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energy

Extracting ourselves from oil

From heat to megawatts

The Sun is responsible for 99.98 % of the thermal density at the Earth's surface and provides almost all our energy either directly or indirectly. It is an inexhaustible source of heat that can be converted into electricity during the day… and even at night.

The Sun was the sole source of energy at the Earth's beginnings, it triggers photosynthesis and its heat governs the rhythms of the water and wind cycles. Since humans first appeared on Earth, the Sun has governed the rhythm of their lives too, although people have learned to exploit it to meet their increasingly sophisticated needs. By 250 BC, the Greeks were already concentrating the Sun's rays on Roman ships to set them on fire. In the 18th century, Antoine Lavoisier managed to heat his solar furnace to 1 755 °C to melt platinum.

Now we are turning our attention to the Sun to generate electricity, among other things. By using light, photovoltaic cells are opening up a highly promising avenue of enquiry, but are not necessarily suited to mass energy production, enabling them to supplant traditional electric power plants. The other avenue is to exploit heat, direct solar radiation, in larger-scale concentrated solar power (CSP) facilities(1).

Even when they are erected in deserts or in areas with a lot of sunshine, CSP plants need to concentrate solar radiation to activate an efficient thermodynamic cycle for producing electricity. Mirrors track the path of the Sun and channel its rays onto a solar collector in which a heat transfer fluid circulates. This in turn feeds a heat-transfer medium (steam or gas such as air), activating a turbine that drives a generator. The principle is simple and the two power-plant variants for CSP – parabolic trough power plants and solar tower power plants – are yielding excellent results.

Power of concentration

Parabolic trough power plants are the most cost-effective and tried and tested means for concentrating solar power. They have achieved an efficiency level close to that of coal-fired electric power plants. Dozens of rows of curved reflectors, each containing a central tube filled with heat-transfer fluid, heat the fluid to a temperature of around 400 °C. This heat collector element (HCE) then feeds a conventional electrical unit.

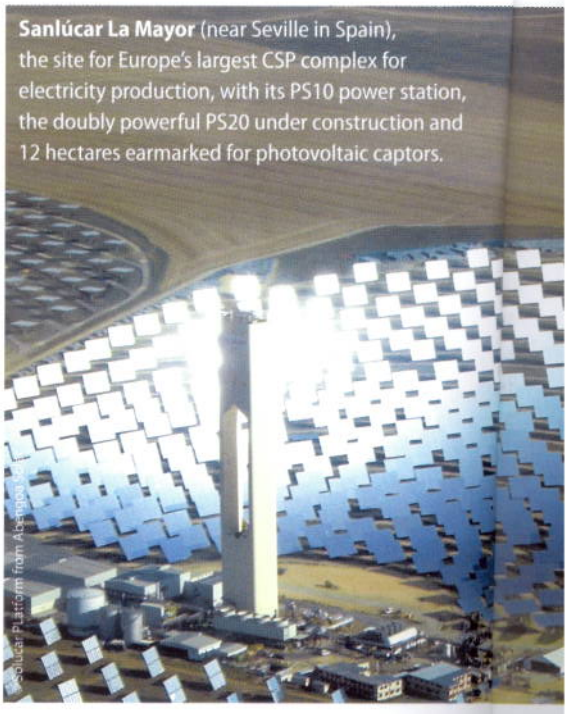
Parabolic concentrators: CSP in miniature

An amazing module is being tested at the Almeria solar platform. The Euro-dish parabolic solar concentrator trains the Sun's rays onto a focal point where a Stirling engine transforms the heat into electricity. It is quick to assemble and not at all bulky. Energy efficiency exceeds 30 %, with a concentration factor of more than 2 000 suns and a temperature of 750 °C.

The dish targets the market for autonomous systems, to pump water for example. For the past 20 years, the concept has been developed in Arizona, mainly by Stirling Energy Systems (SES), which has integrated the dish into a 25 kW module. The module is aimed largely at remote areas where it is difficult to install and maintain CSP systems and to store energy. Another benefit is that the desired power output can be achieved by clustering several modules together. The technology can therefore supply networks with 25–50 MW, using a variable-sized power plant and a capacity for adjustment to achieve economies of scale.

If the current R&D collaboration between manufacturers proves successful, commercialisation is envisaged in 2–4 years from now, with excellent prospects for the future, especially in developing regions.

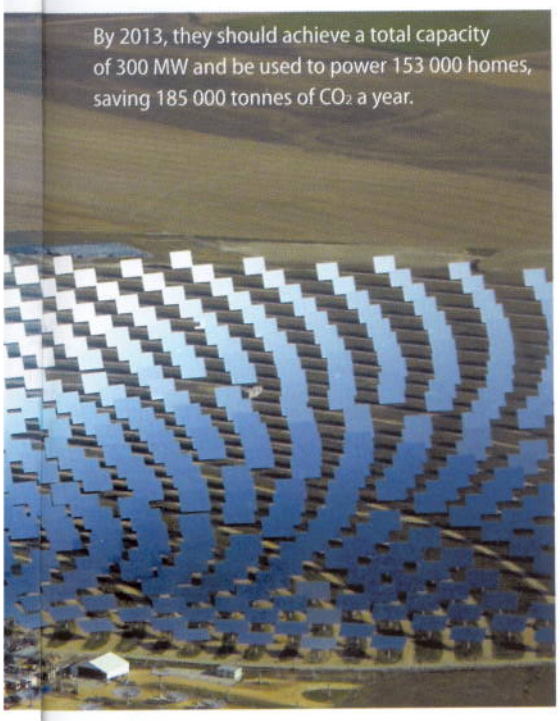
Solar dish by Stirling Energy System (USA). © Randy J. Montoya, Sandia National Laboratories



Sanlúcar La Mayor (near Seville in Spain), the site for Europe's largest CSP complex for electricity production, with its PS10 power station, the doubly powerful PS20 under construction and 12 hectares earmarked for photovoltaic captors. © Solúcar Platform from Abengoa S.A.

Pilot projects for parabolic trough power plants sprang up in the United States in the 1980s and ended up being marketed. Solar electricity generating systems (SEGS) is a collection of nine plants with a total capacity of 354 MW currently in operation at Kramer Junction, in California's Mojave Desert. There are no industrial parabolic trough power plants in service in Europe. "The cost-effectiveness of parabolic trough power plants varies depending on the market and the cost of CO_2. Although parabolic trough technology is reliable, its prospects are limited because its concentration power is restricted to 100 suns, i.e. a maximum of 500°C", explains Gilles Flamant, Director of the Laboratory for Processes, Materials and Solar Energy (PROMES) at France's national scientific research centre (*Centre National de Recherche Scientifique – CNRS*).

As a result, interest has now turned to solar tower power plants, which also came to life in California in the 1980s, with Solar One, later redeveloped to make Solar Two, which have demonstrated the feasibility of power towers. In the case of solar tower power plants, an array of hundreds or thousands of mirrors – called heliostats – project the Sun's rays onto a single collector positioned at the top of a tower. "With a concentration factor of up to 1 000 suns, power towers have much greater development potential in terms of cost-effectiveness."



By 2013, they should achieve a total capacity of 300 MW and be used to power 153 000 homes, saving 185 000 tonnes of CO_2 a year.

Spain, where else?

In Europe, research began in the 1980s and has been concentrated mainly at the Almeria Solar Platform (PSA) in Spain's Tabernas Desert. The Spanish Research Centre for Energy, Environment and Technology (*Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas – CIEMAT*) is currently testing the CESA-1 solar tower power plant and a small solar power system (SSPS) at the Almeria site. Since 2004, the Spanish government has been providing a support framework for the initiative, by setting a guaranteed floor price per solar kWh.

All three of Europe's existing CSP projects are based in Spain. Each project has received European Union funding worth €5 million, which covers only part of the innovation costs. Additional funds are needed to carry out the conventional work, such as assembling the turbine. "Construction of Solar Tres has just begun, while that of Andasol should be completed shortly. The only project currently in commercial operation is the PS10 solar tower power plant, *Planta Solar 10*." (2)

Since 30 March 2007, the PS10 solar power tower has been injecting 11 MW of power into the electricity grid. 10 000 inhabitants consume the annual 21 GWh produced by the power plant. A 14-metre-wide collector placed at the summit of the 115-metre tower absorbs the heat from 624 heliostats into a fluid to produce steam. The four collector panels can concentrate an average power of 55 MW. "The idea is to validate the technology on an operational scale prior to the marketing stage. First the components will be developed in Europe (heliostats, collector) and then the plant's productivity has to be proven."

Storing heat

The problem with CSP is, of course, intermittent sunshine and the fact that generators cannot operate at night. At present the problem is resolved by storing the surplus energy accumulated during the day in large insulated tanks filled with molten salt. The PS10 solar tower power plant can store only 20 MWh, which allows it to offset overcast intervals. However, Solar Tres, which is expected to come into service in 2009, will have a storage capacity of 600 MWh, enabling it to produce its 15 MW continuously throughout summer and to operate for 15 hours after the sun has set, totalling close to 96 GWh annually, spread over 270 days.

In the case of parabolic trough power plants, in late July the Spanish group ACS Cobra and the German firm Solar Millennium will start marketing CSP electricity for the first time in Europe. Their parabolic trough facility, Andasol, will produce 50 MW, supplying nearly 180 GWh of energy every year. If the power supplied is any higher, stores dwindle faster. The 880 MWh stored during the day feed the power plant for only 7.5 hours once the Sun has set.

Dawn of the solar age

In 2005, CSP generated a mere 0.025% of the world's electricity. However, a slow but steady revolution is underway. In late 2007, Algerian Energy Minister, Chakib Khelil, laid the foundation stone of the Hassi R'mel hybrid solar-gas power plant. Shortly afterwards, the Chief Executive Officer of NEAL (New Energy Algeria) announced the construction of a 3 000-km, high voltage direct current (HVDC) connection between Adar and the German city of Aachen.

Solar thermal technologies are undeniably gaining ground. Simple, non-polluting and cheaper all the time, they can help to balance the world's energy relationships and to bring to the fore certain regions in the developing world. ●

Delphine d'Hoop

(1) Also called solar thermal power plants.
(2) All quotes are from Gilles Flamant.

PS10
4 partners, 2 countries (ES-DE)
www.solucar.es/

Solar Tres
4 partners, 3 countries (ES-FR-DE)
www.sener.es/

Andasol
6 partners, 3 countries (ES-DE-SL)
www.mileniosolar.com/

Other resources
www.TRECers.net
www.sollab.eu
www.solarpaces.org/