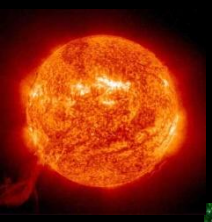
Solar Power Industry Report

Major Solar Thermal Players



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Solar Energy

Solar energy technologies enable production of electricity from sun's radiation received by earth. While, many of the currently available technologies are reliable, and have minimal environmental impact, others are experimental and need further research and development in order to become commercially viable solutions. Some of the benefits of solar power include:

- Independent and stable power source
- Low operating and maintenance costs
- Minimal labor requirements
- Lower capital expenditures as technologies develop
- Protection against rising electricity price

Market Opportunity for Solar Energy

The market for solar power is broad and, more importantly, sustainable well into the future as the demand for power continues to grow in developed and developing markets. There are currently over 1.6 billion people living in 5 million villages around the globe with no electricity.[1] Africa, Asia, and Latin America have impressive solar resources that have yet to be capitalized on and that can potentially fill the supply shortage dominating the global power market.

Other countries including Spain (the global leader in Concentrated Solar Power), Italy, France, South Africa, Portugal, Greece, Germany, and Jordan, are utilizing their untapped solar resources through feed in tariffs that make solar electricity more economically feasible. For example, in Spain there are roughly 400 MW of CSP systems, mostly parabolic trough, under construction. In addition, North Africa also has impressive solar resources, as feasibility studies show that North African power plants could provide about 15% of Europe's electricity needs.[1]

Types of Solar Technology

Two of the main solar technologies being developed by the industry are Photovoltaic (PV), and concentrated solar power (CSP).

- **Photovoltaic Cells (PV)**

  PV technologies make use of silicon solar cells to convert sunlight directly to electricity. PV cells can provide electric power to meet various needs, from small devices such as watches or calculators, to local electric utilities.

- **Concentrated Solar Power (CSP)**

  CSP technologies use reflectors to focus sunlight onto receivers that collect sun's heat. This thermal energy can be used to produce electricity via a steam turbine or heat engine.

PV vs. CSP

PV facilities can convert roughly 10-15 percent Sunlight into grid quality electricity. In comparison, CSP plants, with thermal storage, can harness up to 60-70 percent of the sun's energy into usable heat for power generation.[2]

CSP facilities are also more cost effective. According to Severin Borenstein, the director of the University of California Energy Institute, the cost of solar energy from PV panels could be anywhere from 20 to 40 cents per kWh depending on the size of the panel. In contrast, the cost of power from a solar thermal plant could be as low as 18 cents per kWh over the plant's lifetime. [2] Recent innovations in the industry have brought the cost of power from CSP plants even lower.

It is widely believed that tomorrow's solar solutions will be a combination of PV and CSP technologies. While PV technologies are suitable where direct sunlight is scarce and where small rooftop or scattered power generation is required, CSP clearly reigns supreme for larger scale generation in desert environments with strong direct sunlight. For the purposes of this report, the focus shall be analysis of the state of the CSP market. PV shall be covered in future reports.

Main CSP Technologies:

1. **Dish/Engine Systems:**

   A dish-shaped reflector concentrates sunlight on to a receiver located at the center of the dish. The concentrated beam is absorbed into a receiver to heat a fluid or gas to high temperatures. This fluid or gas is then used to generate electricity in a small piston (Stirling engine) or a micro turbine, attached to the receiver.

2. **Linear Concentrator Systems**

   The two main Linear CSP systems currently in operation worldwide are parabolic trough collectors and linear Fresnel reflectors. Both systems capture the sun's energy with reflectors that focus the sunlight onto a linear receiver tube. The receiver contains a fluid that is heated

[1] S. Price and R. Margolis. "2008 Solar Technology Market Report." US Department Of Energy (DOE). January 2010. Mar 2010 http://www1.eere.energy.gov/solar/pdfs/46025.pdf

[2] Zuboy, J., Sczepanski, S., Moon, S., Gwinner, D., and Nahan, R. "DOE Solar Energy Technologies Program: Overview and Highlights." US Department Of Energy (DOE). May 2010. Mar 2010 http://www1.eere.energy.gov/solar/pdfs/39081.pdf

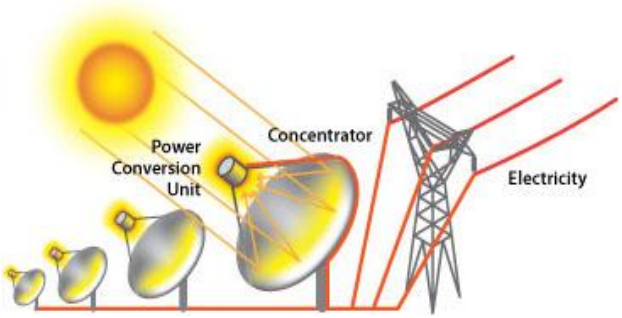
by the sunlight and then used to create steam that powers a turbine to produce electricity.

One way to classify these systems is by the shape of the reflectors. A typical linear Fresnel reflector uses an array of nearly-flat reflectors to concentrate solar radiation onto elevated linear receivers. A parabolic trough system uses curved reflectors as solar collectors to reflect sunlight onto a pipe running along inside of the curved reflectors.

3. Power Tower Systems

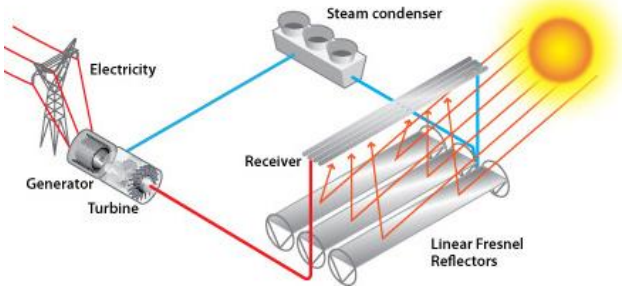
This CSP technology uses flat, sun-tracking mirrors, known as heliostats, to focus sunlight onto a receiver at the top of a tower. The receiver contains a fluid that transfers heat to a steam turbine that generates electricity.

Concept of a dish/engine power plant



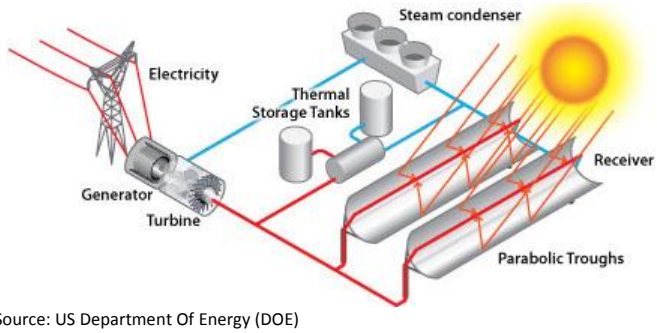
Source: US Department Of Energy (DOE)

Concept of a linear Fresnel reflector power plant



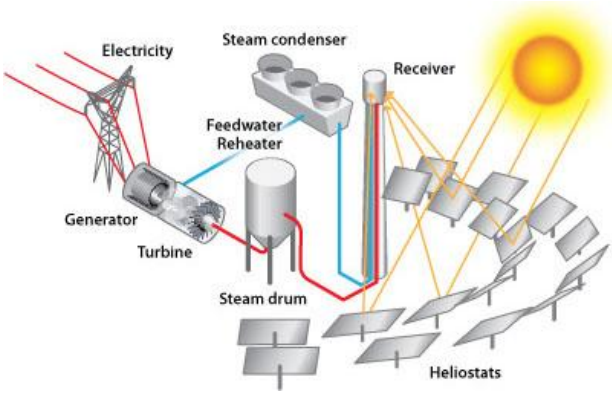
Source: US Department Of Energy (DOE)

Concept of a parabolic trough power plant



Source: US Department Of Energy (DOE)

Concept of a power tower power plant



Source: US Department Of Energy (DOE)

Review of Leading Solar Thermal Companies

Abengoa Solar (Spain)

A publicly listed technology company in Spain with operations in more than 70 countries that focuses on both CSP and PV and can be used and customized for industrial and commercial applications. Abengoa's CSP technologies include parabolic trough and power tower.

In 2009, Abengoa launched its new PS20 solar plant, second commercial tower worldwide, located at the Headquarter in Spain. The new plant was anticipated to produce clean energy to supply the electricity needs of 10,000 homes, preventing the emission of approximately 12,000 tones of CO2 every year.

Acciona Solar Power (Spain)

Majority-owned joint venture of Acciona Energy, that develops, owns, and operates CSP plants. Acciona's parabolic trough system tracks the sun's location and concentrates sun's heat during peak times. The system employs parabolic concentrators with reflectors to concentrate sun's rays onto receiver tubes. Fluid boils through these tubes and is used to produce steam that drives a conventional turbine, which is connected to a generator that produces electricity. The company now operates the 64MW plant with the capacity to generate electricity equal to the needs of roughly 14,000 homes annually.

AORA (Israel)

AORA Solar, formerly known as EDIG Solar, combines a modular concentrated solar tower technology with other heat sources to enable its plants to provide utility power 24 hours a day. Each module, called "solar flower", is said to create 100kW of electricity, targeting small community scale, in contrast to the typical large utility scale or small residential applications.

AORA's system uses compressed (solar heated) air to drive a standard micro gas turbine. The waste heat is then reused to heat water to high temperatures for increased output, in addition to the electric energy output of the turbine.

This system is considered as "hybrid" as it uses fossil fuels in addition to solar radiation. In February of 2009, AORA announced that it completed a $5 million Series A offering led by EZKlein Partners, EDIG Construction, and L&Q Solar. Soon after in June 2009, AORA launched its first hybrid solar thermal power station at Kibbutz Samar in southern Israel.

Ausra (Palo Alto, California USA)

Ausra is a private provider of large-scale CSP solutions for electricity generation and steam production based in the US. Ausra's core technology, the Compact Linear Fresnel Reflector (CLFR), uses flat reflectors to concentrate the sun's heat onto a system of tubes with water, creating high-pressure steam for direct use in electricity generation. A natural gas boiler back-up design can also be installed in addition to the solar system, providing firm capacity for customers around the clock.

Currently, the company has developed a Solar Power Plant & Research Facility in Bakersfield, California, and operates a Solar/Coal hybrid Power Facility in New South Wales Australia. In early 2010, Ausra was fully acquired by AREVA, a leading nuclear vendor and a key player in the electricity transmission and distribution sector.

BrightSource Energy (Oakland, California USA)

BrightSource is a privately held developer of utility-scale solar thermal power plants with operations in Australia, Israel, and the United States. BrightSource has contracted to sell more than 2.6 GW of power to be generated using its Luz Power Tower (LPT) 550 energy system. In mid February, BrightSource announced that the U.S. Department of Energy has committed to provide $1.37 billion in loan guarantees to support the financing of its Ivanpah Solar Electric Generating System.

The approximately 400 MW complex will consist of three separate plants, and provide electricity to Pacific Gas & Electric Company (PG&E) and Southern California Edison. Construction of the first plant is scheduled for late 2010, following permitting review by the California Energy Commission and the Bureau of Land Management. The first plant is scheduled to come online in mid-2012.

eSolar (Pasadena, California USA)

Private developer of power tower technology based in Pasadena, California. eSolar has executed agreements with NRG, ACME, and Penglai to build a total of 3.6GW of its power tower plants over the next 24 months. NRG has begun the permitting process on two 92MW plants in the US and ACME is scheduled to break ground on their first 46MW facility in India in 2010. A typical 46 MW eSolar power unit requires 160 acres and consists of sixteen towers, a turbine generator set, and a steam condenser.

Infinia (Kennewick, Washington USA)

Infinia is a US-based manufacturer and seller of Stirling engines since the 60s. With decades of experience and expertise in Stirling engine technology, the company has developed a 3kW dish/engine system which is scalable from small arrays to multi-MWs deployed in utility-scale solar power plants, called the PowerDish. Infinia has raised more than $100 million in venture capital by February 2010, and has planned roughly $2 billion worth of contracts for its solar power generation product, which the company expects to commercialize by the fourth quarter of 2010.

NextEra Energy Sources (Juno Beach, Florida USA)

NextEra Energy Resources, wholly owned subsidiary of Florida Power & Light Company, is the largest generator of solar energy in the country through operations at the seven Solar Electric Generating Systems facilities in California's Mojave Desert. At these sites, the company utilizes the trough solar thermal technology to capture the suns heat and convert it into grid quality power.

In October 2009, NextEra Energy signed a contract to sell 250 MW of solar thermal power from its proposed Genesis Solar Energy Project in Riverside County, California to PG&E. The proposed Genesis site, which features more than 500,000 parabolic troughs, is one of 14 solar projects identified by the Bureau of Land Management for fast-track consideration to receive permits by the end of 2010. The company intends to break ground in late 2010, with operations beginning about 30 months later.

In addition, the company has also applied to the California Energy Commission for permits to build its proposed 250MW parabolic trough Beacon Solar Project in eastern Kern County, California.

Novatec Biosol (Germany)

Novatec Biosol is one of the few companies that develop Linear Fresnel Reflectors. The basic module of its technology, NOVA-1, consists of 128 primary reflector units with 8 receiver units. Rows of NOVA-1 can be arranged in parallel to form a solar plant of any size. The company has developed a 1.4MW showcase plant in Spain, called the PE1. It is a small scale power plant which helps the company to demonstrate proof of technology and plant design.

In March 2010, Novatec Biosol has started its first project due for commencement of construction, called the PE2. It is part of a $150 million project investment, which 85% of construction and operation has been subcontracted to EBL (Elektra Basel Land), a Swiss utility company.

Siemens (Germany)

Siemens is a German engineering conglomerate with core operations in energy and healthcare. Siemens manufactures and supplies all the relevant solar field components, from solar receivers to parabolic reflectors. In 2009, an agreement was signed at Italy, securing Siemens a 28 percent stake in Italian solar thermal specialist Archimede Solar Energy (ASE). ASE is the producer of solar receivers operating with molten salt mixture as the heat transfer fluid. In the same year, the company acquired Israeli CSP developer Solel as part of a strategy to become the market leader in the solar thermal sector. Solel's CSP technology is a parabolic trough design using molten salt and oil for storage. Through its newly acquired subsidiaries, the company has planned to develop a 50MW solar thermal electricity generation plant in the Northern Cape Province of South Africa in 2010.

SkyFuel (Albuquerque, New Mexico USA)

SkyFuel is a CSP technology and service provider based in the US, offering a glass-free parabolic trough solar thermal collector, called the SkyTrough. The SkyTrough is a 455kW system designed to collect and deliver thermal energy harnessed from the Sun, making it applicable to any system

that requires thermal energy including industrial process heat and electricity generation applications.

In 2009, SkyFuel signed an agreement with Sunray Energy for the installation of its SkyTrough collectors at Sunray's 43MW power plant in California, formerly known as the SEGS I & II sites. This agreement is the first commercial installation of the SkyTrough collector and allows SkyFuel to demonstrate large-scale commercial viability.

SolarReserve (Santa Monica, California USA)

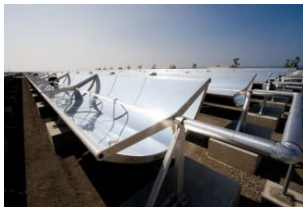
SolarReserve is developing a solar power system that can store seven hours worth of solar energy by focusing mirrors onto millions of gallons of molten salt, allowing the plant to provide electricity 24 hours a day. The solar energy is stored using a massive circular array of up to 17,500 heliostat mirrors. The heliostat field encircles a concrete Solar Power Tower, with a 100-foot high receiver on top, which holds 4.4 million gallons of molten salt. When the heliostats focus the sunlight onto the receiver, the salt is heated to over 1,000 °F.

To generate power when needed or during peak demand periods, the stored molten salt is heated to over 1000 degrees Fahrenheit to produce steam, which is then run through a generator to produce electricity. The cooled salt is then re-circulated to the receiver for re-heating.

The company has applied to regulators in California for permission to build the 150MW Rice Solar Energy Project solar farm near the abandoned town of Rice in San Bernadino County, California.

Sopogy (Honolulu, Hawaii USA)

Sopogy specializes in micro parabolic trough technologies that bring the economics of large solar energy systems to the industrial, commercial, and utility sectors in a smaller, robust, and more cost-effective package. In 2008, the Governor of the State of Hawaii, Linda Lingle, signed a bill into law that authorized the issuance of $35 million in special purpose revenue bonds to assist Sopogy, Inc. in the development of renewable energy on the Island of Oahu.



In early 2010, Sopogy was named the "Venture Capital Deal of the Year." In addition, Sopogy is installing a 1MW plant on the Big Island at the Natural Energy Laboratory of Hawaii Authority with plans for a 10MW plant on other islands.

Stirling Energy Systems and Tessera Solar

Stirling Energy Systems (SES) is one of the few CSP companies that develop dish/engine power plants in the US. SES's sister company, Tessera Solar, is exclusively responsible for the global deployment of its SunCatcher solar dish.

Stirling's SunCatcher is a CSP technology that converts solar thermal power to grid quality electricity. It is a 25kW solar dish that consists of a solar concentrator in a dish structure that supports an array of curved glass reflectors. These mirrors collect and concentrate the suns energy on to a power conversion unit, which then produces electricity.

In January 2010, SES and Tessera launched the 1.5MW Maricopa Solar power plant in Peoria, Arizona, which included 60,000 SunCatcher units. Also, Tessera Solar plans to break ground on two solar plants in California and expects to produce grid quality electricity by the end of 2010. Working with San Diego Gas & Electric and Southern California Edison, these two projects are expected to produce up to 1.75GW of renewable energy using 70,000 SunCatcher units.

Suntrough Energy (California USA)

Suntrough Energy is a solar technology company founded with the goal of developing a solution that makes CSP economically competitive at the 5MW level with fossil fuel generation. Suntrough utilizes the parabolic trough technology, which uses reflectors to concentrate the suns energy to a linear receiving tube filled with oil. The concentrated sunlight then heats the oil, creating steam and powering a turbine.

By doing so, Suntrough has turned the construction of the power plant from a project to a product. As a result, they have successfully commoditized the solar power plant for the very first time.