Key Suppliers in Solar Thermal Power Value Chain and Venture Capital Companies

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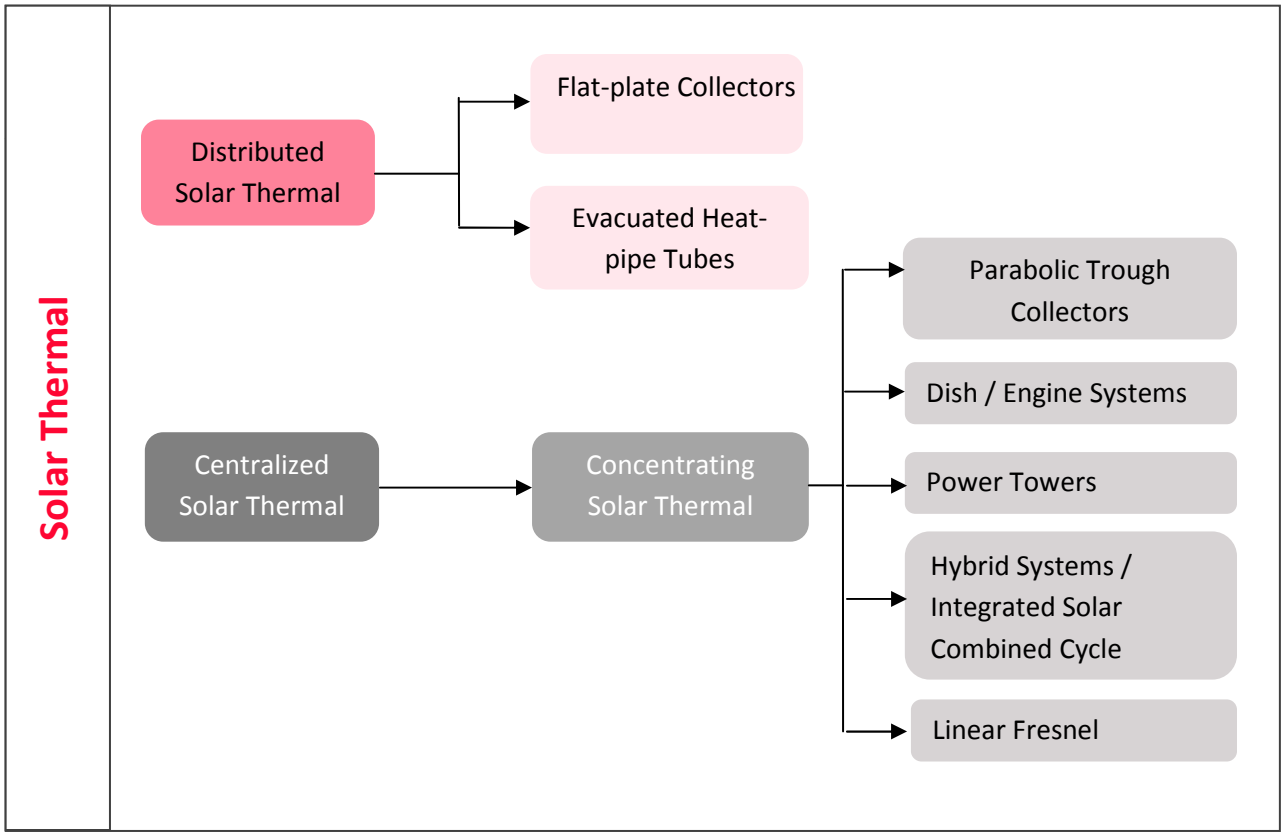
Introduction

Solar is one of the fastest growing alternative energy resources today. There are two primary forms in which energy from the sun is being derived currently: Solar photovoltaics (PV) and Solar thermal. Solar PV uses the light energy from the sun to generate electricity while solar thermal uses the heat from the sunlight to generate heat energy or to generate electricity.

The contribution of solar PV to world electricity generation is only about 0.25% (with an installed capacity of about 15 GW, 2008 data). The contribution to solar CSP (concentrated solar power), the form of solar thermal used for electricity generation, is less than 0.01% (with an installed capacity of only about 0.5 GW worldwide, 2008 data).

The solar thermal energy technology can be broadly classified as follows:



Solar Thermal

Solar thermal is rather a straightforward application of solar energy. The heat produced from solar energy is either directly used (as in case of solar water heaters), or used for converting the liquid into steam, which is then used to drive turbines to produce electricity.

The principles of concentrating direct sunlight into useful thermal energy are very basic. The basic engineering technologies for converting thermal energy into electricity have been commercially demonstrated for over two decades.

Solar Thermal Collectors

A solar thermal collector is a solar collector specifically intended to collect heat: that is, to absorb sunlight to provide heat. Although the term may be applied to simple panels used for heating appliances such as solar water heaters, it usually denotes more complex installations – typically for concentrating solar thermal systems that will be described later in this section.

Distributed Solar Thermal

The solar thermal concept can be used in a distributed manner, on rooftops, to generate small amounts of energy. Distributed solar thermal is normally used for heating (eg. Solar water heaters) and drying purposes (eg. drying of wet raw materials and other industrial feedstock), than for electricity generation.

The solar thermal panels used in distributed solar thermal systems, can be classified as flat-plate solar collectors or evacuated tube solar collectors.

Flat-Plate Solar Collectors

These are durable, weatherproof boxes which contain a dark absorber plate located under a transparent cover. They are still the most common type of collector used for water heating in many countries despite being inferior to evacuated tube collectors in many ways.

Evacuated Heat Pipe Tubes

These are designed such that convection and heat loss are eliminated, whereas flat-plate solar panels contain an air gap between absorber and cover plate which allows heat loss to occur. Further, evacuated heat pipe systems are capable of limiting the maximum working temperature, where as flat-plate systems have no internal method of limiting heat buildup which can cause system failure. Finally, evacuated heat pipe systems are lightweight, easy to install and require minimal maintenance. Flat-plate systems, on the other hand, are difficult to install and maintain, and must be completely replaced if one part of the system stops working.

Centralized Solar Thermal

Unlike the distributed use of solar thermal panels to directly capture the heat energy from the sunlight, centralized solar thermal technology concentrates the sunlight and generates electricity from the heat thus captured.

Concentrating Solar Thermal (CST) or Concentrating Solar Power

Concentrating Solar Thermal generates electricity by using reflective collectors (ex., lenses or mirrors) to concentrate sun light and produce heat (hence the term *thermal*) to convert liquid into steam which is then used to run a conventional thermal power plant.

It has been reported that the theoretical maximum efficiency of CST would be around 95%. Different types of CST can achieve different rates of efficiency. For example, *parabolic troughs* will work at 56%, where as *dish concentrators* will work at 80%.[1]

Since concentrating solar uses existing generators, piping and mirrors, the production costs are much lower than PV solar and don't require special production facilities. The equipments used to collect the heat energy of the sun are called concentrated solar thermal collectors.

Solar Thermal Collectors

CSP produces electricity by converting solar energy into high temperature heat using diverse mirror configurations. The heat is then used to produce electricity through a conventional generator system using turbine. As a result of their size and expense, they are scarcely used on residential applications, and are used in large projects and electrical generation. There are four major CSP systems namely parabolic trough systems, power tower systems/central receiver systems, parabolic dish systems and Fresnel systems.

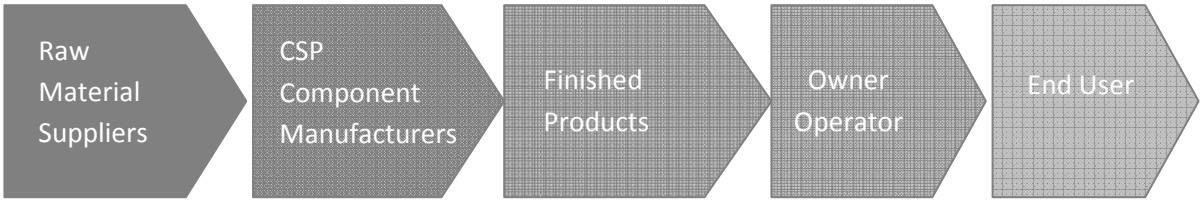
- *Parabolic Trough Systems* - A parabolic trough consists of a linear parabolic reflector that concentrates solar radiation onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned right above the middle of the parabolic mirror and is filled with a working fluid which is heated to produce steam. The reflector is made to follow the sun during the daylight hours by tracking along a single axis. This is one of the most developed, economically viable and widely accepted CSP technologies. Currently, most of the CSP projects under constructions employ this technology.
- *Power Tower Systems/Central Receiver Systems* - A power tower system employs an array of large individually tracking plain mirrors (heliostats) to concentrate solar radiation on to a central receiver on top of a tower to produce steam for electricity generation. Currently, CSP plants in Spain such as PS 10 and PS 20 are implementing central receiver system technology.

[1] http://www.tropical-rainforest-animals.com/solar-electricity.html

- *Parabolic Dish Systems* - Parabolic dish systems are comparatively smaller units consisting of a dish-shaped concentrator that reflects solar radiation onto a receiver mounted at the focal point which heats thermal fluid for power generation. In connection with a stirling engine, this technology has the advantage of functioning as stand-alone systems and can provide decentralized power. Currently, small CSP projects are planned in USA, Europe and Australia using this technology.
- *Linear Fresnel Reflector Systems* - A linear fresnel reflector system uses an array of flat or slightly curved reflectors which reflect solar rays and concentrate them on elevated inverted linear absorber tube for heating the fluids and converting solar energy to electricity. Spain is implementing a pilot project using this technology which is still in nascent stage. Currently, Fresnel systems is less efficient but also less costly than other CSP technologies.
- *Hybrid Systems /Integrated Solar Combined Cycle (ISCC)* –Hybrid systems combine power towers with natural gas power generators currently used at many power plants, creating a system that can continuously generate electricity, even when the sun isn't shining. Hybrid systems are not usually considered a separate category in concentrating solar thermal.

Solar Thermal Value Chain and Suppliers

The Concentrating Solar Power Value Chain



Supplies raw material needed for CSP component manufacturing like steel, copper and brass	A CSP plant has four major systems: the collector, steam generator, heat storage, and central control. The collector system components vary depending on the type of CSP plant.	The finished products include solar technology integrator/ provider and plant developer The developer or the project integrators integrate the manufactured components into a complete functioning plant.	The owners are either the developer or the customers for whom the technology integrators integrate the plant	End use of power by customers or sold to utility companies.

CSP Components and Raw Materials

CSP Components	Materials for CSP components
Collector System	
- Mirrors	
- Receiver	Steel
- Body armour	Plastic
- Body pylons	Copper
- Motion system	Aluminum
- Fasteners	Concrete
Steam generator system	
- Oil expansion tank	Steel
- Heater tanks	Copper
- Oil pump	Aluminum
- Oil pipeline	Concrete
- Valves	Silica
Heat storage system	
- Steel armour	
- Steel piping	
- Temperature sensors	Steel
- Valves	Copper
- Hot pump	Brass
- Cold pump	Aluminum
- Molten salt	Concrete
Central control system	
- Programmable logic controller	
- Controls	
- Sensors	
- Box controls	
- Circuit boards	Plastic
- Temperature sensors	Aluminum

Solar Thermal Suppliers and Companies

List of Key Developers of Solar Thermal Plants (CSP)

Company	Country	Technology
Abengoa	Spain	Trough Systems, Power Towers
Abu Dhabi Water & Electricity Authority	UAE	
Acciona Solar Power	Spain	Trough Systems
Albiasa Solar	Spain	
Ausra	USA	Linear Fresnel Reflectors
Bright Source Energy, Inc.	Oakland, CA	Power Towers
EECH AG	Germany	
Endesa	Spain	
ENEA	Sweden	
Enel-Union Fenosa	Spain	
Enerstar	Canada	
Ener-T Global	Israel	
Environmission	Australia	
Epuron	Germany	
E – Solar (Idealab)	Pasadena, CA	
Eskom	South Africa	
FPL Energy	Mojave, CA	
Grupo Enhol	Spain	
Iberdrola	Spain	
IDEA Ciemat	Spain	
Inland Energy	USA	
Industrial Solar Technology Corp	Golden, CA	
Luz II (BrightSource subsidiary)	Israel	
SAMCA	Spain	
Sener Group	Spain	Trough Systems
Solargenix Energy	Sanford, NC	
Sky Fuel	USA	Trough Systems and Linear

		Fresnel Reflectors
Solar Millennium AG	Germany	Trough Systems
Solar Power Group	Germany	
Solel Solar Systems Ltd	Israel	
Solel, Inc. (Subsidiary of Solel Solar Systems Ltd)	Henderson, NV	Trough Systems
Stirling Energy Systems	USA	Dish Engine Systems and Stirling Engines
Tubo Sol Murcia	Spain	

Source: CGGC, based on company annual reports, individual interviews, and company websites.

Companies Making Concentrating Solar Power Components

Component	Illustrative Companies	Location
Collectors	European Partners	Europe
	Industrial Solar Technology	Golden, CO
	Luz/Solel	Israel
	Solargenix Energy	Sanford, NC
	Solar Millennium AG	Germany
	Sopogy	Honolulu, HI
Mirrors/Reflectors	Alanod	Germany
	Ausra Manufacturing	Las Vegas, NV
	Boeing (formerly McDonald Douglas)	Chicago,IL
	Cristaleria Espanola SA	Spain
	Flabeg	Germany
	Glaverbel	Belgium
	3M Company	St.Paul, MN
	Naugatuck Glass	Naugatuck, CT
	Paneltec Corporation	Lafayette, CO
	Pilkington	United Kingdom
	SCHOTT North America	Elmsford, NY
Mirror/Reflector Film	Alanod	Germany
	3M Company	St.Paul, MN
	Reflec Tech	Arvada, CO
Heat Collection Element	Luz/Solel	Israel
	SCHOTT North America	Elmsford, NY

Steam Generator System	Siemens	New York, NY
Heat Storage System	Radco Industries	LaFox, IL
Central Control System	Abengoa Solar USA	Lakewood, CO
Linear Receiver	Luz/Solel Solar Systems	Israel
	SCHOTT North America	Elmsford, NY
Concentrator Structure	European Partners (Euro Trough)	Europe
	Solargenix	Sanford, NC
Other Components	Other components used in power plant production but not unique to concentrating solar include a natural gas boiler, Stream turbine, steam generator, condenser, and cooling tower	

Source: CGGC, based on company annual reports, individual interviews, and company websites.

Venture Capital Companies

Starfish Ventures, Khosla Ventures and KPCB have invested in Ausra's utility-scale solar thermal which uses a parabolic trough-based system with a "compact linear fresnel reflector" in conjunction with a yet undisclosed thermal storage technology.

Brightsource Energy is developing utility-scale heliostat/power tower plants using high-temperature solar thermal technology. In its prior incarnation 20 years ago as Luz, the team built over 350MW of solar thermal generation capacity. The firm has raised more than $150 million from investors including the following venture capital companies

- VantagePoint Venture Partners
- StatoilHydro Venture
- DBL Investors
- Draper Fisher Jurvetson
- Chevron Technology Ventures

Oak Investment Partners is a multi-stage venture capital firm. The company has invested in eSolar which is building large scale (>46MW) heliostat/power tower systems. eSolar claims that their differentiators include the use of smaller mirrors, designing the components to fit efficiently into shipping containers to keep transportation costs low, and pre-assembly at the factory to minimize on-site labor, resulting in a capital cost reduction compared to existing solar thermal power plants.

In 2008 Heliofocus received a $20 million investment from Israel Corp Green (ICG) and **Musea Ventures**. Claiming high optical and high thermal efficiency, the company's system uses a large parabolic dish concentrating sunlight onto a receiver that feeds a turbo generator. HelioFocus looks to build both small modular plants as well as combined cycle solar power plants.

Unlike dish Stirling, HelioFocus uses a gas turbine that can hybridize with natural gas. Hong Kong's **Entropy Ventures** has invested $3M in Solar & Environmental Technologies, a China-based CSP start-up.
Source: www.greentechmedia.com