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

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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. energy.gov/solar-office
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

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CSP Technical Targets

**O&M TARGET**
$40/kW-year plus $3/MWh

**RECEIVER**
Thermal Efficiency ≥ 90%
Lifetime ≥ 10,000 cycles
Cost ≤ $150/kW
Exit Temp ≥ 720°C

**SOLAR FIELD**
Cost ≤ $50/m²
Lifetime ≥ 30 yrs
Annual Efficiency ≥ 55%
Concentration Ratio ≥ 1000 Suns

**POWER BLOCK**
Net Cycle Efficiency ≥ 50%
Dry Cooled
Cost ≤ $900/kWe

**THERMAL STORAGE**
Energy Efficiency ≥ 99%
Exergetic Efficiency ≥ 95%
Cost ≤ $15/kWe
Power Cycle Inlet Temp ≥ 720°C

**HEAT TRANSFER MEDIUM**
Thermally Stable ≥ 800°C
Compatible with Rec. Performance
Compatible with TES Performance

**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: APOLO (2015)
- **$29M** CSP SuNLaMP (2015)
- **$14M** 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

- University, 24%
- For-Profit Company, 36%
- National Laboratory, 32%
- Non-Profit Research Institute, 8%

$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 sCO₂ 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 sCO₂ 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

Integrated System Design

Integrated Solids System
Component Level Design and Testing
System Design

Integrated Liquids System
Component Level Design and Testing
System Design

Integrated Gas System
Component Level Design and Testing
System Design

Down-Selection to One Path
Integrated System Construction and Testing

Molten Chloride Tank Design

Component Design and Prototyping
Gen3 CSP: Raising the Temperature of Solar Thermal Systems

TOPIC 1

- Sandia National Laboratories

Contributors: VPE and Solex

Contributors: Allied Mineral Products and Matrix PDM
Gen3 CSP: Raising the Temperature of Solar Thermal Systems

**TOPIC 1**

- Brayton Energy

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**Integrated Solids System**
- Component Level Design and Testing
- System Design

**Integrated Liquids System**
- Component Level Design and Testing
- System Design

**Integrated Gas System**
- Component Level Design and Testing
- System Design

**PHASE 1**

**PHASE 2**

**Down-Selection to One Path**

**PHASE 3**

**Integrated System Construction and Testing**

**Receiver Design and Modelling**

**Tower and Solar Field Design**

**Particle TES and Heat Exchanger**

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[Brayton Energy]
Gen3 CSP: Raising the Temperature of Solar Thermal Systems

**TOPIC 1**

- Sandia National Laboratories
- Integrated Solids System
- Component Level Design and Testing
- System Design
- National Renewable Energy Laboratory
- Integrated Liquids System
- Component Level Design and Testing
- System Design
- Brayton Energy
- Integrated Gas System
- Component Level Design and Testing
- System Design

**PHASE 1**

- Down-Selection to One Path
- Integrated System Construction and Testing

**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

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

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

Incentivize the nation’s entrepreneurs to strengthen American leadership in energy innovation.
American Made Challenges: Solar Desalination Prize

CONTEST 1
INNOVATION
$50,000 each

CONTEST 2
TEAMING
$250,000 each

CONTEST 3
DESIGN
$750,000 each

CONTEST 4
TEST
$1,000,000 each

APRIL 2020
SEPT 2020
MARCH 2021
MARCH 2022
SPRING 2022

OPEN TO ALL
CONTEST 1, 2 & 3 WINNERS ONLY

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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.

2018 Real LCOE (U.S. Cents/kWh)

- 2018 Baseline: 9.8¢
- Low Cost Solar Field ($50/m²) and Site Improvement ($10/m²): 2.1¢
- Low Cost Power Block and BOP ($900/kWe): .7¢
- High Efficiency Power Cycle (50% net)*: 1.1¢
- Low Cost TES ($15/kWh), Receiver ($120/kWt), O&M ($40/kWe-yr): .9¢
- 2030 CSP Goal: 5¢

*Assumes a gross to net conversion factor of 0.9

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Heliostat Development Challenges

Challenges:
• Heliostat costs still > $100/m²
• 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?

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