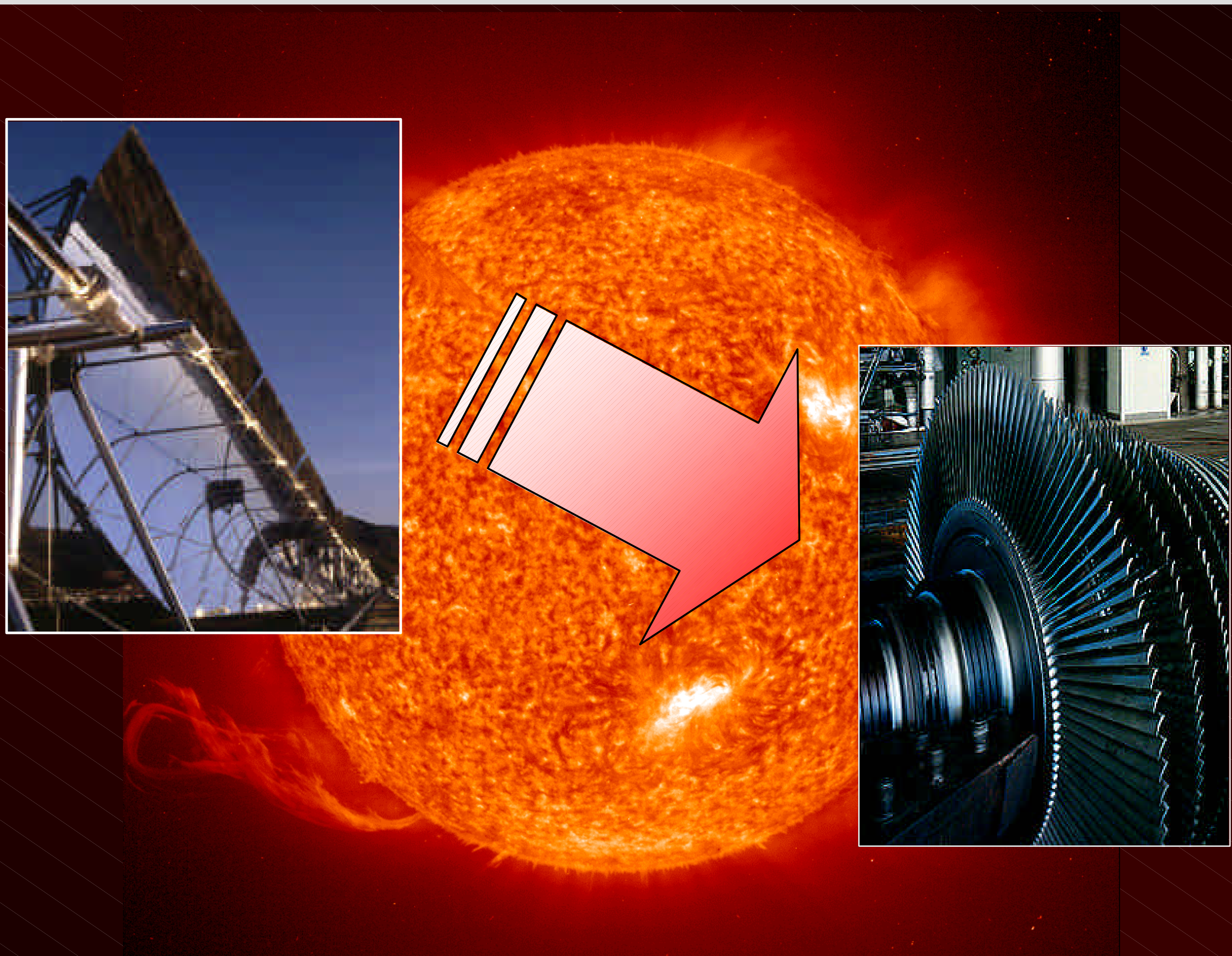
CONCENTRATING SOLAR POWER NOW



SOLAR ENERGY DRIVES CONVENTIONAL POWER PLANTS

Concentrating solar collectors produce high temperature heat to operate steam and gas turbines, combined cycles or stand alone engines for electricity or for combined heat and power.

DAY AND NIGHT POWER SUPPLY

Thermal storage systems allow for night-time solar power generation. Fuels like oil, gas, coal or biomass can additionally be used to deliver electricity whenever required.

LOW COST SOLAR ELECTRICITY

With costs ranging from 10 to 15 ct/kWh, concentrating solar power still requires support, but co-firing and special schemes of finance yield affordable power already today.

SOLUTIONS FOR POWER AND WATER

Process heat from combined generation can be used for seawater desalination, thus helping to reduce the threat of freshwater scarcity in many arid countries.

LARGE POTENTIAL FOR SUSTAINABLE DEVELOPMENT

The concentrating solar power potential exceeds the world electricity demand by more than 100 times.

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Deutsches Zentrum für Luft- und Raumfahrt e.V.
German Aerospace Center
DLR

Federal Ministry for Economic Cooperation and Development

PRINCIPLES AND POTENTIAL OF CONCENTRATI

HOW CAN THE SUN DRIVE A POWER PLANT?

In a simple way: the solar radiation can be collected by different Concentrating Solar Power (CSP) technologies to provide high temperature heat (bottom right). The solar heat is then used to operate a conventional power cycle, such as a steam or gas turbine, or a Stirling engine.

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

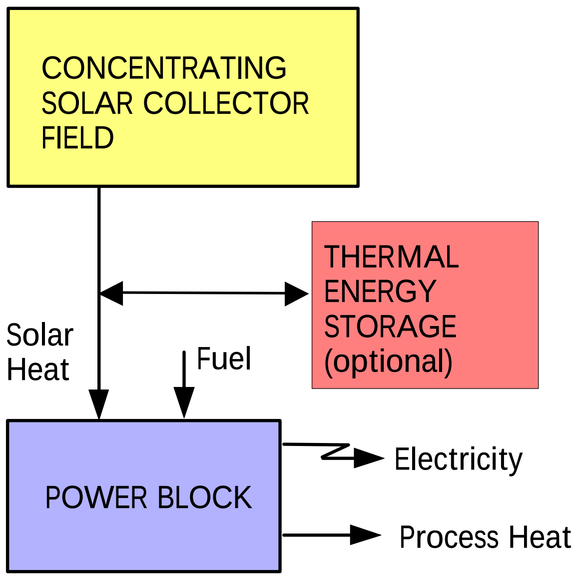
Solar heat collected during daytime can be stored in concrete, molten salt, ceramics or phase-change media. At night, it can be extracted from the storage to run the power block.

Fossil and renewable fuels like oil, gas and biomass can be used for co-firing the plant, thus providing additional power for base or peak load demand.

Combined generation of electricity and heat by CSP is particularly interesting, as the high value solar input energy is used with the best possible efficiency, exceeding 85 %.

Process heat from combined generation can be used for industrial applications, district cooling or sea water desalination.

CSP is one of the best suited technologies to help, in an affordable way, mitigate climate change as well as to reduce the consumption of fossil fuels. Therefore, CSP has a large potential to contribute to the sustainable generation of power.



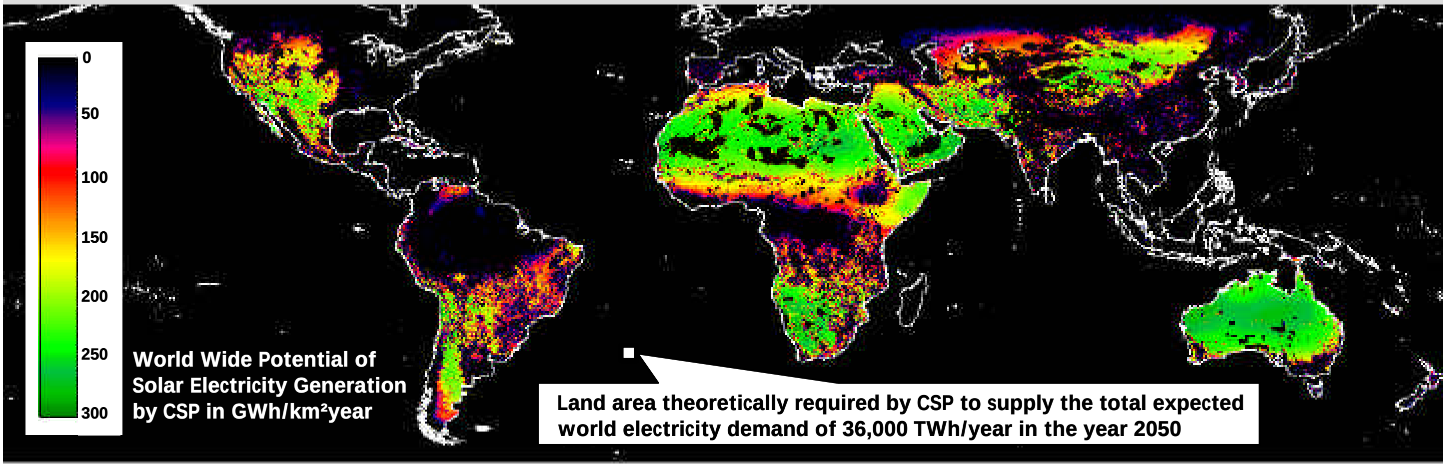
Principle of a concentrating solar power system for electricity generation or for combined heat and power generation

<u>*Please note*</u>*:*

Cost data within this brochure is given in Euro or Euro-cents.

Title photograph of the sun is courtesy of SOHO/EIT. SOHO is a project of international cooperation between ESA and NASA.

NG SOLAR POWER

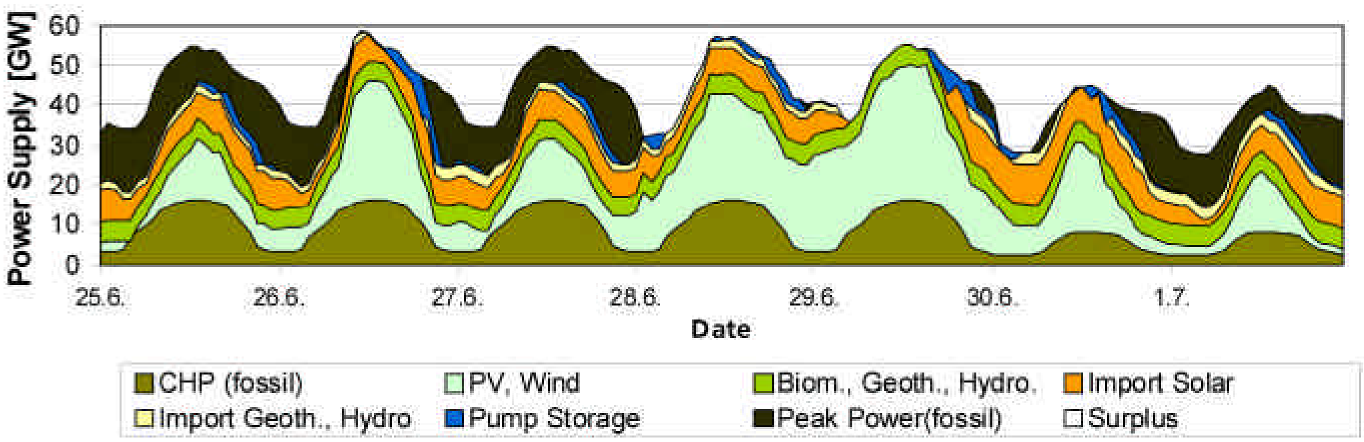


CSP HELPS TO MEET THE IPCC GOALS

In many regions of the world, every square kilometre of land can produce as much as 200-300 GWh/year of solar electricity using CSP technology (top). This is equivalent to the annual production of a conventional coal or gas fired 50 MW power plant or - over the total life cycle of a CSP system - to the energy contained in 16 million barrels of oil. The exploitation of less than 1 % of the total CSP potential would suffice to meet the recommendations of the Intergovernmental Panel on Climate Change (IPCC) for a long-term stabilisation of the climate. At the same time, concentrating solar power will become economically competitive with fossil fuels.

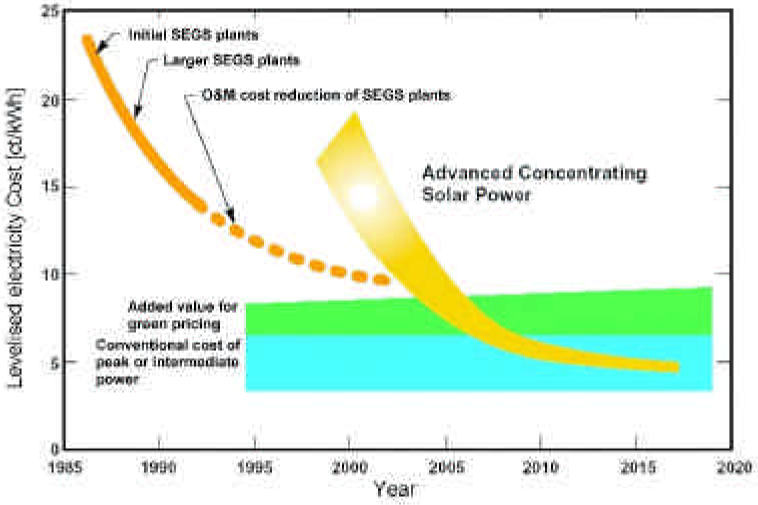
INTERNATIONAL SOLAR ENERGY ALLIANCES

The large solar power potential in the southern countries will only be used to a small extent, if it is restricted by the regional demand and by the local technological and financial resources. But if solar electricity is exported to regions with less solar energy resources, a much greater part of the potential of the sunbelt countries could be harvested for the protection of the global climate. Some countries like Germany already consider the perspective of solar electricity imports from North Africa and Southern Europe as a contribution to the long-term sustainable development of their power sector (bottom).



Time series of load and power generation in Germany in the year 2050 in a scenario assuming environmental and economical sustainability. Import of solar electricity will have the important role of filling the gap between the electricity demand and the supply from national renewable power sources. CHP: combined heat and power.

WHY CONCENTRATING SOLAR POWER ?



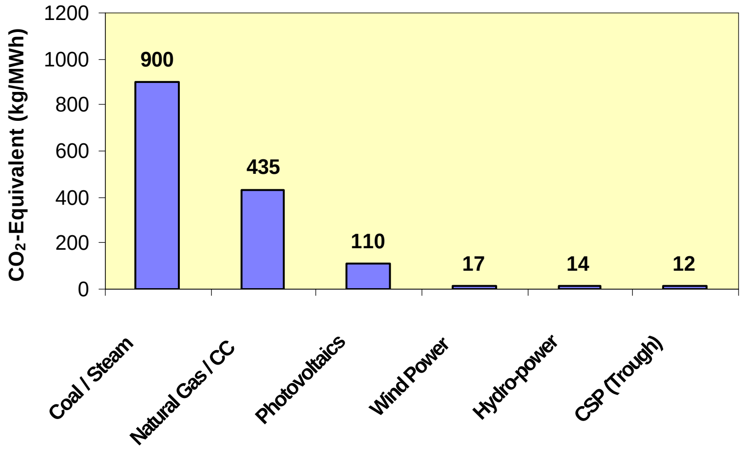
Cost perspectives of CSP until 2020. Source: SolarPaces

ECONOMIC SUSTAINABILITY

The history of the Solar Electricity Generating Systems (SEGS) in California shows impressive cost reductions achieved up to now, with electricity costs ranging today between 10 and 15 ct/kWh. However, most of the learning curve is still ahead (top). Advanced technologies, mass production, economies of scale and improved operation will allow to reduce the solar electricity cost to a competitive level within the next 10 - 15 years. This will reduce the dependency on fossil fuels and thus, the risk of future electricity cost escalation. Hybrid solar-and-fuel plants, at favourable sites, making use of special schemes of finance, can already deliver competitively priced electricity today.

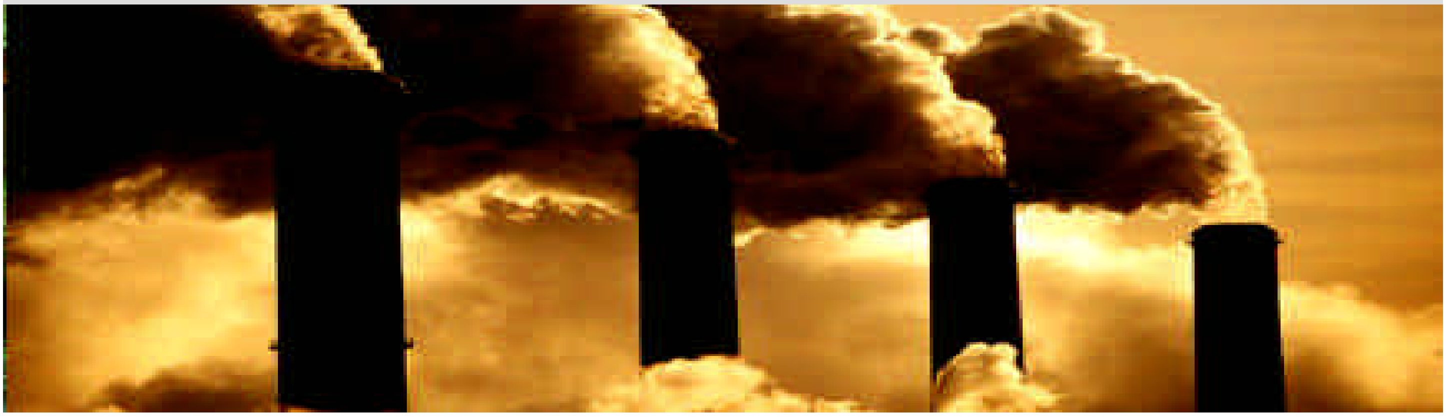
ENVIRONMENTAL SUSTAINABILITY

Life cycle assessment of emissions (bottom) and of land surface impacts of the concentrating solar power systems shows that they are best suited for the reduction of greenhouse gases and other pollutants, without creating other environmental risks or contamination. For example, each square meter of collector surface can avoid 250-400 kg of CO_2-emissions per year. The energy payback time of the concentrating solar power systems is in the order of only 5 months. This compares very favourably with their life span of approximately 25- 30 years. Most of the collector materials can be recycled and used again for further plants.



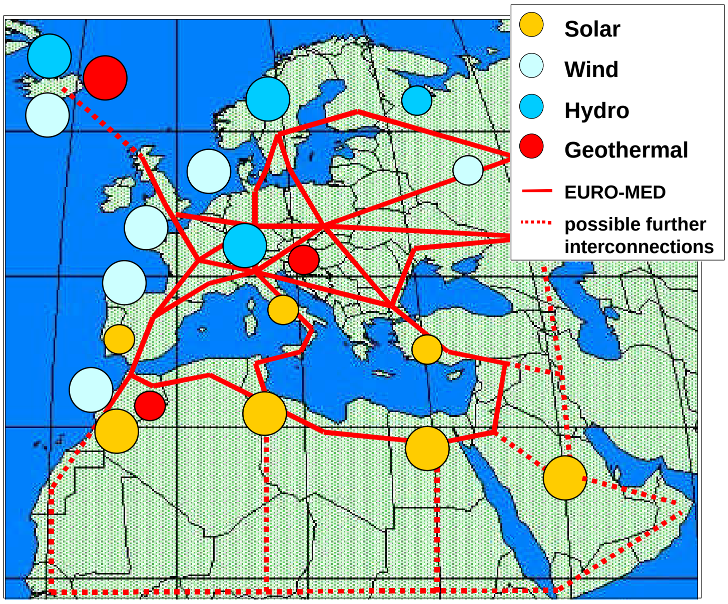
Life Cycle CO_2-Emissions of Different Power Technologies

This life cycle assessment of CO_2-emissions is based on the present energy mix of Germany. CSP value is valid for an 80 MW parabolic trough steam cycle in solar only operation mode. PV and CSP in North Africa. CC: Combined Cycle. Source: DLR.

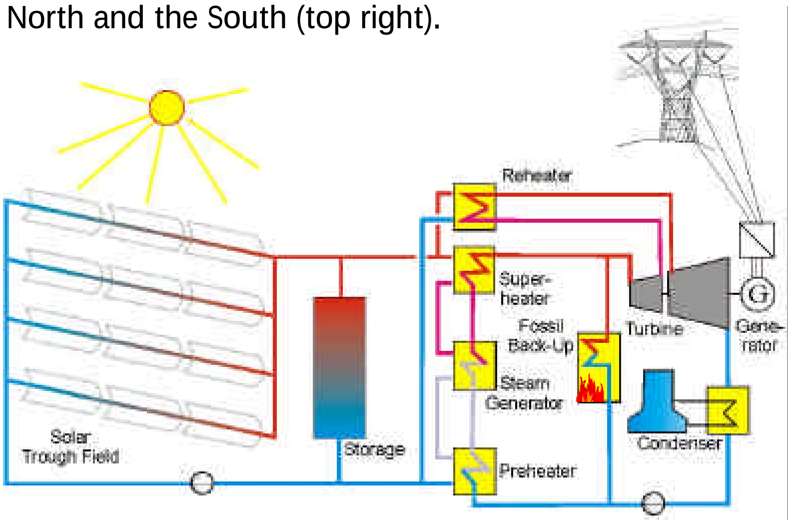


SOCIAL SUSTAINABILITY

CSP systems supply electricity and process heat like any conventional power plant (bottom). Their integration into the grid does not require any measures for stabilisation or backup capacity. On the contrary, they can be used for these purposes, allowing for a smooth transition from today's fossil fuel based power schemes to a future renewable energy economy. Large electricity grids such as a Euro-Mediterranean Power Pool via High Voltage Direct Current Transmission will in the medium term allow for an intercontinental transport of renewable electricity. The existing power line from Spain to Morocco could already be used for this purpose. This concept will help to stabilise the political and economic relations between the countries of the North and the South (top right).



Vision of a Euro-Mediterranean grid interconnecting sites with large renewable electricity resources



Sketch of a Parabolic Trough Steam Cycle Plant

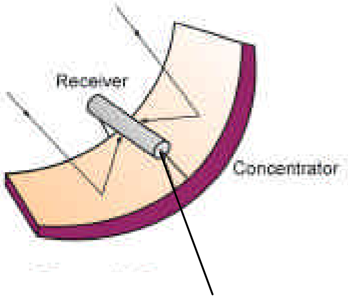
In sunbelt countries, CSP will reduce the consumption of fossil energy resources and the need for energy imports. The power supply will be diversified with a resource that is distributed in a fair way and accessible by many countries. Process heat from combined generation can be used for seawater desalination and help, together with of a more rational use of water, to address the challenge of growing water scarcity in many arid regions. Thus, CSP will not only create thousands of jobs and boost economy, but will also effectively reduce the risks of conflicts related to energy, water and climate change.

CSP TECHNOLOGIES - THE STATE OF THE ART

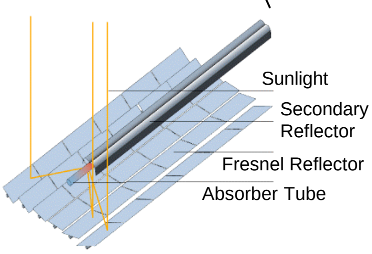

Photo: KJC

PARABOLIC TROUGH SYSTEMS

Steam cycle power plants with up to 80 MW capacity using parabolic trough collectors have been in commercial operation for more than fifteen years (top). A total of nine plants with 354 MW of installed power are feeding the Californian electric grid with 800 million kWh/year at a cost of about 10-12 ct/kWh. The plants have proven a maximum efficiency of 21 % for the conversion of direct solar radiation into grid electricity.



Steam at
350 - 550 °C
80 - 120 bar *



A European consortium has developed the next collector generation, the EUROTROUGH, which aims to achieve better performance and cost by enhancing the trough structure (bottom left). The new collector will be tested in 2003 under real operating conditions in the Californian solar thermal power plants within the PARASOL project funded by the German Federal Ministry for the Environment. While the plants in California use a synthetic oil as heat transfer fluid in the collectors, efforts to achieve direct steam generation within the absorber tubes are under way in projects sponsored by the European Commission in order to reduce the costs further.

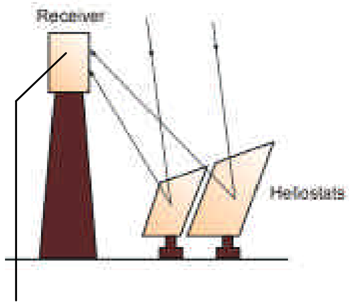
Another option under investigation is the approximation of the parabolic troughs by segmented mirrors according to the principle of Fresnel (bottom right). Although this will reduce the efficiency, it shows a considerable potential for cost reduction. The close arrangement of the mirrors requires less land and provides a partially shaded, useful space below.


Photo: DLR

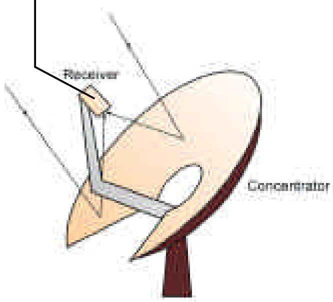

Photo: Solarmundo

http://www.kjcsolar.com
http://www.flabeg.de
http://www.solarmillenium.de
http://www.eurotrough.com
http://www.solarmundo.be

SOLAR TOWER SYSTEMS



Air or Helium at
600 - 1200 °C
1 - 20 bar *



* range of the present state of the art and expected future achievements

Concentrating the sunlight by up to 600 times, solar towers are capable of heating air or other media to 1200 °C and higher (top left). The hot air may be used for steam generation or - making use of the full potential of this high-temperature technology in the future - to drive gas turbines. The PS10 project in Sanlucar, Spain, aims to build a first European steam cycle pilot plant with 10 MW of power. For gas turbine operation, the hot air must pass through a pressurised solar receiver with a solar window (top right). Combined cycle power plants using this method will require 30 % less collector area than equivalent steam cycles. At present, a first prototype to demonstrate this concept is built within the European SOLGATE project with three receiver units coupled to a 250 kW gas turbine.

PARABOLIC DISH ENGINES

Parabolic dish concentrators are relatively small units that have a motor-generator in the focal point of the reflector. The motor-generator unit may be based on a Stirling engine (bottom right) or a small gas turbine. Their size typically ranges from 5 to 10 m of diameter or 5 to 25 kW of power, respectively. Like all concentrating systems, they can additionally be powered by fossil fuel or biomass, providing firm capacity at any time. Because of their size, they are particularly well suited for decentralised power supply and remote, stand-alone power systems. Within the European project EURO-DISH, a cost effective 10 kW Dish-Stirling engine for decentralised electric power generation is being developed by a European consortium with partners from industry and research (bottom left).

http://www.sbp.de
http://www.dlr.de/TT/solartherm/solargasturbine
http://www.klst.com/projekte/eurodish

INITIATING CSP PROJECTS

STEP 1: BASIC PROJECT INFORMATION

The initial step of a CSP project is to identify the basic investment opportunities. First evaluation can be started e.g. by regional authorities with eventual support from CSP experts to assess general information on the market chances, capacity requirement, cost level, revenues, availability of finance, national policies, the level of political risks, the solar irradiation level, possible project implementation structures and the general availability of sites. If the outcome is promising, partners for a project company and sources of finance for project development must be agreed.

STEP 2: PROJECT ASSESSMENT

A pre-feasibility study will include solar energy resource assessment, a preliminary conceptual design of the plant and technical and economic performance modelling for several project alternatives. It will yield a first estimate of the levelised electricity cost and of the economic perspectives of the project. The study will give the general project outlines like administrative requirements, expected environmental impacts, viable schemes of finance and a project implementation structure. This phase will yield a pre-selection and recommendation for the most promising sites. The study will be the basis for the decision about the continuation of the project.

STEP 3: PROJECT DEFINITION

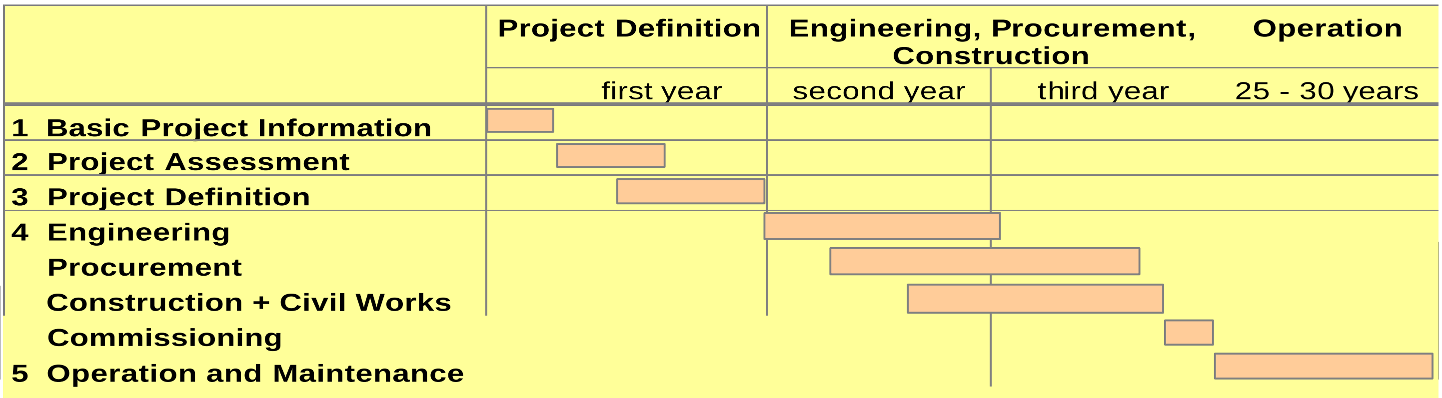
A feasibility study will analyse the most promising project configuration identified in the pre-feasibility phase, going into detail in resource assessment, thermodynamic and economic performance calculations, and specifying major equipment and investment estimates based on budgetary quotes. Usually, an environmental impact study is included. As a result, the project site will be selected and the necessary land will be reserved or purchased by the project company. The study will be the basis for a construction bid and for the related Engineering, Procurement and Construction (EPC) contract, as well as for all the legal and administrative requirements to start the project.

STEP 4: ENGINEER-PROCURE-CONSTRUCT

A consortium bidding for the EPC contract should consist of the construction company, power block supplier, solar plant supplier and an engineering company, all of whom will be experienced in CSP technology. The basis for this phase is a reliable scheme of finance (next page) that allows for electricity costs equivalent to the expected revenues. Due to the fact that fuel is substituted by capital goods, a long term power purchase agreement is a major pre-requisite for the realisation of CSP plants. The final activity of this phase is the grid connection and commissioning of the plant.

STEP 5: OPERATION AND MAINTENANCE

Operation of the CSP plants is expected to last over an economic life cycle of 25 to 30 years.



FINANCING

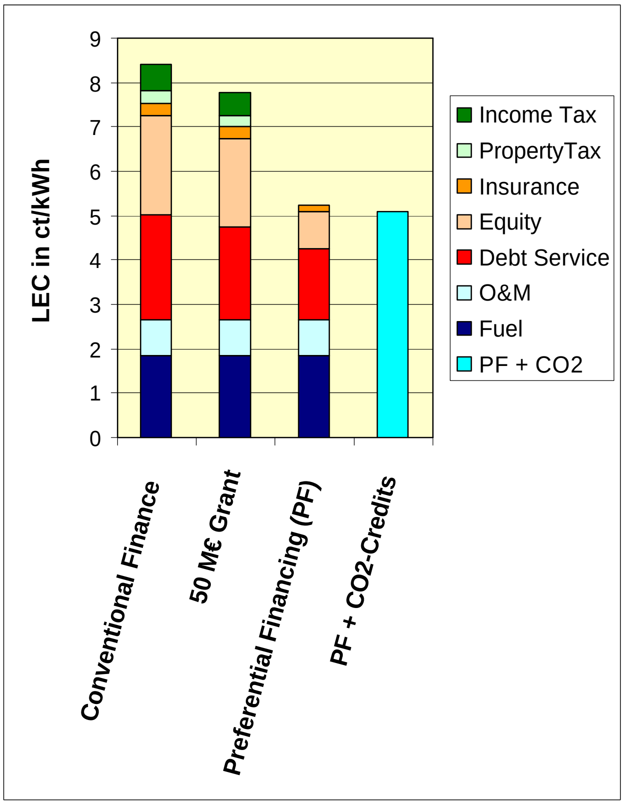
Solar collectors increase the initial investment and the related capital cost in comparison to fuel-fired power plants. Interests for extra debt and equity, insurance costs, taxes and custom duties have to be paid, extra land has to be purchased and extra staff has to be employed. In contrast to that, fuels are purchased without any interest or insurance rates, and are often free of custom duties and taxes or even subsidised by the government.

Therefore, CSP requires start-up finance to enter the market and to follow the learning curve. This can be achieved by an instrument such as the Spanish Renewable Energy Act expected to become operational for CSP by the end of 2002, that will grant a revenue of 15 ct/kWh for CSP plants with maximum 50 MW of power and operated in solar-only mode. For developing countries, a grant by the Global Environmental Facility (GEF) of approximately 50 M€ per plant is expected to be applied to projects in Mexico, Morocco, India and Egypt.

In order to achieve affordable costs today, a combination of financial mechanisms including public-private risk sharing must reduce the capital cost. In addition to the GEF-grant and to CO_2-Credits from the Clean Development Mechanism, all stakeholders of a CSP project including host countries, banks, investors, insurers and suppliers are encouraged to contribute to start-up financing by adapting their profit expectations to the learning curve.

Private participation in start-up finance will require an international public-private-partnership over the whole phase of market introduction in order to reduce the project related risks for all stakeholders to a minimum.

During an executive conference on CSP organised by BMU, GEF and KfW in Berlin in June 2002, the “Berlin Declaration” was issued by an international group of stakeholders that agreed to jointly develop a long term strategy for the market introduction, and to discuss different innovative models of finance in order to start a series of CSP projects.



Example of a fictitious hybrid CSP start-up project showing the effects of several strategies of finance on the levelised electricity cost LEC (Source: DLR)

<u>General calculation parameters</u>: Hybrid 200 MW parabolic trough steam cycle power plant in medium load, solar share 45 %, annual electricity 1000 GWh/y, investment 425 M€, discount rate 3.5 % (real), economic life 25 years, fuel cost 12 €/MWh, avoided CO_2 310,000 t/y.

<u>Parameters for conventional financing and (in brackets) ideal parameters for preferential start-up financing (PF)</u>: Debt interest rate 8 %/y (4 %/y), internal rate of return of equity 20 %/y (8 %/y), insurance rate 1% (0.5 %) of Inv./y, property tax 1.5 % (0 %) of Inv./y, income tax 38 % (0 %) of Inc./y, custom duty 5 % (0 %) of direct investment, production overhead 10 % (5 %), grant 0 M€ (50 M€), CO_2-Credit 0 €/t (5 €/t), risk management private (private & public).

http://www.bmu.de
http://www.solarpaces.org/csp_docs.htm
http://www.en-consulting.com/csp

THE MISSION OF GERMANY

CSP TECHNOLOGY FOR THE WORLD MARKET

German companies are among the world leading technology providers and project developers of concentrating solar power (top). The parabolic trough plants in California, the EUROTROUGH, the EURODISH, the PS10 power tower, and lately, the pressurised air receiver SOLGATE have been developed and produced with major participation of German companies and research centres, most of them represented in the European Solar Thermal Power Industry Association ESTIA. With financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) and the GEF, the first concentrating solar power plant in India will be set up in Mathania, Rajastan.

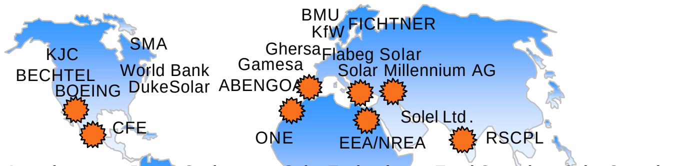
50 % RENEWABLE ENERGY SHARE IN 2050

The energy policy target for Germany is to reach a 50% renewable energy share by the year 2050, including national resources and renewable electricity imports (centre). The instruments to reach this goal range from the Renewable Energy Sources Act to the political and financial support of research and development of renewables, among many other initiatives. The German Federal Ministry for the Environment (BMU) encourages the development of a long-term strategy for CSP market introduction, finance and market expansion.

R&D FOR COST REDUCTION

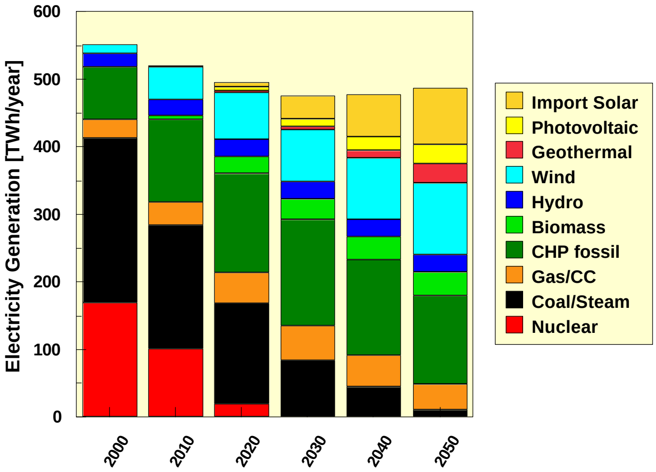
Since the present cost of CSP technologies is a major barrier to their commercialisation, the Federal Ministry for the Environment, with 10 million Euro plus 7 million Euro of industrial contributions, is funding research and development in order to reduce costs and bring CSP into the position to successfully enter the market. Germany has been active in many international research and development activities of the European Commission (bottom) and within the International Energy Agency's SolarPaces Programme.

This brochure was created within the German Future Investment Programme (ZIP) in co-operation of BMU and DLR.



Location	Power Cycle	Solar Technology	Total Capacity [MWe]	Solar Capacity [MWe]
Australia	Steam Preheat	Fresnel (CLFR)	1400	4
Australia	Steam Cycle	Dish	2	2
Crete	Steam Cycle	Trough	52	52
Egypt	Combined Cycle	Investor's Choice	135	35
India	Combined Cycle	Trough	140	35
Iran	Combined Cycle	Trough	135	30
Mexico	Combined Cycle	Investor's Choice	310	40
Morocco	Combined Cycle	Investor's Choice	150	30-50
Spain	Steam Preheat	Trough	50	50
Spain	Steam Preheat	Tower (PS10)	10	10
Spain	Steam Preheat	Tower (SolarTres)	10	10
USA Nevada	Steam Preheat	Trough	30	30

CSP projects under development



Electricity supply within a sustainable energy scenario for Germany. After 2030 electricity will increasingly be employed for the generation of hydrogen for the transportation sector

Direct steam generating parabolic trough test facility at the Plataforma Solar, Almeria, Spain

For more information and to obtain an extended version of this brochure, please contact:

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