DOE CSP R&D:
Storage Award Overview

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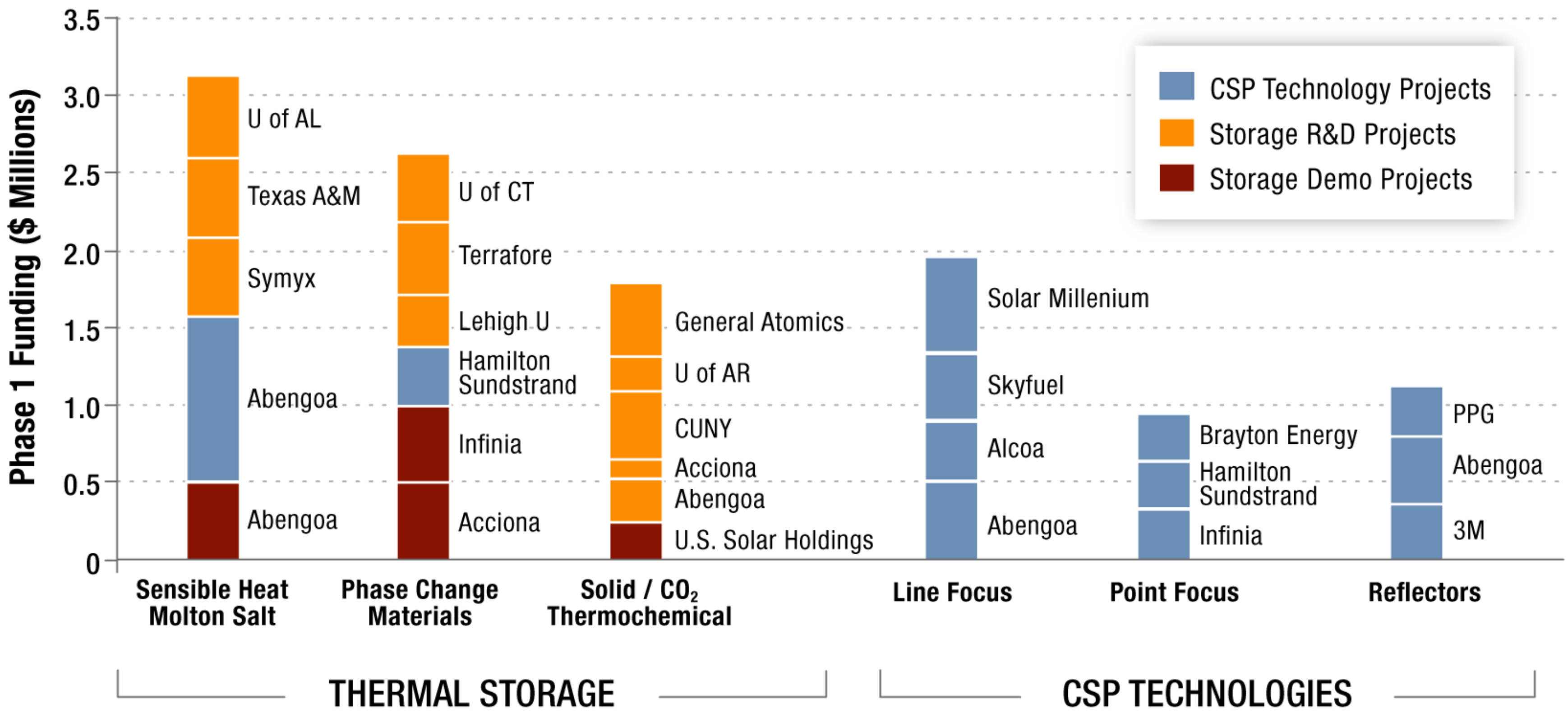
DOE CSP R&D: Industry/University Awards



Storage Breakdown

- Sensible Heat – Molten Salt
  - University of Alabama – Development of low melting point molten salts with high energy storage density
  - Texas A&M – Creation of composite thermal energy storage material using nanoparticles embedded in a molten salt base material
  - Symyx/Halotechnics – Investigation of complex mixtures of inorganic salts to discover low freezing point formulations to be used as heat transfer fluids
  - Abengoa – Identification and demonstration of near-term TES systems for parabolic trough systems
  - Abengoa – Development of technologies required to allow low freeze point molten salts to be used in parabolic trough solar fields

Storage Breakdown

- Phase Change Materials
    - University of Connecticut – Development of a TES system using embedded heat pipes or thermosyphons to reduce thermal resistance of a phase change material
    - Terrafore – Development of a PCM-based TES system using inorganic salts
    - Lehigh University – Investigation of encapsulated phase change materials capable of being used at high temperatures for large scale TES
    - Infinia – Development of a TES system that interfaces with Infinia's commerical dish-Stirling system that utilizing an inorganic salt as a PCM with imbedded heat pipes to increase system thermal conductivity
    - Acciona – Design, validate with a prototype, and then demonstrate an 800MWh$_{th}$ TES system based upon a PCM TES module

Storage Breakdown

- Solid/CO_2/Thermochemical
  - General Atomics – Explore the feasibility of using thermochemical cycles to store heat
  - University of Arkansas – Development of novel concrete materials that can withstand temperatures of 500^{o}C and develop novel techniques to increase heat transfer
  - CUNY – Demonstration of cyclic absorption of heat from either steam or CO_2
  - Acciona – Development of a direct TES system using pressure containment vessels filled with a solid state storage material
  - US Solar – Commercially demonstrate utility-scale thermal storage utilizing either a thermocline or sand-shifter technology

Storage Breakdown

- 2009 ARRA Lab Call
  - ANL – Development of advanced HTFs by incorporating multifunctional engineered nanoparticles in a HTF
  - LANL – Development of a thermally stable working fluid integrated with chemical reactions to store large amounts of latent heat
  - NREL – Explore new metallic, polymetallic or alloy, and inorganic salt nanoparticles coupled with innovative encapsulation strategies
  - ORNL – Demonstrate the possibility of using substituted polyaromatic hydrocarbons for a solar heat transport application
  - PNNL – Development and commercialization of thermochemical energy storage technologies for CSP systems based on parabolic dish concentrators and Stirling Cycle heat engines
  - SRNL – Enhance the heat transfer and solar thermal energy collection by dispersing small volume percentages of nanoparticles into ionic liquid carriers, creating Nanoparticle Enhanced Ionic Liquids

Terrafore

Heat Transfer and Latent Heat Storage in Inorganic Molten Salts for Concentrating Solar Power Plants

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Description

- This project aims to reduce costs of TES systems to <$25/kWh$_{th}$ by using a PCM salt in a thermocline storage system.

Innovative features

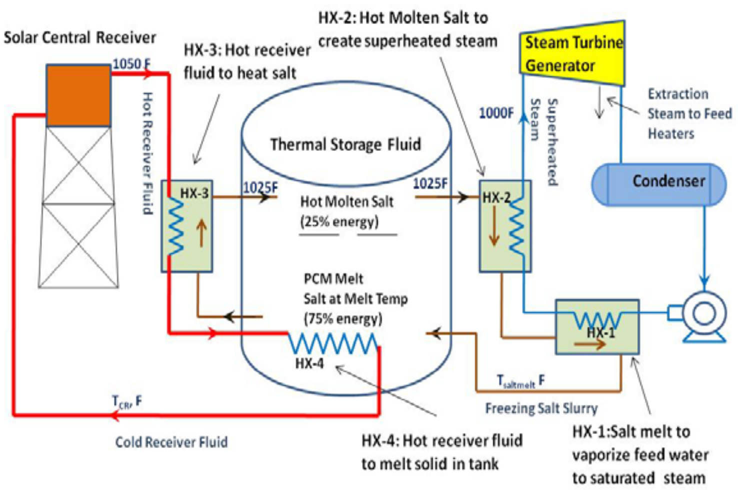
- The proposed storage method utilizes a “dilute eutectic” salt mixture, which allows the salt to maintain a slurry-like consistency when cold.
- To avoid heat transfer penalties that occur when solid salt forms on the heat exchanger surface, Terrafore is working with JPL to develop a coating that prevents solid salt from sticking to the heat exchanger surface.

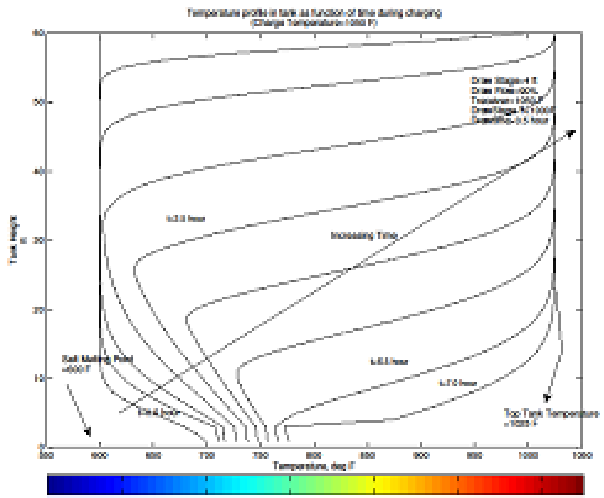
Progress

- After a literature search of over 700 candidate salt compounds, four “dilute eutectic” salt candidates have been selected that meet project requirements for
  - High energy density
  - Low specific cost (Target TES cost <$25/kWh$_{th}$)
  - Salt Operating Temperature Range: Melting Point to 560°C
  - Easy to handle, low toxicity and good resistance to corrosion to steel container
- Have identified 13 candidate coating for the heat exchanger and performed qualitative testing on them. Two have been selected for further testing in Phase 2.
- Preliminary work investigating active thermocline management has been performed.

Resources

- Total Project: $1.83M
  - DOE Funds: $1.44M
  - Cost Share: $394k





Molten Salt-Carbon Nanotube Thermal Energy Storage for Concentrating Solar Power Systems

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Description

- The objective of this project is to create a composite thermal energy storage material using nanoparticles embedded in a molten salt base material, characterize the thermophysical properties of the composite material, and assess the utility of the composite material in a concentrating solar power application.

Innovative features

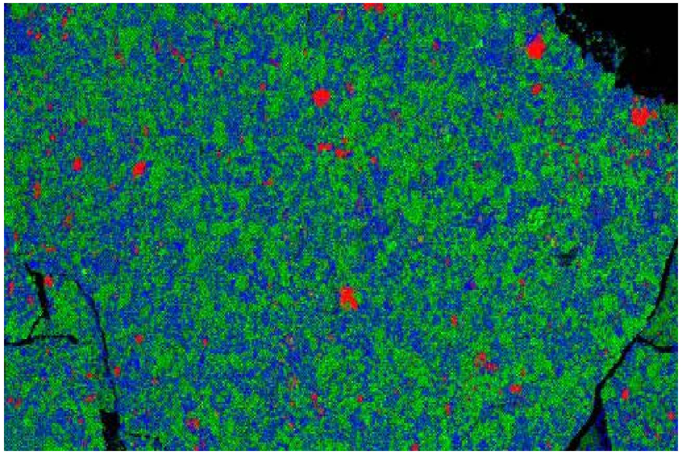
- This project is looking at embedding nanoparticles into molten salt base fluids to improve fluid heat capacity and thermal conductivity.

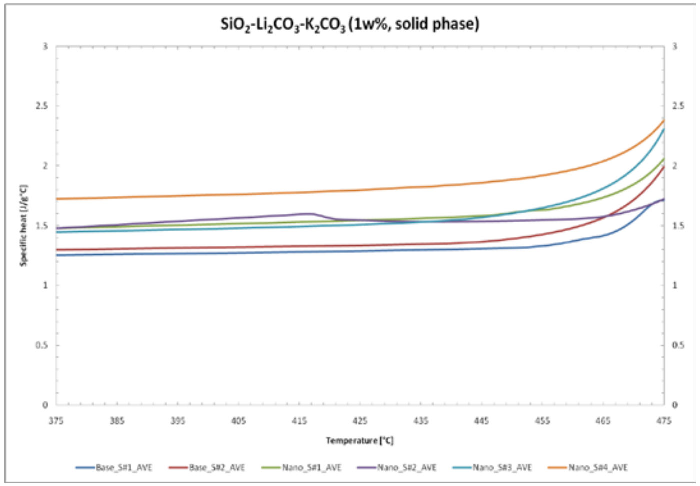
Progress

- A literature search was done to look for possible base and nanoparticle materials for use in high temperature applications.
- A variety of base and nanoparticle material mixtures have been researched to examine the heat capacity improvements that can be achieved with these various combinations. Heat capacity improvements of 10-75% have been observed thus far.
- Four separate methods of nanoparticle fluid creation have been examined. The combined heat and reduced pressure method and drop-by-drop method of incorporating nanoparticles into the base fluid have been found to sufficiently disperse the nanoparticles in the base material.

Resources

- Total Project: $1.88M
  - DOE Funds: $1.5M
  - Cost Share: $375k





Description

- The goal of the project is to explore the feasibility of using thermochemical (TC) cycles to store heat from a concentrated solar power (CSP) plant.

Innovative features

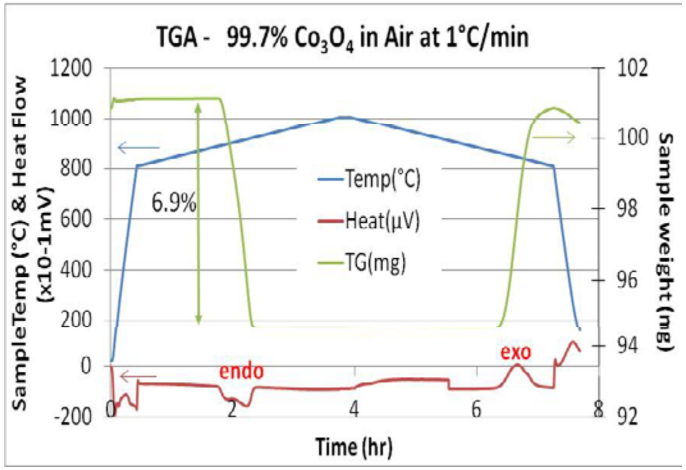
- Thermochemical heat storage is used to store energy. The proposed thermochemical cycles are all redox reactions of metal oxides.

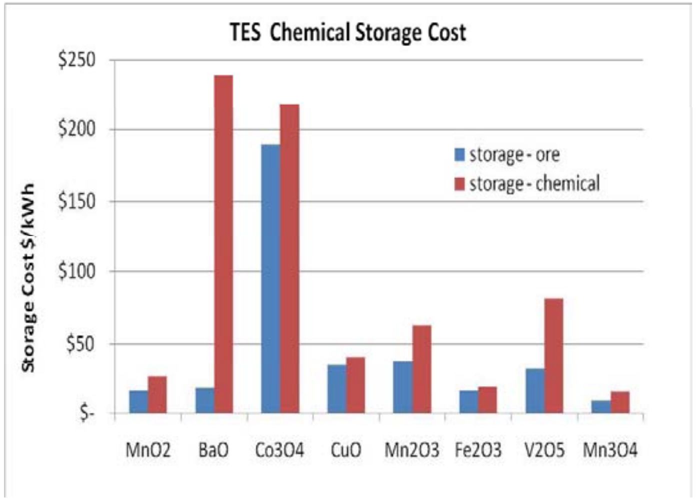
Progress

- Using software and literature research, hundreds of metal oxide cycles have been researched, and 5 have been selected for further research. Cycles were selected based upon potential to meet DOE cost targets for TES (<$15/kWhth). The cycles selected for further research are:
    - MnO_2
    - Mn_2O_3
    - Mn3O4
    - BaO
    - Fe2O3
- Initial kinetic results have been poor for all but one investigated cycle that was too expensive to use in a large scale TES system, but an alloying method has been researched as a possibility to improve kinetics. Initial test results are promising.

Resources

- Total Project: $2.43M
    - DOE Funds: $1.5M
    - Cost Share: $933k





Thank You

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