Solar thermal power plants – Export hits without a domestic market

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Solar thermal power plants only use the direct solar irradiation, and are therefore hardly usable in Germany. Nevertheless, German companies and research institutes are among the global technology leaders. This can only be achieved via suitable international partnerships. This presentation provides details of the major international networks in this area. Examples will be used to show how German technologies and research results can be positioned on the international market.

1. Introduction

Parabolic trough collectors, which generate electricity in a conventional power plant via high-temperature heat, have been used in the Mojave Desert in California for over 20 years. For a long time, no-one emulated this success story. However, the global challenge presented by the climate change and the oil prices shock have highlighted the advantages of this technology and have led to a veritable construction boom, initially encouraged by an electricity feed-in act in Spain. Now, construction is underway throughout the earth's sun belt.

Two different systems for large-scale solar thermal electricity generation in sunny countries are currently available:

- **Line-focusing systems**, which direct the concentrated radiation in their caustic line to an absorber tube with a selective coating, reaching temperatures of up to 400 °C in the heat transfer medium circulating there.
- **Point-focusing systems**, in which three-dimensionally curved, sun-tracking individual mirrors (heliostats) direct the solar radiation to a heat exchanger (receiver), which is located at the top of a tower. These systems can reach higher temperatures than the line-focusing systems.

Both technologies aim to replace the heat generated by fossil fuels in conventional power plants fully or partially. Their attraction is that the high-temperature heat generated can be stored very cost-effective (compared with electricity) and efficiently, to allow continued operation as clouds pass or after sunset. If low quantities (<15%) of additional fossil combustion in the power plant are possible, this concept can be used to provide electricity as required with great reliability, to replace fossil fuel-fired power plant capacities fully.

1977	Initiation of the SSPS (IEA) and CESA projects (Spain)
1979	Seven countries combine to build SSPS in Almería (DLR for Germany)
1985	CESA and SSPS systems merge to become PSA test centre
1981	First solar thermal electricity generation in Europe
1987	Spanish-German cooperation agreement on 50:50 basis (DLR/CIEMAT)
1990	PSA qualifies as a large-scale European system
1994	First joint EU projects (DLR/CIEMAT)
1998	Change of the cooperation model to project-specific cooperation
2004	Start of cooperation between DLR/ Fraunhofer on Fresnel collectors
2006	PSA celebrates 25th anniversary
2007	First commercial electricity generation in Spain

SSPS = Small Solar Power System
CESA = Central Electro-Solar de Almeria (solar tower)

Table 1
Overview of the history of German-Spanish cooperation at PSA

Figure 1
Plata-forma Solar test centre in Almería (Spain)

2. International cooperation as a basis for technological development

The development of this technology was initiated as early as the late 1970s by the International Energy Agency (IEA) (*Table 1*).

Even that far back, Germany already played a leading role when DLR was commissioned to coordinate the project of building the SSPS demonstration system in Almería, Spain. After it had successfully proven that solar thermal electricity generation in Europe was possible in 1981, operation of the plant was continued as a test centre under the name "Plataforma Solar de Almería (PSA)" (*Figure 1*) by a partnership of the Spanish CIEMAT and DLR.

PSA developed into the European test centre where key commercial systems which were subsequently introduced on the market, were developed and tested. This benefitted Spanish and German companies in particular. At the end of the 1990s, when it became clear that the technology had not succeeded in specific market penetration, the German side had to step back its influence due to decreasing funding and since then, it has had a guest role at PSA. In the early 2000s, the indications of market penetration of the technology in Spain increased and the development was intensified again. Other German research partners, e.g. Fraunhofer ISE became involved in these activities in 2004. The Spanish feed-in act passed in 2004 led to the construction of commercial solar thermal plants in Spain, which fed electricity into the grid in 2007 for the first time.

In order to further decrease costs, however, further research and development work is required in this area. As this has always been associated with very large and expensive test infrastructure, four major European research institutes pooled their expertise and infrastructure in 2003 to form the Sollab association, which features the Swiss Paul Scherer Institute (together with ETH Zurich) and the French CNRS in addition to the DLR and CIEMAT. This facilitated improved access to the test infrastructure for German companies.

Another key to the spread of this technology to other countries in the sun belt was the IEA's SolarPACES cooperation, which was based on the previous activities in Almería, and now comprises 16 member states (*Figure 2*). In this network, in which DLR performs major coordination activities, new markets, in particular in the USA, Egypt, Algeria, Australia, Italy, Israel, UAE and South Africa, were opened, which are now largely supplied by German countries.

Figure 2
SolarPACES network of the International Energy Agency (IEA) which currently has 16 member states

3. Market situation and the role of the German industry

Worldwide, approx. 0.6 GW of solar thermal power plants are operated, while approximately the same capacity is currently under construction, most of it in Spain and the USA. Other projects in the 6 – 8 GW range are in development around the world (*Figure 3*).

In particular, German and Spanish manufacturers are dominant. In addition to the project development and turnkey delivery of solar arrays and power station blocks, German companies are leaders in production of key components such as mirrors, absorber tubes and steam turbines. In addition to this, major German energy suppliers act as investors and, in the medium-term, probably also as operators of solar thermal power plants.

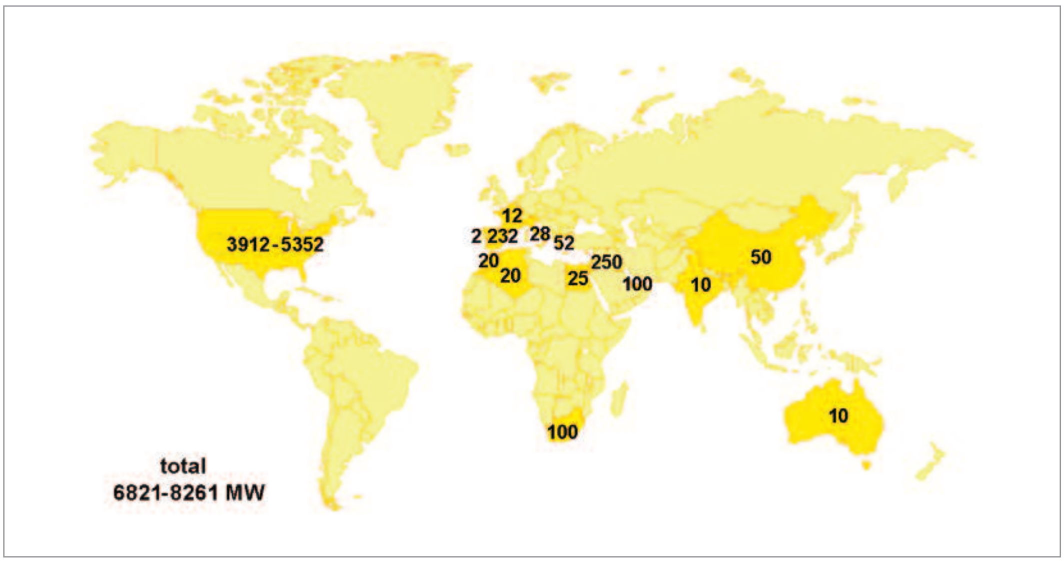

Figure 3
Solar thermal power plant capacities at an advanced planning stage

4. Competitive advantages through research and development

As solar thermal power plants have no domestic market in Germany, the industry competes on international markets. Its key to success is in the delivery of superior high-tech components and the ability to provide system solutions from one source. All technical and financial risks are covered. The major German companies from the energy industry are well positioned.

The key remains that they deliver top technology and are therefore technologically always one step ahead of competitors. This is where the German research landscape and, in particular, the Renewable Energy Research Association (FVEE) come into play, which can prepare technological development and assist in industrial implementation. Four examples of this are listed below.

4.1 Direct evaporation

DLR, in cooperation with German and Spanish partners, has led the development of solar steam generation technology, in which the thermal oil in a parabolic trough collector is replaced by water or steam, since the mid-1990s. It saves investment in the expensive special oil and the corresponding heat transfer mediums, allows higher process temperatures and thus better system efficiencies.

On the DISS test system (Direct Solar Steam) at PSA, processes were identified as safely technically controllable, comprehensive component tests were performed, and simulation models and control concepts were developed and validated. Also, the most recent investigations confirmed the economic relevance of this technology.

As the next step before market introduction, the demonstration of the overall system with multiple parallel evaporation trains in the power plant-relevant scale (approx. 5 MWe) is imminent. For this purpose, it is planned to implement a corresponding pilot system with German industrial partners in the vicinity of the planned ANDASOL III power plant in Southern Spain (*Figure 4*), which consists of one collector array of roughly 2-3 collector strings. On one hand, this collector array must be operated continuously to evaluate and demonstrate the long-term stability of the components and the every-day operability of the system. On the other hand, it will be designed so flexibly that it will permit the investigation of various operation strategies. A 5 – 15 MWh innovative heat storage system is to be integrated in this test system, and be subjected to extended operation in the power plant, to demonstrate feasibility in real operation. In the demonstration system of a Fresnel collector with the involvement of DLR and Fraunhofer ISE at PSA, direct evaporation was used and tested successfully in the last two years.

4.2 Component development and qualification

High-temperature stable efficient receiver systems are a key component for the parabolic trough and the Fresnel technology and are required by various collector companies worldwide.

Figure 4
50 MWe Andasol power plants near Guadix (Spain)

With the assistance of Fraunhofer ISE and DLR, the Schott CSP Solar company developed the evacuated receiver PTR-70. With the aid of this technology, heat losses of the absorber tubes through which the heat transfer fluid flows are minimised. At an operating temperature of 380 °C, an emission level of under 7% is reached in the newest coatings. The problem of hydrogen diffusion from the thermal oil has been solved via barrier coatings and getter materials. In addition to the receivers for thermal oil, pipes with reinforced steel walls are offered for direct evaporation.

The parabolic mirrors and collector design for the SKAL-ET collector were developed by a German company, Flagsol. The curved special mirrors consist of white glass coated with silver which has a thickness of 4 to 5 mm. The mirrors are 2 to 2.8 square metres in size. The company also supplies the control systems for the solar array, a key component for operating the overall system. In linear Fresnel collectors, high-temperature stable absorber tubes are also used, which are stable up to 450 °C in air. The secondary concentrators, which consist of borosilicate mirrors coated on the front by Fraunhofer ISE, can also withstand elevated temperature loads.

With concentrating primary mirrors and parabolic trough, Fresnel and tower heliostats, the optimal focusing of the sun on the respective receiver structure is important. With highly-developed characterisation and qualification methods for the mirror components, both FVEE institutes contribute to quality assurance in power plant construction. Important elements include ensuring the mirror shape, spectral reflectivity and the endurance of the components. The question of measurement and in particular the degradation of complete collector arrays requires further development of the methods used to date. Standardisation of the methods is advanced worldwide as part of the IEA SolarPaces programme.

4.3 Operation optimisation via forecasts

The system developed in the CSP FoSyS project will serve to predict electricity production of an individual power plant. Currently, no such integrated systems are available. Therefore, CSP power plants only operate with restrictions on the day-ahead and intraday electricity market, which means that they lose out on major economic advantages.

The project distinguishes three applications for this type of a prediction system:

1. Participation in the Spanish electricity market
2. The application for the license for grid access
3. The optimisation of power plant operation with the aspects of maintenance, solar array control, production planning and safety

The prototype resulting from the project is to be integrated in the parabolic trough power plant Andasol 3. However, the prototype is to be modular, which means that only a part, the power plant model, is specialised for the technology of a parabolic trough power plant. Thus, a product derived from the prototype can be used for all concentrating technologies, which use direct radiation as an energy source. For this purpose, only the power plant modelling must be adapted to other technologies.

Even the legal conditions which are analysed in this study, generally do not depend on the selected technology. That means that the same legal conditions can be used in nearly all cases, both for parabolic trough technology and in the other concentrating technologies.

4.4 UniSolar

Currently, massive expansion of solar thermal power plant capacity in the states of North Africa is being discussed intensively. An example of this is the DESERTEC concept co-developed by DLR. This power plant expansion aims to produce electricity at low cost in North Africa in solar thermal power plants, and to transport it to Europe and Germany in particular via high voltage direct current lines. In the medium term, it is planned to source 15% of European electricity requirements from these sources. In order to implement this massive expansion, political, technical, economic and socio-political priorities must be set at an early stage. The implementation of the DESERTEC concept thus also supports the heightened cooperation between the EU member states and countries of the Southern Mediterranean as part of the Union for the Mediterranean. UniSolar, funded by the German Federal Foreign Office, is based on this concept and can be viewed as a first step to practical implementation.

The objective of the project is the technological cooperation and targeted support of those countries in North Africa, which just started implementing the first solar thermal power plants. Technical optimisation options for commissioning and operation are to be used specifically and contribute to increasing the efficiency of the solar power plant section and the overall electricity generation. The local capacities are to be expanded via educational programmes, training courses, workshops and technology transfer, and a specific cooperation with the German industry is to be made possible. The distribution of the technology is to be guaranteed via correspondingly trained and supported local contacts and networking with one another. They can competently accompany and support project developments and technology developments in the target countries. These measures are intended to promote sustainable implementation of solar power plants and the development is to be speeded up via multiplier effects.

Target groups for the expansion of capacities and distribution of the technology on the North African side are research institutes, universities, industrial companies, experts, engineering firms, decision-makers and power supply companies in Egypt, Algeria, Tunisia and Morocco. Other states in Africa are to be added during the course of the project.

The Renewable Academy Berlin, with the support of Fraunhofer ISE, also offers workshops on solar thermal power plants around the world for decision-makers and engineers as part of the TREE project (Transfer Renewable Energy & Efficiency) funded by BMU.

5. Summary and outlook

A technologically leading role is the requirement for participating successfully in the rapidly growing market for solar thermal power plants.

The lack of a domestic market requires global operating companies and an internationally well-networked research and access to test facilities in the sun belt. Both is currently the case; however, rapidly increasing research budgets, in particular in the USA, China and the Gulf states, can lead to a shift in the market in the medium term. Therefore, public research and development budgets adjusted for the increasing turnover of the companies and their own research expenditure must be added to maintain a leading role in Germany.