

Solar Thermal Power

**Solar Thermal Heat
CSP Concentrated Solar Power
Edition 3 – 2010**



The Solar Thermal Report

Ed 3 2010

Introduction

Solar thermal energy is a relatively new technology which has already shown enormous promise. It is a larger energy source than is commonly perceived and it consists of three technologies. The report consists of three sections each covering one of these technologies and its markets.

- * Low temperature ST Collectors for water, building and process heat
- * Solar thermal cooling
- * CSP - Concentrated Solar Power - Solar thermal power generation
 - STEG (Solar Thermal Electricity Generation), Rankine-Cycle STPP
 - ISCC (Integrated Solar Combined-Cycle System)

ST collectors have more capacity and produce more energy than wind power and more than geothermal, solar PV and ocean energy combined. By 2009 there were 147,000 MW of wind power, 174,000 MW of solar thermal collectors for water heating and building heating or cooling installed, but only about 1,000 MW of high temperature solar thermal collector generating capacity and about 17,000 MW of solar PV capacity.

The major direct use solar thermal market is China, which leads the world by a long margin, followed by the United States, Germany and Turkey. Although the installed capacity of CSP, solar power generation is still small it has started to take off in the last two years, notably in Spain and the United States.

Report Scope

This report describes solar thermal energy technology in its various applications. Although CSP power generation is probably better known, ST collectors employ a much lower level of technology and convert far more of the sun's energy into useful heat. Perhaps least well known and in its infancy, but a technology of the future, is ST cooling. The report describes the various technologies: collectors, receivers, heat storage systems and energy conversion units. The two principal CSP generation alternatives are outlined; STEGS, the original dedicated ST generating technology and ISCC, in which solar thermal power is integrated with fossil fuel power.

Electricity cannot be stored in any large measure, but heat can. Because solar thermal energy, like wind, is intermittent, the storage of heat is crucial to its success. Energy captured during sunny periods of low demand can be stored for use in periods of high demand.

The last two or three years have seen strides forward in all solar technologies and many 50 to 100 MW CSP power generation projects are being developed, with larger ones in the pipeline. The major direct use solar thermal markets - China, USA, Turkey, Germany and Japan are outlined and current market sizes provided. Israel is important for per capita use but relatively small in total. Between them, they have 75% of the global market for solar thermal collectors and ancillary equipment.

The growing CSP markets of Spain and the United States are outlined, with lists of projects already competed, under construction and planned.

Like all renewable technologies, except hydropower, solar thermal is expensive and is heavily dependent on state support, such as tax breaks, FITS (feed-in tariffs) or RPS (Renewable Portfolio Standards). Spain has achieved a leading position in developing wind power and solar PV, and is now following suit with solar thermal, by enacting very attractive support measures. However, the high rate of subsidy for solar PV resulted in an unexpected explosion of construction in 2007 and 2008, far exceeding the government targets, incurring huge unanticipated cost liabilities for the government and totally distorting the market. The result was a cap on solar PV subsidies in 2009. Many people consider it likely that support for solar thermal will be capped to prevent it following the same path. This is reviewed in the report.

Key topics covered:

- The main technologies
- The different components of the technologies
- The development of solar thermal technology
- The world market for direct use solar thermal appliances
- Major direct use solar thermal country profiles
- Solar thermal power generation technology

- The current status of CSP solar thermal electricity generation, with profiles of the major markets
- Costs and future cost development of STP solar thermal power

In this report the global solar thermal energy market is detailed, analysed and discussed. This makes this report an excellent reference for those needing a reliable and detailed overview of this relatively new technology. National developments in solar generation and projects under development are listed with details in all countries where the technology is being developed. Costs are reviewed and cost projections are shown from the major studies and the analysis which has been carried out.

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Contents

1.	Executive Summary	7
	Technology, Costs and Benefits	8
	Global solar thermal market.....	9
2.	Development of Solar Thermal Technology	10
	Conditions of use	11
	Solar thermal energy and the environment.....	12
3.	Solar Thermal Direct Use – Low and Medium Temperature Collectors sales 2008	13
	Passive Solar Heating.....	13
	Geographical distribution of solar thermal installations	13
	China	16
	Products	16
	Applications.....	17
	Japan.....	18
	India.....	18
	Solar thermal power plants	19
	Solar pond desalination systems in industrial environment.....	20
	Solar pond desalination systems for drinking water supply.....	20
	Israel.....	20
	Turkey	21
	USA.....	21
4.	Solar Thermal Cooling	23
	Solar cooling technologie	23
	Photovoltaic Cooling	23
	Solar Thermal Cooling	23
	Open Cycles – Desiccant Cooling Systems	24
	Market development.....	24
5.	Solar Thermal Power Generation Technology	26
	Concentrators and Receivers	26
	Parabolic Trough.....	26
	Mechanical Tracking.....	27
	Fresnel Principle Solar Collectors.....	28
	Parabolic Dish Systems.....	29
	Central Receiver Systems - Solar Tower	29
	Solar Chimney Power Plants	30
	Power Conversion System.....	32
	Rankine-Cycle Systems.....	32
	ISCC, Integrated Solar Combined Cycle Systems	32
6.	TES Thermal Energy Storage.....	35
	Types of storage.....	35

Sensible heat storage	35
Concrete	35
Molten salt.....	36
Latent heat storage/phase change materials	37
Inorganic PCMs	38
Organic PCMs	38
Development of TES for CSP	39
Indirect system	39
Single-tank Thermocline.....	39
Direct molten-salt heat transfer fluid	39
7. CSP Solar Thermal Power Generation – Past, Present and Future	41
Large Scale Solar Thermal Electricity Generation.....	41
A Brief History of the Development of Solar Thermal Generation Technology.....	41
Current Status of Solar Thermal Electricity Generation - 2009	43
Spain.....	43
Plants in operation, being built and proposed in Spain 2009.....	43
United States	45
Plants in operation, being built and proposed in the US in 2009.....	45
Federal and regional initiatives	46
State initiatives	46
Solar thermal projects under construction or approved for construction in other countries	47
Algeria	47
Australia	47
Brazil.....	47
Denmark	47
Egypt.....	47
Greece	47
India	48
Iran.....	48
Israel	48
Italy	48
Jordan.....	48
Mexico	49
Morocco.....	49
South Africa	49
8. Costs of STP Solar Thermal Power	50
Commercialisation World Bank.....	51
World Bank Plan Phase 1	51
World Bank Plan Phase 2	51
World Bank Plan Phase 3	52

Sargent and Lundy Study.....	52
Figure 8.1: LEC Levelised Energy Cost, solar trough and tower technology, 2004-2020	52
9. National Policies for Renewable Energy.....	54
Renewable energy targets.....	54
Feed-in tariffs and RPS.....	55
EU and feed-in tariffs	71
US and RPS.....	71
The feed-in tariff in Europe.....	71
The evolution of RPS Policy in the United States.....	72
Comparison of feed-in tariffs and RPS	73
Europe – the EU Renewable Energy Directive	74
Investor confidence, price, and policy cost	74
Effectiveness	74
Innovation and technology diversity.....	74
Ownership structure	74
Conclusion.....	74
Feed-in tariffs in the United States.....	74

Figures

Figure 2.1: Global insolation levels	11
Figure 3.1: Solar collector sales and installed base, 2000 to 2008 MW.....	14
Figure 3.2: Leading countries' sales of solar thermal collectors, 2000 to 2008, MW.....	14
Figure 3.3: Leading countries' installed base of solar thermal collectors, 2000 to 2008, MW.....	15
Figure 3.4: Cumulative installed capacity of solar thermal collectors in major European countries, thousand square metres 2000-2008.....	15
Figure 3.5: Market shares of solar thermal product types in China, 2000.....	17
Figure 3.6: SWH systems on the roofs of Chinese buildings	18
Figure 3.7: Advertisement for the Climax Solar-Water Heater in 1891	21
Figure 3.8: Climax Solar Water Heater in the US, 1896	22
Figure 3.9: Early solar thermal roof panels	22
Figure 5.1: Parabolic trough.....	26
Figure 5.2: Side view of a EuroTrough ET150 collector unit (150m length).....	27
Figure 6.1: Schematic for CSP plant with molten salt storage	36
Figure 7.1: Regions developing solar thermal projects	41
Figure 8.1: LEC Levelised Energy Cost, solar trough and tower technology, 2004-2020	52
Figure 9.1: National renewable energy policies in EU countries.....	72
Figure 9.2: US states with RPS regulations, 2007.....	73

Tables

Table 6.0.1: Comparison of Solar Thermal Power Technologies	31
Table 6.1: Sensible storage materials, solid and liquid, temperature, average heat capacity and media cost.....	36

Table 6.2: Selected low temperature inorganic salt hydrate PCMs , with melting points and average heat capacity	37
Table 6.3: Selected low temperature inorganic salt hydrate PCMs , with melting points	38
Table 6.4: Selected low temperature organic PCMs , with melting points	38
Table 7.1: Early solar thermal power plants	42
Table 7.2: CSP plants in operation 2009 in Spain	43
Table 7.3: CSP plants under construction in 2009 in Spain.....	43
Table 7.4: CSP plants announced in 2009 in Spain	44
Table 7.5: CSP plants in operation 2009 in the US.....	45
Table 7.6: CSP plants announced in 2009 in the US.....	45
Table 8.1: Cost of parabolic trough STPP in recent feasibility studies	50
Table 8.2: Estimated cost of central receiver STPP in \$/kW	50
Table 8.3: Estimated current US cost and performance of conventional power plants	51
Table 8.4: Required investment in STP by Phase	51
Table 9.1 Renewables targets and support schemes of European countries	56
Table 9.2 Non-European countries with renewable energy targets and plans	65
Table 9.3: State RPS resource tiers	75

2. Development of Solar Thermal Technology

Solar energy is usually divided into two categories, although they are sometimes employed together in installations.

- **Solar thermal** energy is generated from heat and employs heat directly to heat water or buildings, or to produce steam to power electricity generators.
- **Solar photovoltaic** electricity is generated from light, employing photovoltaic modules or cells, which convert sunlight into electricity using cells with semi conductors.

This report is concerned with the first of these technologies, solar thermal energy conversion. Solar photovoltaic energy is the subject of another report published by ABS, SPV Solar PV Report Ed 6, 2009.

Solar thermal energy can be sub-divided into two categories:

Solar heating or **direct** use – by far the largest category at present, the heat from the sun is captured and used to heat or cool water, using low or medium temperature thermal collectors.

CSP, concentrated solar power – heat from the sun is concentrated and used to generate heat and electricity, using high temperature collectors

Solar thermal collectors are classified as low, medium, or high temperature. Low temperature collectors are flat plates generally used to heat swimming pools. Medium-temperature collectors are also usually flat plates but are used for creating hot water for residential and commercial use. High temperature collectors concentrate sunlight using mirrors or lenses and are generally used for electric power production. These are known as CSP (concentrated solar power) units.

Solar thermal is one of only three renewable energy resources which generate heat, the other two being geothermal and biomass. Since deep geothermal is limited to few locations and biomass will be used extensively for electricity generation and transport, low and medium temperature solar thermal energy will be an important contributor to low temperature heat.

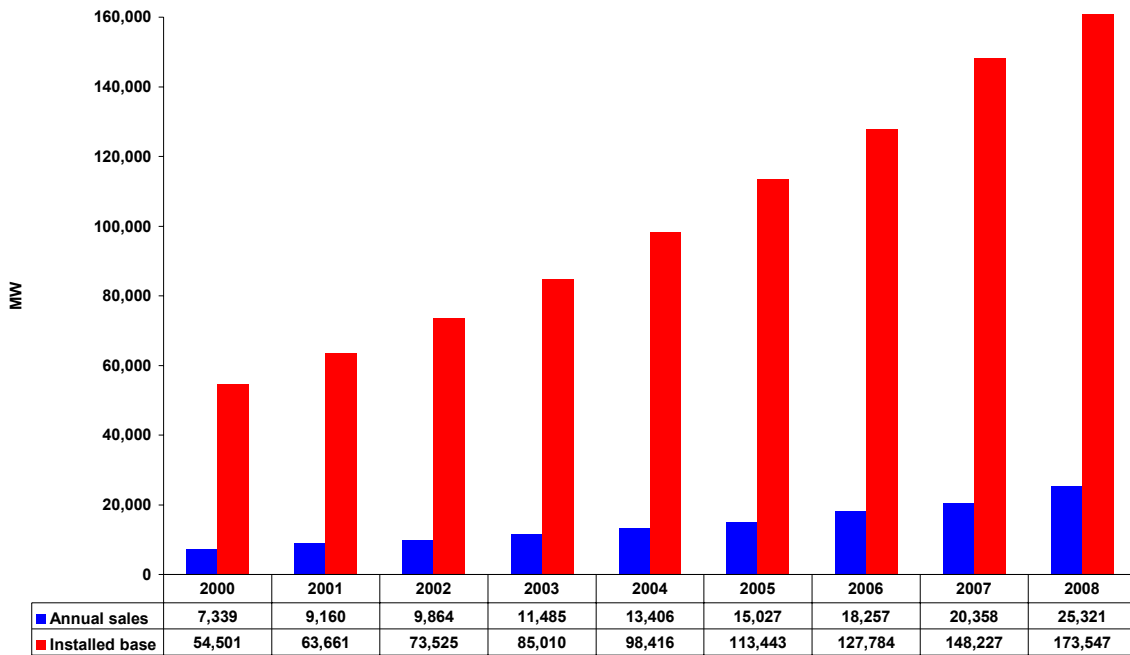
Heat can be stored thermally. Depending on the temperature of the collectors, the heat can be used later to heat or, with heat exchanger, to cool a building, or to generate electricity. In CSP plants heat is transferred to a thermal storage medium in an insulated reservoir during the day for power generation at tonight. Thermal storage media include concrete, graphite, pressurised steam, a range of phase change materials and molten salts such as sodium and potassium nitrate and mixtures of the two.

Low and medium temperature collectors solar thermal currently have a far higher installed energy capacity than solar thermal collectors used to generate electricity, and also far higher than the installed capacity of solar PV. In comparison, by 2009 there was 147,000 MW of wind power, 174,000 MW of solar thermal collectors for water heating and building heating or cooling installed, 17,000 MW of solar PV capacity, but only 1,000 MW of high temperature solar thermal collector generating capacity.

Solar thermal energy can be directly used for cooling and dehumidification. Cooling technologies include single- and double-effect absorption chillers, adsorption chillers, and solid or liquid desiccant systems. There are 81 solar cooling systems in the world, of which 73 have been counted in Europe, 7 in Asia and one in Mexico, with a total solar collector area of about 24,000 m² and a total capacity of 9 MW chilling power.

China leads the world overwhelmingly in low and medium temperature solar use, with 99 GW installed at the end of 2008. The US was in second place with 23 GW, Germany third 12 GW and Turkey with 11 GW. Apart from the Chinese lead, low and medium temperature collectors are most developed in the industrialised countries of Europe, but they are important in some developing countries where they enable large cost savings, with simple devices such as solar cookers and solar water heaters. These appliances use solar heat directly. All technologies operating through solar heating come under the category of solar thermal. These include non-grid solar thermal technologies; water heating systems, solar cookers and solar drying applications etc. These technologies help conserve energy in heating and cooling applications. Solar thermal appliances can be manufactured with a low level of technology and are ideally suited for developing countries. In industrialised countries, solar thermal technology has more advanced applications such as solar thermal building designs. All of these solar thermal devices use heat directly from the sun. They are cheap to manufacture and cost nothing to use.

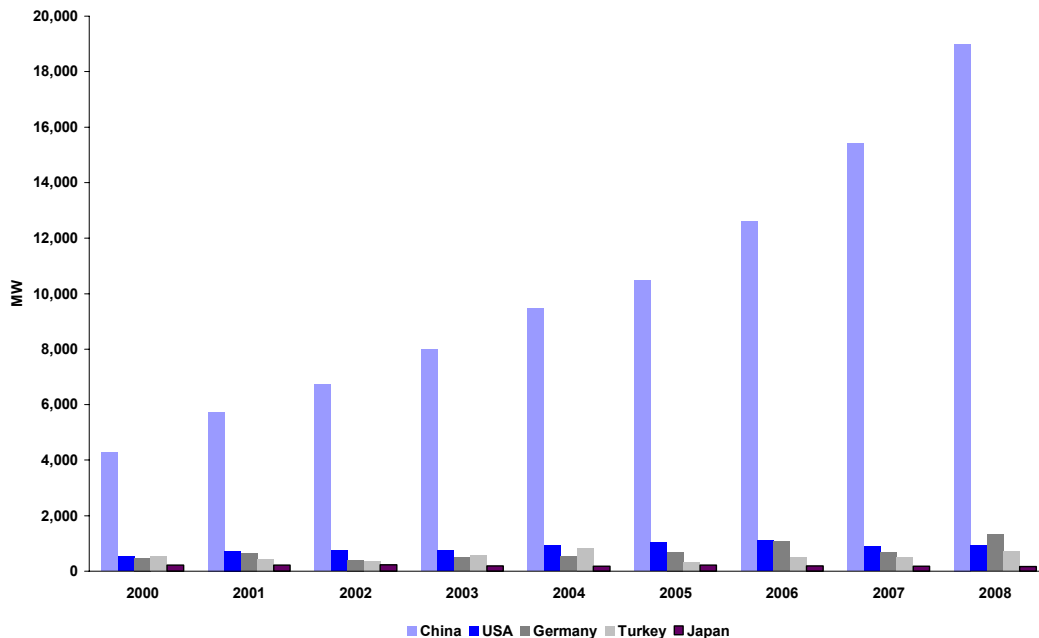
Figure 3.1: Solar collector sales and installed base, 2000 to 2008 MW



Source: ABS Renewable Energy Database, EIA

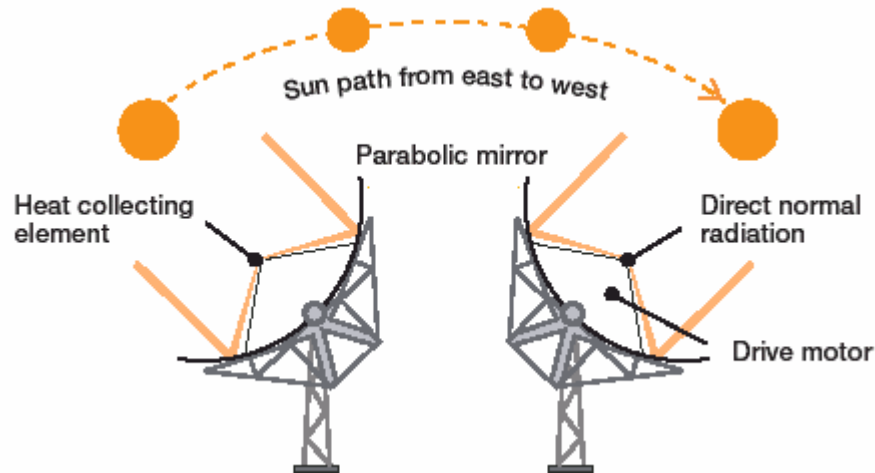
The global solar thermal market is dominated by China, which had a 75% share of global sales in 2008, amounting to an estimated 19,000 MW of capacity (this is a preliminary estimate based on several different figures). Germany increased sales from 672 MW to 1,334 MW and had the second highest sales with 5%. The US had 922 MW or 4%, and Turkey had 3% and Australia 2% and no other country had more than 1%. Although Japan has very high solar PV sales it is insignificant in solar thermal.

Figure 3.2: Leading countries' sales of solar thermal collectors, 2000 to 2008, MW.



Source: ABS Renewable Energy Database, EIA

Figure 6.3: Operating principles and daily tracking of a parabolic trough collector



Source: European Solar Thermal Industry Association

An alternative to mechanical trackers is being developed in Australia, known as Yeoman's Floating Solar Concentrators. These are designed as a low-tech, low-cost solution and use 5m² concrete flotation modules and strips of low-iron glass mirrors set on the top surface of a Fresnel structured parabolic trough. To protect them from impact damage, a simple high-flow irrigation pump can flood the top surface of the modules in minutes, sinking them in half a meter of water. Steam can be produced at high temperatures and pressures at 60% efficiency. Final efficiency will depend on turbine operation and other factors. Full scale ponds are planned to be 110 meters in diameter and contain 340 individual modules. They would have an estimated peak output of 1.5 MW, and an estimated capital cost of AU\$ 1 million/MW.

Fresnel Principle Solar Collectors

Another potential technology under investigation is a parabolic line-focusing concept with segmented mirrors, employing the Fresnel principle. Although this will reduce efficiency, the developers expect a considerable potential for cost reduction, since the closer arrangement of the mirrors requires less land and provides a partially shaded, useful space underneath.

A Linear Fresnel Reflector (LFR) array is a line focus system similar to parabolic troughs in which solar radiation is concentrated on an elevated inverted linear absorber using an array of almost flat reflectors. With the advantages of low structural support costs, fixed fluid joints, a receiver separated from the reflector system, and long focal lengths allowing the use of conventional glass, LFR collectors have attracted increasing attention. The technology is seen as a lower cost alternative to trough technology for the production of solar steam for power generation. An LFR can be designed to have similar thermal performance to that of a parabolic trough per aperture area, but recent designs tend to use less expensive reflector materials and absorber components which reduce optical performance. However, this lower performance is outweighed by lower investment and operation and maintenance costs. Fresnel collectors also have other advantages, such as allowing use of the land below the mirror fields for other economic purposes, such as horticulture. In 1999, the Belgian Company Solarmundo erected the largest prototype of a Fresnel collector, with a collector width of 24 m and a reflector area of 2500 m². The next step will likely be a pilot plant to demonstrate the technology in a large scale system under commercial operational conditions. Most convenient and cost-effective would be a plug-in solution of a Fresnel collector connected to an existing power plant. The Australian company Solar Heat and Power is planning a 24,000 m² pilot CLFR array for attachment to a coal-fired station in late 2003.

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