Deutsches Zentrum für Luft- und Raumfahrt e.V.

German Aerospace Center

Institute of Technical Thermodynamics

Solar Thermal Power Plants : Solar Collectors instead of Fuel

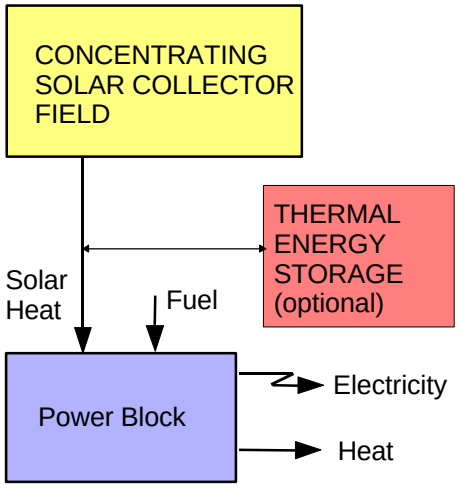


Solar Power Towers (left) and Parabolic Trough Power Plants (centre) as well as Parabolic Dish Engines (right) are concentrating solar power technologies. Parabolic trough plants with 354 MW of presently installed capacity are in commercial operation since many years. Power Towers and Dish Engines have been tested successfully in a series of demonstration projects.

The technical principle is quite simple: high temperature heat from a concentrating solar collector is used to operate a conventional thermal power cycle, like e.g. a steam turbine, a gas turbine or a Stirling engine.

Solar heat can be stored during the day in concrete, ceramics or phase change media. At night, it can be extracted from the storage to run the power block.

Fossil and renewable fuels like oil, gas and organic waste can be used for co-firing the plant, allowing a granted power availability for base load or peak load demand.



Co-generation of electricity and heat is particularly interesting, as the high value solar input energy is used with the best possible efficiency of over 85 %. Possible applications cover the combined production of electricity, industrial process heat, district cooling and sea water desalination.

Solar thermal power plants will have a considerable share on clean electricity generation in the next century. They are one of the best suited technologies to achieve the global goals of emission reduction. E.g., the energy payback time of a solar thermal power plant is in the order of 0.5 years.

DLR-Institute of Technical Thermodynamics, Pfaffenwaldring 38-40, D-70569 Stuttgart, Germany
Tel.: ++49-711-6862-423; Fax.: ++49-711-6862-783; e-mail: Franz.Trieb@DLR.de

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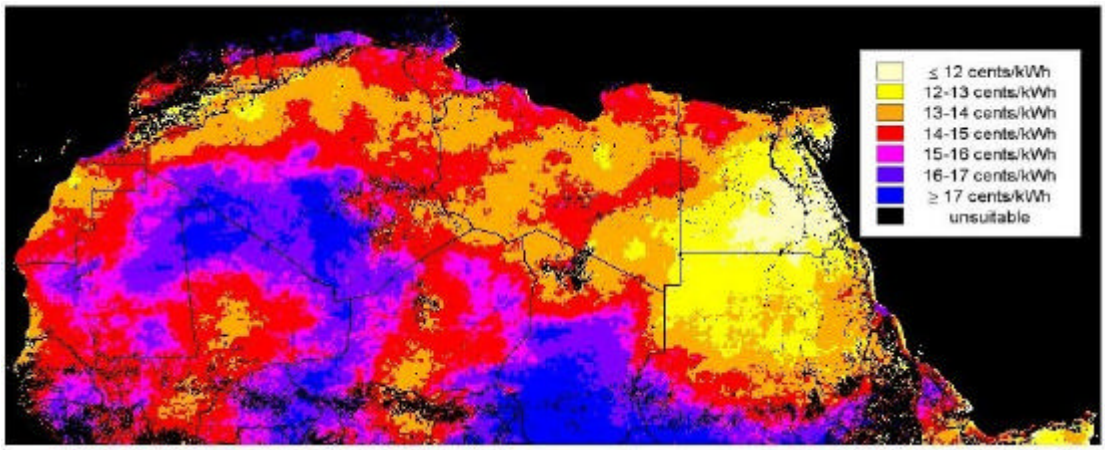
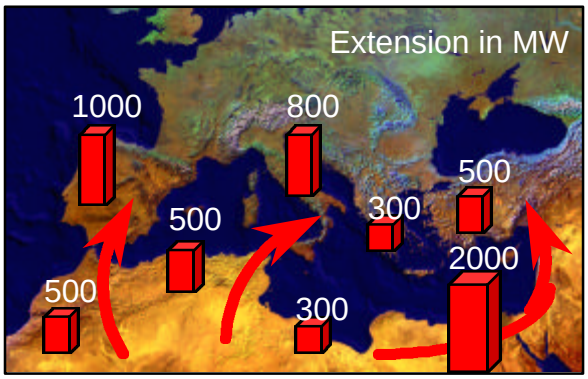
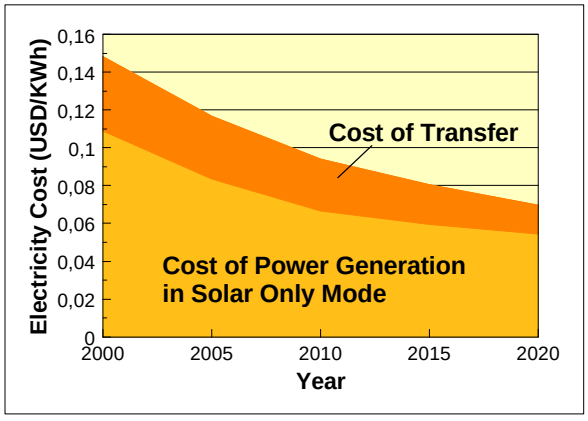
Solar Thermal Power Plants : Perspective of a Strategic Alliance of Europe and Maghreb



A recent site ranking study by DLR reveals that on 1 % of the land area in North Africa, solar thermal power plants in solar only operation mode could generate 16 million GWh of solar electricity per year at a cost of less than 12 US-cents/kWh. This potential already exceeds by 30 % the world electricity demand of 1998.





Extending the solar thermal power market will further reduce costs. Until 2010, 6000 MW of electric capacity could be installed in the Mediterranean Region, at first to feed regional grids. 350 millions of tons of carbon dioxide emissions would be avoided by this measure.

Further extension after 2010 could be coupled to a high voltage direct current interconnection to Europe for export of solar electricity from the Maghreb. In the medium term, the cost of imported solar electricity from the Maghreb will be competitive to other clean electricity sources in Central Europe.

The exchange of technology and solar power in the frame of a strategic economic alliance for the environment will have a lasting effect on the relations of Maghreb and Europe.

Assumptions: Single Plant Capacity 200 MW, No clusters. Rankine Cycle, Solar Share 100 %, Capacity of HVDC grid 2000 MW, Distance 3300 km, Loss of Transfer 16 %, Interest Rate 8 %, Depreciation 25 a, Implementation according to the SYNTHESIS-Concept.

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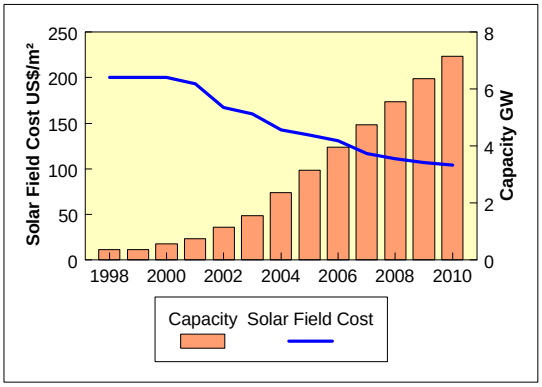
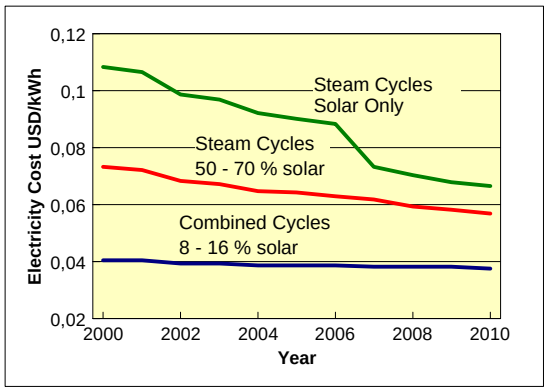
Solar Thermal Power Plants : Private Start-Up Funding through the SYNTHESIS-Programme





Today, solar thermal power plants in hybrid fossil/solar operation and without financial support can generate electricity at a cost between 4 and 12 US-cents/kWh, depending on the solar radiation resource, the technical design etc.. Extending the world wide installed capacity from today 354 MW to 7000 MW until 2010 will bring down the solar collector field cost to roughly 50 % of its present level. This will then yield electricity costs between 3.5 and 7 US-cents/kWh.

Reducing the Capital Cost

by low
- loan interest rates
- equity interest rates
- insurance premia
- risk surcharges
- taxes and land cost.

+

revenues from emission reduction

→ competitive electricity cost from the beginning

SYNTHESIS - Goals until 2010

7,000 MW capacity in 50 plants

23,000 GWh/year of solar electricity

400 million tons of CO_2-reduction

12,500 jobs

1 % the of world power market by solar

The total investment of the programme is expected to be approximately 16 billion US$, of which 94 % will be covered by electricity sales. The remaining necessary start-up funding will mainly be covered by private measures to reduce the capital cost.

Moreover, the World Bank's Global Environmental Facility (GEF) is supporting projects for emission reduction by providing grants on the investment.

Leading German companies have recently agreed to jointly develop, build and operate solar thermal power plants and to trigger the market introduction of solar thermal power. First projects are now developed under this frame.

Assumptions: Plant capacity 200 MW for Rankine cycles, 800 MW for combined cycles. Thermal storage introduced by 2007. Direct radiation 2350 kWh/m²a. Interest rate 8 %/a. Economic lifetime 25 years. Implementation according to the SYNTHESIS-Concept.

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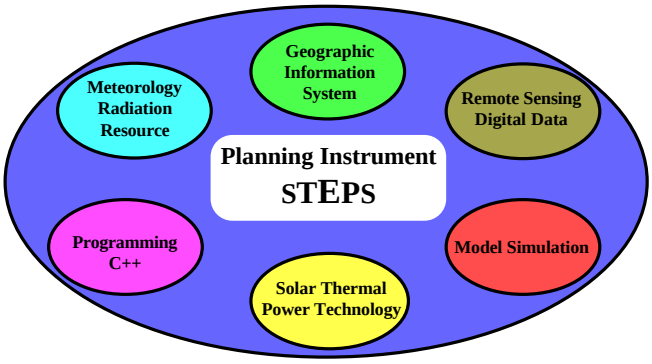
STEPS : An Instrument for Solar Thermal Power Planning, Siting and Analysis of Country Resources



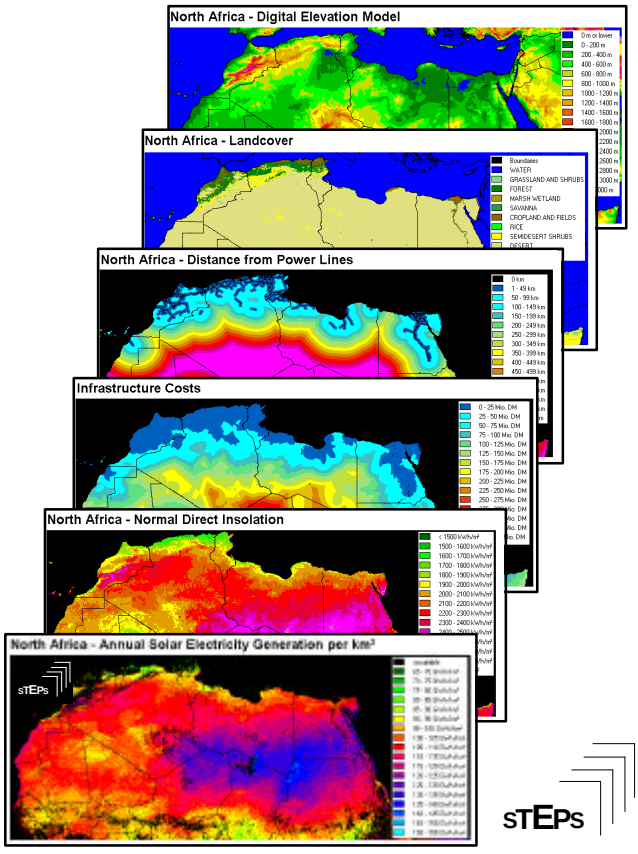
Site evaluation of solar thermal power plants is a highly interdisciplinary task. STEPS uses a geographic information system (GIS) that allows the management of area related geographic, infrastructural, meteorological, economical and geopolitical data. The site data is used as input for a simulation tool that yields the potential of solar electricity generation in high temporal and geographic resolution.

Land slope, land use by cities and agriculture, forests, water, swamps or very rugged soils may exclude the construction of solar thermal power plants.

Distances to streets, to the power grid and to cooling water resources are calculated by the Geographic Information System and transformed into costs.

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 assessment of potential sites for solar power plants with STEPS can cover large regions and provide well founded information on performance, energy yields, energy potential, cost and site ranking of solar thermal electricity generation.



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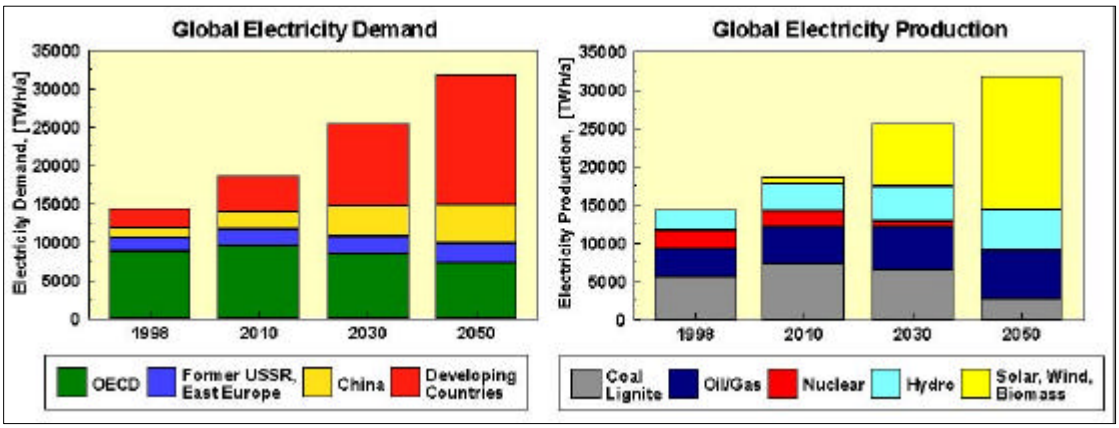
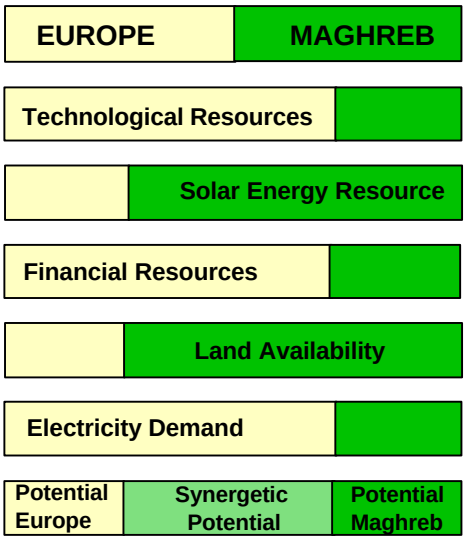
The Importance of Solar Thermal Power Plants for Global Sustainable Development



The above scenario of the world power demand shows the challenge resulting from the goals of emission reduction established by UNFCCC: in spite of the reduction of the power demand in the industrial countries by more efficient energy use, the global power demand will more than double by 2050, mainly due to the growing electricity demand and intensity in today's developing countries. If not having disappeared at all, nuclear power will play a minor role by that time due to an increased international awareness of the related risks. Renewable energy sources will therefore by 2050 have to supply more than today's electricity demand in order to establish a world power production compatible with stable atmospheric conditions.

The key importance of solar thermal power now becomes evident: solar thermal power plants are immediately applicable in the bulk electricity sector of many sunbelt countries during the phase of strong growth expected in the coming decades, making in fact use of that growth to "solarise" the electricity sector.

The potential of solar power resources is large enough to achieve the international goals of climate protection, not only by covering a considerable part of the growing electricity demand of the sunbelt countries, but also by making use of south-north-synergies and solar power import/export schemes for cost-efficient solar energy use in the north.



The Synergetic Solar Energy Potential of Europe and Maghreb

Qualitative display only. Source: Hamburger Klimaschutz-Fonds

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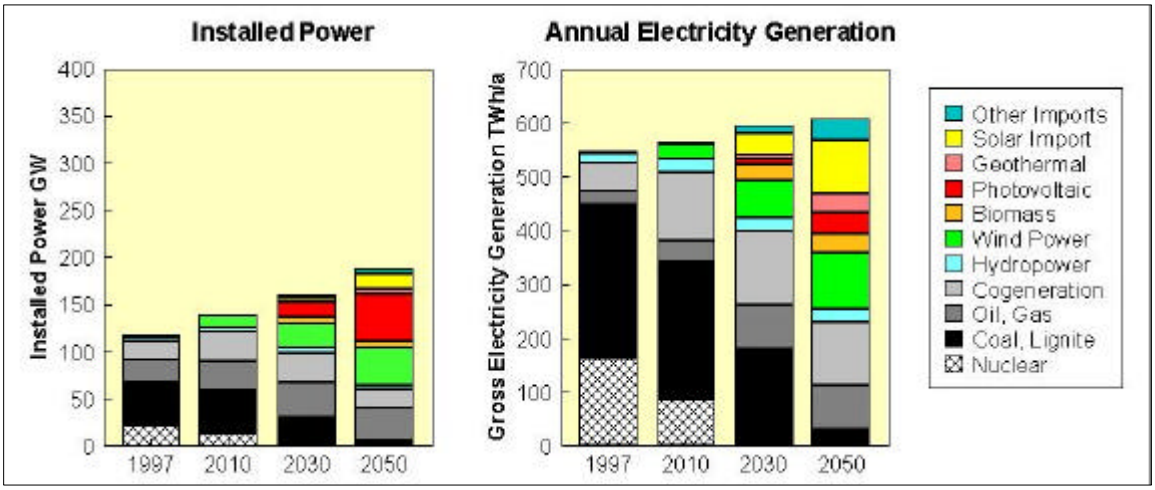
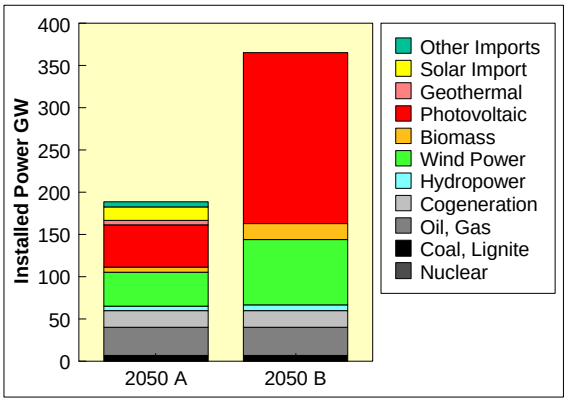
Solar Electricity Imports in Northern Countries
A Renewable Energy Scenario for Germany



The above figure shows a scenario of electricity generation from renewables in Germany up to the year 2050. The electricity supply that is presently based on nuclear and fossil sources will have to change considerably in order to meet the international requirements for climate protection and equally the German policy of non-nuclear power generation. Nuclear power will disappear until 2030, and a shift from coal to gas powered co-generation and combined cycle power plants will have to take place. The scenario includes the use of national and import energies like solar thermal power from Maghreb, hydro energy from Island and Scandinavia and geothermal power from Island, which will be imported through high voltage direct current transmission lines.

Comparing this scenario to an equivalent one that depends exclusively on national renewable power sources, the advantage of renewable power imports becomes obvious: the necessary installed power capacity is reduced by 50 % with a corresponding reduction of the investments and the average electricity cost.

This is mainly due to the higher capacity factor of renewable import power plants located usually at very good sites where 5000 to 7000 annual full load hours of operation can be achieved, while the national sources of wind and solar power in Germany yield an average of only 800 to 1500 full load hours per year. Another drawback of the B-scenario is the fact that the German resources would have to be exploited up to their potential limits.



Installed power capacity needed for two equivalent German electricity supply scenarios with 60% renewable energy share in 2050

A based on national and imported renewables
B based only on national renewables

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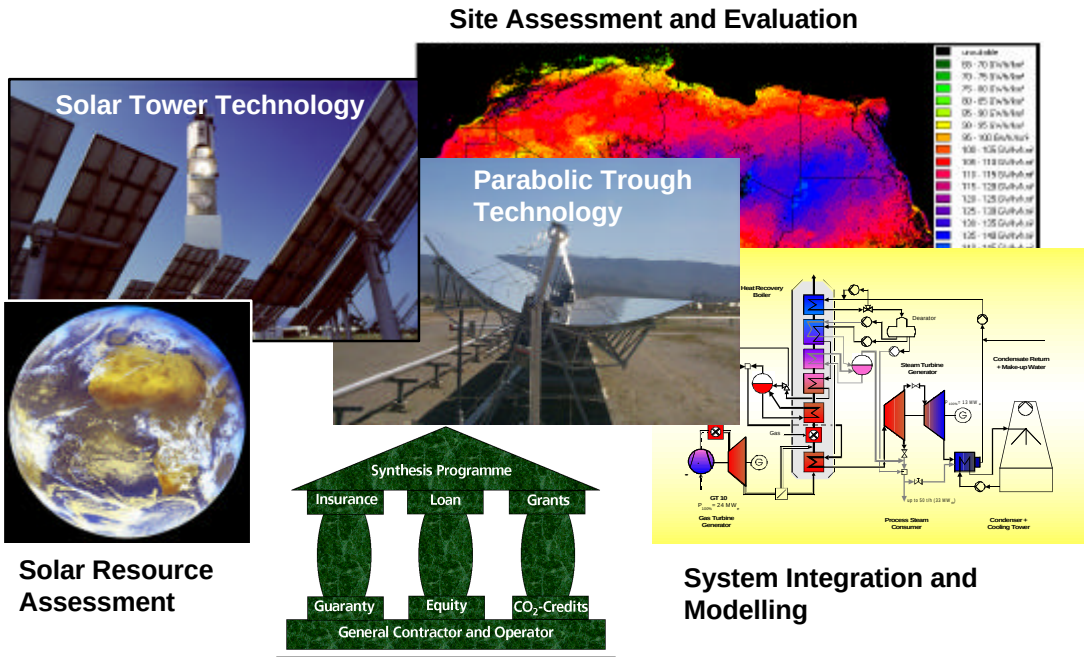
Solar Thermal Power Plants: The Role of DLR in Market Introduction



The German Aerospace Center (DLR) is one of the leading research establishments in Germany. High temperature solar thermal concentrating technologies are a major field of research of DLR's Energy Division. DLR is e.g. operating the world's first direct steam generating parabolic trough collector system at the Plataforma Solar in Almeria, Spain. This technology will in the long term substitute the expensive, oil-based heat transfer loop applied up to now, e.g. in the Californian plants.

A new receiver for solar towers developed at DLR's Institute of Technical Thermodynamics in Stuttgart allows to feed solar energy directly to gas turbines or combined cycle systems, with a dramatic increase of the solar-electric conversion efficiency.

At the Institute of Atmospheric Physics of DLR in Oberpfaffenhofen, satellite images from the German Remote Sensing Data Center are processed to derive solar radiation intensity and cloud coverage for large areas of the world. On this basis, detailed simulation and modelling of different power plant configurations can be performed by DLR's Department of Solar Energy Technology in Cologne.

Technical and economical feasibility studies, project evaluation studies and country road-maps for solar power build-out are provided by DLR's Department of Systems Analysis and Technology Assessment in Stuttgart.

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