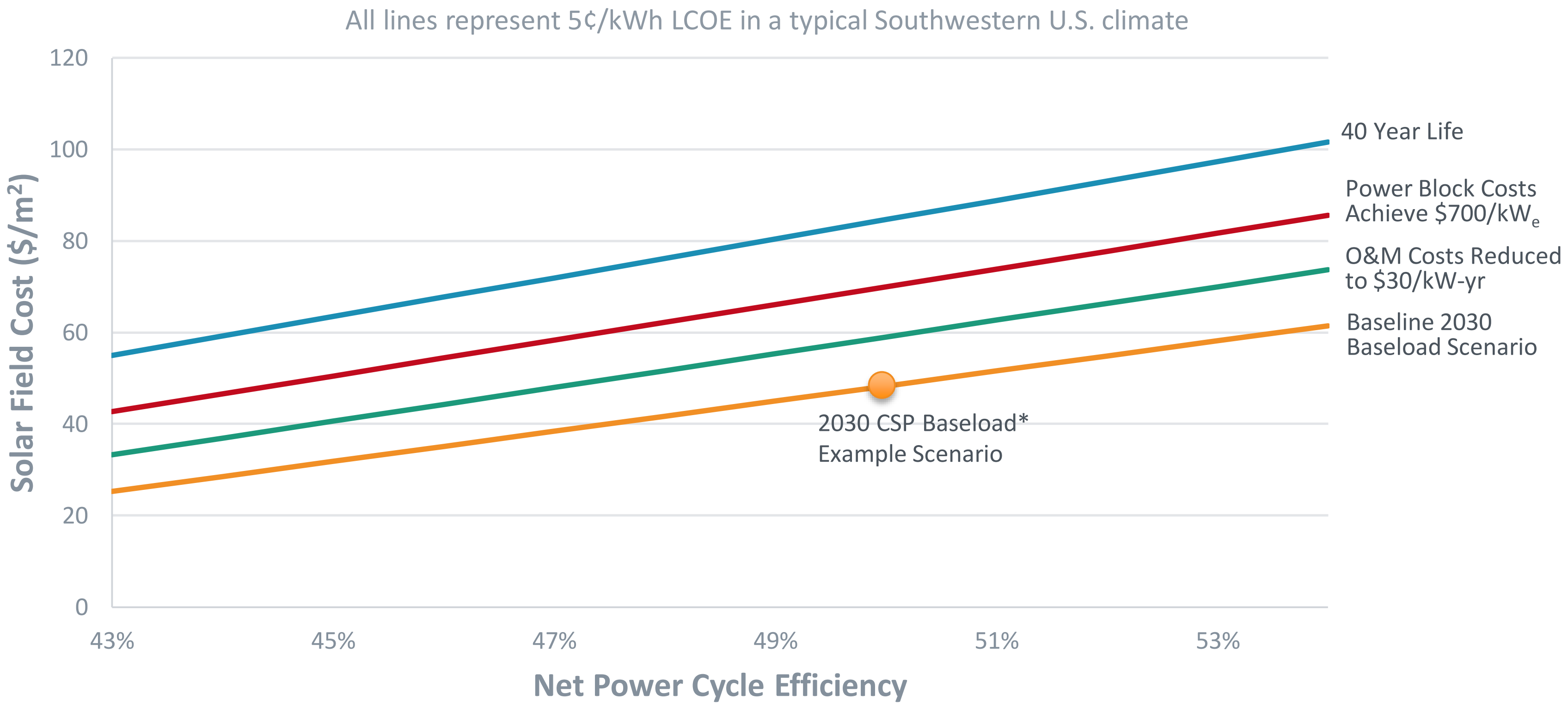
A Pathway to 5 Cents per KWh for Baseload CSP



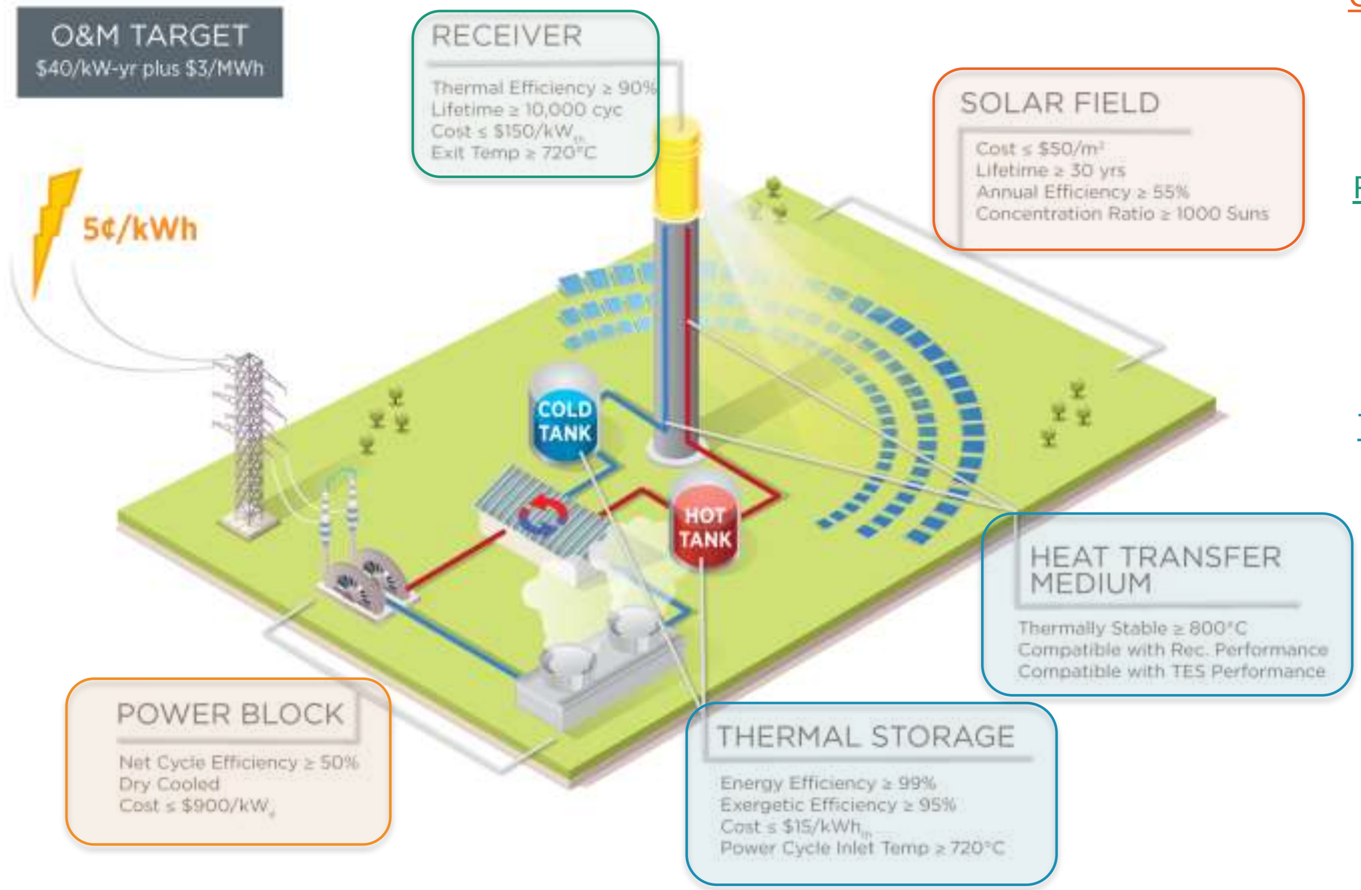
*Assumes a gross to net conversion factor of 0.9

Pathways to Achieving SunShot 2030 Goals



*Baseload power plant is defined as a CSP plant with greater than or equal to 12 hours of storage

CSP Technical Targets



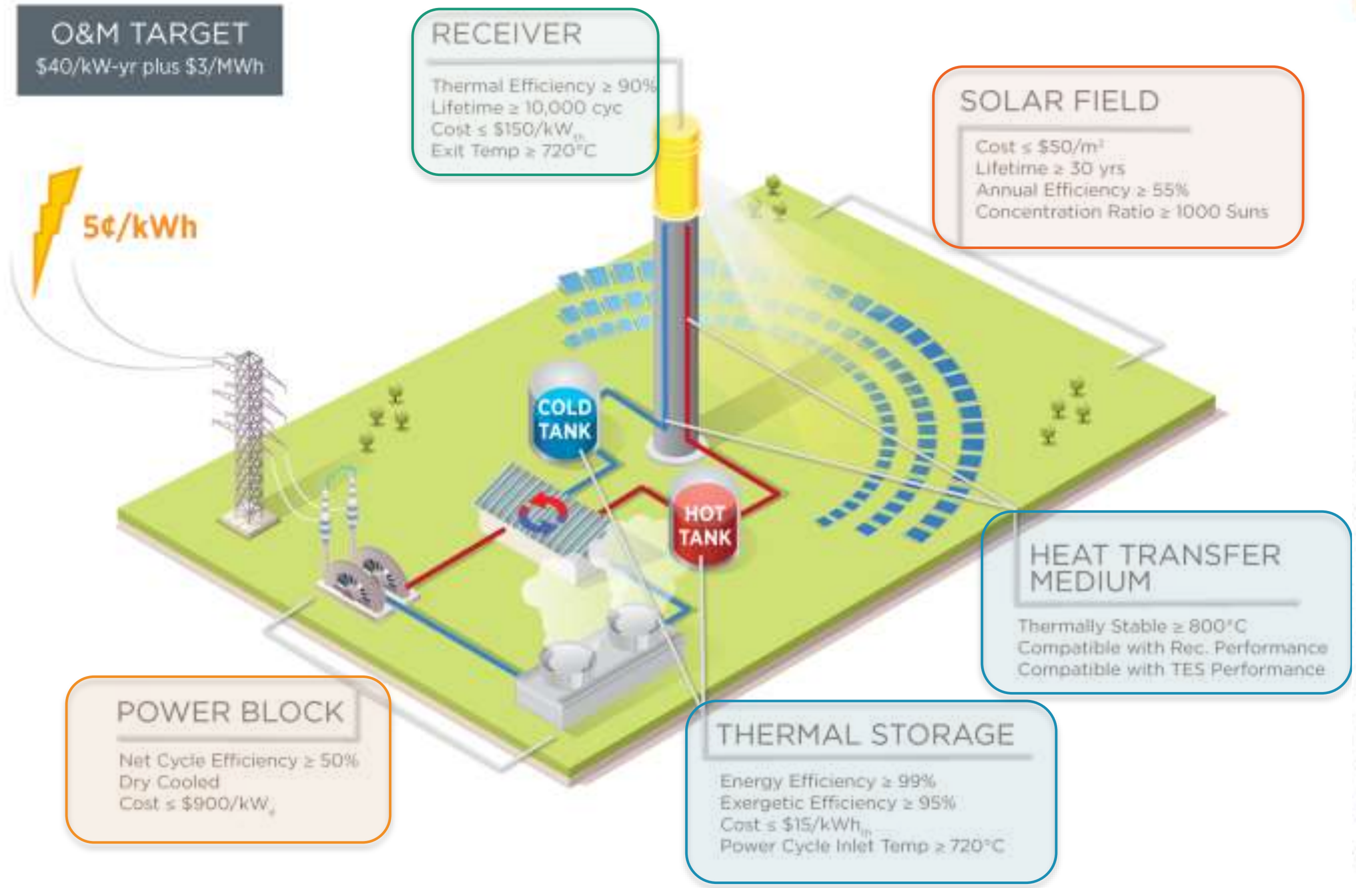
Collector Field
- Optical Physics
- Structural design and dynamics
- Manufacturing and automation
- Sensors and control

Receivers
- Optical properties
- Coatings
- High temperature materials
- Chemistry
- Heat Transfer, Fluid Mechanics

TES and HTF
- Chemistry
- High temperature materials
- Materials Science
- Heat Transfer, Fluid Mechanics

Power Block
- High temperature materials
- Turbomachinery
- Manufacturing and automation
- Sensors and control

CSP Technical Targets

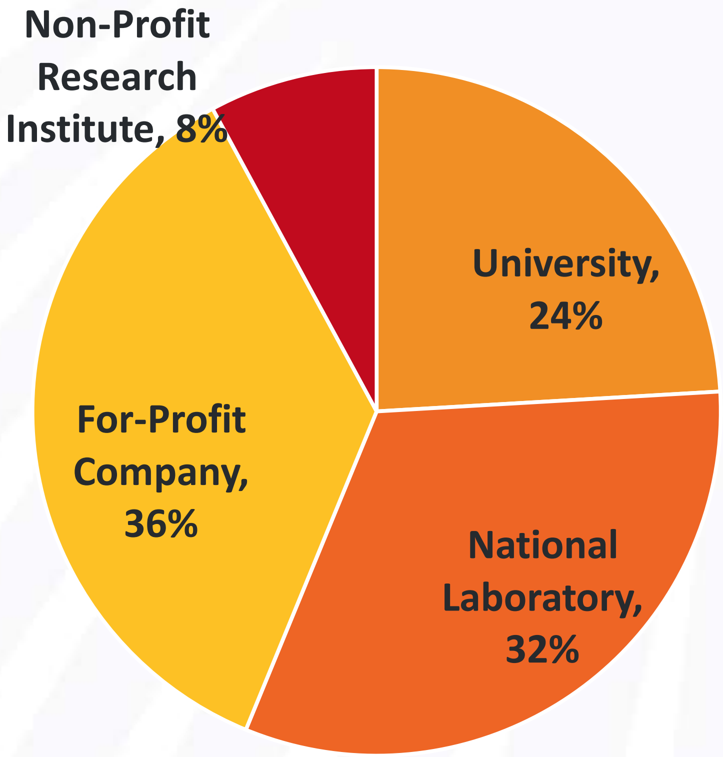


Competitive Programs

$43M FY20 SETO FOA (2020)
$30M FY19 SETO FOA (2019)
$22M FY18 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)

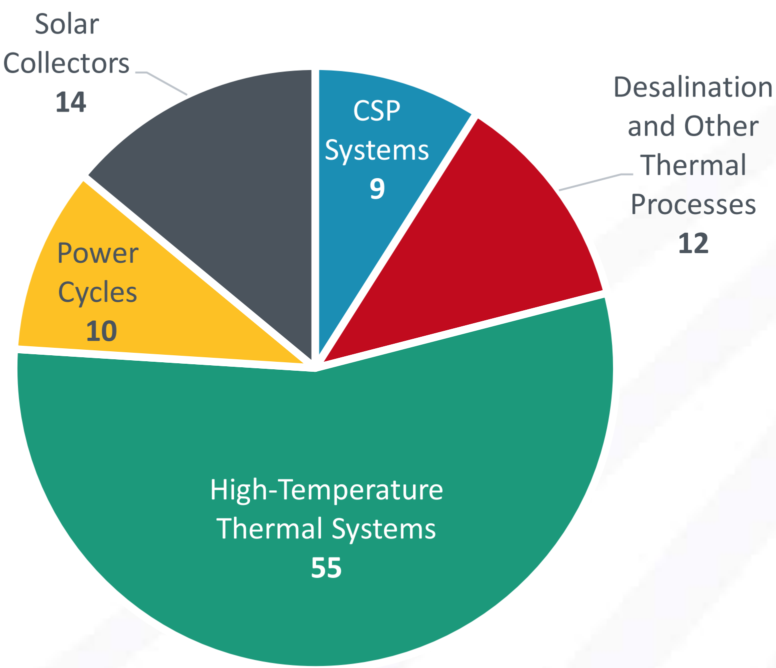
CSP Track Portfolio

- CSP Systems
- Power Cycles
- High-Temperature Thermal Systems
- Solar Collectors
- Desalination and Other Industrial Processes

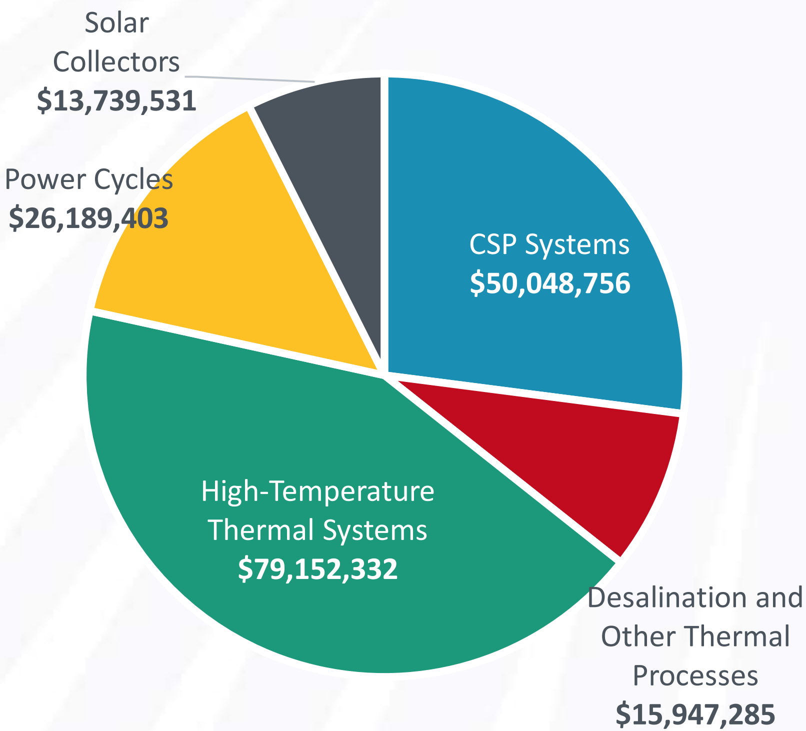


CSP Portfolio Breakdown by Topic

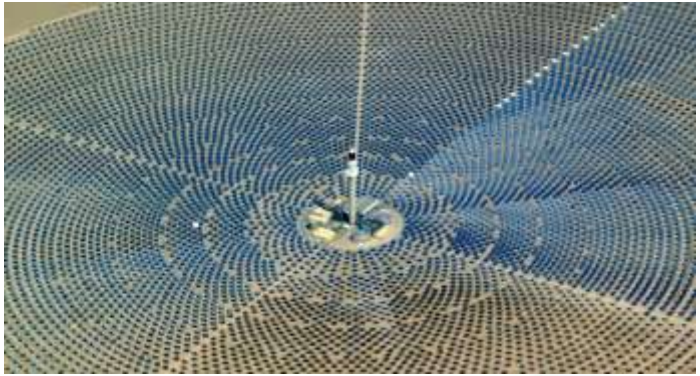
Projects by Topic



Funding by Topic



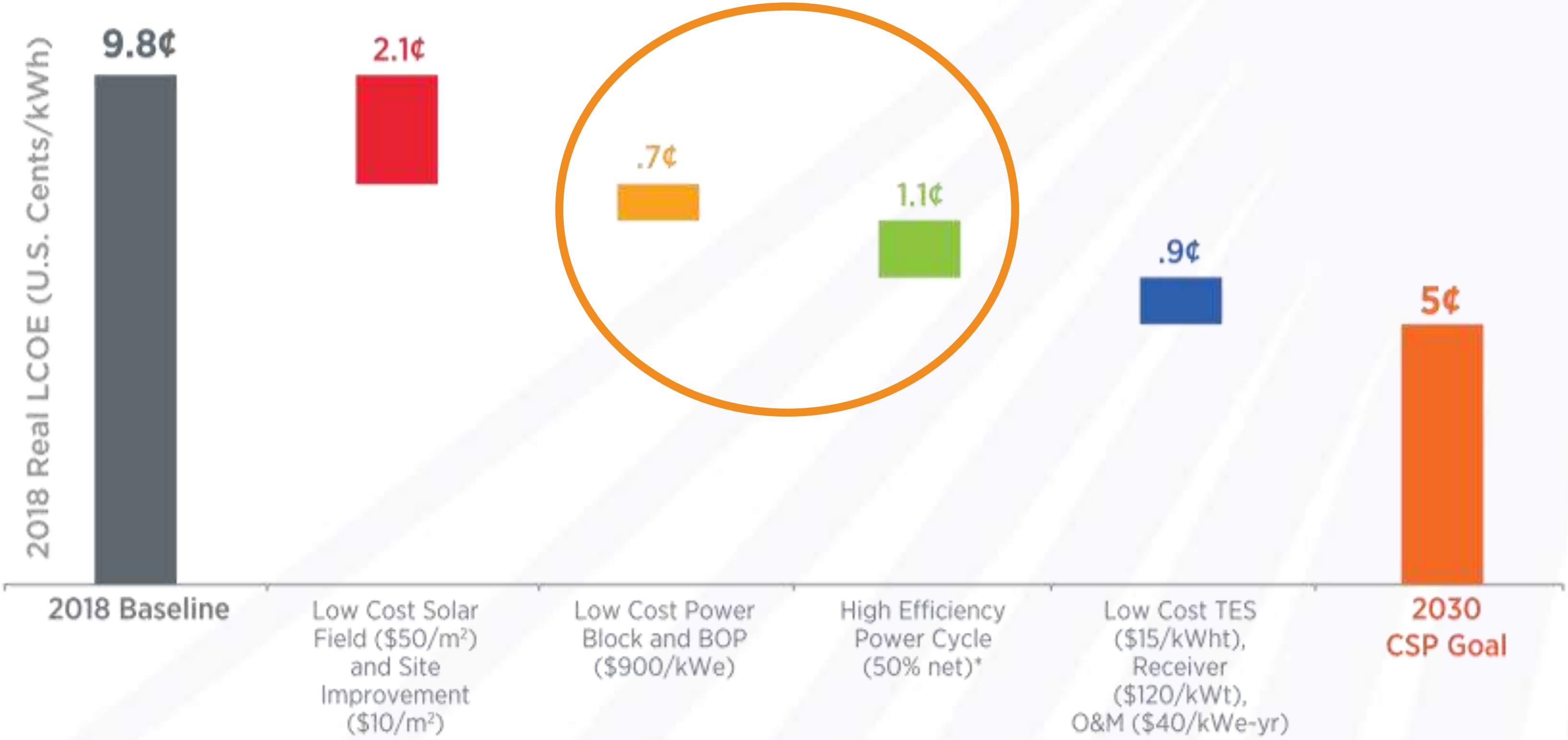
Topic Areas: CSP Systems



The CSP track funds work in analysis and development of fully integrated solar thermal systems, including:

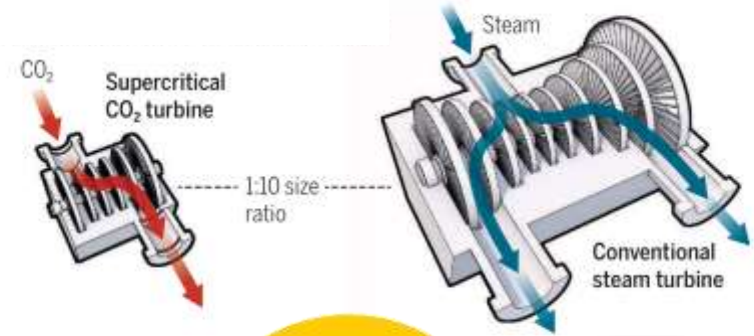
- Market and systems analysis to inform strategic goals
- Gen3 CSP ‘Topic 1’ teams developing fully integrated systems
- Hardware and modeling tools to improve the performance of existing commercial technologies

Topic Area: Power Cycles



*Assumes a gross to net conversion factor of 0.9

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 (Sub 100 MW)
- Operational Simplicity (No Phase Change)

CSP Specific R&D Challenges

- Higher Temperature Thermal Transport System
- Expanding Temperature Change (Sensible TES)
- Ambient Temperature Variability (Dry Cooling)
- Variable Solar Resource

Irwin, Le Moullec. "Turbines can use CO_2 to cut CO_2." *Science* 356.6340 (2017): 805-806.

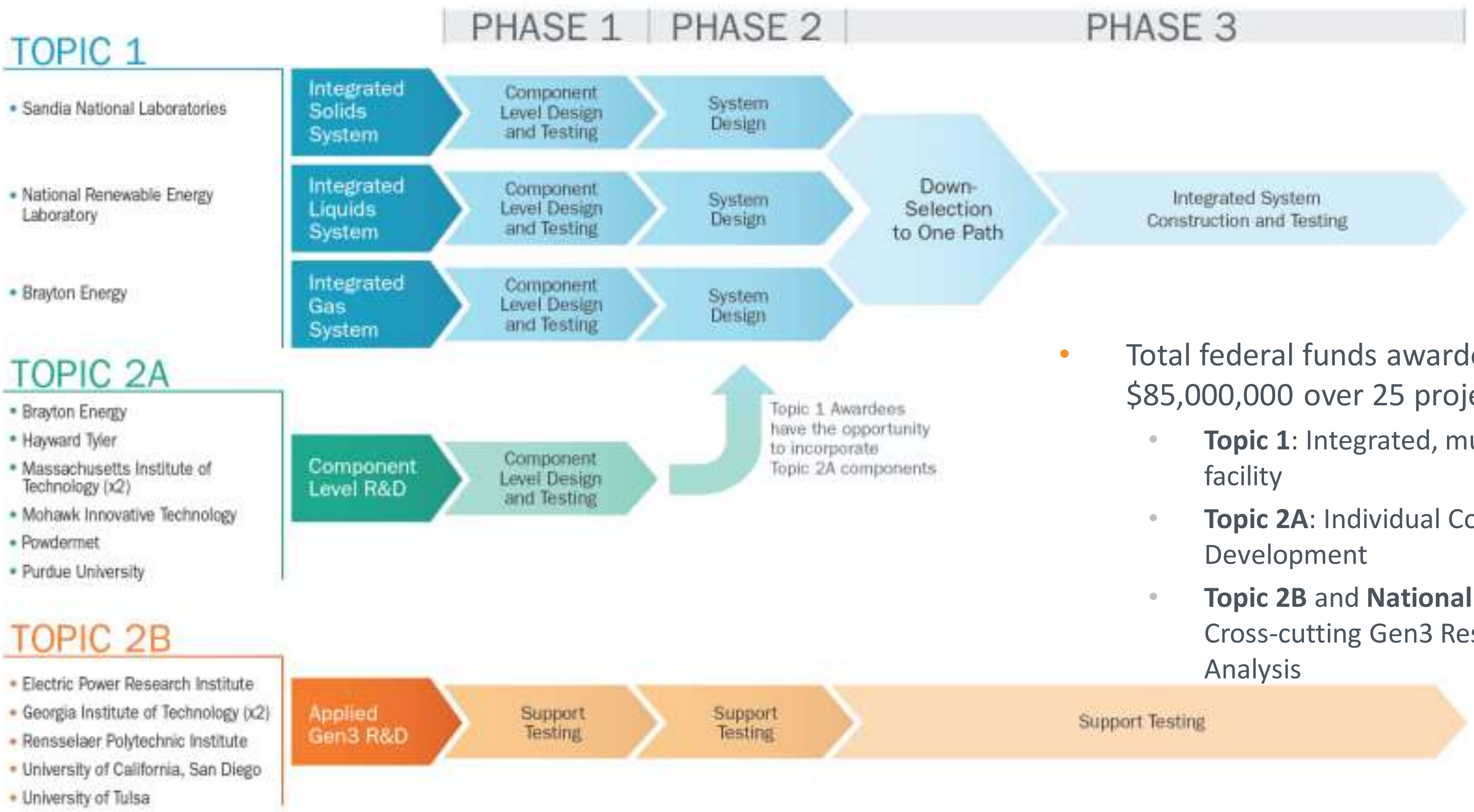
Topic Areas: High-Temperature Thermal Systems

$$\eta = 1 - \frac{T_C}{T_H}$$

Sub-topics:

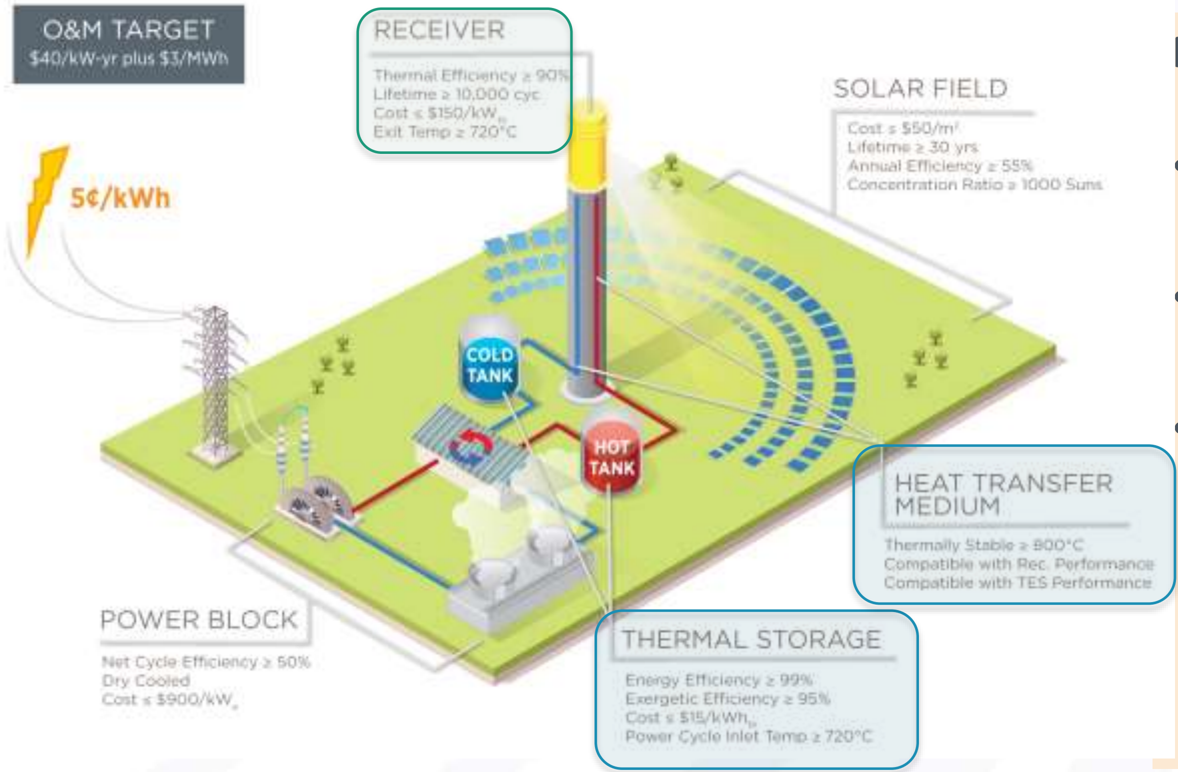
- Gen3 CSP Components
- Thermo-physical/chemical characterization
- Thermal Energy Storage
- Metals and Materials

Gen3 CSP: Raising the Temperature of Solar Thermal Systems



- Total federal funds awarded in 2018: $85,000,000 over 25 projects in 3 Topics:
  - **Topic 1**: Integrated, multi-MW test facility
  - **Topic 2A**: Individual Component Development
  - **Topic 2B** and **National Lab Support**: Cross-cutting Gen3 Research and Analysis

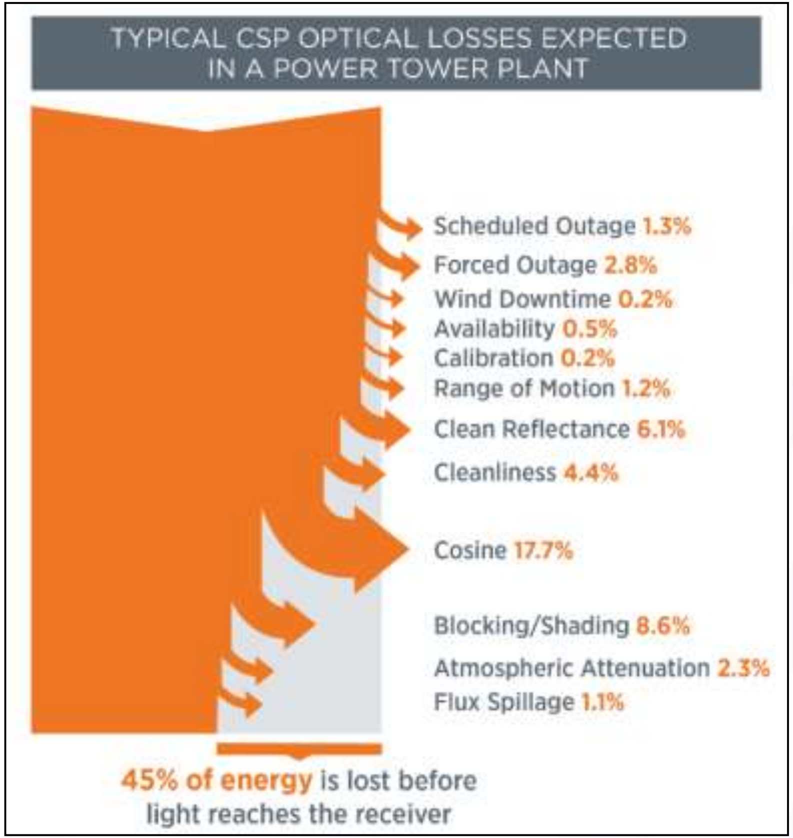
Topic Areas: High-Temperature Thermal Systems



Research Areas:

- High-efficiency, stable receiver coatings
- Next-generation Thermal Energy Storage
- Advanced receiver and heat exchanger designs, materials, and manufacturing

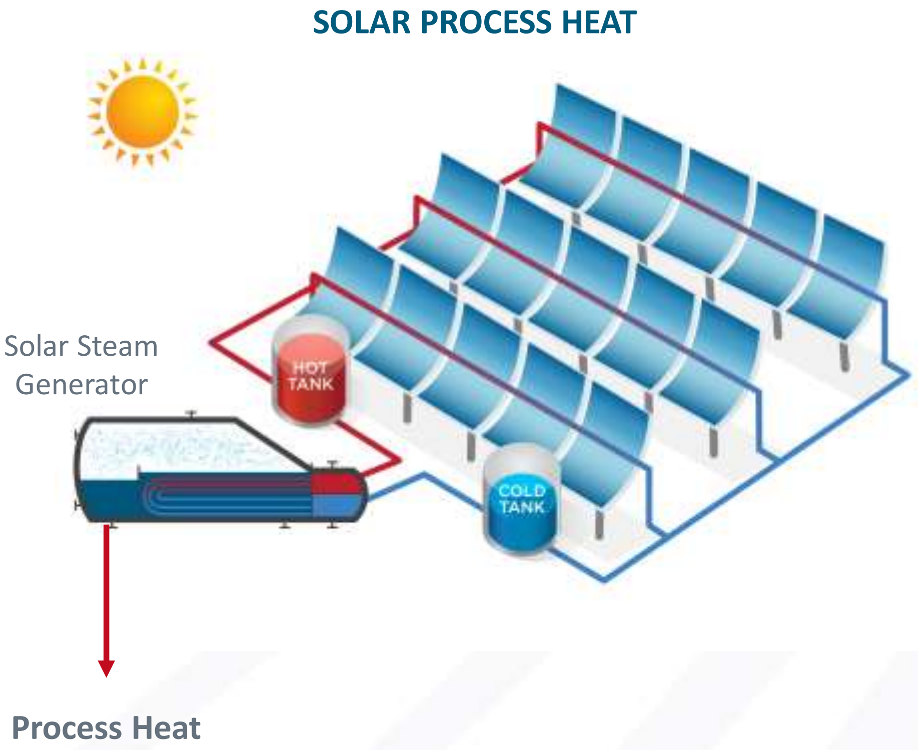
Topic Areas: Solar Collectors



Priority Areas:

- 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

Topic Areas : Desalination and Other Industrial Processes



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)

Topic Areas : Desalination and Other Industrial Processes

- Multi-million dollar prize was announced on September 25, 2019
- Multi-phase competition, progressing from concept design through demonstration
- Will seek to connect technology developers with test facilities and potential customers

SolarPACES 2020 Conference

SolarPACES 2020 will be held in **Albuquerque, New Mexico, USA** from **September 29 – October 2, 2020**.

Call for Abstracts available at http://www.solarpaces-conference.org/

Abstract Due Date: May 1, 2020

SolarPACES (Solar Power and Chemical Energy Systems) is the premier international conference and network for **advancing commercial deployment and research and development** of concentrating solar-thermal power (CSP) and related technologies.

CSP Team

Technology Managers

Mark Lausten, PE

On contract from BGS

Levi Irwin, PhD

On contract from Mantech

Matt Bauer, PhD

Andru Prescod, PhD, MBA

On contract from Mantech

Rajgopal 'Vijay' Vijaykumar, PhD

Shane Powers

On contract from Mantech

Science and Technology Policy Fellow

Nikkia McDonald, PhD

Financial Analyst

Patty Clark, MBA

On contract from Allegheny S&T

Technical Project Officer

Christine Bing, MBA

Operations

Meisha Baylor

On contract from Red Horse

Agenda – Monday, April 6

Time	Session
1:30PM–2:00PM	**CSP Track Introduction** *Avi Shultz, Program Manager*
2:00PM-2:15PM	**CSP Review Panel Introduction** *Fred Redell, Chair, CSP Track Review Panel*
2:15PM-3:00PM	**High-Temperature Thermal Systems: Gen3 CSP Overview** *Matt Bauer, Technology Development Manager* *Shane Powers, Technology Development Manager*
3:00PM-4:00PM	**High-Temperature Thermal Systems: Gen3 CSP Discussion** *All*
4:00PM-5:00PM	**Internal Review Panel Discussion**

Agenda – Tuesday, April 7

Time	Session
11:00AM–11:10AM	**CSP Systems: Analysis and Commercial Support Overview** *Mark Lausten, Technology Development Manager*
11:10AM–11:30AM	**CSP Systems: Analysis and Commercial Support Discussion** *All*
11:30AM-11:50AM	**Power Cycles: Supercritical CO_2 Brayton Cycle Development Overview** *Rajgopal Vijaykumar, Technology Development Manager*
11:50AM-12:30PM	**Power Cycles: Supercritical CO_2 Brayton Cycle Development Discussion** *All*
12:30PM-12:45PM	**Desalination and Other Industrial Processes Overview** *Andru Prescod, Technology Development Manager*
12:45PM-1:15PM	**Desalination and Other Industrial Processes Discussion** *All*

Time	Session
1:15PM–1:45PM	**Break/Lunch**
1:45PM–2:00PM	**Solar Collectors Overview** *Andru Prescod, Technology Development Manager*
2:00PM–2:45PM	**Solar Collectors Discussion** *All*
2:45PM–3:00PM	**High-Temperature Thermal Systems, Part 2 Overview** *Levi Irwin, Technology Development Manager*
3:00PM–3:35PM	**High-Temperature Thermal Systems, Part 2 Discussion** *All*
3:35PM–3:40PM	**Single Year R&D Programs Overview** *Matt Bauer, Technology Development Manager*
3:40PM–4:00PM	**Single Year R&D Programs Discussion** *All*
4:00PM-5:00PM	**Internal Review Panel Discussion**

Agenda – Wednesday, April 7

Time	Session
11:00AM–12:30PM	**Internal Review Panel Discussion (Avi available for Questions)**
12:30PM–12:45PM	**Break**
12:45PM–2:15PM	**Reviewer Roundtable with SETO Staff**
2:15PM–2:45PM	**Break**
2:45PM–3:45PM	**Track Chairs Discussion with Planning and Strategy Reviewers**
3:45PM–4:00PM	**Break**
4:00PM–5:00PM	**Track Chairs and P&S Roundtable with SETO Leadership**

Thank You

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