DOE Concentrating Solar Power 2007 Funding Opportunity Project Prospectus

DOE Solar Energy Technologies Program

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Enabling a New Vision for Concentrating Solar Power: GigaWatt-Scale Facilities for Clean Electricity

- **Although improvements in levelized cost of energy (LCOE) will allow CSP to reach 5 – 7 cents/kWh and compete with traditional generation technologies, at today's 12-14 cents/kWh it is too expensive**
- **The Southwest United States has some of the best resources in the world for generating Concentrating Solar Power (CSP)**

- **Concentrating Solar Power currently has the capacity to generate power at the utility scale**
- **Innovative thermal storage technology will enable solar energy generation day and night, a capability desired by utilities**

DOE's Roadmap for CSP will develop GW-scale technologies and support market development

Technology		FY2008-FY2010	FY2011-FY2014	FY2015-FY2020
Trough Systems		Establish/expand U.S. supplier base through manufacturing initiative, optical testing to optimize receiver and concentrator designs	Develop next-generation system capable of 450°C operation integrated with molten-salt storage.	Develop advanced collectors, receivers, selective coatings, and working fluids designed to operate at 550°C.
Advanced Technology Systems		Evaluate new concepts (e.g. CLFR, distributed power tower), test components, develop dish technology designed for mass production	Down-select best options, support prototype designs, identify key technology improvement opportunities.	Integrate high temperature CSP systems with advanced gas turbine/CC technology, reduce system cost through RD&D and manufacturing initiative.
Thermal Storage		Develop thermocline thermal storage, evaluate two-tank molten salt system, develop new storage medium and heat transfer fluids	Adapt storage system to advanced technology design, address cost, performance, operation and O&M issues	Develop advanced thermal storage up to 550°C for troughs and up to 1200°C for advanced CSP/CC technologies.

Supporting Market Transformation Activities:

- Support State and utility deployment efforts
- Work with Loan Guarantee Program to adapt loan guarantees to industry business process
- Work with BLM, State and local governments to mitigate land and permitting barriers
- Provide resource assessment to industry and utilities
- Provide analyses supporting CSP access to transmission

Concentrating Solar Power Solicitation Objectives

Lay the framework to exceed DOE goals through advanced CSP concepts

- Applicants may propose either an entire system or focus on a component of a CSP system.
- Objective is to identify and develop new approaches that could dramatically lower the cost of CSP.
- Enable new technologies to position CSP to be the economical solution for baseload national energy consumption post 2015

Provide funding to develop thermal storage technology to increase the dispatchability of CSP technology within the electricity grid.

- Develop low cost, high temperature storage that enables trough technology to reach its 2020 cost goal.
- To achieve the goal, storage cost of less than $15/kWh thermal is desired with round trip efficiencies at or greater than 93%.

Establish a United States based manufacturing infrastructure for low cost CSP trough components.

- Lower the cost of major components of a trough system and to establish manufacturing capability of those components in the United States.

CSP Project Selection Summary

Projects will develop and deploy innovative CSP technologies that address market barriers for utility-scale generation of electricity.

Projects include diverse technological approaches:

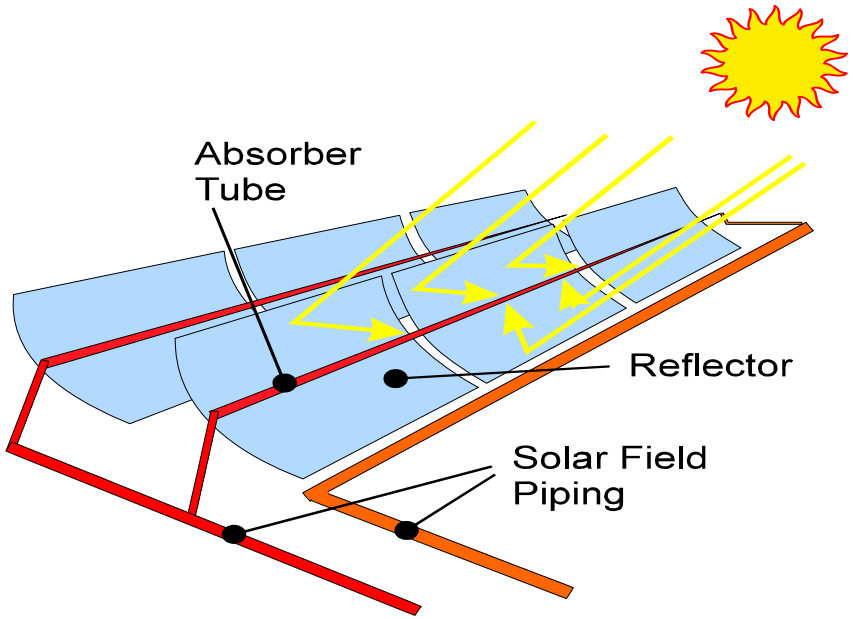
- **Parabolic trough technology**
- **Power tower technology**
- **Dish engine system technology**
- **Advanced linear Fresnel technology**
- **Thermal energy storage and transport liquids**
- **U.S. manufactured, advanced low cost mirrors**
- **U.S. manufactured, low cost collector structures**

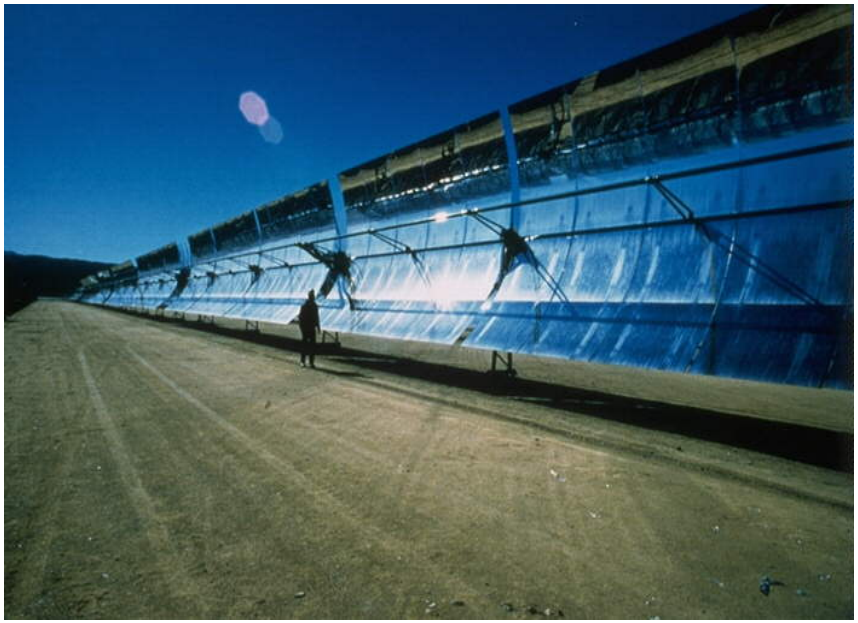
DOE Cost Targets for CSP

- **5 – 7 cents/kWh with 6 hours thermal storage by 2015**
- **5 cents/kWh with 12-17 hours thermal storage by 2020**

Concentrating Solar Power Technology Descriptions

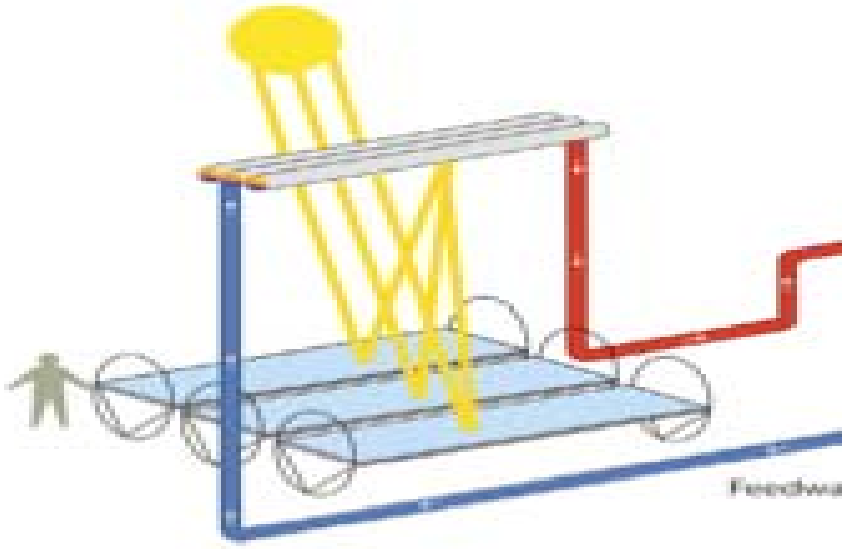
Parabolic Trough Technology





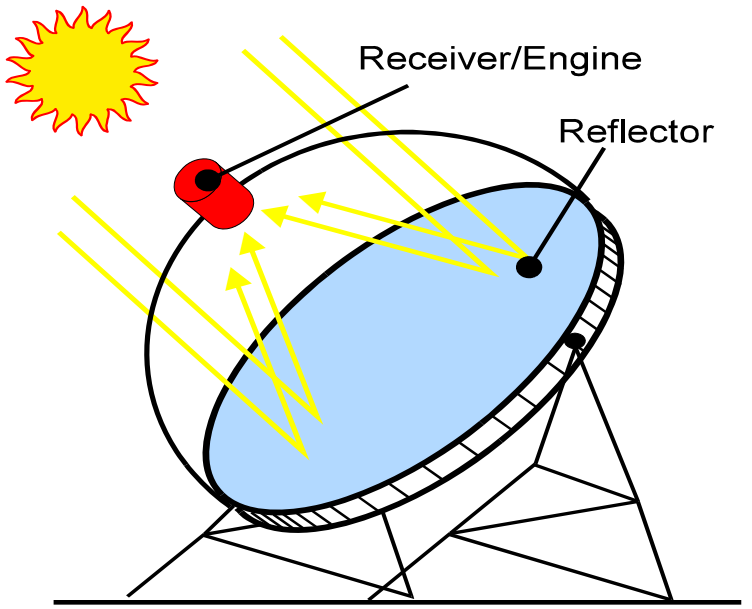
- A long parabolic mirror with a absorber tube running its length at the focal point.
- Sunlight is reflected by the mirror and concentrated on the absorber tube. The trough is usually aligned on a north-south axis, and rotated to track the sun.
- Heat transfer fluid (oil or molten salts) runs through the tube to absorb the concentrated sunlight. The heat transfer fluid is then used to heat steam in a traditional turbine generator.
- Trough systems are sensitive to economies of scale and are estimated to be most cost effective around 250+MW.

Linear Fresnel Trough Technology



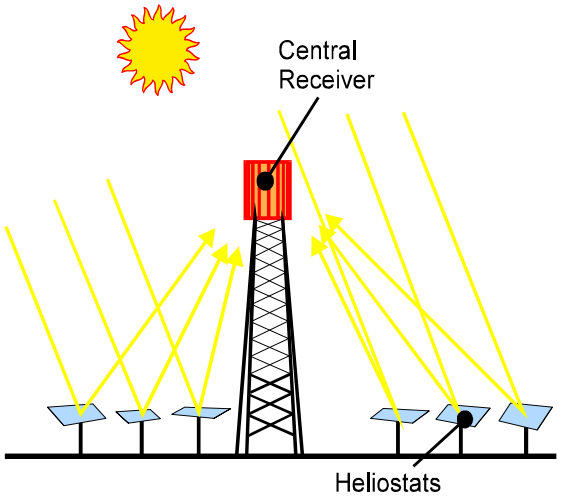
- A linear Fresnel power plant uses a series of long, narrow, shallow-curvature mirrors to focus light onto one or more linear absorbers positioned above the mirrors and generates power using a traditional steam turbine.
- These systems aim to offer lower overall costs by sharing a heat-absorbing element between several mirrors while still using the line-focus geometry that allows reduced complexity in the tracking mechanism.
- The absorber is stationary and so fluid couplings are not required. The mirrors also do not need to support the absorber, so they are structurally simpler. When suitable aiming strategies are used, this can allow a denser packing of mirrors on available land area.

Dish Engine System Technology



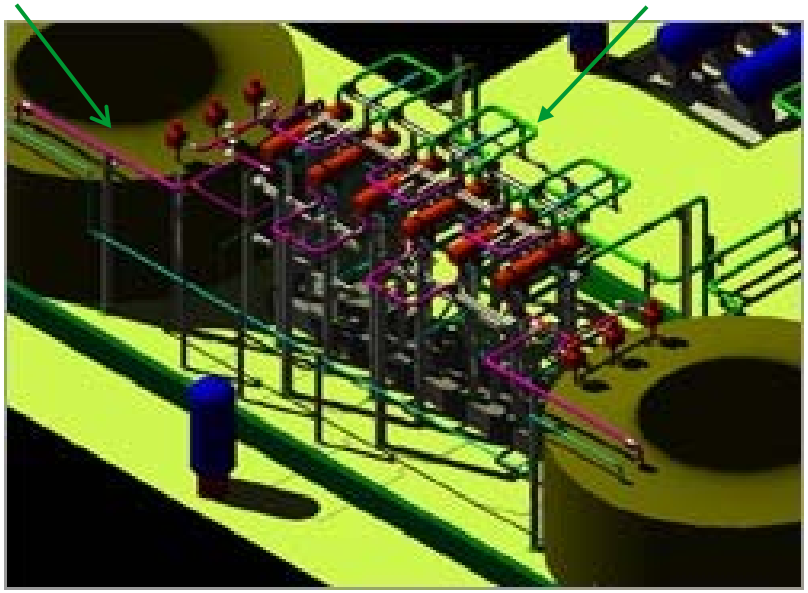
- A dish system uses a large, reflective, parabolic dish. It focuses all the sunlight that strikes the dish up onto to a single point above the dish, where a thermal receiver is used to capture the heat and transform it into energy.
- Dish systems, like power towers, can achieve much higher temperatures due to the higher concentration of light which they receive. Typically the dish is coupled with a Stirling engine, but also sometimes a steam engine is used.
- Dish engine systems are a distributed mode of solar thermal energy, ranging in output from 1kw-30kw.

Power Tower Technology



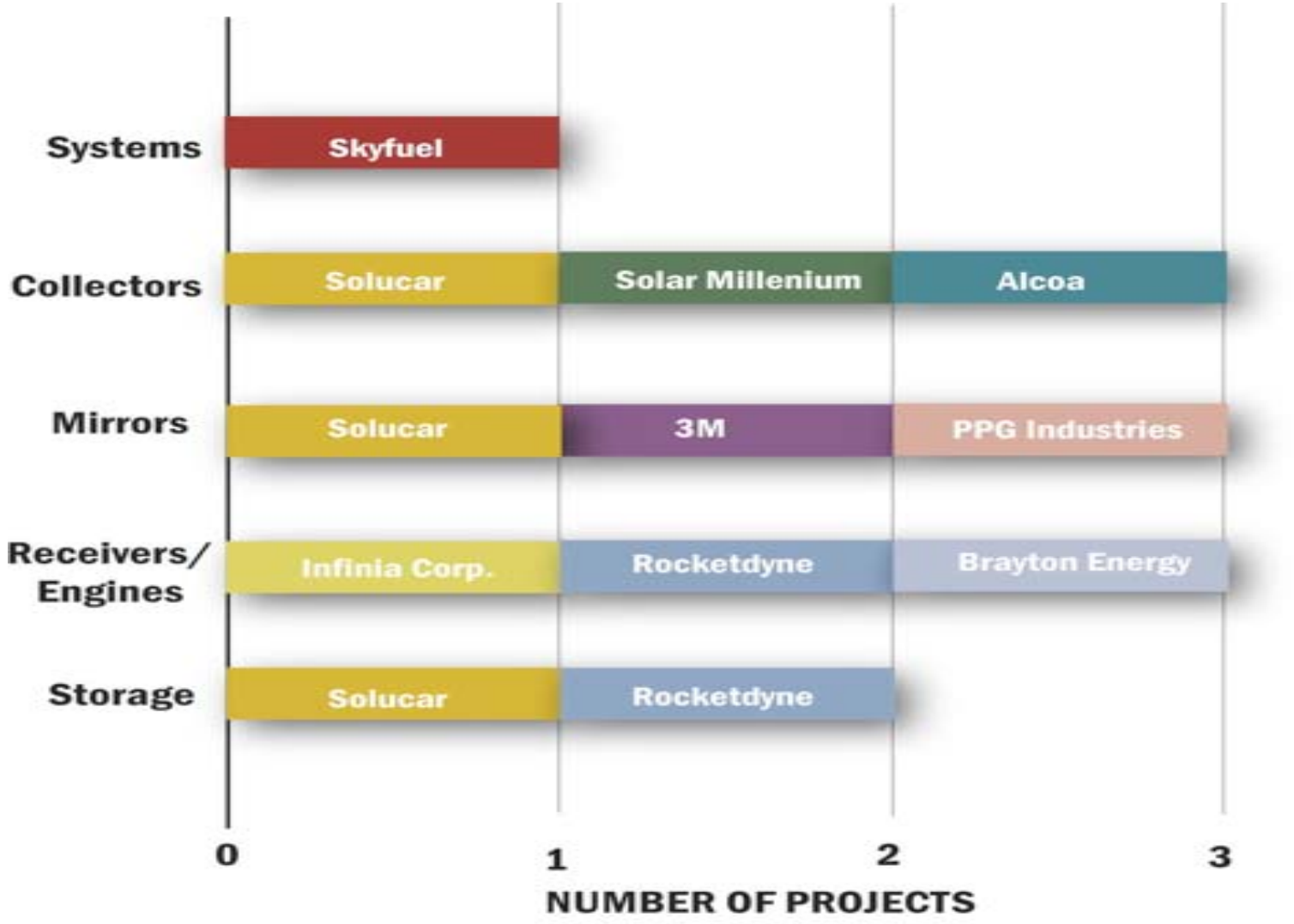
- Power towers use an array of flat, moveable mirrors called heliostats to focus the sun's rays upon a receiver on a central tower.
- The high energy at this point of concentrated sunlight is transferred to a heat transfer fluid that can store the heat for later use.
- Molten salts are currently being investigated which will allow solar energy from the afternoon to be stored to generate steam throughout the evening.
- Power towers are also sensitive to economies of scale due to their power block requirements and will likely be most economical above 250MW.

Thermal Storage using Heat Transfer Fluids



- Thermal energy storage uses high heat capacity fluids as heat transfer and storage mediums.
- Innovative heat storage technologies allows for dispatchability of solar thermal power by closely matching daily production with utility grid demand.
- DOE's 2020 goals of 12 – 17 hours of thermal storage will allow CSP power plants to have up to 60-70% capacity factors

DOE's Concentrating Solar Power Projects Support a Comprehensive Technology Portfolio



DOE-funded companies across the country will be involved in advancing CSP technology while expanding U.S.-based manufacturing supply chains

Concentrating Solar Power Project Selections

3M Company

Cleanable and Hardcoat Coatings for Increased Durability of Silvered Polymeric Mirrors

Technologies Addressed

Trough Component Manufacturing

Description

Improved abrasion resistance and cleanability of the front surface of a silvered polymeric mirror that decreases the rate of reflectance loss and irreversible soiling by 50% relative to an untreated surface

DOE Goals Served

LCOE / U.S. based manufacturing

CSP LCOE Impact	$.005/kWh

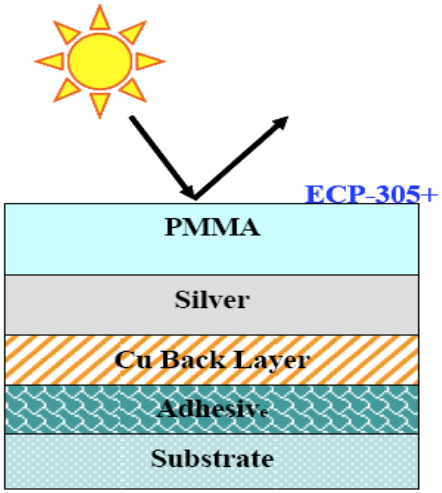


Figure 3. Schematic of ECP-305+ mirror construction

Resources ($)		
Total Project	DOE Funds	Cost Share
$437K	**$350K**	**$87K**

Alcoa, Incorporated

Reflector Technology Development and System Design for Concentrating Solar Power (CSP) Technologies

Technologies Addressed

Trough Component Manufacturing – Collectors & Mirrors

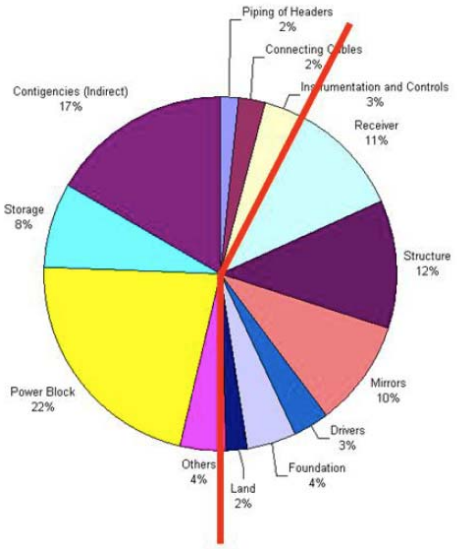
Description

Lower trough system costs through design optimization of the collector assembly including reduced reflector weight, improved supporting structure joint design, and increased reflector stiffness.

DOE Goals Served

LCOE / U.S. based manufacturing

CSP LCOE Impact	Up to 20%



- Solar Field
  - Structure (spaceframe) ~12%
  - Mirrors ~10%
  - Receiver ~11%
  - Land, Foundation, Drivers ~9%
- Represents about 40% of total system cost

Figure 1. Generic Parabolic Trough CSP Cost Breakdown

Source: ECOSTAR – European Concentrated Solar Thermal Road-Mapping (SES6-CT-2003-502578)

Resources ($)

Total Project	DOE Funds	Cost Share
$500K	**$400K**	**$100K**

Brayton Energy LLC

Brayton *SolarCAT* Solar Power Conversion System

Technologies Addressed

Dish engine system micro-turbine / Brayton cycle engine.

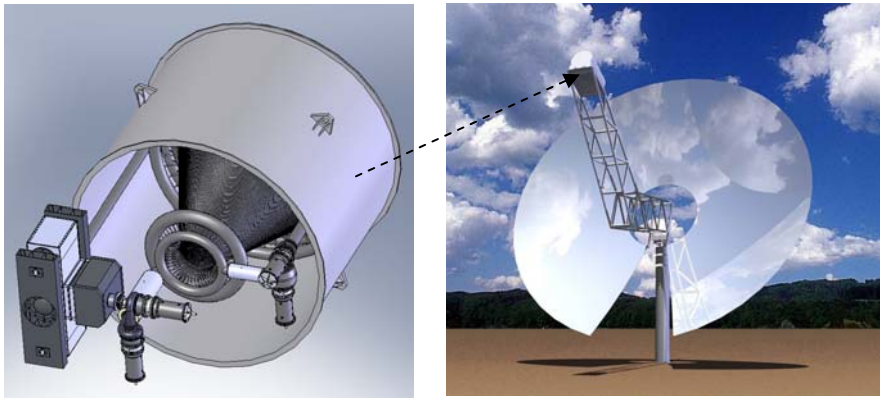
Description

Lower capital costs and increased system reliability through improved engine and receiver efficiency; and improved mechanical integration of engine, combustor, and receiver.

DOE Goals Served

Innovative CSP technologies

CSP LCOE Impact	Potential to achieve DOE 2015 cost target



Brayton cycle (gas turbine) employing an intercooled-recuperated-reheat cycle mounted on a large parabolic dish. The system contains energy storage enabling peak power of 200 kWe. The patented turbo-alternator power module uses air bearings and is totally oil and liquid-free. The hybrid system incorporates a hydro-carbon combustor, integrated with the solar receiver.

Resources ($)		
Total Project	DOE Funds	Cost Share
$377K	**$300K**	**$77K**

Solucar/Abengoa

Parabolic Trough Collectors

Technologies Addressed

Trough Component Manufacturing - parabolic trough concentrators

Description

Development of innovative and improved parabolic trough concentrator designs that can have a major impact on this cost element.

DOE Goals Served

LCOE / U.S. based manufacturing

LCOE Impact	Potential to meet DOE 2015 cost target

Resources ($)		
Total Project	DOE Funds	Cost Share
$624K	**$499K**	**$125K**

Solucar/Abengoa

Advanced Polymeric Reflectors

Technologies Addressed

Trough component manufacturing - mirrors

Description

An advanced solar reflective material will be transitioned from laboratory scale to limited production runs at commercial scale.

DOE Goals Served

LCOE / U.S. based manufacturing

LCOE Impact	$.005/KWh

Resources ($)

Total Project	DOE Funds	Cost Share
$560K	**$448K**	**$112K**

Solucar/Abengoa

Molten Salt Heat Transfer Fluid

Technologies Addressed

Advanced low cost thermal storage for CSP power plants

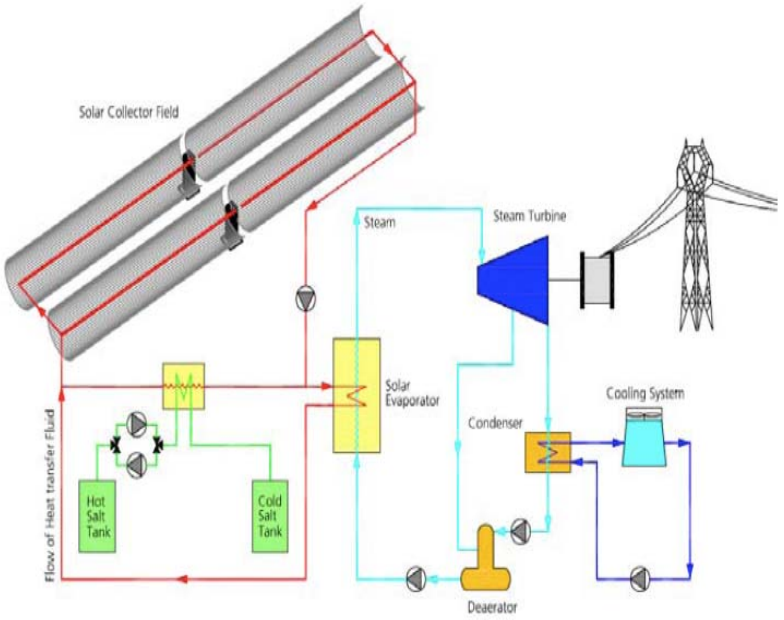
Description

Combine the use of a molten salt heat transfer fluid with molten salt thermal energy storage to reduce costs and increase the dispatchability of CSP plants.

DOE Goals Served

LCOE / Thermal energy storage

LCOE Impact	10-15% with storage



Resources ($)		
Total Project	DOE Funds	Cost Share
$1.39M	**$1.09M**	**$0.3M**

Hamilton Sundstrand SLS Rocketdyne Corporation

Central Receiver Panel Fabrication and Testing

Technologies Addressed
Advanced CSP Components – Power Tower

Description
Manufacture and testing of a large scale (200 MW) molten salt solar receiver panel for power tower technology.

DOE Goals Served
Innovative CSP technologies

CSP LCOE Impact	Up to $.08/KWh

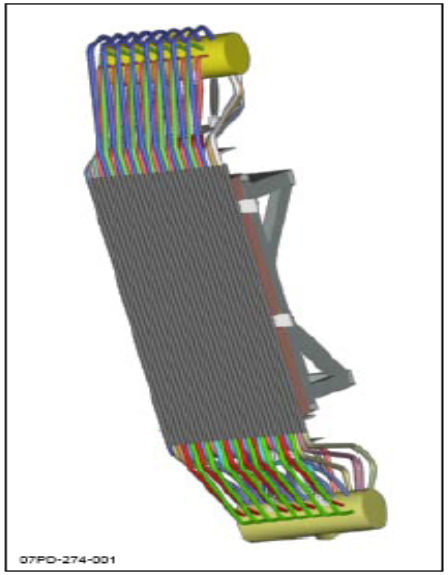


Figure 2. Rocketdyne Prototype Receiver Test Panel has all the Features Required in a Large Plant

Resources ($)		
Total Project	DOE Funds	Cost Share
$400K	**$320K**	**$80K**

Hamilton Sundstrand SLS Rocketdyne Corporation

Molten Salt Pump

Technologies Addressed
CSP Thermal Storage – Molten Salt Pump

Description
Design, build and test a long-shafted (~50 feet), molten salt pump able to operate at 1,050 degrees Fahrenheit; a critical component for both trough and tower technologies.

DOE Goals Served
LCOE / Thermal energy storage

LCOE Impact	$.0035/KWh

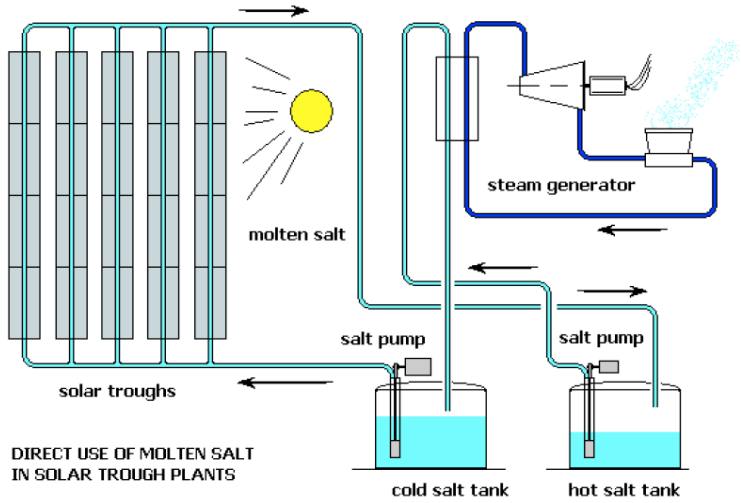


Figure 2. Salt Pumps are Critical Hardware for Direct Use of Molten Salt in Thermal Storage System for Solar Trough Plant

Resources ($)		
Total Project	DOE Funds	Cost Share
$452K	**$362K**	**$90K**

Infinia Corporation

30KW Maintenance Free Stirling Engine

Technologies Addressed

CSP Receivers – Stirling Engine

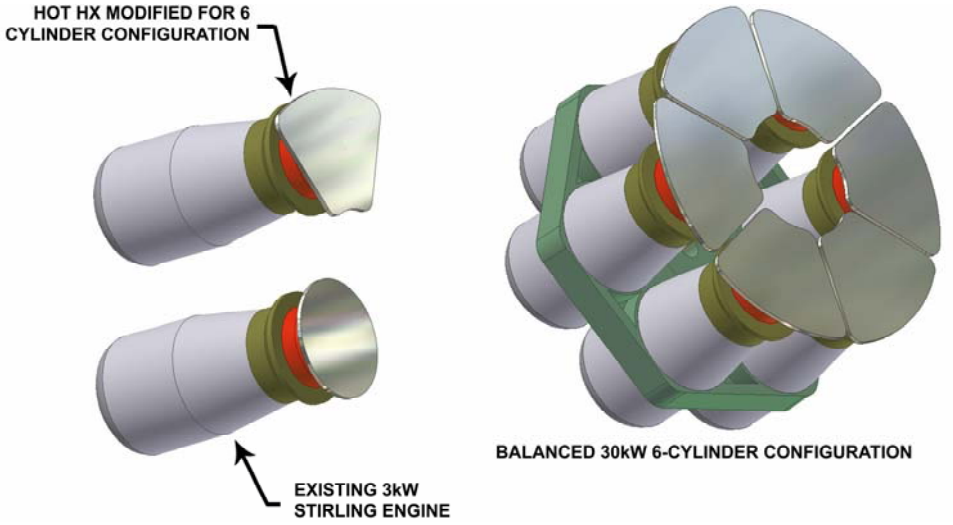
Description

Six modified free piston engines combined to form a 30kW Six-cylinder Stirling engine for high-performance, high reliability dish concentrating solar power.

DOE Goals Served

Innovative CSP technologies

LCOE Impact	Potential to meet DOE 2015 cost target



Resources ($)		
Total Project	DOE Funds	Cost Share
$408K	**$321K**	**$87K**

PPG Industries

High Value Mirrors

Technologies Addressed

Trough component manufacturing – mirrors

Description

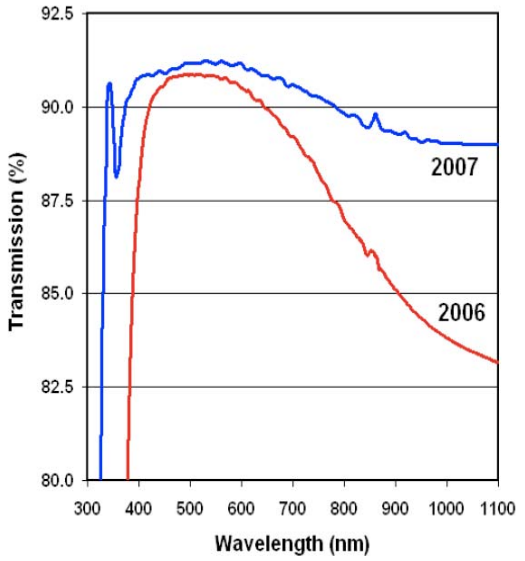
Develop mirrors that include an inorganic coating that protects the mirror from chemical attack, an organic coating that protects the mirror from mechanical attack, and a low-cost fabrication process.

DOE Goals Served

LCOE / U.S. based manufacturing

LCOE Impact	Greater than 6%

Figure 2: Optical Transmission Spectra for PPG Low-Iron Glasses Showing Performance Improvement With the New (2007) Composition



Resources ($)		
Total Project	DOE Funds	Cost Share
$403K	**$323K**	**$80K**

SkyFuel Incorporated

Linear Fresnel Power Tower CSP Plant

Technologies Addressed

Advanced CSP technologies – Linear Fresnel Power Tower

Description

Advanced CSP system, using linear Fresnel reflective technology, to achieve significantly lower delivered electricity costs from utility-scale solar thermal power plants.

DOE Goals Served

Innovative CSP technologies

LCOE Impact	Potential to meet 2020 DOE Target

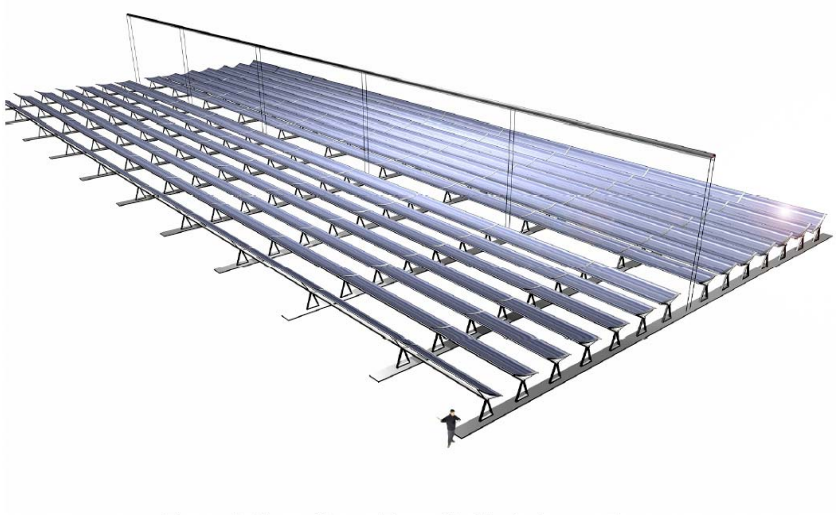


Figure 2: Linear Power Tower™, Single Segment

Resources ($)		
Total Project	DOE Funds	Cost Share
$589K	**$435K**	**$154K**

Solar Millennium LLC

Advanced High-Temperature Trough Collector Development

Technologies Addressed
Trough component manufacturing - collector

Description
Design and manufacture of a higher performance, lower cost, trough collector system with the potential to operate with molten salt heat transfer fluid and storage.

DOE Goals Served
LCOE / U.S. based manufacturing

LCOE Impact	Up to 19%

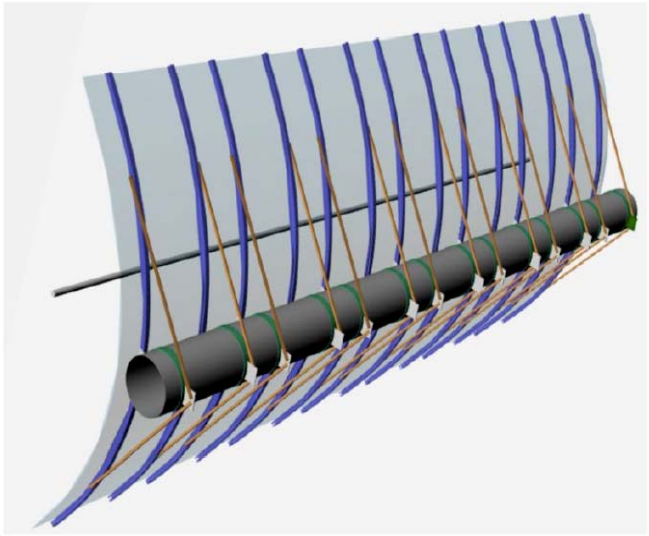


Figure 1 Backside view of NTPro collector

Resources ($)		
Total Project	DOE Funds	Cost Share
$470K	**$376K**	**$94K**