

Company Profile on Solar Thermal Power Consulting, Research and Development

Company Profile

DLR (Deutsches Zentrum für Luft- und Raumfahrt e.V.) is Germany's Aerospace Research Establishment and focuses its program of work on the three key areas: aviation, space flight and energy technology. With over 4400 employees, the German Aerospace Center is the **largest establishment for engineering sciences, research and management in Germany**. It is sustained by public funds and third party financing. The utilisation of solar power is the long-term perspective of DLR's large-scale solar power market introduction and implementation efforts, its experimental development programme and its participation in solar thermal demonstration facilities. DLR maintains research centers in Cologne, Stuttgart, Braunschweig, Lampoldshausen, Göttingen and Oberpfaffenhofen in Germany.

DLR participates in **solar power testing facilities** such as the German-Spanish solar test center Plataforma Solar de Almería (PSA) in Spain and the PAREX parabolic trough test facility in Cologne, Germany. With its own experience as solar plant contractor and operating agent, DLR can offer best references as independent consultant in this field including market knowledge about all international solar thermal key component suppliers.

Over 17 years of continued **techno-economic systems analysis**, laboratory research and pilot scale demonstration have since then been carried out in the field of solar thermal technologies including parabolic trough, central solar tower and dish Stirling systems. With the active promotion of the commercial solar tower project PHOEBUS in Jordan and the participation in the EU's THERMIE projects Colon Solar and THESEUS in Spain and Greece, DLR has gained long year experience in technology, independent solar thermal site and feasibility studies, detailed cycle modelling and performance prediction, system engineering, solar field design, economic and financial analysis with the geographical focus on the Mediterranean region.

Through the **International Energy Agency's SolarPACES** Implementing Agreement, DLR is participating in the prominent Solar Two project in the U.S. and in the Kramer Junction Cost Reduction Programme at the Californian Solar Electricity Generating Systems (SEGS). The SolarPaces expert missions to potential host countries for Solar Thermal Analysis, Review and Training (START) are an important issue in project initialisation.

DLR's system analysis and system engineering experience with hybrid solar/fossil systems goes back to the early 1980s, when DLR started modelling and optimising such hybrid plants with a solar component and a fossil component for the GAST and subsequently for the PHOEBUS project. Extensive modelling tools have been developed since by the various groups of DLR in Almeria, Cologne and Stuttgart for simulating any possible solar/fossil Rankine, Brayton and Combined Cycle configuration to obtain hourly, daily and annual solar/fossil related output as well as to analyse the instantaneous dynamic behaviour of solar boiler systems. These **simulation models and software tools** have been qualified with experimental system data obtained during the measurement campaigns at the Plataforma Solar.

In 1997, the **SYNTHESIS Programme** was initiated by DLR and the Foundation for Climate Change of Hamburg (HKF). The goal of this programme is to realise a continuous series of 50 projects until 2010 and to provide an attractive frame of finance and risk-management during the start-up phase. Thus, DLR and its partners can assist in the **financial engineering** of a project. In-deep economic analysis of the costs, cash-flows and internal rates of return of solar thermal power projects can be performed with the available simulation tools.

With the development of the Expert System for the Assessment of Solar Thermal Power Stations (STEPS) since 1997, DLR's Department of Systems Analysis in Stuttgart has

initiated an innovative approach to the market and site assessment of solar power stations. STEPS combines a **geographic information system**, satellite data and simulation tools available at DLR for the exhaustive analysis of countries, regions or continents for a ranking of the best sites for solar thermal power project development.

Solar Thermal Reference Projects

Furthermore DLR has gained recognised experience in the field of solar thermal power systems through co-operation with electric utilities, equipment manufacturers, international agencies and financial organisations in the following examples:

- Operating Agent of the **IEA Small Solar Power Systems Project**, implementation of a 500kW_e central receiver system and a 500kW_e parabolic trough system
- Participation in the **20MW_e industrial Gas Cooled Solar Tower Project GAST**, in which DLR was responsible for the scientific evaluation of a technology program for the development of components for a 20MW_e air cooled central receiver system
- Participation in an industrial consortium that developed and tested the **2.5MW_{th} PHOEBUS Volumetric Air Receiver** and advanced heliostats for a 30 MW_e solar tower plant in Jordan
- Lead of the project: Development of the **REFOS Pressurised Volumetric Air Receiver** (350 kW_{th}) with quartz window and secondary concentrator, developed by DLR, for solar air preheating to 800°C in combined cycle power plants.
- Demonstration of an **Multiple Effect Solar Desalination Plant** at Plataforma Solar de Almería with a desalination capacity of 80m³/d
- Lead of the **Solar Hydrogen Project HYSOLAR** in co-operation with Saudi Arabia
- Implementation of a **LS-3 type parabolic trough test facility** at Plataforma Solar
- Implementation of a 3000m² parabolic trough test loop for direct steam generation within the **European DISS project** at the Plataforma Solar de Almería
- Development of new heat absorption elements for parabolic trough collectors within the **German PAREX project**
- Participation in the study "**Solar Thermal Power Plants for the Mediterranean Region**" for the German Ministry of Research.
- Participation in the European Commission Study „**Assessment of Solar Thermal Trough Power Plant Technology and its Transferability to the Mediterranean Region**“ with utilities and equipment manufacturers
- Participation in the EU Joule Project, "**SOLGAS Hybrid Combined Cycle Cogeneration Plant based on Central Receiver Technology**", Engineering of the Power Cycle, Market Study
- Participation in the European Commission's FIRE project on the „**Financing of Renewable Energy Systems**“ in Europe
- Lead of the **IEA-SolarPACES START Missions** to Egypt, Jordan and Brazil
- **Life Cycle Assessment of Greenhouse Gas Emissions** of Solar Thermal Power Plants
- Initiation and back-stopping of the "**SYNTHESIS Programme for the Market Introduction of Solar Thermal Power Plants**" based on private initiative and support.
- Feasibility study for a "**Combined Cycle Cogeneration Plant for Electricity, Cooling and Sea Water Desalination for Dubai Industrial Park**".
- **Expert System for the Assessment of Solar Thermal Power Stations (STEPS)** based on satellite data and a geographic information system.

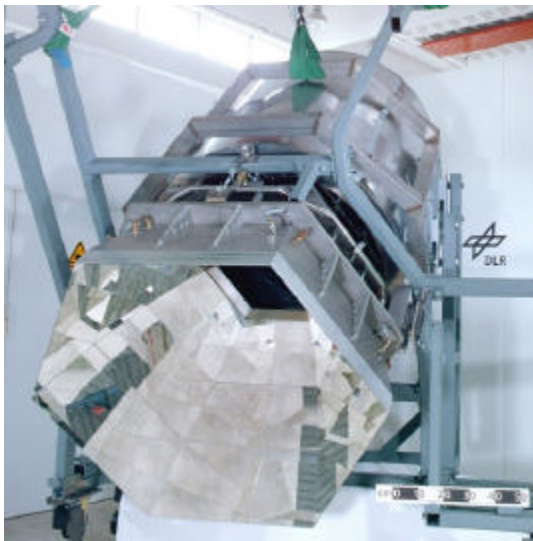
Engineering and Component Development of Solar Tower and Parabolic Trough Technology

With its 20 year experience in international solar tower and trough projects like SSPS, GAST, PHOEBUS, TSA, REFOS, HELIOMAN, ACUREX, PAREX and DISS, the DLR has leading expertise in

- Sizing and designing solar systems
- Preparing tender specifications and evaluating offers
- Engineering, procurement and construction contracts
- Construction supervision and acceptance testing
- Operation and maintenance
- Flux and temperature distribution measurement with video and IR camera systems
- Efficiency measurements of all system components



REFOS volumetric pressurised receiver tested at CESA-1 Solar Tower Facility at Plataforma Solar



REFOS volumetric pressurised receiver with secondary reflector on the mounting rig at DLR's Institute of Technical Thermodynamics in Stuttgart

Innovative components of solar thermal concentrating systems are developed in several institutes of DLR and tested at the Plataforma Solar of Almeria (PSA) in Southern Spain.

One recent example is the volumetric pressurised receiver for solar tower systems REFOS. It allows the heating of a gas turbine's combustion air at about 800 °C and 15 bar pressure. With this system, which has successfully completed its first tests at the PSA, it is possible to drive gas turbines or combined cycle systems - which constitute around 60 % of the world's power plant market - with solar power.

In the next years, this system will be adapted to larger units of several MW of power, and will allow solar-electric conversion peak efficiencies of up to 30 %.

Other examples of component development are solar catalytic absorbers for solar chemical receivers, hybrid gas-and-solar fired receivers for parabolic-dish-Stirling-engine and parabolic-dish-gas-turbine systems, and direct steam generating parabolic trough components.

System Integration and Test of Solar Tower and Parabolic Trough Technology

While most of DLR's component development takes place in Germany, hardware system integration and tests are performed at the Plataforma Solar de Almeria in Spain, where DLR participates in the European solar test center of the Spanish research establishment CIEMAT.

Besides solar thermal electricity generation, other technologies like solar process heat, solar cooling, solar chemical processes and solar water desalination are evaluated.

Highly qualified personnel provides services to industry for onsite tests and evaluation, like e.g. the development and testing of stretched membrane heliostats by Steinmüller, Germany.



Aerial view of the Plataforma Solar de Almeria, Spain, with solar tower and parabolic trough test facilities

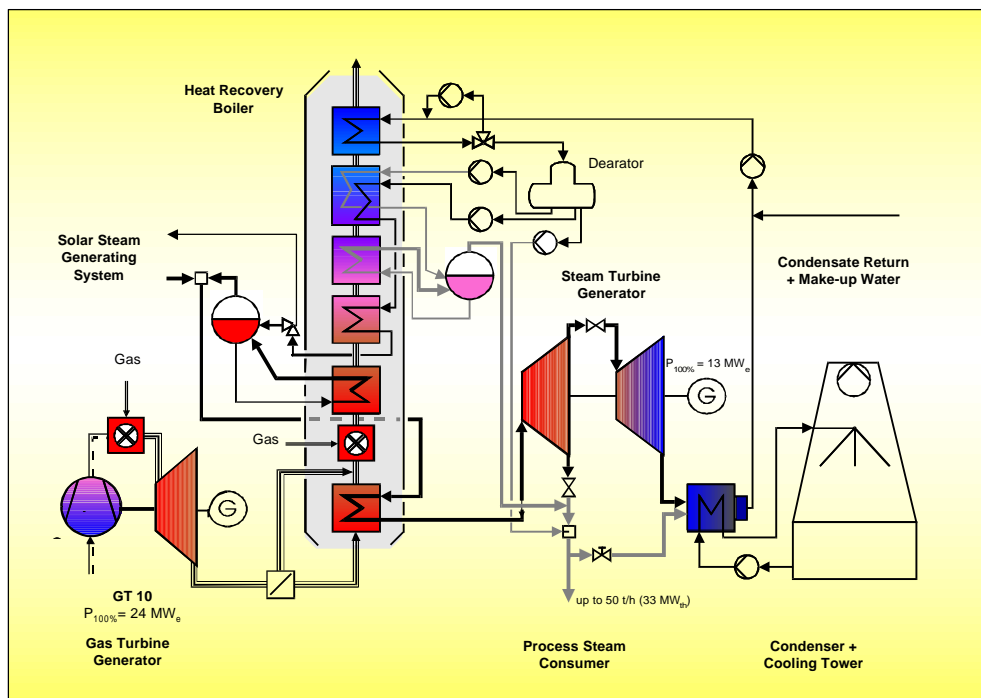


500 meter parabolic trough for direct steam generation at the PSA

Parabolic trough collectors usually use oil as heat transfer fluid, with a maximum operating temperature of 400 °C. Their application is restricted to steam turbine power plants, that make up around 40 % of the world's power plant market. Direct steam generating parabolic troughs (DISS) will substitute the oil-loop technology introduced by the Californian Solar Electricity Generating Systems (SEGS). It is expected that the replacement of the intermediary oil-loop between the solar field and the power block will lead to considerable cost reductions, and the solar-electric conversion efficiency will be enhanced. Since March 1999, DLR is operating and testing the world's first 500 meter DISS-string at the Plataforma Solar.

Performance Simulation and Modelling

DLR's system analysis and system engineering experience with hybrid solar/fossil systems goes back to the early 1980s, when DLR started modelling and optimising such hybrid plants with a solar component and a fossil component for the GAST and subsequently for the PHOEBUS project. Extensive modelling tools have been developed since by the various groups of DLR in Cologne, Almeria and Stuttgart for simulating any possible solar/fossil Rankine, Brayton and Combined Cycle configuration to obtain hourly, daily and annual solar/fossil related output as well as to analyse the instantaneous dynamic behaviour of solar boiler systems. These simulation models and software tools have been qualified with experimental system data obtained during the measurement campaigns at the Plataforma Solar. To analyse and optimise the integration of a solar component in a power plant, DLR can offer detailed cycle analysis using programs like TRNSYS, KPRO or Gate Cycle.



Hybrid Solar/Fossil Combined Cycle System with Co-generation of Electricity and Steam, modelled with a 5 minutes time-step simulation by TRNSYS by DLR's System Engineering Group in Cologne.

With those simulation tools, several international studies have been performed, like e.g. the European Joule/Thermie projects SOLGAS and COLON SOLAR in Spain, representing a solar tower system coupled to an industrial hybrid combined cycle cogeneration plant, the European Thermie project THESEUS in Crete - a solar only steam cycle plant, a hybrid combined cycle system for an industrial park in the United Arab Emirates, and others.

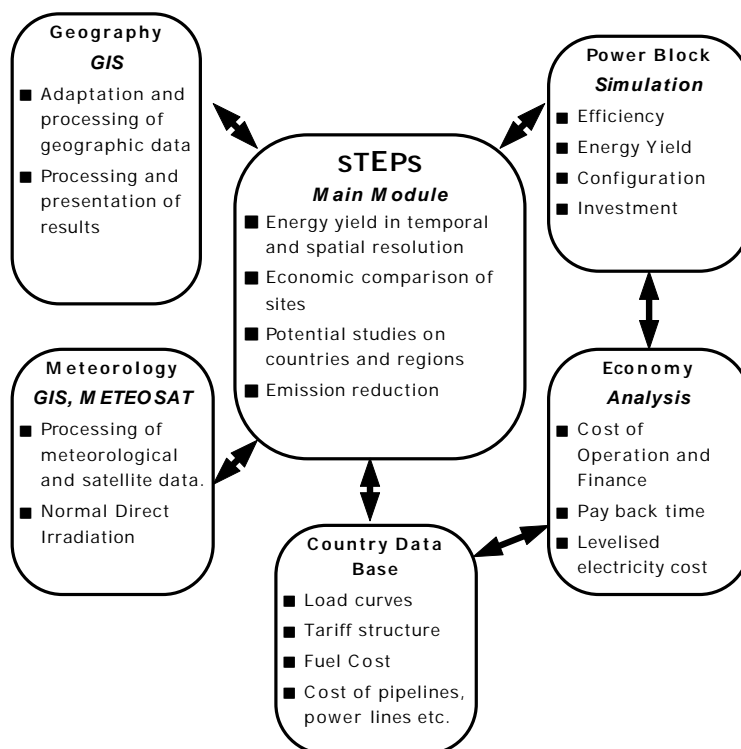
The numerical models cover the whole range from pre-feasibility analysis to in-depth thermodynamic component simulation. Together with DLR's tools for solar radiation resource assessment and economic analysis, they supply the basis for early-stage techno-economic assessment and feasibility studies.

Site Evaluation and Country Assessment

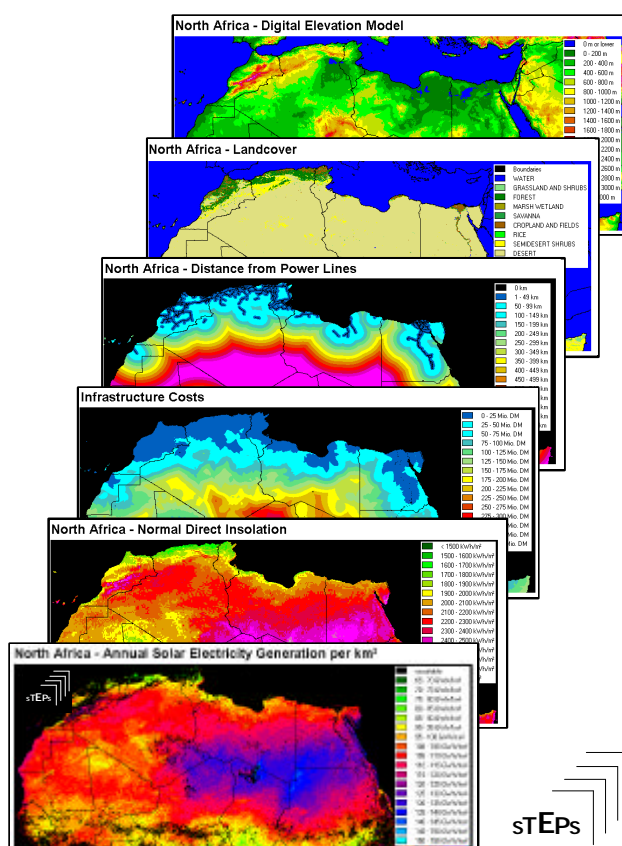
Site evaluation of solar thermal power plants is a highly interdisciplinary task. DLR's site assessment tool STEPS uses a geographic information system (GIS) that allows the management of geographic, infrastructural, meteorological, economical and geopolitical data. For each point of the map, the performance of solar thermal power plant is calculated under the prevailing local conditions.

Land slope, land use by cities and agriculture, forests, water, swamps or very rugged soils may exclude solar thermal power plant erection.

Distances to streets, to the power grid and to cooling water resources can be calculated by the GIS and transformed into infrastructure costs.



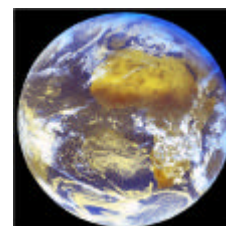
The modular structure of STEPS



The solar direct radiation resource is the most important parameter for planning. Solar radiation intensity with a temporal resolution of 1 hour and a geographic resolution of 2.5 km is obtained from satellite images and detailed modelling of the atmosphere

The STEPS analysis of solar power plants covers the total area of a region and provides well founded information on performance, energy yields, potentials, environmental impact and costs of solar thermal electricity generation.

**METEOSAT Image
for the analysis of
cloud coverage,
DLR-DFD
Oberpfaffenhofen**

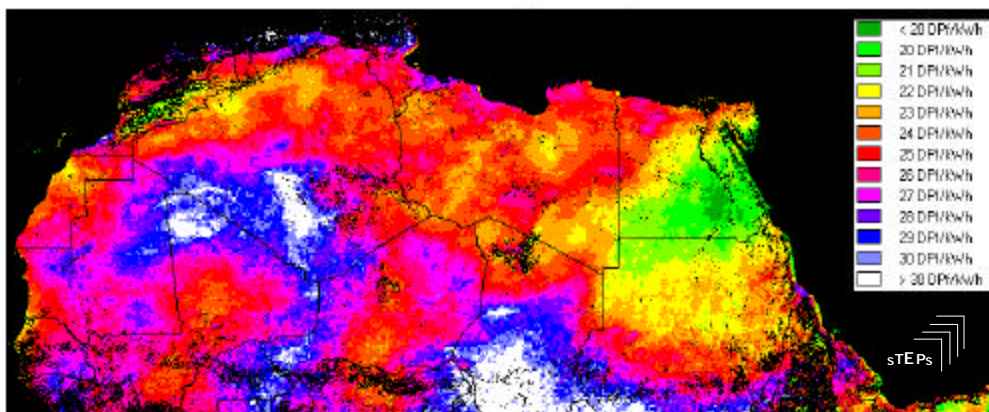


Consulting Services for Industry and Finance

DLR's study group has participated in a number of assessment studies for solar thermal power and cogeneration plants in the Mediterranean Area, specially Spain, Crete, Morocco, Egypt, Jordan, and also in India and in the United Arab Emirates.

In the frame of those projects, DLR offered consulting to international funding institutions, governments, non-governmental organisations, industry, finance and insurance companies involved in solar thermal power projects.

In-deep economic analysis of the costs, cash-flows and internal rates of return of solar thermal power projects can be performed with the available powerful evaluation and simulation tools.

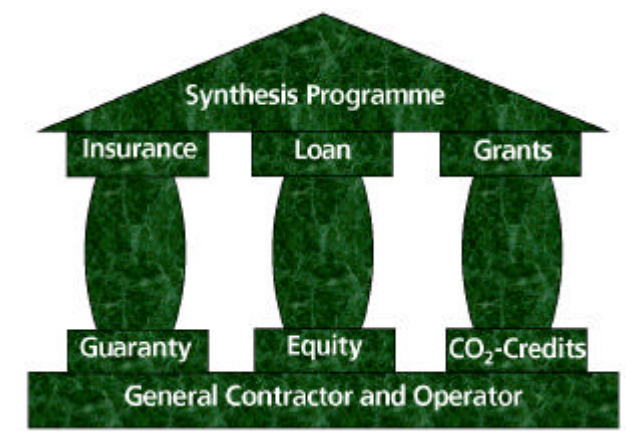


Cost of solar thermal power in Northern Africa (200 MW units, solar only operation)

In 1997, the "SYNTHESIS Programme" for the market introduction of solar thermal power was proposed and initiated by DLR and the Foundation for Climate Protection of Hamburg (HKF). The goal of this programme is to initiate a series of projects and to provide an attractive frame of finance and risk-management based on private funding. DLR has assisted in the strategic financial engineering of that project and in the consulting of banks, insurance companies and industry involved. The strategic targets of the Synthesis programme have been confirmed by a recent study of the World Bank.

The areas of consulting in the frame of the SYNTHESIS programme cover feasibility studies, technical and financial engineering, tender preparation, technical assistance, strategic consulting, monitoring, training, international know-how transfer, assessment, evaluation, research and development.

Right: SYNTHESIS programme for finance, risk management and market introduction based on private initiative



For Further Information Please Contact

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