The Solarserver
Forum for Solar Energy

German
Solar-Report

Add to Favorites

Banner Advertising | Bulletin Board | Events | Solar Magazine | Funding for Solar Energy | Companies | Solarstore (G) | Non-Profit Organizations | Lexicon | Basic Knowledge | Educational Institutions | Imprint | Contact Us | Home

Solar Magazine

Solar Report
Solar News
Solar Links
Solar Energy System of the Month
Solar point of view
Solar Interviews
Solar Archive:
- Photovoltaics
- Solar heating
- Solar Building
- Fuel Cell
- Solar News Archive

Your Suggestion

search

Solar-Reports:

- Concentrated solar power: Versatile technology with huge potential for clean and affordable energy
- Photovoltaic market trends 2010: Worldwide growth; uncertainty in the German market
- Solar-assisted heating and cooling of buildings: technology, markets and perspectives
- United States PV market becomes a global demand leader by 2012
- Third generation thin film solar photovoltaic technologies on track to breakthrough
- Concentrating Solar Power (CSP): Outlook on Large Potentials and the MENA Region
- The Price of Policy Risk – Empirical Study Looks at the Willingness of European Photovoltaic Project Developers to Invest

Concentrated solar power: Versatile technology with huge potential for clean and affordable energy

by Christian Roselund
2010-05-03

During this decade, Concentrating solar power systems (CSP), which focus the light of the sun to generate power, could emerge as the most widely used solar technology in the planet.[1] CSP has several distinct advantages that make it the most practical solar technology for many applications: it can be produced at a lower cost per kWh and has more efficient storage options than photovoltaics (PV), it has better economies of scale and wider uses than small-scale solar hot water, and CSP plants can take advantage of existing components and manufacturing processes as they utilize many technologies similar to those used by fossil fuel generation plants.

Solar-Report as PDF-Document

Concentrating Solar Power: CSP also holds the greatest potential to deliver power and, in many cases, drinking water to those in the developing world who have limited access to both. Courtesy Solar Millennium AG; DESERTEC Foundation

The United States and Spain currently lead the world in both planned and operational CSP. Global development of these technologies is uneven, and, like other solar technologies, is more driven by policies and economics than by solar potential. However, CSP also holds the greatest potential to deliver power and, in many cases, drinking water to those in the developing world who have limited access to both. The solar report on solarserver.com provides an overview on technologies and market development worldwide.

CSP has distinct geographical limitations; even in best case scenarios these technologies will likely not be supplying power to Swedes or Canadians in the foreseeable future. However, for many areas in a large belt encompassing the tropics and some temperate climates, where a large portion of the earth's inhabitants live, CSP offers an affordable, practical and renewable form of electricity production that can represent a dramatic reduction in greenhouse gas emissions compared to conventional fossil fuel generation.

The scale of concentrated solar is set to increase dramatically as projects in the planning and construction stage come online. More than 800MW of CSP plants are currently operational, and this number will likely reach 1GW around 2011, however in the United States and Spain alone 17GW of plants are planned or under construction.[2]

Courtesy ACCIONA Energy S.A.; Bell Independent Power

What is CSP?

CSP is a term for technologies that concentrate the sun's rays, and can be used for systems that either direct these rays onto photovoltaic solar cells (CPV) or heat a fluid, which is then used to generate electricity via conventional turbines, stored for later use, or used to supply heat for industrial processes. The first kind, where light is concentrated onto a photovoltaic surface is called concentrating photovoltaics (CPV). CSP often refers specifically to systems which heat fluids (which can also be called concentrated solar thermal), and this report uses the term CSP to refer only to these technologies.

There are four main CSP designs currently in use at the utility scale: parabolic troughs, tower systems, parabolic dishes and linear (Fresnel) troughs. Parabolic troughs currently account for over 90% of the generation capacity in installed CSP, however many in the solar industry speculate that tower systems will become more widely used than parabolic troughs in the future.

1. Types of CSP systems

Parabolic troughs

Parabolic trough systems consist of rows of curved mirrors that concentrate the sun's rays onto a central tube containing the fluid to be heated. The mirrors utilize a tracking system to follow the sun, typically rotating on one north-south axis. The sunlight on the mirrors is concentrated 70-100 times and the fluids are heated to temperatures as high as 400 degrees Celsius. Many of these systems use synthetic thermal oil, which is used to create super-heated steam to run turbines.

The 64 MW Nevada Solar One installation in the US state of Nevada is an example of a parabolic trough system. Courtesy: SCHOTT AG

Solar tower plant by eSolar. Courtesy: Ferrostaal AG

Solar Tower systems

Tower systems use a field of heliostats (large mirrors with sun-tracking capabilities) focused on a single point in a tower to heat a fluid. Tower systems concentrate sunlight 600-1000 times to heat transfer fluids including molten salts, water, air and other gases from 800 to over 1000 degrees Celsius.

If pressurized gas or air is used as the transfer media, it can be used to directly replace natural gas in conventional gas/steam combined cycle turbine. The 11MW Planta Solar 10 (PS10) and 20MW PS20 towers near Seville, Spain are tower systems.

Dish engines

Dish engines use parabolic dishes to concentrate sunlight onto a receiver in the focal point of the dish, heating a fluid which then runs a turbine or sterling engine. These technologies typically heat fluids to 750 degrees Celsius.

"SunCatcher" dish stirling engines. Courtesy: CPS Energy

Linear (Fresnel) troughs

Linear troughs operate similar to parabolic troughs, except that the mirrors used are flat and much of the hardware is simpler. These systems cost less than parabolic trough systems, but are less efficient.

Hybrid systems

Many of the CSP systems in place combine their CSP operation with a natural gas combined cycle turbine to generate power when the sun is not shining. An example of a hybrid system is NextEra Energy Resources' SEGS plants in California's Mojave Desert, which utilize a natural gas backup system.

MicroCSP

Solar company Sopogy (Honolulu, Hawaii, US) has developed a microCSP system that utilizes technology similar to parabolic trough systems, only on a smaller scale. Sopogy's SopaNova system has a capacity of 3kW for electricity and hot water production, and is advertised for both on-grid and off-grid applications. In December of 2009, a 2MW plant using Sopogy microCSP units opened in Hawaii.


Left: microCSP system by Sopogy.Right: The world's first MicroCSP plant Holaniku at Keahole Point, Hawaii, Courtesy Sopogy

2. Technical issues

Storage

A major advantage of CSP is easier, more efficient storage than PV systems allow. With adequate storage and/or hybrid backup systems CSP plants can provide both base-load and dispatchable (on demand) power, like conventional fossil fuel plants.[3]

Power storage for CPS systems typically takes the form of storing heat for later use, as opposed to some PV systems which use battery backup systems to store electric charge. While this solution is typically more cost-effective, there is no one-size fits all solution for thermal storage for the different systems, and solar thermal storage systems must be designed with the type of fluid, operating temperature and pressure, and other factors considered. Many operational systems currently directly store heat using the steam generated or indirectly store heat via molten salt.

Systems using concrete and other mediums to indirectly store heat are also in development. For parabolic trough systems, molten salt stands out as a superior heat storage medium, and the Andasol parabolic trough plant in Spain uses molten salt as a storage medium.

Courtesy: Solar Millennium AG

Solar Cooling

Cooling is also an issue for CSP. CSP systems are typically cooled using either water or air. The use of water to cool systems can put additional stresses on desert environments, where may CSP facilities are located. However, using air to cool systems means higher investment costs and 5-10% lower efficiencies.

3. The state of CSP worldwide

90% of operational CSP plants are located in the United States and Spain.[4] The American Southwest has greater potential and the United States has a slightly larger total installed capacity, however on a per capita basis Spain produces far more power with CSP than the United States. Spain has ten operational CSP plants between 1 and 50MW.[5]

Much of the concentrated solar power currently in use in the United States was built between 1986 and 1992, in a series of plants in California's Mojave Desert, the Solar Energy Generating Systems (SEGS), which total 354 megawatts. The United States did not put another CSP plant online until the 64MW Nevada Solar One plant in 2007.

Solar thermal experimental and demonstration power plant in Jülich. The technology for the core of the facility, the receiver, was developed and patented by the German Aerospace Center, DLR, together with the Jülich Solar Institute, provided scientific guidance and support for the planning, design and operation of the power plant.

Courtesy DLR

Australia, France, Germany[6] and Israel have all completed CSP systems, however none of these is larger than 2 MW. Germany does not receive enough of the right kind of sunlight to make it suitable for large-scale development of these technologies. CSP plants are under construction in Algeria, Egypt, Italy and Morocco, and of course in Spain. In both Spain and the United States a large number of CSP plants have been proposed.

4. Geography and CSP

CSP systems require different and more specific qualities of sunlight than PV systems. CSP requires Direct Normal Irradiation, which means light that is not scattered by cloud cover, fumes or dust. The best sites are in the tropics and at high altitudes. Many areas in temperate climes which are considered suitable for PV are less suitable for CSP technologies. Sites that considered suitable get 2,000 kWh/year of direct sunlight; optimal sites get more than 2,800 kWh/year.[7]

The Southwestern United States, Mexico, Australia, Spain, Iran, India, Pakistan, Chile, Argentina, Brazil, as well as most nations in the Middle East and much of the continent of Africa all have areas of strong potential for CSP. Some of the best locations for CSP are in the deserts of Northern Chile, South Africa, Egypt, Libya and Western Australia.[8]

5. Cost

Costs of CSP production vary according to the solar resource where the plant is located, and levelized electricity costs for currently operational parabolic trough systems range from USD$0.17 - 0.25/kWh, though proponents claim costs can be as low as USD$0.15 in places with very good solar radiation. As with other solar technologies, the vast majority of the costs are materials and construction, and investment costs range from USD$4.20 - 8.40 per watt, depending on the solar resource and the size of the storage options.[9]

Costs are expected to decrease 2-5% per year due to innovation in systems and components, improvement of production technology, increase of the overall efficiency, enlargement of operation hours, bigger power blocks, decrease in the O&M costs, learning curve in construction and economies of scale.[10]

6. Uses of CSP

CSP is typically used to generate electricity, however the heat generated by CSP can also be used for sterilization and for heating and absorption chilling.

Water desalination is one potential use of CSP that has been widely studied. Globally 1.2 billion people live in communities that do not have regular access to clean water. Until now, desalination has been an energy intensive and prohibitively expensive way to meet those needs, however many nations are looking at solar technologies to bring down these costs. Saudi Arabia's King Abdulaziz City of Science and Technology and IBM are currently pursuing a pilot water desalination project using CPV, and in 2007 the German Aerospace Center published a study on using CSP to desalinate water either using the electricity or the process steam in combined generation.[11]

The National Renewable Energy Laboratory (NREL) and the German Aerospace Center, DLR, are cooperating on CSP research. Courtesy DLR/Markus Steur.

7. Future of CSP

Spain

While Spain has an enormous number of CSP plants planned, many of those plants may not be eligible to participate in the nation's feed-in tariff upon completion, due to caps imposed after an unsustainable expansion of all kinds of solar projects following the increase in Spain's feed-in tariff in 2007 to EUR$0.18/kWh for solar PV projects between 100kW and 50MW.[12]The tariff for solar thermal projects had already been increased in 2004.

The latest figures from Spanish solar thermal industry association Protermo Solar show 15 solar thermal plants under construction for a total of 668MW with an additional 35 proposed plants between 8 and 50 MW.

California's Mojave Desert

Currently the most promising location for CSP is the Mojave Desert in California. California has multiple policies to encourage solar development, not the least of which is the state's renewable portfolio standard, which sets a mandate for utilities to get 33% of their electricity from renewable sources by 2020.

Currently the California Energy Commission and the US Bureau of Land Management, which manages public lands, have received applications for 12 CSP and hybrid CSP/natural gas projects in Southern California. If all these plants are built, they will add 4.8GW of CSP. Among these 12 proposed projects is the Ivanpah Solar Power facility, which will consist of three separate solar tower projects to total 392 MW.[13]

The Mediterranean and North Africa (MENA)

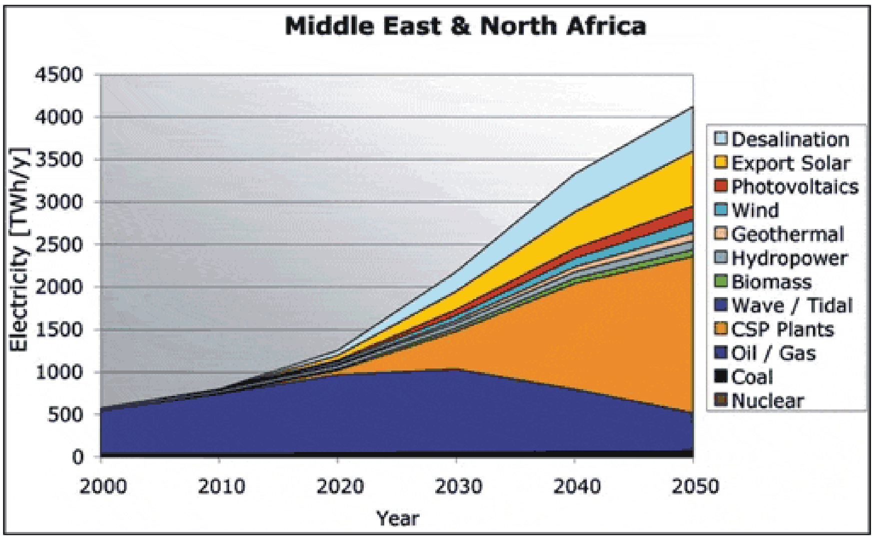
While the vast majority of Europe outside Spain has little potential for CSP, solar plant developer Nur Energie has submitted applications for two 50MW projects on the Greek islands of Crete and Rhodes.

Several North African and Middle East nations are also pursuing CSP, but at a rate much slower than Spain and California. In 2004 Algeria became the first OECD nation to pass a feed-in tariff. Algeria is developing a hybrid combined cycle gas turbine and CSP plant at Hassi R´mel, with 25MW of CSP. Morocco is also constructing a project that includes 20MW of CSP as part of a larger hybrid plant.[14] The Kingdom of Jordan was making steps towards a 100MW CSP project in 2008 and 2009, but declined a funding offer in January 2010, stating concerns about repaying the large debt that would be incurred.[15]

Among North African Nations, Egypt is closest to developing a CSP plant. In Flagsol GmbH (Cologne, Germany) and Orascom Construction Industries (Cairo, Egypt) completed construction of the troughs and lines for a 150MW combined parabolic trough CSP and natural gas plant at Kuraymat, 100 miles south of Cairo.

The Desertec Initiative

Perhaps one of the most ambitious plans for concentrated solar power is the Desertec Initiative. In 2008 the Desertec Foundation was created to advance a plan to generate power in the Sahara Desert with CSP, PV and wind farms and transmit much of this power to Europe via high-voltage DC lines. The plan aims to provide 15% to 20% of Europe's electricity this way.[16]



TRANS-CSP MENA energy mix for energy supply and climate protection. Courtesy: Trans-Mediterranean Renewable Energy Cooperation (TREC)

In 2009 twelve European and North African companies and utilities joined forces to create the Desertec Industrial Initiative (Dii). Desertec singles out CSP's ability to provide base-load power as a key element of the plan, and states that in North Africa and the Middle East, CSP is "the only source that can really cope with rapidly growing electricity consumption".[17]

Nur Energie has proposed a project in Tunisia for ten 20MW CSP plants to supply power as part of this initiative. Under Nur Energie's proposal, HVDC lines would carry this power to Rome, Italy.[18]

[1] IPEA, Global Market Outlook Until 2013, (2009)
[2]Greenpeace, ESTELA, Solar PACES, >Concentrating Solar Power Global Outlook 2009, p.7
[3] Greenpeace, ESTELA, Solar PACES, Concentrating Solar Power Global Outlook 2009, p.32
[4] International Energy Agency, Renewable Energy Essentials: Concentrating Solar Power, (2009) (pamphlet)
[5] Protermo Solar map of solar installations (2010): http://protermosolar.com/boletines/boletin24.html#destacados03
[6] Renewable Energy World March 12, 2009: http://www.renewableenergyworld.com/rea/news/article/2009/03/salt-free-solar-csp-tower-using-air
[7] Breyer, Christian and Knies, Gerhard, Global Energy Supply Potential of Concentrating Solar Power, (2009), p. 2
[8] Breyer, Christian and Knies, Gerhard (2009), p. 2
[9] International Energy Agency, Renewable Energy Essentials: Concentrating Solar Power, (2009) (pamphlet), Greenpeace, ESTELA, Solar PACES, Concentrating Solar Power

Global Outlook 2009, p.13
[10] ESTELA, Solar Power from the Sun Belt, (2009) p. 20
[11] German Aerospace Center, Concentrating Solar Power for Seawater Desalination
[12] http://www.solarpaces.org/News/Projects/Spain.html
[13] California Energy Administration website: http://www.energy.ca.gov/siting/solar/index.html
[14] http://allafrica.com/stories/200804060020.html
[15] The Jordan Times, January 6, 2010: http://www.jordantimes.com/?news=22935
[16] Desertec website, http://www.desertec.org
[17] Desertec Foundation, *Clean Power from Deserts*, 2009, p. 31
[18] Nur Energie brochure, available on the Nur Energie website, http://www.nurenergie.com

Additional Solar-Reports:

The photovoltaics industry: against all odds, strong growth continues
PV production: The dawn of the "gigawatt" fab
Review Intersolar 2008: the largest solar fair of the world
2008 Photovoltaic trends: Innovative thin film technology and large-scale power plants
Large photovoltaic power plants: average growth by almost 100 % since 2005

Research Agenda provides a Vision for European Photovoltaic Solar Energy Technology
Organic photovoltaics: solar power from extremely thin tinted films and polymer films
Intersolar on its way to becoming the Solar World Fair
Building integrated Photovoltaics (BIPV): Solar electric power systems conquer large roofs and façades
Solar thermal in Europe: expanding markets, state-of-the-art technical solutions
Photovoltaic investments outside Germany? Looking into the southern EU states
Solar power from the desert rather than desert in Germany

New Study: Renewable Energy can replace abandoned Nuclear Energy in Germany
BBC Interview with Dr. Knies (TREC): The energy source of the future is solar
Photovoltaic industry achieves record profits, discussion over high module prices continues
Chinese solar modules penetrating the German market
Solar Roof Tile Exhibition shows developments in photovoltaic roofing
Intersolar 2006: Solar technology and demand at an all-time high

New Photovoltaic Factories and Capacities in Germany
Renewable Energy in Australia
Cooling with Solar Heat: Growing Interest in Solar Air Conditioning

Building Solar: The Prospects and Costs of Living with the Sun
Fuel Cell Research and Development in Southern Germany
The Photovoltaic Market in Japan: Unquestioned Leadership of World Market
The National Energy Plan
Trade Fair Intersolar 2001 Presents World Wide Solar Technology for the First Time
Solar Thermal Technologies in the United States
An Overview of Photovoltaics in the USA
The Year 2000: Breakthrough for Solar Technology in Germany

Fuel Cells and Solar Hydrogen-A Power Package for the Future?