**Session XXX**

# Thermal Energy Storage: Gaps and Bridges for Concentrating Solar Power Technologies

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## Abstract

Implementation of thermal energy storage (TES) systems into concentrating solar power (CSP) technologies is paramount, not only to increase their capacity, but also to provide resilience during periods of time without sunlight. While there have been multiple lab-scale and pilot plants which have demonstrated the ability for TES systems to meet the power demand reliably, commercial scale CSP plants have struggled to meet the 24-hour demand. The US Department of Energy (DOE) has recently issued two main research calls with similar aggressive goals. The SunShot Initiative and the CSP Gen3 challenge, both which targets a 50% thermal-to-electric conversion efficiency,16-hour thermal storage, $0.06 kWh and a 30-year operating lifetime. Moreover, CSP technologies can be coupled with a TES system for water heating and HVAC applications. In this work, the state-of-the-art TES systems are reviewed and their techno-economical capabilities and limitations, for multiple applications such as water, HVAC, and power generation, are discussed.

## Background

Energy storage is a key to a renewable energy-powered world. For CSP systems, TES systems are the most cost-competitive alternative to store solar energy to meet the grid-load demand during off-sun hours. "This makes CSP with thermal energy storage (TES) an effective solution to the integration challenge, delivering renewable energy while providing important reliability and stability to the grid while also enabling increased penetration of variable renewable electricity technologies[1]." Currently, Nitrate molten-salt power towers such as Crescent Dunes (Figure 1) operate at temperatures up to 565°C which provide the energy to drive a steam-Rankine cycle[1,2]. However, in order to achieve the SunShot initiative goal of 50% power-conversion efficiency, CSP technologies will need to be coupled with a novel supercritical carbon dioxide ($sCO_2$) Brayton power cycle which is expected to operate at temperatures as high as 750°C[1,3]. Such higher temperatures will require alternative HTFs to today's molten Nitrate salts, which are limited to <600°C. The DOE Gen3 program aims to address these challenges and identify suitable heat transfer media (HTM), along with suitable solar receivers, to deliver these high temperatures.

Figure 1: Crescent Dunes Solar Energy Plant in Tonopah, Nevada (source: SolarReserve)


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## Gen3 CSP Program Discussion

In order to investigate the integration challenges of a CSP-TES system with a $sCO_2$ power cycle, the DOE has issued "The Generation 3 Concentrating Solar Power Systems (Gen3 CSP) funding program will build on prior research for high-temperature concentrating solar thermal power (CSP) technologies. Projects will focus on de-risking CSP technologies by advancing high-temperature components and developing integrated assembly designs with thermal energy storage that can reach high operating temperatures.[4]" The Gen 3 program is analyzing three potential paths to meet the requirements established.

**Gas-Phase Technologies**

This technology pathway seeks to achieve high thermal and thermodynamic system efficiency through the use of an inert gas-phase HTF within pressure-containing absorber and thermal storage geometries. Significant progress has been made on receiver design for high-pressure operation under the SunShot program, and multiple institutions have put forward designs that demonstrate viability by way of modeling, lab-scale, and on-sun testing activities. Nonetheless, this pathway relies on a TES integration with molten-salt or particle storage which poses an additional challenge to the heat exchange and conversion efficiencies.[1]

**Molten-Salt Technologies**

While molten-salt technologies represent the most familiar path toward the Gen3 goals, knowledge around the selection of a high-temperature molten salt is needed, especially with regard to materials that are can operate at high-temperatures while maintaining acceptable strength, durability, and cost targets; especially, in regards to the corrosion mechanisms, which vary among candidate salts.[1]

**Particle Technologies**

While many of the components in the particle-based CSP system are mature and have been developed by industry, the unique application for solarized $sCO_2$ systems at high temperatures and high $sCO_2$ pressures ($\geq$ 20 MPa) does provide some unique challenges. Specifically, the transport and heating of the particles with concentrated sunlight poses additional challenges related to efficient particle heating, flow control and containment, erosion and attrition, and conveyance.[1]

Based on current knowledge of the three power tower technologies, all three paths have the potential to achieve the SunShot goals. Further development, modeling, and testing is currently undergoing by Universities and National Laboratories throughout the US, along with many international partners. The expectation for this on-going research is to bring the technologies to a stage where integrated system tests and pilot demonstrations are possible and realistic.

## References


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