U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

Solar Energy Technologies Program

DOE Concentrating Solar Power 2008 Funding Opportunity Project Prospectus

"Advanced Heat Transfer Fluids and Novel Thermal Storage Concepts for Concentrating Solar Power Generation"

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Solicitation Objectives

U.S. DEPARTMENT OF ENERGY

The Funding Opportunity Announcement identifies and supports long-term research and development (R&D) activities and near-term demonstration in two areas that may increase the efficiency and reduce the cost of concentrating solar power (CSP) systems to make them cost competitive:

1. **Improved Heat Transfer Fluids (Advanced HTF)**
   - **Identify and characterize novel fluids or fluid types that possess the physical and chemical properties required for an improved HTF and thermal storage fluid for CSP technologies**

2. **Novel Thermal Energy Storage Concepts (Novel TES Systems)**
   - **Generate and evaluate novel concepts for thermal energy storage (TES) that have the potential to reduce the cost of TES to less than $15/kW$_{thermal}$ and achieve round trip efficiencies greater than 93%.**
   - **Work in TES may be applicable to any or all CSP technologies (parabolic trough, power tower, linear Fresnel, or concentrating dish)**

Concentrating Solar Power Project Selections

Topic 1 – Advanced Heat Transfer Fluids Research and Development

Symyx Technologies

"Deep Eutectic Salt Formulations Suitable as Advanced Heat Transfer Fluids"

Technologies Addressed

Advanced Heat Transfer Fluids (HTF)

Project Description

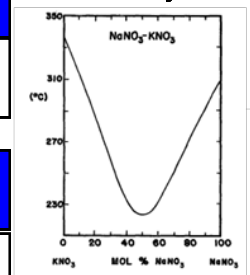
Combinatorial screening of salt mixtures with four or more components. Candidate mixtures will exhibit reduced freezing point and higher thermal stability than currently available HTF.

DOE Goals Served

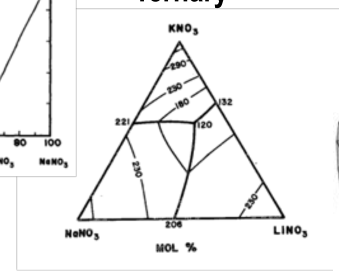
LCOE / Innovative CSP technologies

LCOE Impact Up to 15% reduction

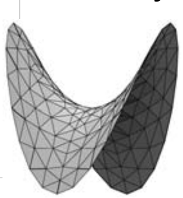
Binary



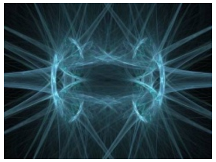
Ternary



Quaternary



Complex formulation



Project Participants

Symyx Technologies / Sunnyvale, CA

Sandia / Albuquerque, NM

Resources ($)

Total Project	DOE Funds	Cost Share
$2,635K	$1,500K	$1,135K

Concentrating Solar Power Project Selections

Topic 3 – Thermal Energy Storage Research and Development

General Atomics

U.S. DEPARTMENT OF ENERGY

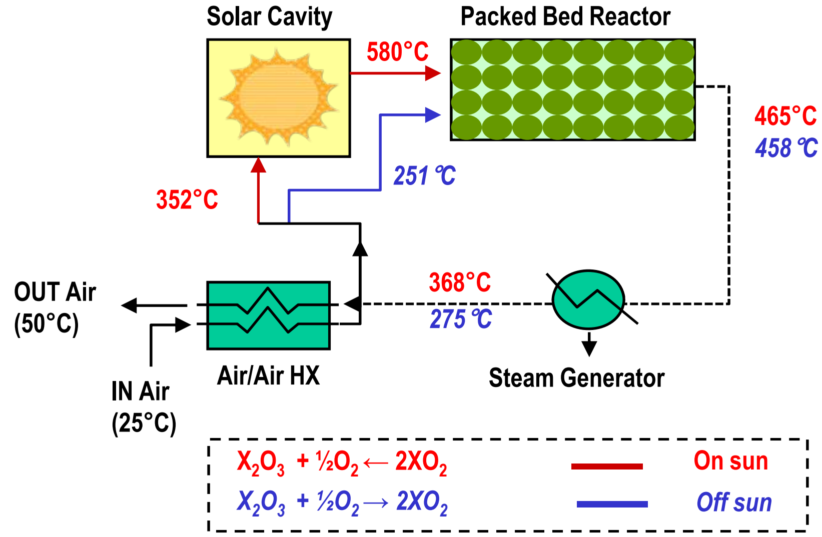
"Thermochemical Heat Storage for Concentrated Solar Power"

Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

Utilizing CSP heat to conduct the reduction step of a REDOX reaction and store solar energy in chemical bonds. Heat is released via materials oxidation with air at elevated temperature.



DOE Goals Served

LOCE & Thermal Energy Storage

Project Participants

German Aerospace Center (DLR)

LCOE Impact	<$0.07/KWh

Resources ($)

Total Project	DOE Funds	Cost Share
$2,434K	$1,500K	$934K

University of Connecticut

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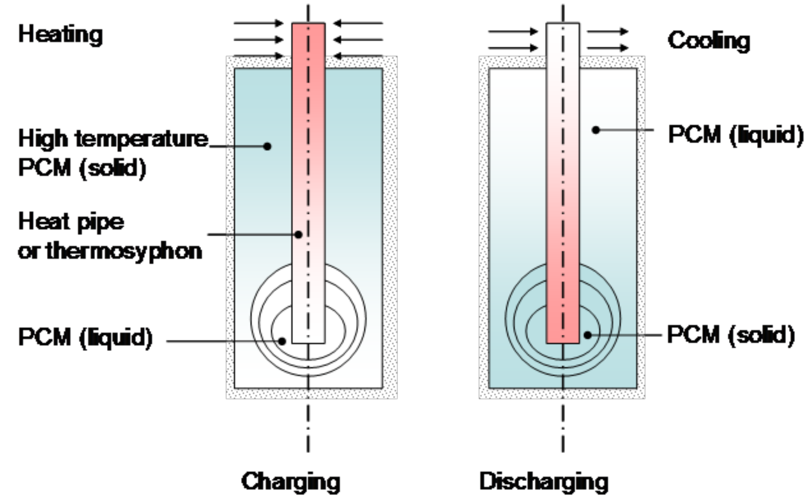
"Novel Thermal Energy Storage for Concentrating Solar Power"



Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

Improve the performance of thermal energy storage systems involving phase change materials by incorporating thermosyphons or heat pipes to reduce the resistance to heat transfer.

DOE Goals Served

LCOE / Thermal Energy Storage / Innovative CSP technologies

LCOE Impact Up to 6¢ / kWh

Project Participants

Thermacore, Inc. / Lancaster, PA

Aavid Thermalloy / Concord, NH

Hamilton Sundstrand Rocketdyne / Canoga Park, CA

Resources ($)

Total Project	DOE Funds	Cost Share
$1,687K	$1,290K	$397K

University of Arkansas

U.S. DEPARTMENT OF ENERGY

"Development and Performance Evaluation of High Temperature Concrete for Thermal Energy Storage"

Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

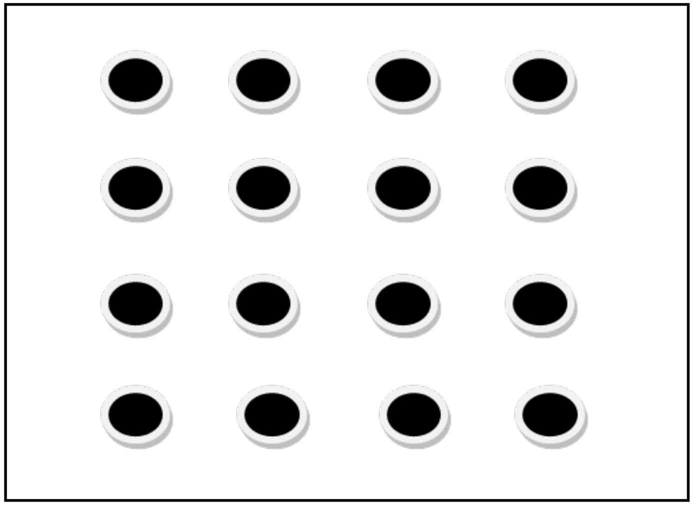
Develop high performance concrete to store thermal energy. Novel methods to transport heat will be implemented and tested to reduce the charging in time as well the storage cost by increasing the range of temperature

DOE Goals Served

LCOE / Thermal Energy Storage / Innovative CSP technologies

LCOE Impact

Potential to achieve 2015 target- $0.07/kWh



Ultra High performance concrete (UHPC) with steel tubes

Project Participants

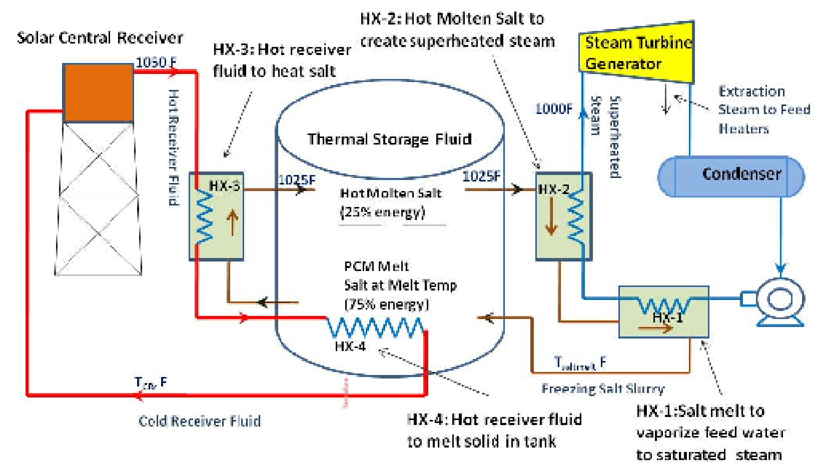
NA

Resources ($)

Total Project	DOE Funds	Cost Share
$770K	$616K	$154K

Terrafore, Inc.

“Heat Transfer and Latent Heat Storage in Molten Salts for Concentrating Solar Power (CSP) Plants”



PCM-based TES reduces container size by 37% to 56%

Technologies Addressed

Novel Thermal Energy Storage (TES) for Power Tower, Trough, Linear Fresnel

Project Description

- Develop solutions to two main technology barriers for using Phase Change Material (PCM) for TES:
- Improve heat transfer during solidification or recovery of stored heat
- Identify economical, acceptable salt mixtures with melting points in the range of 275^{o}C to 450^{o}C

DOE Goals Served

LCOE/ Thermal Energy Storage/ Innovative CSP Technologies

LCOE Impact

6% reduction in LCOE

Project Participants

Terrafore, Inc. / Riverside, CA
University of California / Riverside, CA
Hamilton Sundstrand/Rocketdyne / Canoga Park, CA
Jet Propulsion Laboratory / Pasadena, CA

Resources ($)

Total Project	DOE Funds	Cost Share
$1,834K	$1,439K	$395K

ABENGOA SOLAR INC

U.S. DEPARTMENT OF ENERGY

"Advanced Thermal Energy Storage for Central Receivers with Supercritical Coolants"

Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

Identify preferred combination of Rankine cycle (subcritical or supercritical), receiver coolant (nitrate salt, supercritical steam, or supercritical CO_2), and thermal storage (hot/cold tank or thermocline)

DOE Goals Served

LCOE / Thermal Energy Storage / Innovative CSP technologies

LCOE Impact	Reduction of 10%

Project Participants

Abengoa Solar Inc / Lakewood, CO
Abenecs / Chesterfield, MO
Tietronix Software, Inc / Houston, TX

Resources ($)

Total Project	DOE Funds	Cost Share
$1,943K	$1,105K	$838K

Lehigh University

"Novel Thermal Storage Concepts for Concentrating Solar Power Generation"

Technologies Addressed

Novel Thermal Energy Storage (TES)

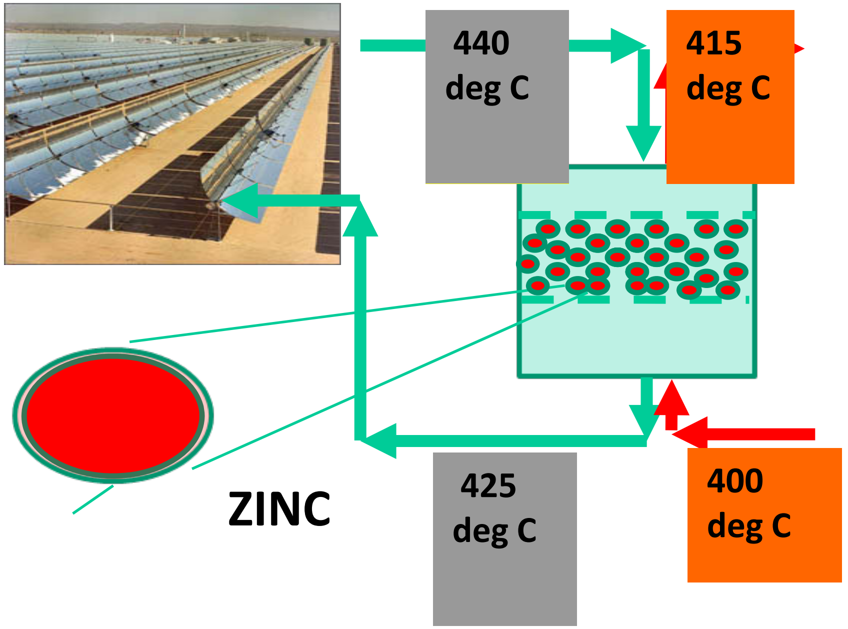
Project Description

The proposed R/D focuses on developing encapsulated phase-change material (EPCM; Zn in Nickel, Salts in SS) in spherical or tubular forms, either of which would be assembled into heat exchangers for thermal exchange.

DOE Goals Served

LCOE / Thermal Energy Storage / Innovative CSP technologies

LCOE Impact	$0.12 / kWh



Project Participants

Lehigh University / Bethlehem, PA

Resources ($)

Total Project	DOE Funds	Cost Share
$1,497K	$1,103K	$394K

The Research Foundation of CUNY - The City College

"A Novel Storage Method for Concentrating Solar Power Plants Allowing Operation at High Temperature"

Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

Development and testing of a novel storage method that can be applied to all existing CSP technologies. The design proposed substantially extends both upper and lower operating temperature constraints, which allows reduction of the costs below the cost goals fixed by DOE.

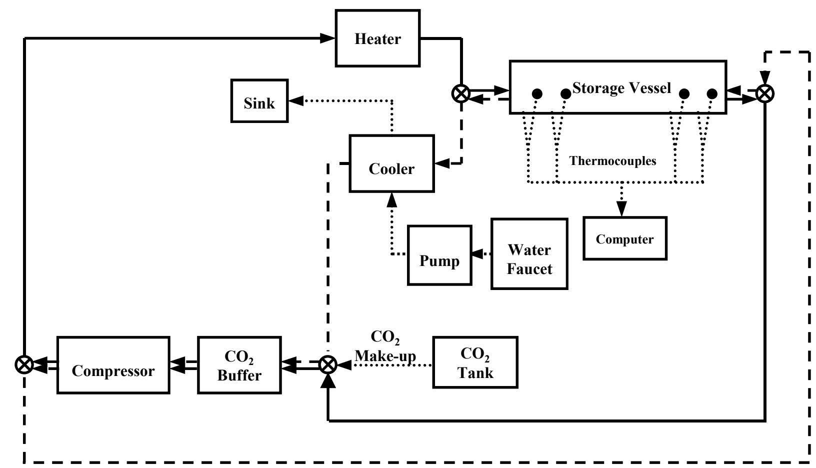
DOE Goals Served

LCOE / Thermal Energy Storage

LCOE Impact	< $15/KWh thermal

Figure 3.a: CSP Storage with CO_2

___ : Heat Storage Cycle _ _ : Heat Recovery Cycle



Project Participants

The City College of CUNY / New York, NY

Resources ($)

Total Project	DOE Funds	Cost Share
$1,904K	$1,328K	$576K

Acciona Solar Power

U.S. DEPARTMENT OF ENERGY

"Sensible Heat, Direct, Dual-Media Thermal Energy Storage Module"

Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

Design and validate, at prototype level, a reliable, unsophisticated, and scalable sensible heat Thermal Energy Storage module with round trip efficiency in excess of 93%.

DOE Goals Served

LCOE / Thermal Energy Storage

LCOE Impact	Potential to meet DOE 2015 cost target

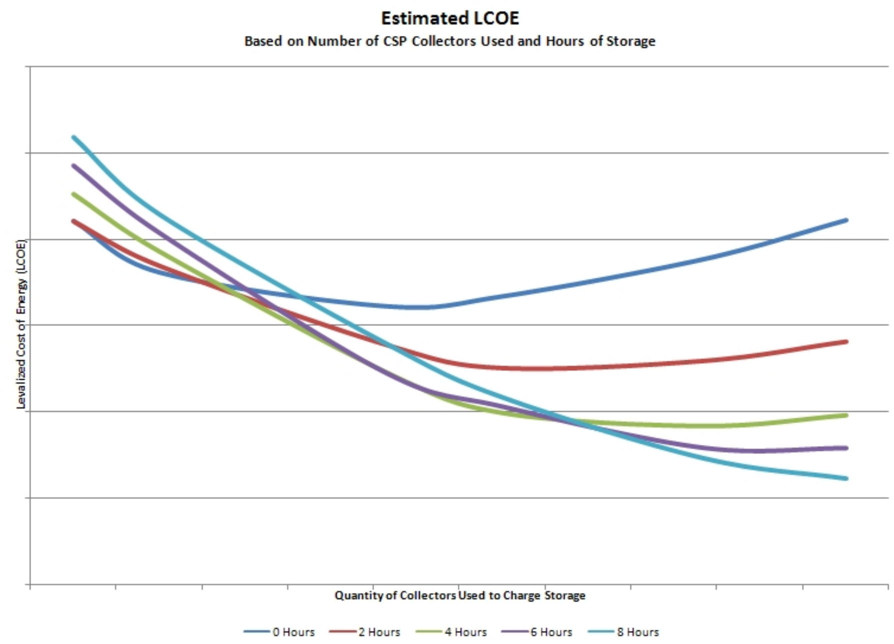


Figure 1 – Estimated LCOE Based on Hours of TES

Resources ($)

Total Project	DOE Funds	Cost Share
$687K	$550K	$137K

The University of Alabama

U.S. DEPARTMENT OF ENERGY

"Novel Molten Salts Thermal Energy Storage for Concentrating Solar Power Generation"

Technologies Addressed

Novel Molten Salts Thermal Energy Storage (TES)

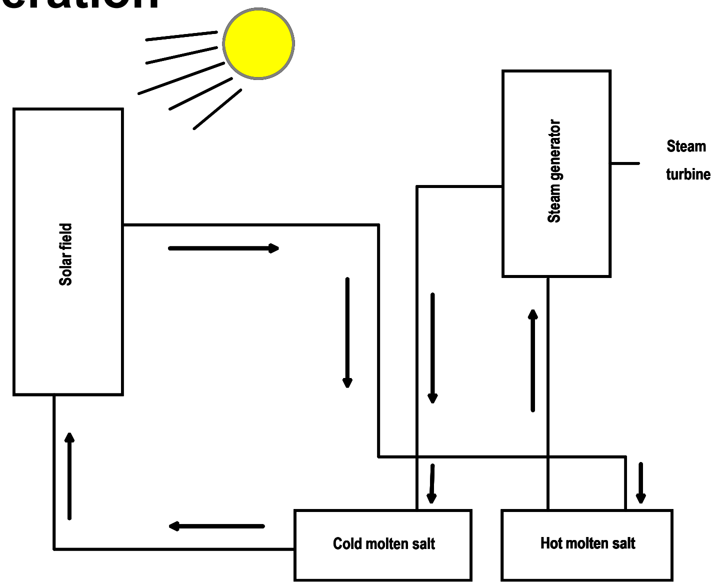
Project Description

Determine and characterize a novel low melting point molten salts mixture to increase the thermal energy density and lower the power generation costs.

DOE Goals Served

Thermal Energy Storage

LCOE Impact	> 50% in storage



Project Participants

United Technologies Research Center (UTRC)/ East Hartford, CT

Resources ($)

Total Project	DOE Funds	Cost Share
$1,895K	$1,500K	$395K

Texas A&M University

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

Technologies Addressed

Novel Thermal Energy Storage (TES)

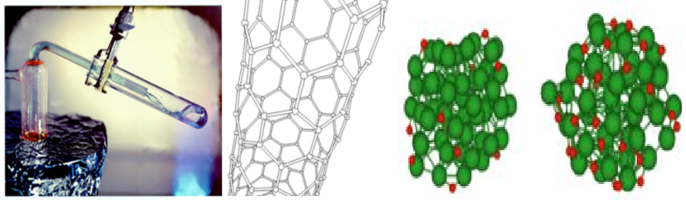
Project Description

Lower capital costs and improve system availability by creating molten salt-nanoparticle hybrids to improve the heat capacity and thermal conductivity of the thermal energy storage medium.

DOE Goals Served

LCOE / Thermal Energy Storage / Innovative CSP technologies

LCOE Impact	TES < $15/KWh(thermal)



Project Participants

Texas A&M University

College Station, Texas

Resources ($)

Total Project	DOE Funds	Cost Share
$1,875K	$1,500K	$375K

Concentrating Solar Power Project Selections

Topic 4 – Thermal Energy Storage Near-Term Demonstration

US SOLAR

U.S. DEPARTMENT OF ENERGY

"CSP Energy Storage Solutions – Multiple Technologies Compared"

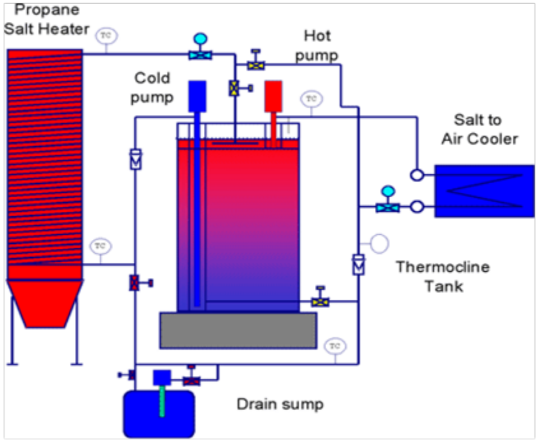


Figure 2. Thermocline test at Sandia National Laboratories. *Credit: Sandia National Laboratories*

Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

Side-by-side development and comparison of two thermal energy storage technologies: 1) Re-"proof" and refinement of oil-based thermocline. 2) Use of sand for TES, "Sand Shifter".

DOE Goals Served

Thermal Energy Storage

LCOE Impact

Potential to achieve DOE 2015 cost target

Project Participants

US Solar, Arizona Public Service, University of Arizona, Georgia Tech, Arizona State University, Klondyke Construction, IronCo Renewables.

Resources ($)

Total Project	DOE Funds	Cost Share
$4,356K	$2,038K	$2,318K

ABENGOA SOLAR INC

U.S. DEPARTMENT OF ENERGY

"Reducing the Cost of Thermal Energy Storage for Parabolic Trough Solar Power Plants"

Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

Evaluate several topologies for parabolic trough plants with storage, performing cost comparisons to determine relative advantages. Select two topologies for development into demonstrator systems.

DOE Goals Served

Identify opportunities for cost reduction in near-term TES systems.

LCOE Impact	Reduction of 10%

Project Participants

Abengoa Solar Inc / Lakewood, CO
Abenecs / Chesterfield, MO

Resources ($)

Total Project	DOE Funds	Cost Share
$12,498K	$6,999K	$5,499K

INFINIA

U.S. DEPARTMENT OF ENERGY

"Innovative Application of Maintenance-Free Phase-Change Thermal Energy Storage for Dish Engine Solar Power Generation"

Technologies Addressed

Development and demonstration of Novel Thermal Energy Storage (TES) Integrated with Infinia's solar dish Stirling Engine System

Project Description

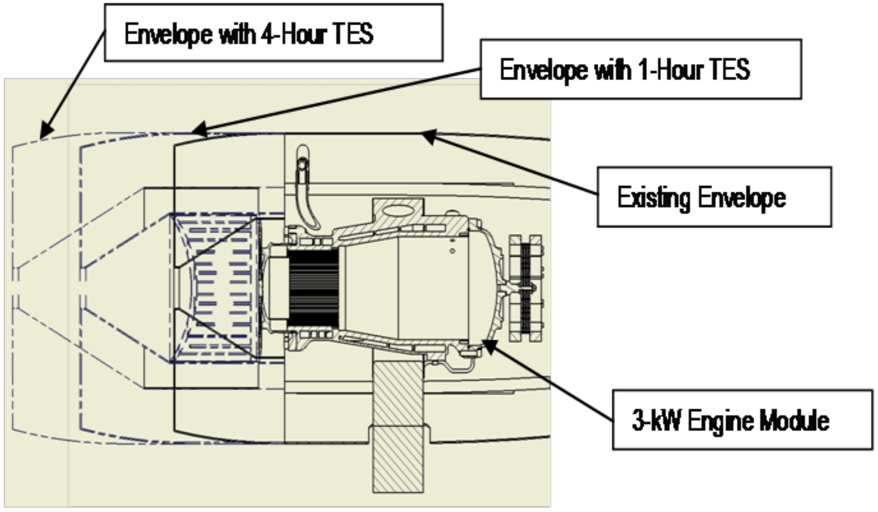
The TES system uses proven, stable thermal salts to store energy by utilizing both latent heat and sensible heat of a phase change salt. The salt is directly coupled to the Stirling engine locally, allowing for a maintenance free, long-life solution with no pumping. The project will culminate in the fielding of 40+ systems

DOE Goals Served

Develop advanced TES to support the goal of reaching system LCOE of $0.07/kWh

LCOE Impact

20% and greater



Project Participants

Thermacore / Lancaster, PA

Applied Research Laboratory / College Station, PA

L. Barry Penswick, Consultant / Stevenson, WA

Resources ($)

Total Project	DOE Funds	Cost Share
$9,361K	$5,423K	$3,938K

Acciona Solar Power

"Indirect, Dual-Media, Phase Changing Material, Modular Thermal Energy Storage System"

Technologies Addressed

Novel Thermal Energy Storage (TES)

Project Description

Design, validate at prototype level, and than demonstrate a full size, 800 $MW_{thermal}$, 4 hour, TES system based on Phase Changing Material modules, with round trip system efficiency in excess of 93%.

DOE Goals Served

LCOE / Thermal Energy Storage

LCOE Impact	Potential to meet DOE 2015 cost target

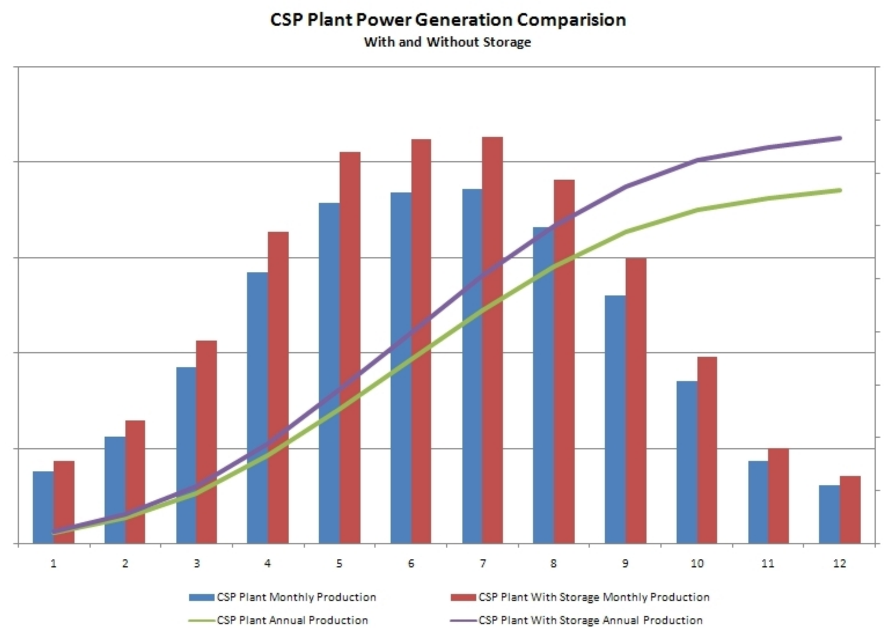


Figure 1 - Comparison plot of a CSP plant without TES and a CSP Plant with TES.

Resources ($)

Total Project	DOE Funds	Cost Share
$22,500K	$7,000K	$15,500K

Thank You

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