# Spain Pioneers Grid-Connected Solar-Tower Thermal Power

By Thomas R. Mancini, Executive Committee chair,
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**Solar electricity will shortly start feeding into Spain's grid from the Sanlúcar Solar PS10 central-tower plant in Andalucia. It will be Europe's first commercial plant of its sort. This advance owes much to years of dedicated system testing and project development at the collaborative Plataforma Solar de Almería and the efforts of the IEA's SolarPACES programme.**

A page in the history of solar concentrating power (CSP) will shortly turn when a massive solar power-tower plant near Seville starts delivering electricity to Spain's grid. Until now, commercial-scale solar thermal power has been confined to solar trough technology. This new 11-MW-rated PS10 plant, developed by Sanlúcar Solar, S.A., uses proven technologies that have evolved through the R&D efforts of SolarPACES member organisations, notably glass-metal heliostats and a solar-steam receiver. Solúcar is working on three more plants, PS20, AZ20 and AZ50, all in sites adjacent to the PS10 plant.

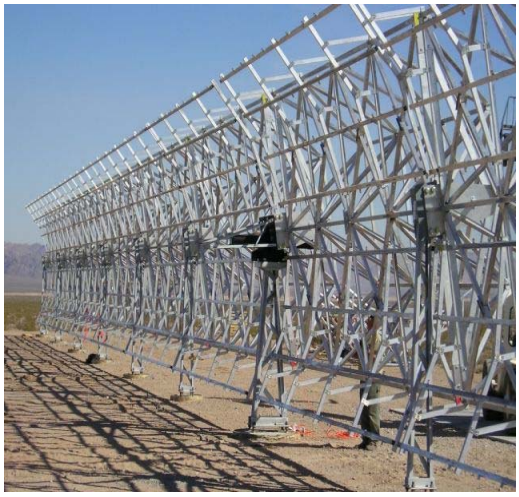
Thomas R. Mancini, Executive Committee Chair, IEA's SolarPACES programme

There are very good reasons why Spain's developers are racing forward with solar projects, aside from progress with the technology. Through a ministerial ruling in March 2004, the Spanish government removed economic barriers to grid-connection of renewable energy. The widely applauded Royal Decree 436/2004 equalises conditions for large-scale thermal and photovoltaic plants and guarantees feed-in tariffs. So exploiting the sun's rays now has a much sharper competitive edge, reassuring the financing community and industrial players. "Today, Spain is probably the hottest spot on earth for CSP project development", declared the recent report *Concentrated Solar Thermal Power - Now!*, published by Greenpeace, ESTIA[1] and the IEA's SolarPACES programme. By 2010, Spain is expected to boast some 500 megawatts (MW) of CSP installed capacity. Worldwide, the study estimates, solar thermal-sourced electricity could represent as

[1] European Solar Thermal Industry Association

much as 5% of global demand by 2040. More than 57 million tonnes of $CO_2$ emissions would be avoided each year.

The hot news is not confined to Spain. In the United States, Solargenix, Inc. has now completed construction of a 1-MW Organic Rankine Cycle trough plant in Arizona providing enough power to serve some 200 average-size homes. Its solar collector designs are based on designs that have evolved through R&D activities in SolarPACES countries. Following up, Solargenix broke ground earlier this year on construction of Nevada Solar One, a 64-MW trough plant in Boulder City, Nevada.



The Nevada Solargenix Solar One solar troughs take shape

Some of the early pioneering commercial dish and trough installations were built in the United States. Parabolic trough power plants with 354 MW of solar electric generating capacity have been feeding enough power for half a million homes into the California grid since the mid-1980s.

Behind these achievements lie many years of systems testing and project development in SolarPACES countries. Efforts on the technology front have been supported by policy recommendations to local, state and national governments from SolarPACES members and working groups, which have helped smooth the way to commercial feasibility. As a result of SolarPACES activities through the Global Market Initiative, it has been possible to align the policy/economic context with advances in technology development in SolarPACES countries, and so get full-scale, commercial projects up and running.

Michael Geyer, SolarPACES Executive Secretary at the EuroTrough Facility of the Plataforma Solar de Almeria

These exciting developments will certainly be a welcome inspiration to other countries because producing electricity from the energy in the sun's rays is in fact a rather straightforward process. Direct solar radiation can be concentrated and collected by a range of CSP technologies based on large, sun-tracking mirrors to provide medium- to high-temperature heat. This heat is then used to operate a conventional power cycle, for example through a steam turbine or a Stirling engine.

Solar heat collected during the day can also be stored in liquid or solid media such as molten salts, ceramics or concrete. In the future, phase-changing salt mixtures could be the storage medium. After sunset, the solar heat can be extracted from the storage medium to keep the turbine operating.

**Peak load, base load**

Solar thermal power plants designed for solar-only generation are ideally matched to summer noon peak loads in prosperous areas with significant cooling demands, such as Spain or the south-western United States. Using thermal energy storage systems, solar thermal operating periods can even be extended to meet base-load needs. For example, the 50-MWe AndaSol solar trough power plants promoted in Spain (discussed below) are designed with six to twelve hours of thermal storage, which increases annual availability by some 1,000 to 2,500 hours.

Wherever there is high direct radiation from the sun, there are opportunities for solar thermal. In many regions of the world, just one square kilometre of land can generate as much as 100-130 gigawatt hours (GWh) of electricity per year from solar thermal technology. This is as much electricity as we would expect from a 50 MW conventional coal- or gas-fired mid-load power plant, and enough to keep the lights on in a town of 25,000 inhabitants in western continental Europe. Over the total life cycle of a solar thermal power system, output would be equivalent to the energy contained in more than 5 million barrels of oil.

The PS10 solar tower plant being completed by Sanlúcar SA (Abengoa), Seville (Spain)

So it is easy to understand the enthusiasm for CSP in Spain, which targets a 29.4% share for renewables in electricity generation by 2010. Motivated by the economic incentives and drawing on the worldwide state-of-the-art technical expertise accumulated locally at the Plataforma Solar de Almería in Andalucia, Spain is pressing ahead.

The box describes some of the numerous commercial projects currently under development in Spain.

"First Stone Ceremony" of the 50MW Andasol-1 solar thermal plant, July 20th, 2006 at Aldeire, Province of Granada (Spain). From left to right: Jose Alfonso Nebrera, General Director at Cobra; Franciso Vallejo Serrano, Minister for Innovation, Science and Enterprises of the Autonomous Region of Andalucia; Hans-Joachim Fell, Member of the German Parliament; Matthias Machnig, Secretary of State of the German Federal Ministry for Environment, Nature Protection and Nuclear Safety; Antonio Valverde Lozano, Mayor of Aldeire.

- Two 50 MWe solar trough power plants – AndaSol-1 and AndaSol-2 – are being promoted jointly by ACS Cobra and the Solar Millennium group in the region of Andalucia, each with a 510,120 m² SKAL ET solar collector field and six hours' thermal storage. The AndaSol-1 project obtained financial closure in May 2006 and has received a € 5 million grant from the European Commission's (EC) Fifth Framework Programme, along with financial support from the German Federal Ministry for Environment. Construction started in July 2006 and will be completed in 2008. A third plant, AndaSol-3, is under joint development by Solar Millennium and the Spanish electric utility Hidrocantabrico. ACS Cobra and Solar Millennium have started development of various 50 MW follow-up plants in Southern Spain.

- A 15 MWe solar-only power tower plant – the Solar Tres project – is in the hands of the Spanish company SENER, employing United States molten-salt technologies for receiver and energy storage. Its 16-hour molten-salt storage system will be able to deliver power around the clock. The Solar Tres project has received a € 5 million grant from the EC's Fifth Framework Programme.

- A 15 MWe solar trough power plant – EuroSEGS – is being promoted by the Spanish EHN group in co-operation with SolarGenix at Montes de Cierzo near Pamplona.

- More than a dozen 50 MW parabolic trough plants are now being promoted by national electric utility companies such as Iberdrola and Hidrocantabrico-Genesa all over Southern Spain.

The magnitude of expected capacity growth in Spain was highlighted when Greenpeace Spain and Protermosolar (the national association of solar thermal project developers) decided to join forces to raise Spain's targeted capacity in the next revision of the national plan for promotion of renewable energies from 200 MW to 1,000 MW, and thus provide for delivery of more dispatchable clean peak power for the summer dry seasons

In August 2005, the Spanish Government approved a new Renewable Energy Plan, setting a new target of 500 MW by 2010.

All the projects outlined above are in the hands of industry consortia and run as commercial CSP undertakings responding to the favourable market conditions established or expected around the world. Supporting these efforts, the SolarPACES programme's participating countries continue to develop next-generation CSP technologies and to work on market development to foster the policies needed to sustain continued project development.

**Benefits of international collaboration**

The SolarPACES programme has a long history of addressing the essentials. Since its early days as the "Small Solar Power Systems" (SSPS) Implementing Agreement, created in 1977, its CSP community has striven to reduce total costs of technology development by dividing the tasks and sharing development responsibilities for the various CSP subsystems (concentrator, receiver, storage). This work has continued to bear much fruit within the SolarPACES co-operation, the successor Implementing Agreement initiated in 1991.

Typical examples of this form of collaboration are the CSP projects on component development and testing at the Plataforma Solar de Almeriá, and similar component development activities at the Weizmann Institute in Israel, the SunLab facilities in the United States, or the solar furnace at Odeillo in France. In many cases, and with European co-funding, project partners focus on different subsystems, engineering services or scientific tasks for the trans-national project. All participants consequently have full access to the results and technology. In some of these projects, countries outside IEA membership can be involved in such work through the SolarPACES organisation. The results are disseminated through SolarPACES channels, thus avoiding duplication of work at other research laboratories.

**The SolarPACES Programme**

The SolarPACES programme brings together teams of national experts from around the world to focus on the development and marketing of concentrating solar power systems (also known as solar thermal power systems). Participants represent: Algeria, Australia, Egypt, the European Commission, France, Germany, Israel, Mexico, South Africa, Spain, Switzerland and the United States.

Highlighting the considerable potential for using CSP technologies in many developing countries, SolarPACES is the IEA Implementing Agreement with participants from the largest number of non-IEA member nations.

SolarPACES is one of some forty IEA international collaborative R&D programmes.

Much added value is generated for all SolarPACES members by the collaborative development of systems, components and standardised methodologies and tools. Some

specific examples are: development of complex CSP simulation tools; exchange of unique flux measurement devices; conduct of joint calibration campaigns for flux measuring devices; use of each other's CSP test facilities for component tests; joint development of standardised evaluation procedures; and sharing of solar resource data.

At the same time, participation in the SolarPACES programme often helps reinforce national R&D capabilities by improving conditions for personnel exchanges or training, as well as access to information, technology or equipment. The former IEA SSPS Implementing Agreement was the birthplace for this form of exchange. It provided the genesis for the Plataforma Solar de Almeriá, which is where many leading CSP experts received their first CSP hands-on education. Drawing on this experience, the SolarPACES follow-up work always gives high priority to personnel exchange, training and student programmes. Opportunities to send local CSP pioneers to CSP test facilities of other SolarPACES members is one of the motivations that has prompted SolarPACES members from non-IEA countries like Algeria, Egypt or Mexico to join. In this same context, START Missions (Solar Thermal Analysis, Review and Training) offer a vehicle for getting information and expert assistance to countries around the world with good CSP potential. To date, START missions to Algeria, Brazil, Egypt, Jordan and Mexico have heightened interest in CSP.

Needless to say, the collaborative research framework offers participants access to wide-ranging and innovative areas of R&D. SolarPACES is very much involved, for example, in thermo-chemical processes for hydrogen production like solar reforming of natural gas, solar steam-gasification of petroleum coke or solar carbothermic production of zinc.

**Exploiting resources and knowledge**

Given the abundance of opportunities for project development around the world, the CSP industry is now very interested in access to more precise resource data. SolarPACES has addressed this need by establishing a new task on resource assessment, in co-operation with other IEA Implementing Agreements. This joint activity focuses on development of methodology and a database to evaluate direct normal solar radiation from satellite images in high spatial and temporal resolution. The SolarPACES website now presents an interactive map showing solar radiation in different countries around the world, also current CSP project development for each country.

A similar collaboration was initiated when the sister IEA Implementing Agreement dealing with solar heating and cooling pointed to the current interest in high-temperature collectors for solar industrial process heat application. The SolarPACES programme now takes part in a dedicated new shared task, to which our members are bringing their experience on concentrating solar collectors, on performance, costs and operation, and on maintenance issues.

**Attractive for Non-OECD countries**

Given the vast potential for harnessing the sun's rays through CSP, it is no accident that the IEA's SolarPACES programme has attracted significant participation among non-OECD countries. Projects are under development in Egypt and Morocco with the support of the Global Environment Facility (GEF) programme, as well as in Algeria, Iran, Israel and South Africa.

At the 13th International SolarPACES Symposium in Seville this June, Samir Hassan, Executive Chairman of Egypt's New and Renewable Energy Authority (NREA), reported that financing has been granted by the Japan Bank for International Cooperation (JBIC) and that four consortia have been qualified for bidding for the 150 MW combined cycle with 30 MW solar field at Kuraymat, near Cairo.

Without additional support from GEF's CSP portfolio, Algeria has set up a national programme for the promotion of renewable energy sources in the frame of its Sustainable Energy Development Plan for 2020. Algeria was the first non-OECD country to publish a feed-in law in March 2004 with elevated tariffs for renewable power production, including solar thermal power for both hybrid solar-gas operation in steam cycles and integrated solar, gas-combined cycle plants (ISCC). In June 2005, the first Request for Proposals (RfP) was published by the New Energy Algeria (NEAL) Agency for a 150 MW ISCC plant with parabolic trough technology to be privately financed and operated. At the June 2006 SolarPACES Executive Committee meeting, NEAL's President Tewfik Hasni, reported that the bid had been won by the Spanish Abengoa group.

Most of these projects will help satisfy growing domestic electricity demand by integrating a solar field (usually between 30 MWe and 68 MWe) in a much larger combined-cycle power plant, thus creating ISCC plants.

A recent resource-mapping study by the German Aerospace Center (DLR) suggests that CSP plants could provide for up to 50% of electricity in the Middle East/North Africa (MENA) region by 2050. Another DLR study looks at the outlook for exporting clean solar electricity to Europe via high-voltage direct-current transmission. This could provide firm capacity for base load, intermediate and peaking power, effectively complementing European electricity sources. In such a scenario, the period 2020 to 2025 could see a transfer of 60 terawatt-hours (TWh) per year and these solar electricity imports could subsequently be extended to 700 TWh a year by 2050, or about 15% of Europe's electricity demand. High solar irradiance in MENA and low transmission losses of 10%-

15% would yield a competitive cost for imported solar electricity of around 0.05 €/kilowatt-hour (kWh), according to this study.[2]

**A promising future for solar thermal**

Solar thermal technology certainly has rich potential. According to the Greenpeace/ESTIA/SolarPACES scenarios published in 2005, solar thermal technology is destined to move from being a relatively modest renewable energy source to a significant contributor in 2040, alongside current market leaders like hydro and wind power. Today's total installed capacity of 355 MW will have exceeded 6,400 MW by 2015. That is 18 times today's capacity. By 2025, the annual installation rate will be 4,600 MW/year. By 2025, total installed capacity around the world will have reached the impressive figure of 36,850 MW.

Equally impressive are the scenarios for electricity output from solar thermal power plants. Assuming that the first installations will operate for 2,500 hours per year and that later installations have internal storage systems to increase this to 3,500 hours per year by 2025, and to 5,000 hours per year by 2040, solar thermal power will be growing at a pace that already achieves an annual output of more than 95 TWh in 2025 and over 16,000 TWh by 2040. That would represent as much as 5% of global demand. More than 362 million tonnes of $CO_2$ emissions would be avoided each year in 2025.

Against today's backdrop of increasingly serious energy-security and climate-change challenges, these projections are ample justification for a yet more vigorous effort to give solar thermal its rightful place in the energy mix. The IEA's SolarPACES programme[3] is well placed in the mainstream solar thermal community to provide leadership in pursuing that goal.

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[2] Further reading:

Philibert, Cédric, (2004), *International Technology Collaboration and Climate Change Mitigation: Case Study 1: Concentrating Solar Power Technologies*. OECD/IEA Information Paper, Paris

DLR, 2005. *MED-CSP, Concentrating Solar Power for the Mediterranean Region*. Institute of Technical Thermodynamics, Stuttgart, DE.

DLR, 2006. *Trans-CSP, Trans-Mediterranean Interconnection for Concentrating Solar Power*. Institute of Technical Thermodynamics, Stuttgart, DE.

[3] Implementing Agreement for the Establishment of a Project on Solar Power and Chemical Energy Systems (SolarPACES)