DOE CSP R&D:
Storage Award Overview

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DOE CSP R&D: Industry/University Awards

U.S. Department of Energy Solar Energy Technologies Program
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 commercial 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\textsubscript{th} TES system based upon a PCM TES module
Storage Breakdown

- Solid/CO₂/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°C and develop novel techniques to increase heat transfer
  - CUNY – Demonstration of cyclic absorption of heat from either steam or CO₂
  - 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

Description
• This project aims to reduce costs of TES systems to <$25/kWhth 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/kWhth)
  • 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
Texas A&M
Molten Salt-Carbon Nanotube Thermal Energy Storage for Concentrating Solar Power Systems

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:
  • MnO₂
  • Mn₂O₃
  • 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