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

SOLAR ENERGY TECHNOLOGIES OFFICE

Next Generation Receivers

R&D Virtual Workshop Series

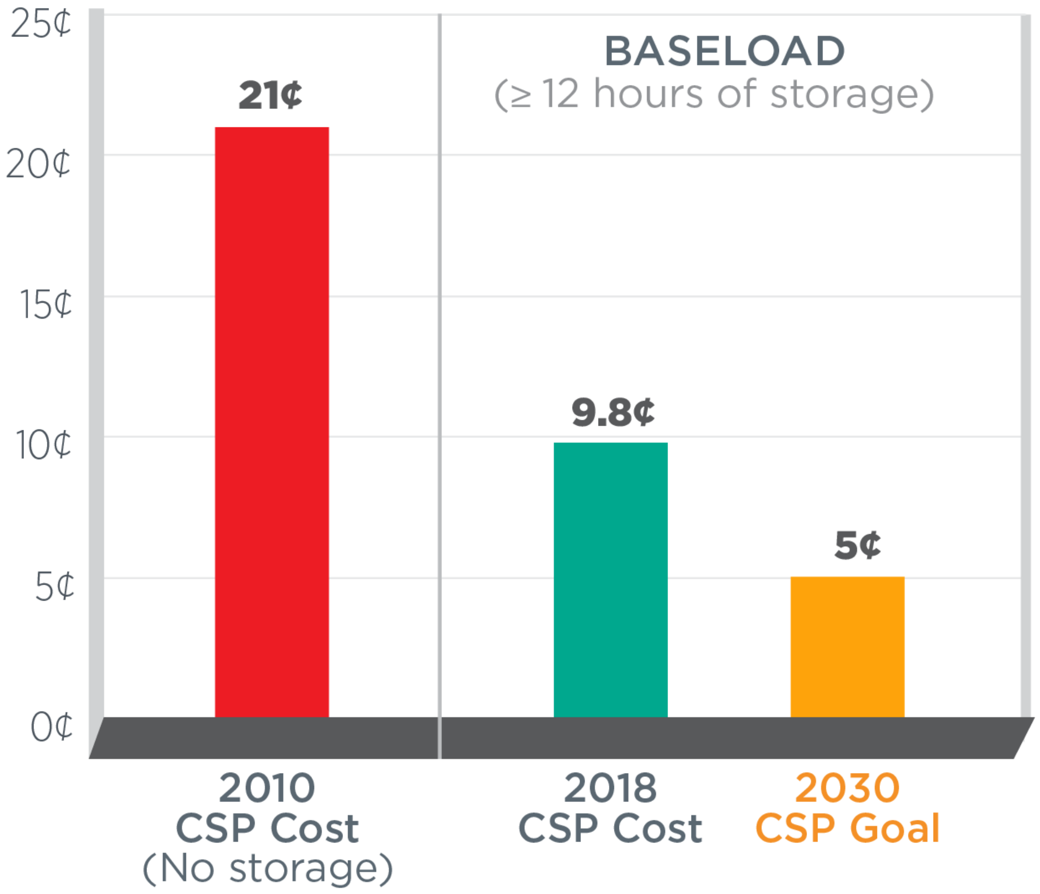
Concentrating Solar Power Program

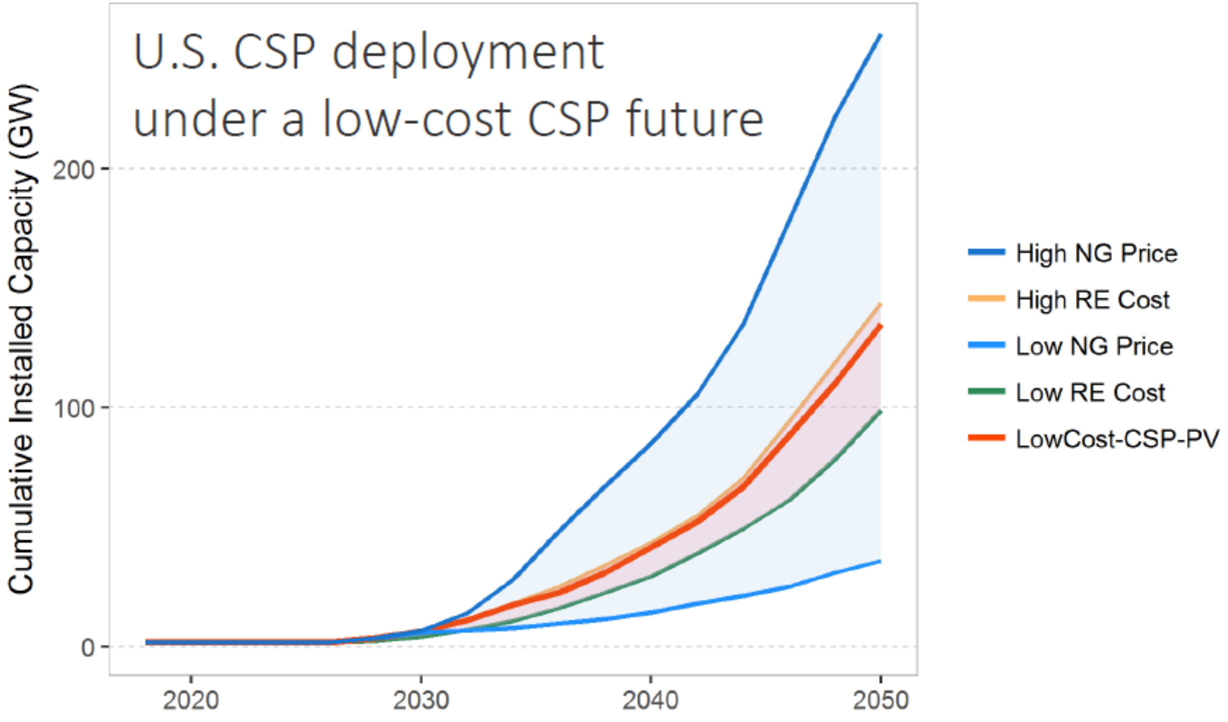
Avi Shultz, CSP Program Manager

Matthew Bauer, CSP Technology Manager, US DOE

matthew.bauer@ee.doe.gov

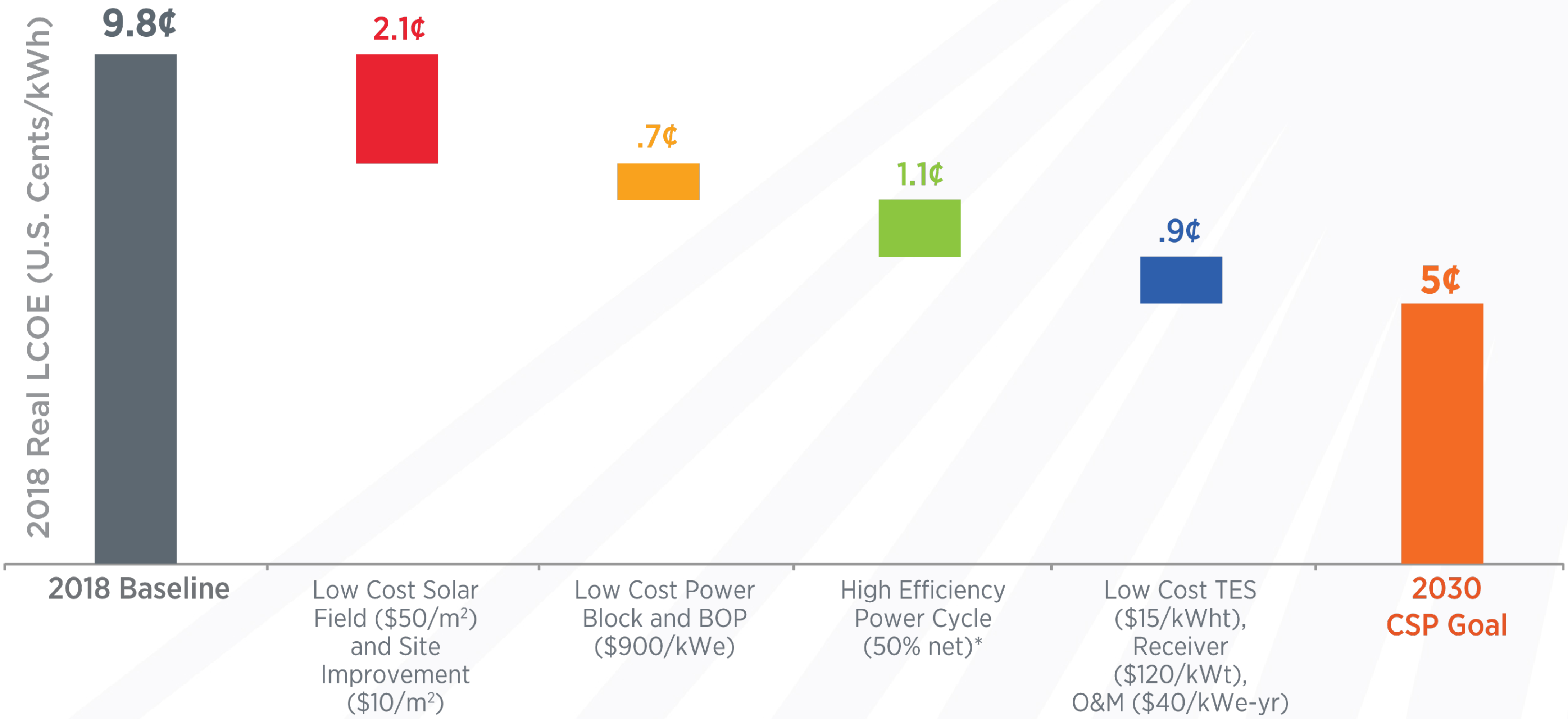
Progress and Goals: 2030 LCOE Goals





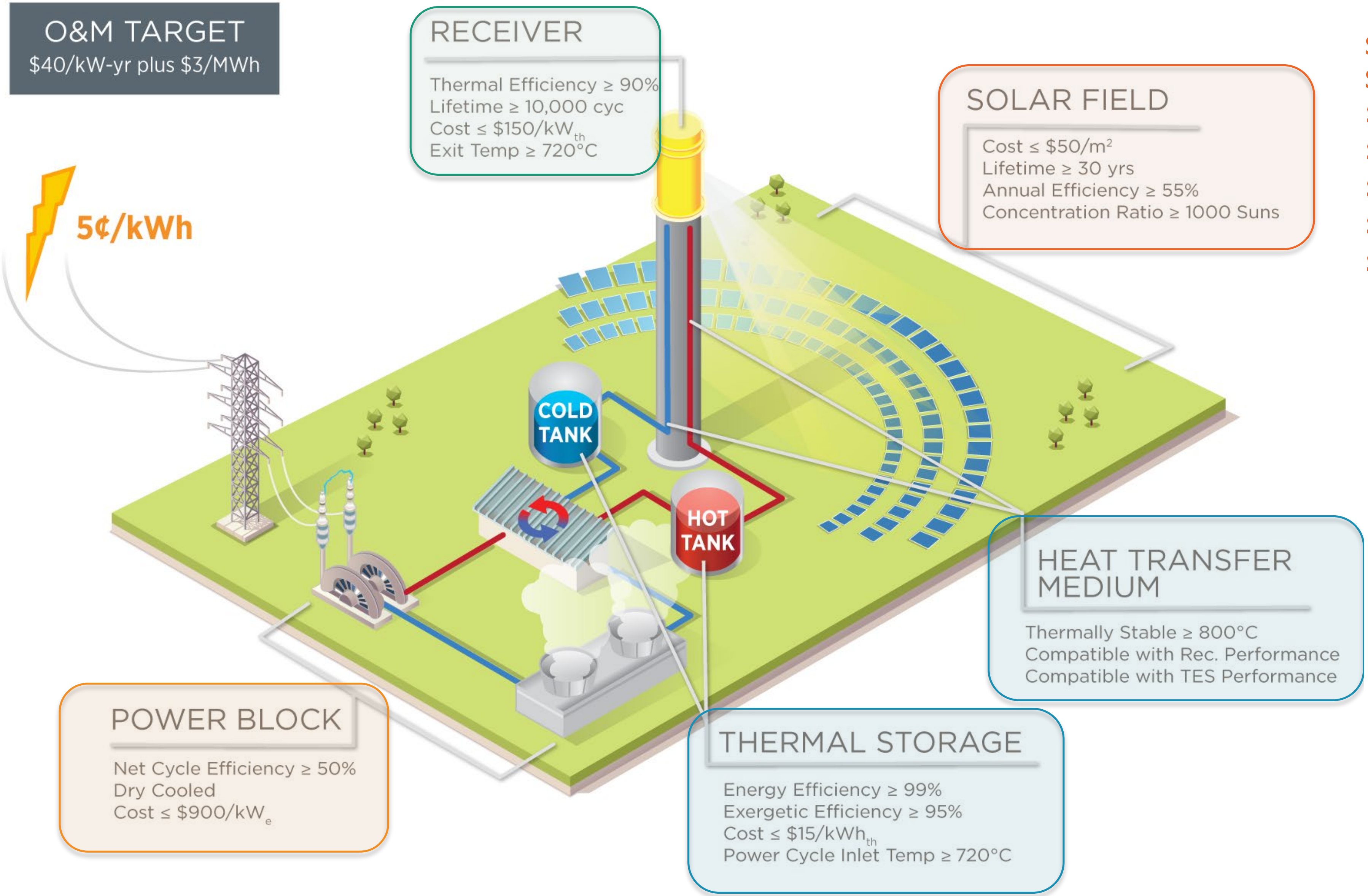
Murphy, et al. **2019**, NREL/TP-6A20-71912

A Pathway to 5 Cents per KWh for Baseload CSP



*Assumes a gross to net conversion factor of 0.9

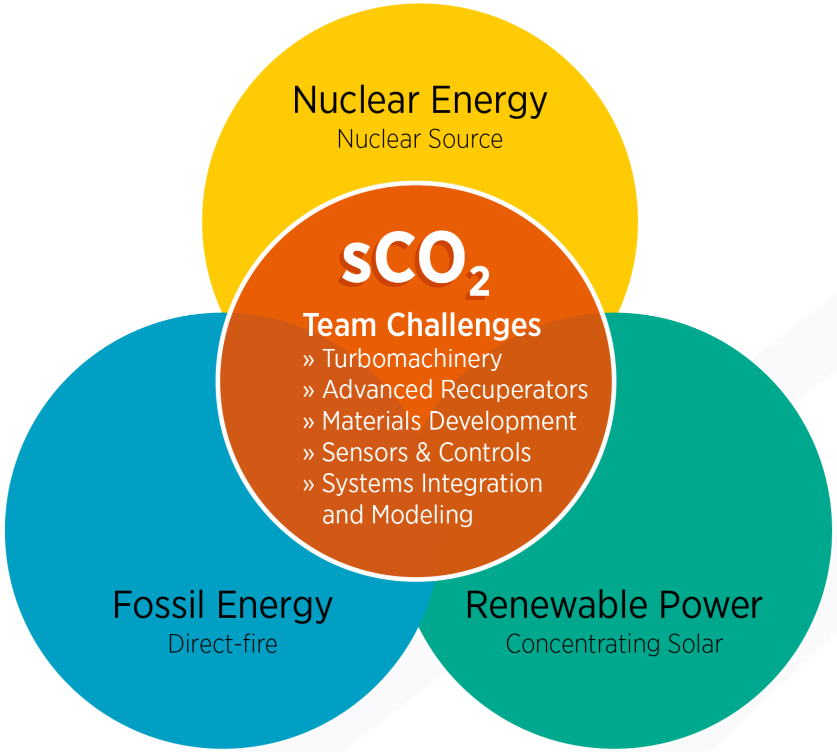
CSP Technical Targets



Competitive Programs

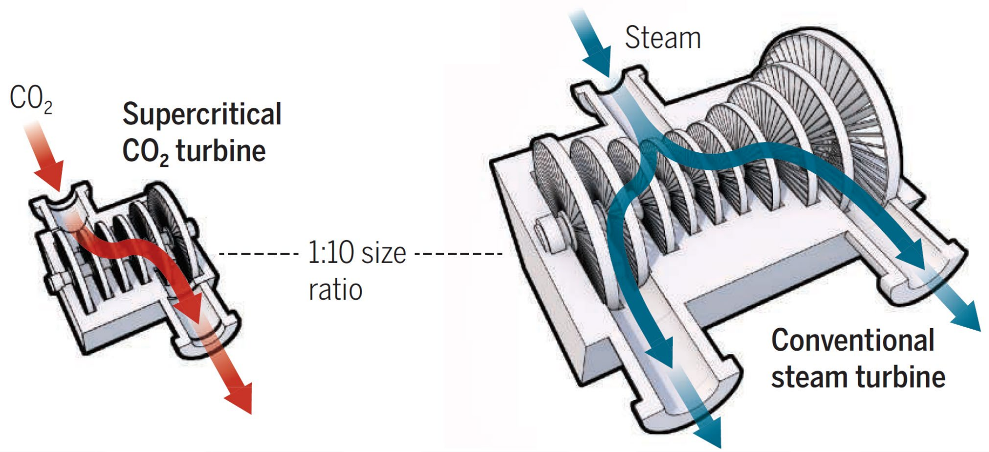
$43M	FY 2020 SETO FOA (2020)
$30M	FY 2019 SETO FOA (2019)
$22M	FY 2018 SETO FOA (2019)
$21M	Solar Desalination (2018)
$22M	FY19-21 National Lab Call (2018)
$70M	Gen3 CSP Systems (2018)
$15M	Gen3 CSP Lab Support (2018)
$9M	COLLECTS (2016)
$32M	CSP: APOLLO (2015)
$29M	CSP SuNLaMP (2015)
$1.4M	SolarMat 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)

Next Generation CSP will Leverage Next Generation Power Cycles

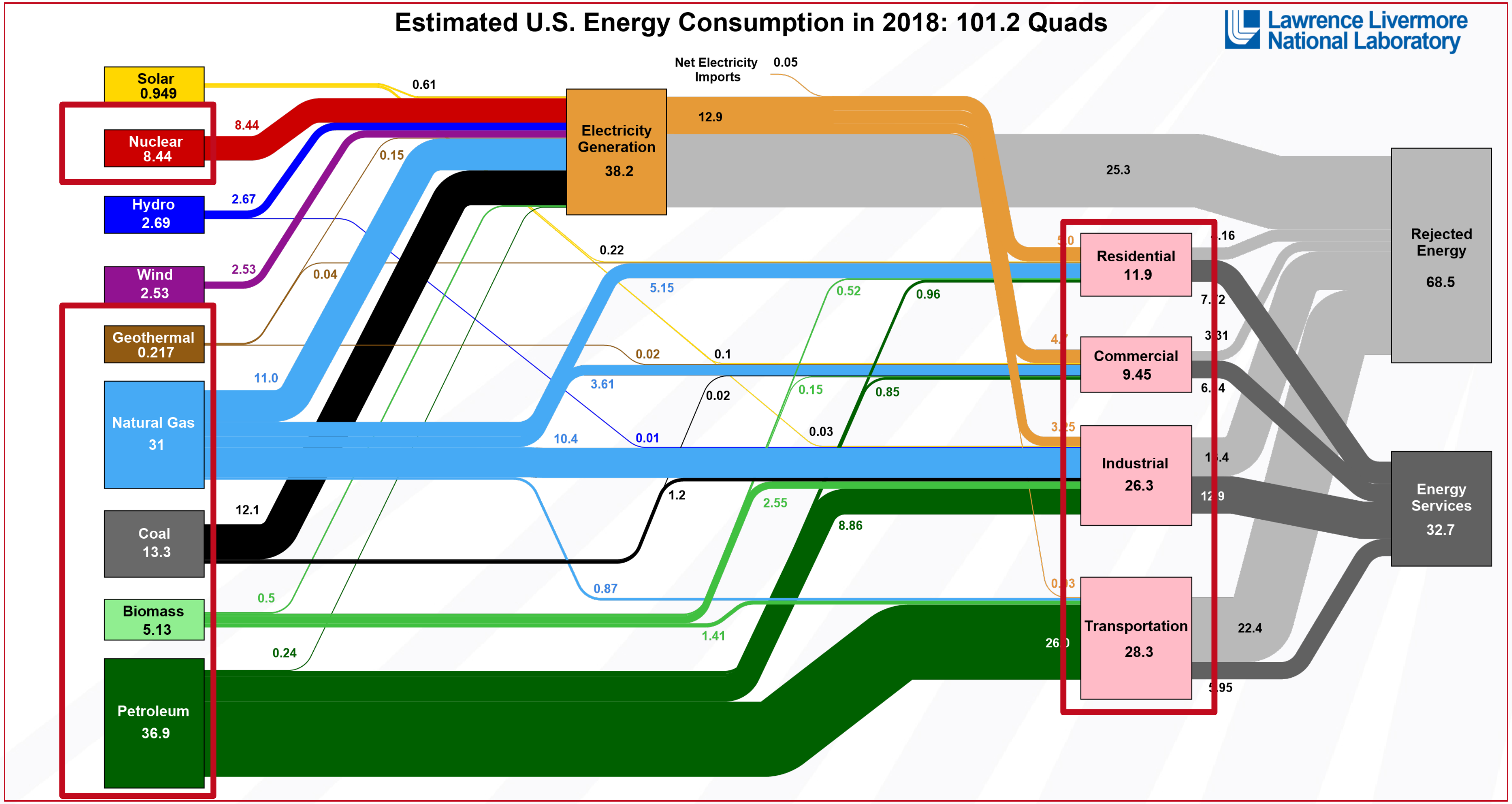


Advantages of the sCO_2 Brayton Cycle:

- 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



Solar Thermal can Integrate with the Existing Energy System



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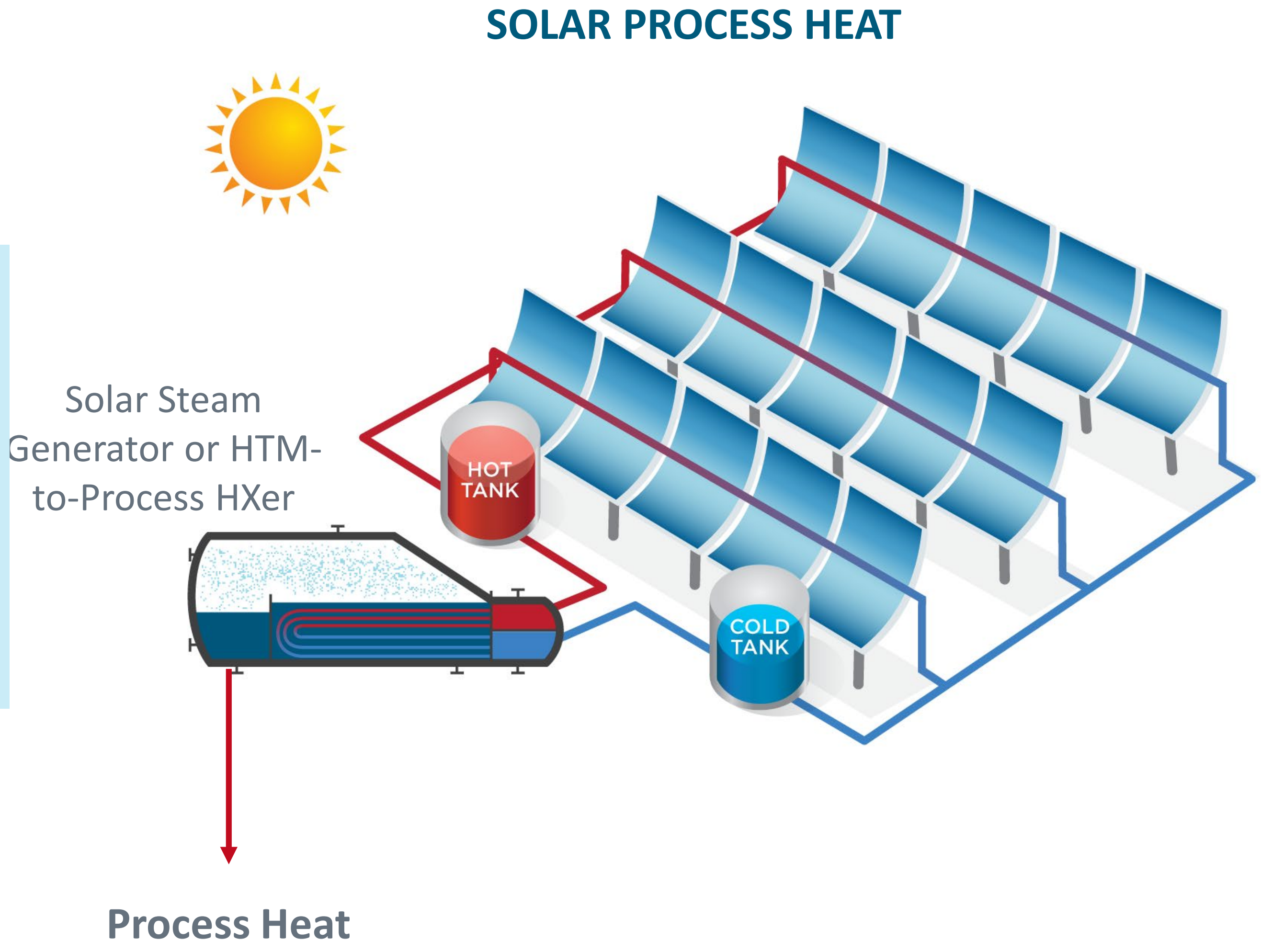
Solar Thermal Industrial Process Heat

Thermally-Driven Industrial Processes:

- Desalination
- Enhanced Oil Recovery
- Agriculture and Food Processing
- Fuel and Chemicals Production
- Mining and Metals Processing



SOLAR ENERGY TECHNOLOGIES OFFICE

CSP R&D Virtual Workshop Series

- Autonomous, Integrated Heliostat Field & Components – **October 20th, 2020**
- Next Generation Receivers – **October 29th, 2020**
- Unlocking Solar Thermochemical Potential – **November 12th, 19th, December 3rd, 2020, 11am – 2pm ET**
- Pumped Thermal Energy Storage Innovations – **November 17th, 2020, 1-5pm ET**
- CSP Performance and Reliability Innovation – **December 10th, 2020, 11am – 2pm ET**

*Full details and registration links will be posted here:

https://bit.ly/CSP-workshops

Problem Statement and Workshop Goals

Problem Statement

- ❑ Concentrated Solar Thermal applications are limited by the conditions (temperatures and solar flux) and control of converting concentrated light to thermal energy.
  - Gen3 CSP (for a 700°C sCO_2 Power Cycle)
  - Other Novel Electricity Generation embodiments
  - Long Duration Thermochemical Energy Storage
  - Solar Fuels
  - High Temperature Process Heat
  - Commodity Production

Workshop Goal

- ❑ Enable CSP stakeholders to engage with SETO and CSP Receiver experts in an informal panel format to share insights and lessons learned for developing and de-risking new receivers for new systems.
  - All statements made by panelists and participants are personal reflections, based on their experiences.
- ❑ Consider framework for advancing receiver innovations from idea to commercial adoption.

Generic Metrics Historically Used by SETO

Cost: $150/kW_{th}$

- Receiver Panel
- Piping (riser, downcomer)
- Interconnects
- Auxiliary Components
- Cold Pump, Circulator, *etc*.

Efficiency: 90% Optical to Thermal

- Incident Flux on Target / Thermal Energy Delivered to Storage
- Consider Pressure and Parasitic Losses
- Receiver Optical Properties
- Convection (wind)
- Conduction not recuperated

Lifetime: 30 Years

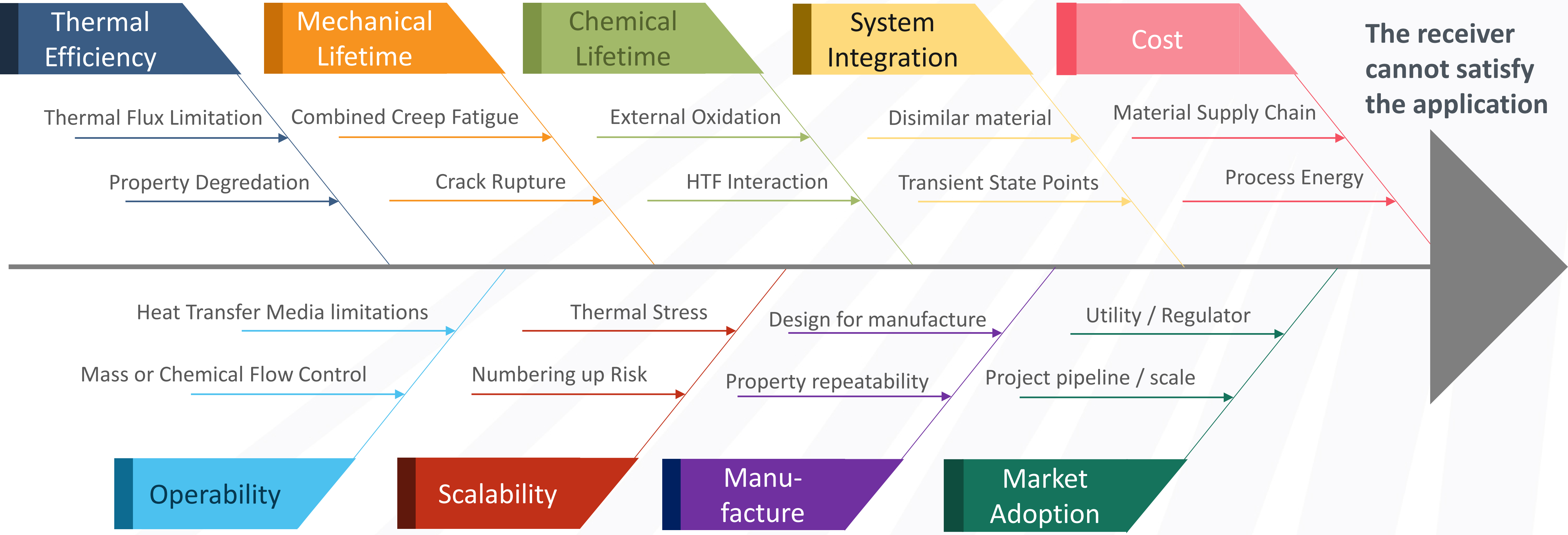
- Consistent with Financial Models informing SETO's Cost and Performance Targets
- Part Replacement accounting for additional O&M is a viable strategy

Application Specific Targets

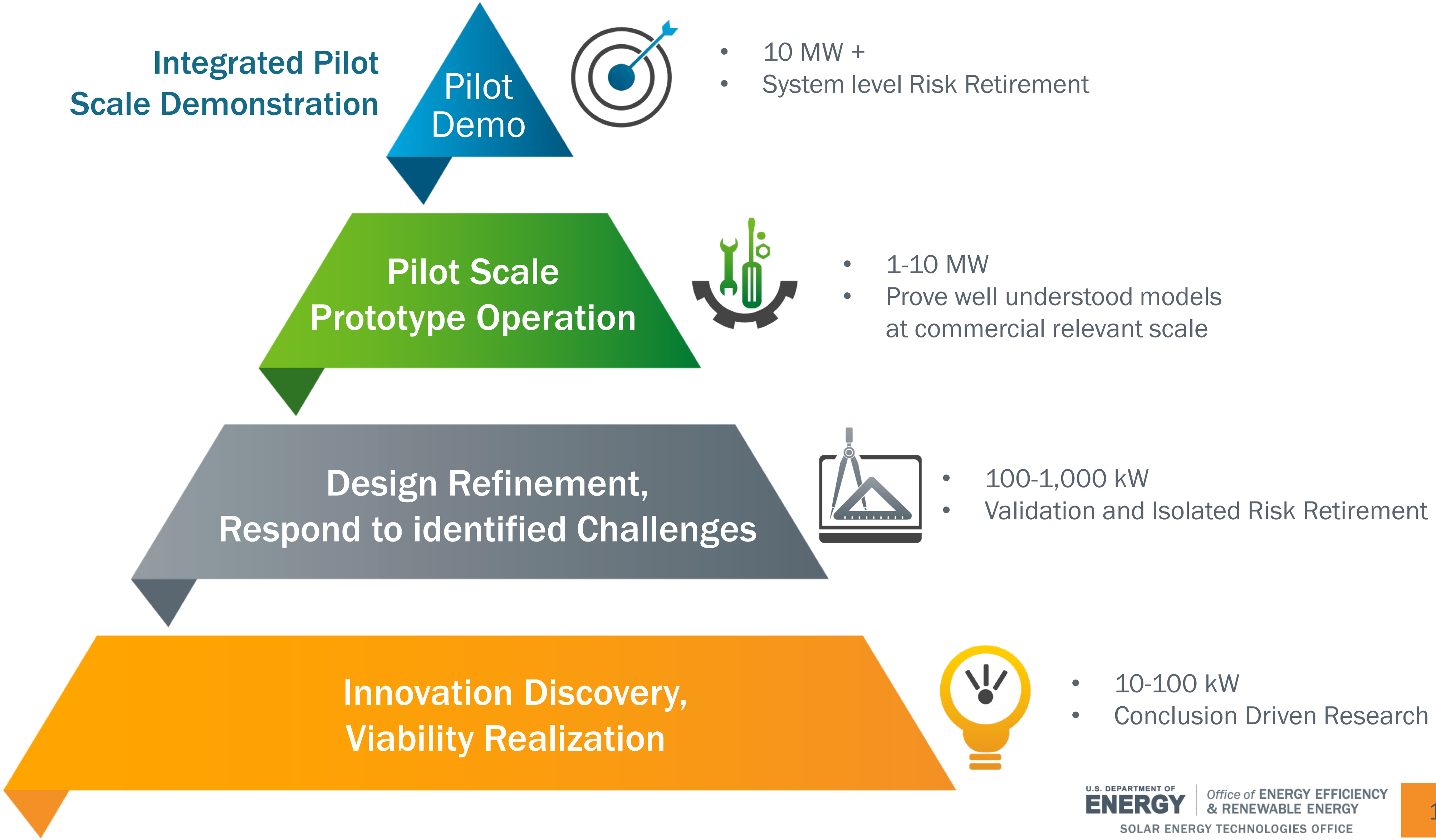
- Gen3 CSP: Outlet Temperature > 720 °C
- Compatible with Dispatchable Thermal Energy Storage

Factors preventing innovative receivers

Ishikawa diagram approach



Thinking through Risk within Tiers of Technology Maturity



Overlooked Target Audience

Who uses the knowledge from the campaign?

How does the audience impact development efforts?

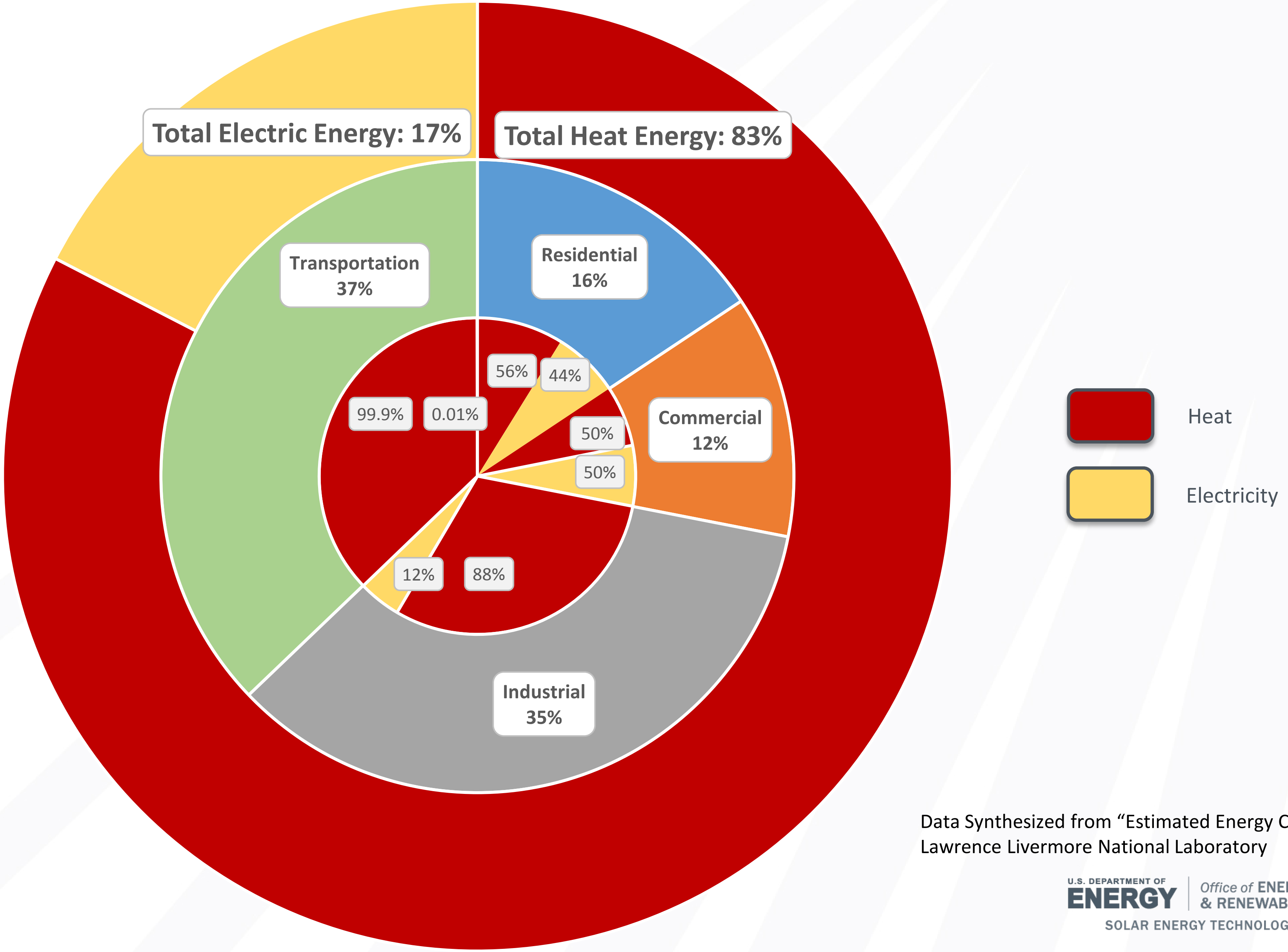
Target Audience:

- Research Peers
- Materials Manufacturers
- System Integrators
- Component Producers
- Commercial Project Developers
- Chemical or Commodity Producers
- Financers
- Utilities

Type of outputs

- Data Sets
- Manuscripts
- Sharable Code
- Off Design Performance
- Design Drawing
- Risk Assessment Formalism
- Market Analysis

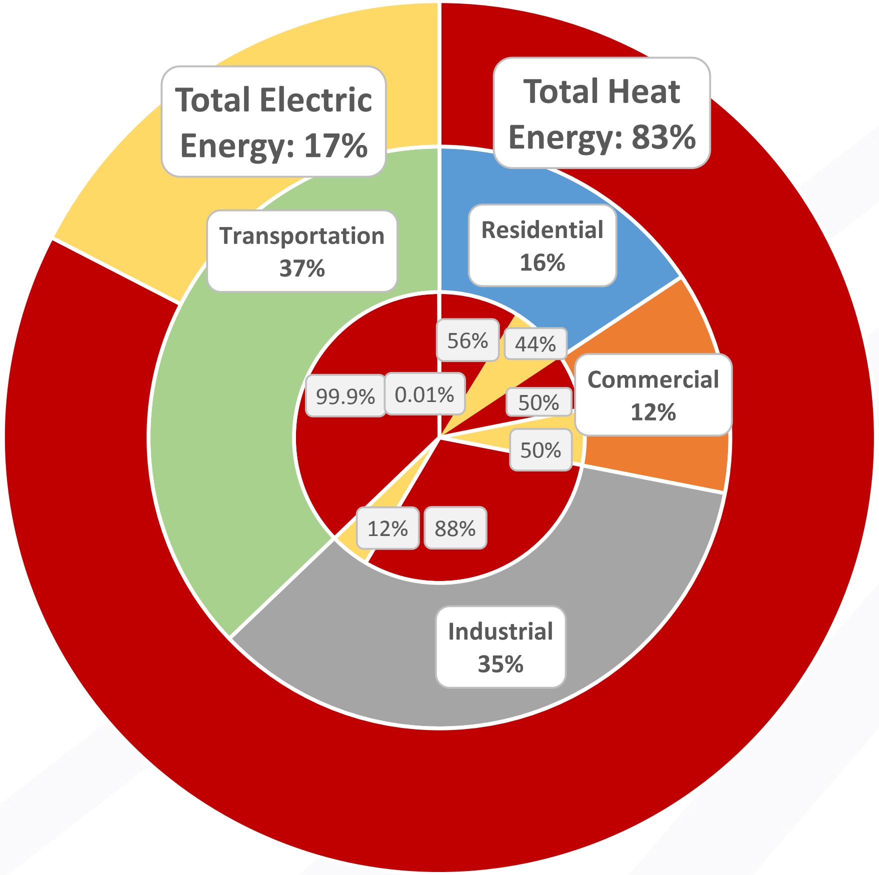
U.S. Energy use by Sector



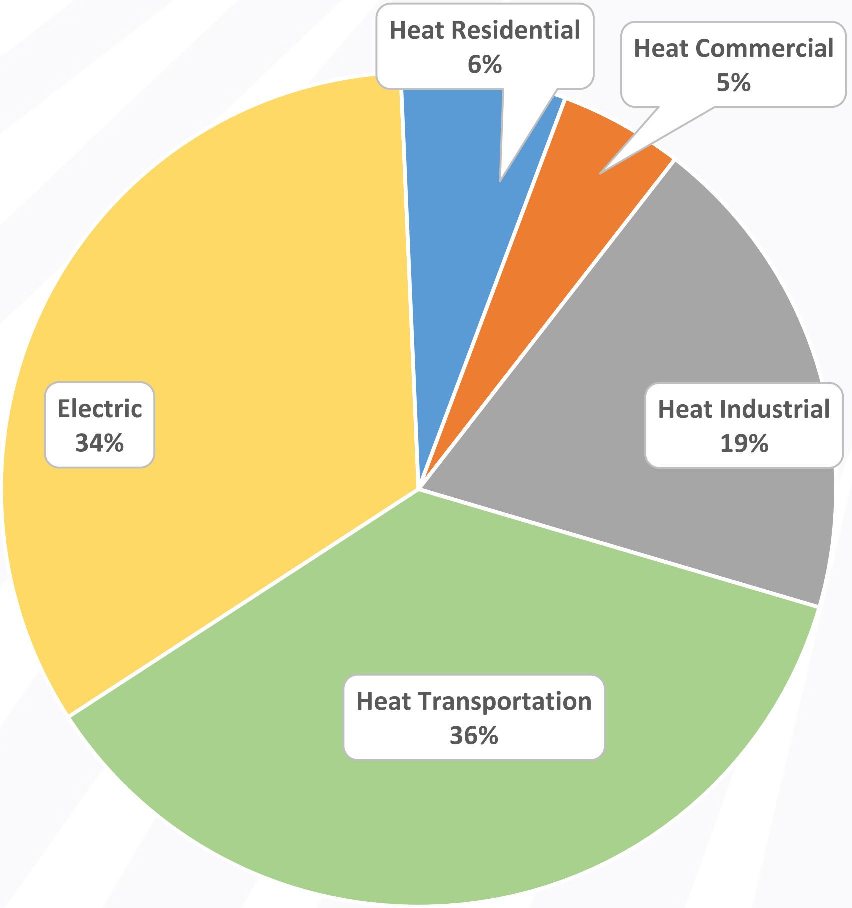
Data Synthesized from "Estimated Energy Consumption in 2019"
Lawrence Livermore National Laboratory

U.S. Carbon Dioxide Emissions by Sector

Energy Use



CO_2 Emissions



Data Synthesized from "US Carbon Dioxide Emissions in 2018"
Lawrence Livermore National Laboratory

Innovation is Critical!

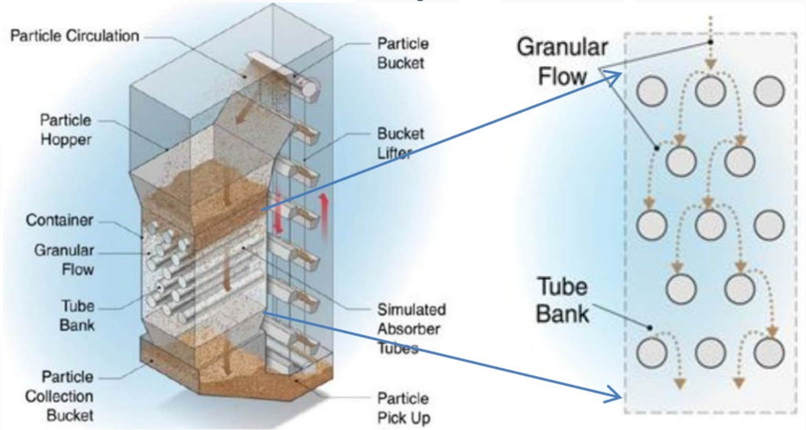
Ceramic Tubular Products

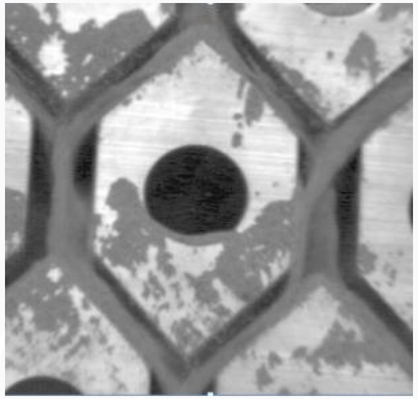
Silicon Carbide Composite

Jeff Halfinger: ctp-usa.com

National Renewable Energy Laboratory

"Black Body" Enclosed Particle Receiver

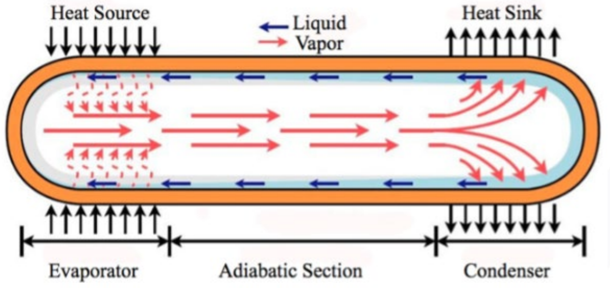




Zhiwen Ma

Los Alamos National Laboratory

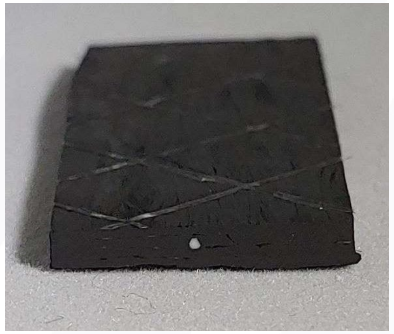
Counter Gravity Heat Pipe Receiver

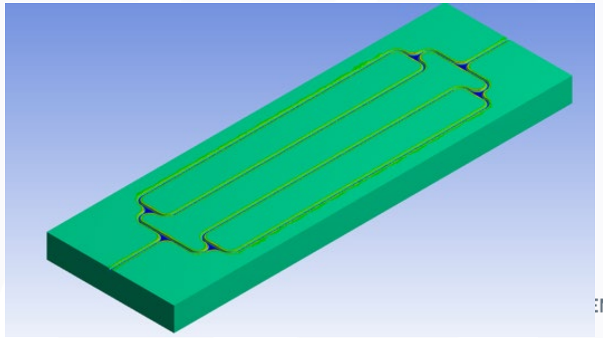


Steve Obrey

University of Tulsa

Microvascular Carbon Composite Receiver

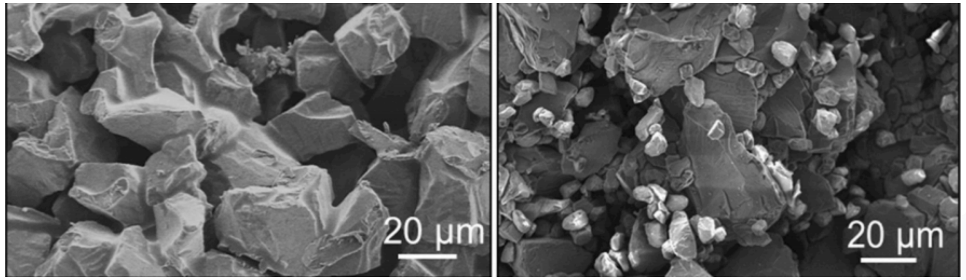




Michael Keller

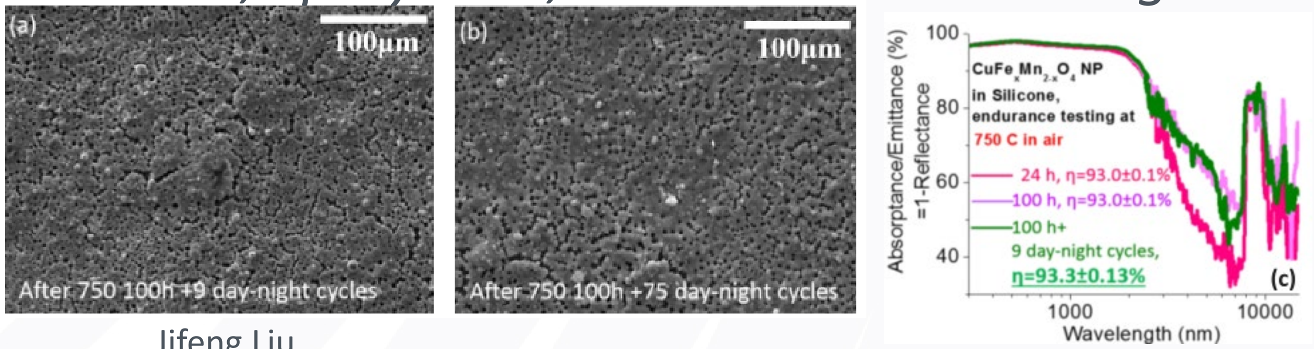
Innovation is Critical

Argonne National Laboratory
Binder Jet Add. Manf. with MAX Phase Mats.



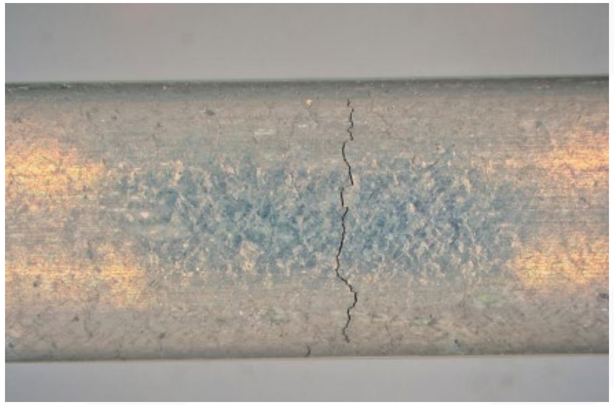
Dileep Singh

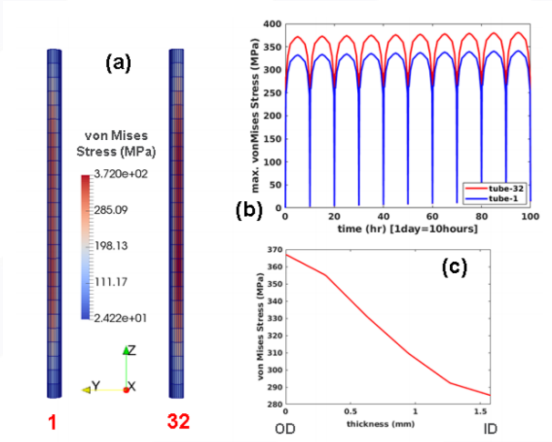
Dartmouth College
Stable, Spray-able, Solar Selective Coatings



Jifeng Liu

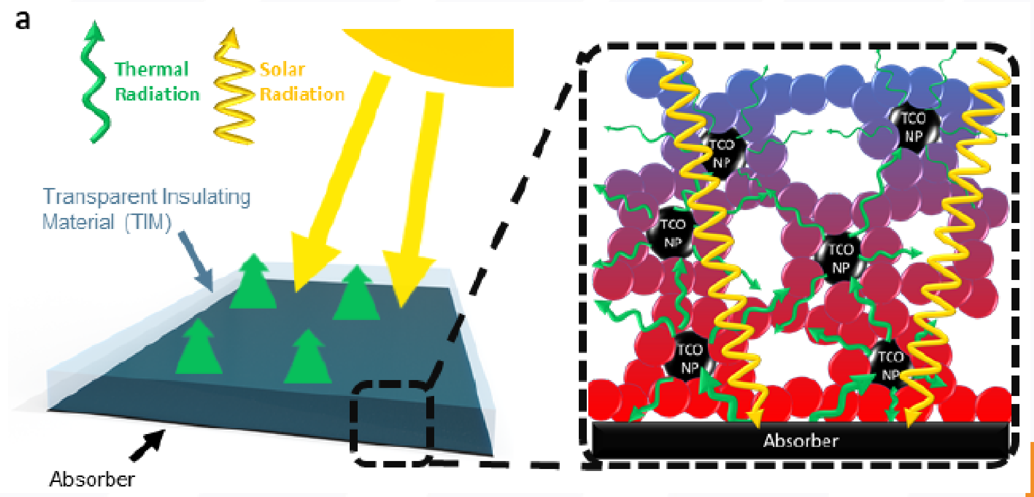
Idaho National Laboratory
Creep-Fatigue Behavior in Nickel Alloys





Mike McMurtrey

University of Michigan
Spectrally Selective Aerogels



Andrej Lenert

Agenda

Time	Session
1:00PM–1:30PM	**Introduction and Workshop Overview** Avi Shultz, *DOE Program Manager, Concentrating Solar Power* Matthew Bauer, *DOE Technology Manager, Concentrating Solar Power*
1:30PM–3:00PM	**Panel – First of a Kind Receiver Development for Gen3 CSP** Cliff Ho, *Sandia National Laboratories* Shaun Sullivan, *Brayton Energy* Craig Turchi, *National Renewable Energy Laboratory*
3:00PM–4:30PM	**Panel – Impactful R&D for Technology Adoption** Brian Fronk, *Oregon State University* Michael Wagner, *University of Wisconsin* Mark Messner, *Argonne National Laboratory* David Wait, *Nooter/Eriksen*
4:30 PM	**Closing Remarks** Matthew Bauer, *Department of Energy*


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

First of a Kind Receiver Development for Gen3 CSP

Cliff Ho SNL

2012: Particle Receiver / System

2015: Particle Mass Control

2018: Gen3 Particle Pilot Plant

Shaun Sullivan Brayton Energy

2012: Direct sCO_2 Receiver

2015: Metal Hydride Receiver/System

2018: Gen3 Gas System

Craig Turchi NREL

2012: sCO_2 Turbine Test

2015: CSP System Analysis

2018: Gen3 Liquid Pathway to SunShot

Panel 1 Themes (FOAK Gen3 Receivers)

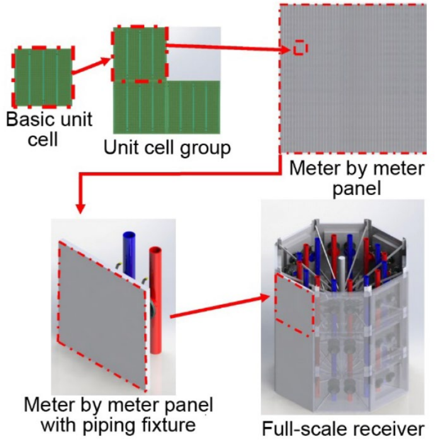
- When scaling innovations from lab-scale research to on-sun demonstration and to commercial scale deployments, what are the key risks that are often overlooked in the development process?
  - What overlooked technical metrics/objectives should be considered in both early and late stages of receiver R&D?
  - What accomplishments are needed to adequately de-risk a receiver for 10 MW demonstration and beyond?

- What innovations could impact, improve, or shift the paradigm for a Gen3 System's receiver?

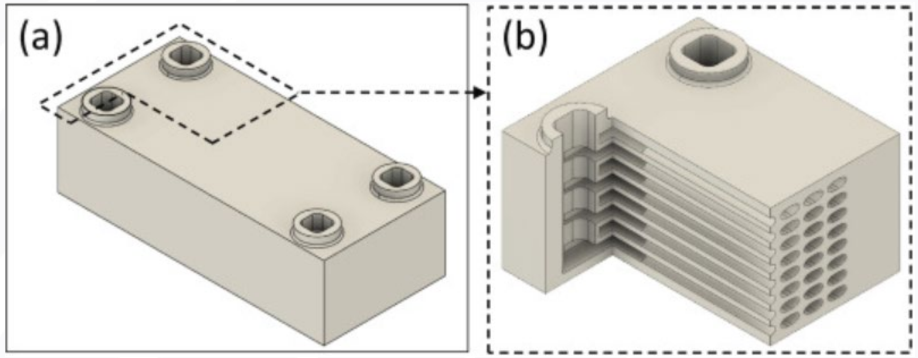
- How should a system integrator go about balancing constraints between the receiver and the remainder of the power plant?

Impactful R&D for Technology Adoption

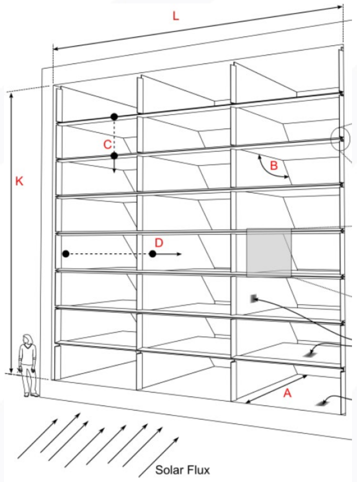
Brian Fronk Oregon State U.



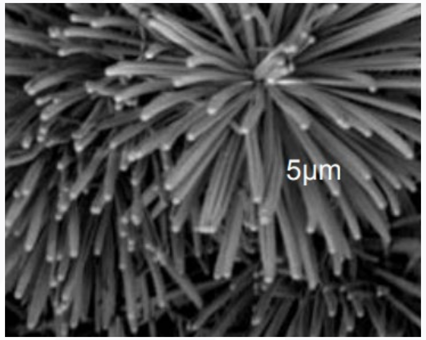
Mark Messner Argonne National Laboratory



Mike Wagner U. of Wisconsin



David Wait Nooter/Eriksen



Panel 2 Themes (Impactful Receiver R&D)

- When scaling innovations from lab-scale research to on-sun demonstration and to commercial scale deployments, what are the key risks that are often overlooked in the development process?
- How does one go about making an innovation bankable?
  - For a specified risk, how is an adequately de-risked handoff achieved?
  - What standards exist for proving and scaling up innovations?
- What risks exist physically interfacing a specified innovation with the remainder of the system? How are they overcome?

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