Environmental and Energy Study Institute

Fact Sheet

Concentrated Solar Power

Focusing the sun's energy for large-scale power generation

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Concentrated solar power (CSP) is a method of electric generation fueled by the heat of the sun, an endless source of clean, free energy. Commercially viable and quickly expanding, this type of solar technology requires strong, direct solar radiation and is primarily used as a large, centralized source of power for utilities. In contrast, photovoltaic cells are effective in a wider range of regions and applications. CSP plants generate power best during the late afternoon – during peak demand – and can displace the use of fossil fuel plants that emit the greenhouse gases that cause climate change. As energy storage technology continues to advance, more CSP plants will be able to provide baseload power throughout the night.

TECHNOLOGY

CSP, also called solar thermal power, uses mirrors to focus sunlight onto a heat-transfer medium. The steam produced from the heat-transfer medium powers a turbine or engine that generates electricity. Depending on the type, CSP plants can supply up to 100 megawatts (MW) with a potential to produce up to 300 MW, on par with other utility-scale power plants. Effective CSP requires solar radiation of at least 5.5 kWh/m^2/day – California averages 6.75-8.25 kWh/m^2/day[1] – and functions best in arid, flat locations. The U.S. Southwest, Sahara Desert, and Australia have the highest potential capacity for CSP in the world.[2]

TYPES OF CSP SYSTEMS

Parabolic Trough: Long, curved mirrors pivot to concentrate sunlight onto tubes filled with a heat transfer fluid, generally oil or water, whose steam moves a power-generating turbine. These systems are the most developed CSP technology and have operated in the United States since the 1980s. Optimal capacity size is 150-250 MW – enough to power 44,000 homes – although 80 MW is the largest plant size today. Alternately, one U.S. company, Sopogy Inc., has created a "Micro CSP" system that uses a scaled-down parabolic trough system for distributed generation on rooftops.[3]

Linear Fresnal Reflectors (LFR): Still in the demonstration stage, LFR systems function like parabolic trough systems but use flat mirror strips instead of curved mirrors. Although less efficient than other CSP systems, the cheaper expense of flat mirrors lowers initial investment cost.

California Parabolic Trough Plants Productive for 25 Years

California's Solar Electric Generating Systems I-IX have generated 12 million MW and earned more than $2 billion since 1984.

www.ecoleaf.com/green_energy/solarthermalpower.html

Dish/Engine: Mirrored dishes (resembling those for satellite television) track the sun and concentrate its heat onto a power-generating unit that has an engine powered by a heat-responsive fluid. Stirling engines, the most common type of engine for this system, do not require the extensive water cooling system needed for steam engines because its engine is powered by the expansion-contraction of hydrogen gas as it is heated and cooled. The newest systems have a 31.5 percent sun-to-grid energy conversion efficiency, the highest among CSP plants.[4] However, they have a smaller production capacity of 0.003-0.025 MW.[5] The first commercial deployment of a dish/Stirling system array is planned for 2010.[6]

Power tower: Fields of flat mirrors focus sunlight onto a central receiver filled with a heat-transfer fluid, most often molten salt, which can trap thermal energy for long periods. These systems concentrate heat at higher temperatures than other CSP systems, improving their conversion efficiency. A 20 MW power tower system came online in April 2009 outside Seville, Spain,[7] and the early Solar Two demonstration plant, a 10 MW facility that operated from 1996-1999 in Barstow, California, had a storage tank which provided three hours of electricity when the sun was not shining.[8]

NIGHTTIME GENERATION

CSP generates power during daylight hours when demand for electricity is greatest. The heat transfer process ensures stable generation for 15-30 minutes, enough time to endure passing clouds, but during the night or extended cloud cover, power generation requires one of two options: supplemental fuels or thermal storage. The majority of CSP today is supplemented with natural gas so a plant can provide baseload power at all times. Like most CSP systems, many natural gas plants use steam engines to generate power, so the two systems can be hybridized easily. Alternatively, thermal storage technology can allow CSP plants to meet baseload demand without the use of backup fuels. CSP systems with storage can operate by sunlight alone for 70 percent of the year, as opposed to 15-30 percent without storage.[9] One branch of the U.S. Department of Energy (DOE)'s Solar Energy Technologies Program is conducting research on advanced heat-transfer fluids and storage techniques.

Andasol I Powers through the Night

This 50 MW parabolic trough plant located in Spain has a two-tank molten salt heat storage system that can generate electricity for an additional 7.5 hours, even after the sun goes down. It began operation in December 2008, and two sister plants nearby will be finished in 2011. German parent company Solar Millennium also plans to build a similar plant in Nevada by 2011.

www.nrel.gov/csp/solarpaces/operational.cfm

WATER AND LAND IMPACTS

Because CSP functions best in sunny desert climates, water scarcity is often an issue. CSP plants with a steam engine require a cooling system to recirculate the water used. Wet cooling systems can use 758-957 gallons of water per MWh, a level comparable with coal plants.[10] Dry cooling systems, such as the Heller system, use air instead of water and can reduce water usage up to 97 percent. However, they are more expensive and can reduce energy efficiency by 5 percent.[11]

Land requirements vary from a single rooftop for Micro CSP to 500 acres for a power tower system. The largest non-hybrid CSP system, Nevada Solar One, is a 64 MW parabolic trough plant on 400 acres. The acreage needed to generate power from coal or hydroelectric dams is higher when the mining or reservoir sites are considered.[12] In 2009, the Department of the Interior designated 24 areas in six Western states — totaling 670,000 acres of federal land — as Solar Energy Study Areas, where environmental impact statements and solar resource surveys will be conducted by a new task force in the Bureau of Land Management.[13] This advance work will accelerate the permitting process for future projects.[14]

PRODUCTION CAPACITY

All solar power, including photovoltaics, generated only 0.09 percent of U.S. energy supply in 2008, but capacity is growing.[15] Currently, the United States is the world leader in installed CSP capacity, with 429 MW operating in three states (see chart below). Approximately 7,000 MW from CSP is in development in the United States alone,[16] and of that, 3000 MW from CSP is expected to be operational by 2011.[17] The DOE projects that 2 million homes could be powered by CSP in the United States in 2020.[18]

CSP Plants Operating in the United States[19]

Name and Location	Built	Principals	Capacity	Type
SEGS (Solar Electric Generating Systems) I-II Daggett, CA	1985-1986	Cogentrix (owner/operator), Luz (developer), Southern California Edison (utility)	44 MW	Trough-natural gas hybrid; SEGS I had a thermal storage system with a three-hour capacity that was damaged by a fire in 1999.
SEGS III-VI Kramer Junction, CA	1987-1989	NextEra (owner/operator), Luz (developer), Southern California Edison (utility)	5 x 30 MW each	Trough-natural gas hybrid
SEGS VIII-IX Harper Lake, CA	1990-1991	NextEra (owner/operator), Luz (developer), Southern California Edison (utility)	2 x 80 MW each	Trough-natural gas hybrid
APS Saguaro Tucscon, AZ	2006	Arizona Public Service (owner/ operator/utility), Solargenix Energy (developer/solar provider)	1 MW	Trough
Nevada Solar One Boulder City, NV	2007	Acciona/Solargenix Energy (developer/operator), Nevada Power (utility)	64 MW	Trough
Kimberlina Solar Thermal Energy Project[20] Bakersfield, CA	2008	Demonstration project by Ausra USA	5 MW	Linear Fresnal Reflector
Keahole Solar Project[21] Kailua-Kona, HI	2008	Demonstration project by Sopogy	0.5 MW	Micro Trough
Sierra SunTower[22] Lancaster, CA	2009	eSolar (developer), Southern California Edison (utility)	5 MW	Power Tower

Selected CSP Projects in Development[23]

California

- 34 projects planned with 9,183 MW potential capacity, including:
  - 1600 MW from Stirling engine systems
  - 747 MW from power tower systems
  - 177 MW from LFR systems
- 8 projects, totaling 4228 MW, are currently in the review process.

Mojave Desert

- 1 project with 553 MW potential capacity planned for construction mid-2009-2011
- 25 year power purchase agreement made in 2007 between Solel and Pacific Gas & Electric
- Currently the world's largest solar plant in development

Florida

- A hybrid of gas and parabolic trough systems with 75 MW potential capacity of solar power
- Projected to supply 11,000 homes in Martin County by 2011
- Power purchase agreement between Lauren Engineers & Constructors and Florida Power & Light

U.S. Army

- 500 MW photovoltaic-CSP project for the Army training center at Fort Irwin, California
- Commission won by private company partnership between Clark Energy Group and Acciona
- Possible expansion to 1000 MW
- The project value could be worth $2 billion

Spain has the second-most installed CSP capacity at 182 MW and has much more under development. More than 1000 MW of CSP projects have begun construction since Spain's feed-in tariff (see next section) was introduced in 2002.[24] Israel has a demonstration power tower plant and larger trough projects in the works. Large-scale CSP plans have been announced in Jordan, South Africa, United Arab Emirates, and others. Egypt, Morocco, and Mexico received financial support from the Global Environment Facility of the World Bank to build parabolic trough hybrid systems, although the implementation process has been slow.[25] In the most ambitious plan yet, Desertec Foundation is gathering the support of companies from Germany to potentially build a 100,000 MW CSP project in the Sahara Desert and power lines across the Mediterranean Sea to connect it to Europe. [26]

COSTS AND INCENTIVES

CSP plant construction takes about two years and requires hundreds of thousands of tons of steel, copper, plastic, and concrete. Eighty percent of the cost for CSP is related to construction, compared to 20 percent of the total cost of fossil fuel plants.[27] However, unlike coal or natural gas, the fuel cost for CSP is zero, and operations cost up to 30 percent less than natural gas plants.[28] CSP plants last for decades — the first CSP plant built in 1984 is still working efficiently — and offset the energy used in the manufacturing process in only five months.[29]

The average prices in the United States for electricity generated from natural gas and coal are 9 and 6 cents/kWh, respectively, while CSP costs about 14-16 cents/kWh.[30] CSP becomes more cost effective during peak demand, the late afternoon, a time when solar power generation is also high. Additionally, several studies project that the cost of building these systems should come down as the industry matures, bringing the prices as low as 5 cents/kWh.[31]

Clean Energy Jobs

A 2006 study commissioned by the National Renewable Energy Laboratory found that **94 permanent jobs were created for every 100 MW of CSP generating capacity**, compared to 13 and 56 jobs for single- and combined-cycle natural gas power plants, respectively.

http://www.nrel.gov/csp/troughnet/pdfs/39291.pdf

Policy measures can accelerate the deployment of CSP. Spain and Israel have feed-in tariffs — laws stipulating that utilities pay an above-market price for renewable energy over a fixed time period — that have spurred growth, but the United States has been less consistent in its support for the industry. Because CSP projects take around six years from planning to completion, investors need a stable, long-term price signal.[32] In the 1980s, nine parabolic trough plants were built in California under favorable tax incentives and power purchase agreements (and still function today), but after funding lapsed, no new plants came online until 2006. At the national level, the *Emergency Economic Stabilization Act of 2008* (P.L. 110-343) renewed the 30 percent investment tax credit for solar energy for eight years, three months before it was due to expire, and allowed public utilities to claim the credit. In July 2009, the DOE Solar Energy Technologies Program announced an additional $52.5 million in grants for research and development of CSP baseload systems.[33] The cap-and-trade initiative passed by the U.S. House of Representatives in the *American Clean Energy and Security Act of 2009* (H.R. 2454) would put a price on emitting greenhouse gases, making CSP and other carbon-free energy technologies more economically viable. Another provision of H.R. 2454 would create a Renewable Electricity Standard that would mandate 20 percent of the nation's electricity to be generated from renewable resources (including solar) by 2020. It remains to be seen whether such legislation will pass the U.S. Senate and become law.

DOE Goal: 1000 MW by 2010

The Department of Energy is partnering with the Western Governors' Association on the Southwest Concentrating Solar Power 1000-MW Initiative. If successful, this initiative could bring CSP prices down to 7 cents/kWh.

http://www.nrel.gov/csp/1000mw_initiative.html

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