Fact Sheet Concentrating Solar Power (CSP)

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November 2008

CSP in 80 words

Concentrating Solar Power is the technique of Solar Thermal Power stations. In conventional power stations heat from burning coal, gas or oil, or from a nuclear reactor is applied to produce high-pressure steam. The steam feeds a steam turbine connected to an electric generator. In a Solar Thermal Power station the rays from the shining sun are concentrated by means of mirrors onto the boiler of a conventional power plant. The solar heat replaces the fire: CSP-plants are sustainable thermal power stations..

CSP Technique

Mirror systems.
The solar rays are concentrated by means of mirrors and deposit their heat onto a receiver, causing a huge rise in temperature. The mirrors must rotate continuously to compensate for the earth's rotation. There are four CSP mirror configurations:

1. Parabolic trough mirrors; they have a line focus, are North-South oriented, and rotate along one axis
2. Linear Fresnel mirrors; they have a line focus, and rotate along one axis
3. Solar tower with a field of heliostat mirrors which rotate along two axes and have a point focus
4. Solar dish with a point focus.

Receivers.
The receivers are covered by a spectral-selective layer in order to reduce radiation loss.
The receiver tubes in the focal line of parabolic trough mirrors operate at 400^0C and are isolated by means of a glass tube containing vacuum. The receiver section of a linear Fresnel field consists of a secondary mirror and a receiver tube, operating generally at 300^0C without vacuum isolation. The receiver in the top of a solar tower is either a thick-walled steam boiler, or a ceramic air heating system reaching temperatures up to 800^0C. In the receiver of a solar dish a Stirling engine transforms heat into mechanical energy.

Heat transport and storage.
The existing parabolic trough plants apply a silicone oil to transport heat from the receivers to the steam boilers. Application of liquid alkali nitrates, with better thermal stability, is under study. Linear Fresnel systems apply direct steam production in the receiver tubes.
Heat storage enables operation of the CSP plant at night. The operating liquid is Na/KNO_3 at $300\text{-}400^0$C. When thermocline storage is used, up to 80% of the heat is stored in cheap materials like gravel or concrete.

Turbines.
Parabolic trough plants apply super-heated steam and re-heating between two turbine sections.

Linear Fresnel plants apply wet steam and turbines that are suited for operating with wet steam. In the future solar driven gas turbines in solar towers enable the establishment of combined-cycle solar power stations.

Cooling and seawater desalination.
Solar thermal power plants are generally cooled by means of cooling towers which consume water. Some suppliers deliver plants which are cooled by means of air in order to save precious fresh water. CSP plants along the coast can be equipped with MED or membrane distillation desalination, in which the waste heat from the plant is applied as heat source for the distillation process.

Current (November 2008) situation of CSP

The solar thermal power plants that were built in California in 1985-1991, 350 MW in total, are functioning well. After a 15 years period of stagnation, CSP-investments are growing fast. In Spain the PS10 solar tower near Sevilla (11 MW) was connected to the national grid in March, 2007. A 20 MW solar tower is under construction on the same site. Near Guadix three 50 MW parabolic trough plants are under construction. They will be equipped with thermal storage, allowing for 7 hours of power production after sunset. The first plant, ANDASOL-I, was put into operation in November 2008. The total amount of planned CSP capacity in Spain amounts to 1950 MW.
In Boulder City, Nevada, a 64 MW parabolic trough plant started production in 2007. In the USA trough and Fresnel plants are planned with a total capacity of 2500 MW.
CSP plants, many gigawatts in total, are under construction and planned in Portugal, Morocco, Algeria, Libia, Egypt, Jordan, United Emirates, and other countries.

Economics of CSP

General
CSP is still at the beginning of the learning curve. The kilowatthour costs are about equal to the kWh costs of wind turbines in 1985. They depend on the average intensity of the direct solar irradiation (DNI). At locations with a high (>2500 kWh/m^2/a) DNI like California the current CSP costs are 12-14 €cts/kWh, but in a less favourable location like Southern Spain they are about 22 €cts/kWh, see also [Ref.7] for costs in North-Africa. Capital costs are dominating, especially the costs of the mirror fields. They amount to about 200 €/m^2, including the receivers.

Southern Morocco.
On good locations in Southern Morocco the DNI is 2500 kWh/m^2/a. The 24-hours average irradiation strength on a horizontal surface is 1440 kWh/m^2/a. Assuming 8 hours of effective sunshine per day this is 493 W/m^2 irradiating the mirrors on average. The optical efficiency (solar heat → steam) is about 60%, the electrical efficiency (steam → electricity) 33%, so the productivity of the solar field in Morocco is 98 W/m^2 or 98 MW/km^2. A standard 50 MW CSP-plant without thermal storage needs 0.51 km^2 of mirror surface. The investment for the mirror field is therefore about €100 million. The investments for the conventional part of the power station (turbines, generators, cooling etc.) must be added to this amount.

Future CSP costs.
In an extensive, peer-reviewed report of Sargent&Lundy [Ref.1] a break-down was made of all factors that will reduce costs for parabolic trough plants and solar towers. The result of this study is as follows. When a continuous and consistent CSP investment program is performed, leading to the establishment of at least 3 GW in 15 years, the kilowatthour price of solar thermal power plants will drop to about 6 $cents or 5 €cents/kWh.

Electricity can be transported over long distances using High-Voltage Direct-Currrent (HVDC) technology. The energy losses during transport of electricity from Southern Morocco to central Europe over a distance of 3500 km are 10-14%. Together with the capital costs of the cables and the HVDC transformation stations this leads to transport costs of about 1.5 €cents/kWh. So in the future, solar electricity will be available day and night in Germany or The Netherlands for about 6.5 €cents/kWh.
Du Marchie [Ref.2] made global solar scenario studies assuming a mirror field price of 40 €/m^2. A total global solar scenario is designed including thermal energy storage, chemical energy storage (still to be developed), electricity transport over 3500 km, taking varying demand into account. The investment needed for a total solar electric power supply amounts to 18% of the global GDP during one year. The investment for a total nuclear electric power supply based on breeder reactors will be about equal.
The US Department of Energy (DEO) made the following statement in a Report to Congress [Ref.3]: "At the end of a 14-years period CSP could provide hundreds of gigawatts of electricity at 5 to 6 cents/kWh without further subsidies while also providing economic, environmental, and security benefits.
Federal policy-makers must weigh the benefits of subsidizing increased CSP deployment against the cost to taxpayers and electricity ratepayers."

Political support for CSP

Why is political support for CSP needed?
From all renewable energy sources solar energy has by far away the greatest potential. CSP is the only solar energy technology which is able to replace base-load power plants such as coal fired power stations. CSP is therefore the best technology to solve the climate problem, the energy problem and the water problem. As long as the kilowatt hour prices of solar thermal power plants are still higher than the fossil-fuel fired power stations, all governments should make legislations which forces, at least tempts companies and banks to invest in CSP.

Current situation (2008).
In the South Western USA the power demand is maximum during the day because of the heavy load from air conditioning, resulting in high power prices during daylight. CSP-plants are already viable under these circumstances. The obligatory portfolio standards forcing grid companies to produce a certain amount of renewable electricity are an effective driving force leading to CSP investments, because CSP is already the cheapest renewable energy option at these locations. The extension of the Federal Investment Tax Credit (ITC) law, which was approved by the American Congress in October 2008, will trigger energy companies to make real CSP investments.
In Spain an effective feed-in law, guaranteeing 26 €cents/kWh in the first 25 years of the CSP-investment, is attracting much private capital for CSP investments. Many other sunny countries are preparing feed-in laws for solar energy.

Measures on the national scale.
Solar thermal power has the prospect of becoming viable in 90 countries, the so-called sunny countries. Developed countries with large DNI like Australia and South Africa should copy the successful obligatory portfolio standards laws of California and Nevada or stimulate CSP investments by means of copying the successful Spanish feed-in law.
Sunny oil and gas exporting countries should invest part of their high income in CSP plants, transforming their oil and gas based power production into solar power production. As a result the oil and gas, otherwise consumed for domestic electricity production, becomes available for the world market. These countries can become exporters of solar electricity.

Governments of not sunny OECD countries should stimulate the financing of CSP investments of their national companies in poor sunny countries like sub-Sahara Africa.

Measures on the bi- and trilateral scale.
Not sunny OECD countries and sunny developing countries (like for instance The Netherlands and Tunisia) should combine forces: companies from both countries invest in solar technologies in the South, and for instance in wind in the North. Both countries present themselves as one party in the coming post Kyoto negotiations in Poznan and Copenhagen, enabling them to accept strong CO_2-reduction obligations at lower costs.
Gas exporting and trading countries like Algeria, Libya and The Netherlands should cooperate, directing a part of their large incomes from gas towards CSP investments. These countries should start a cooperation combining CSP-investments and preferred gas delivery, enabling the so-called "Gas-Rotonde" to become a "Gas-CSP-Rotonde" [Ref.6]

Measures on European and MENA scale.
(MENA = Middle East & North Africa). The DESERTEC Concept [Ref.4] gives a scenario for an ambitious CSP-development.
A Solar Mobilization Fund [Ref.5] with one billion euro's start capital should be established as secure business partner for CSP investing companies in sunny countries that are regarded to be less stable. The SMF purchases electricity and water en sells it to the local grid companies for commercial prices. The losses of SMF are covered by the European and (to a less extent MENA) governments, or by European power consumers.

Measures on global (United Nations) scale.
With an amount which is equal to 18% of one year of GDP of all countries of the world, all electricity supply can be transformed from coal, gas, oil, and uranium to the sun as primary energy source [Ref.2]. Or, when the world would resolve to invest 1% of its GDP in solar thermal power plants, all coal consuming power plants in the world could be made obsolete and could be closed within 20 years. The main source of CO_2 would than be shut down. The greatest attack against our climate would be repelled.

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