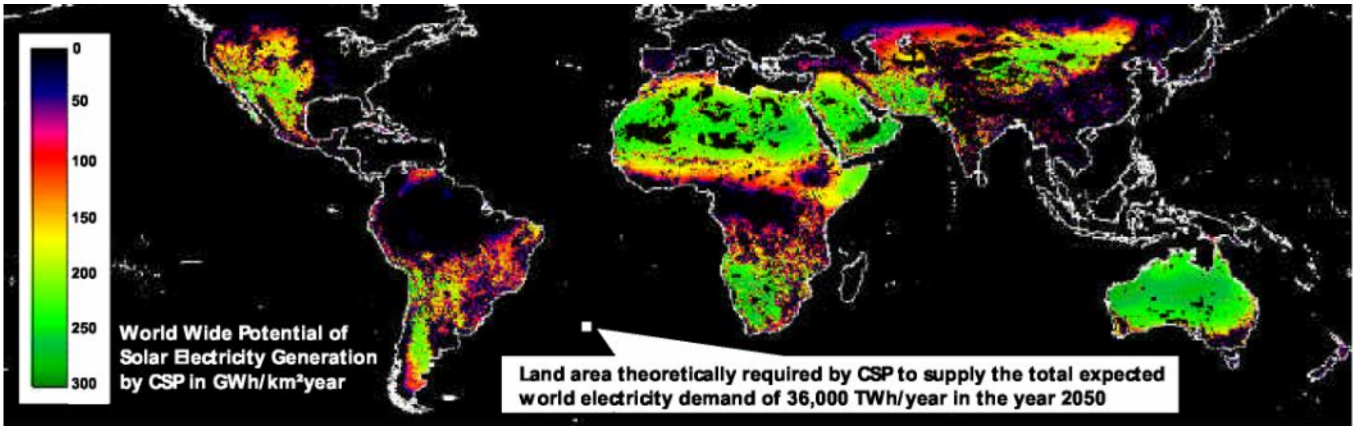
POTENTIAL OF SOLAR ENERGY

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

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.

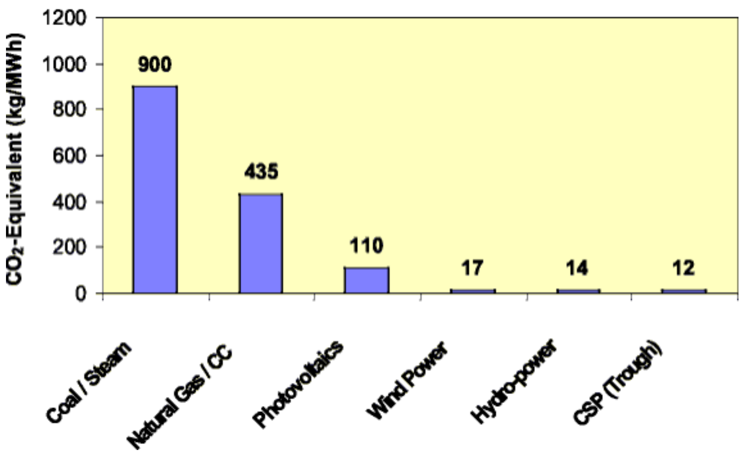


Figure: Life Cycle CO_2-Emissions of Different Power Technologies

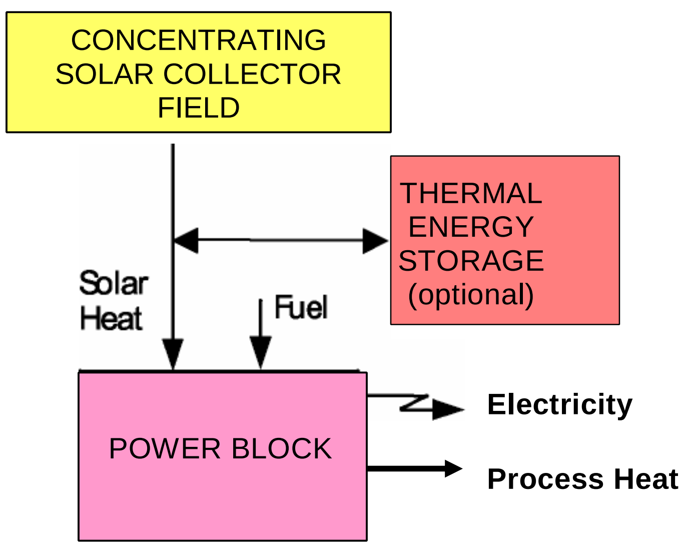
This life cycle assessment of CO2-emissions is based on the present energy mix of Germany. CSP value is valid for an 80 MW parabolic trough steam cycle in solar only operation mode. PV and CSP in North Africa. CC:Combined Cycle. Source: DLR.

SOCIAL SUSTAINABILITY

In sunbelt countries, solar power 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.

The rays of the sun are collected by different technologies to concentrate on a focal point to provide high temperature heat. This solar heat is then utilized to operate a conventional power cycle, such as a steam or gas turbine, or a Stirling engine and the technology used, is known as Concentrating Solar Power (CSP) technology.

Parabolic Trough, Parabolic Dish Engines and Solar Power Towers are the current CSP technologies. Parabolic trough power plants with 354 MW 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 in the world.



Principle of a CSP system for Power Generation or for Combined Heat and Power Generation

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.

CSP TECHNOLGIES

Power Generation by CSP mainly can be done in the following ways:

- Parabolic Trough Systems
- Parabolic Dish Engines
- Solar Tower Systems

PARABOLIC TROUGH SYSTEMS

System Description

Steam cycle power plants with up to 80 MW capacity using parabolic trough collectors have been in commercial operation for more than fifteen years. 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.

Figure: Kramer Junction California Solar Thermal Power Plant

A European consortium has developed the next collector generation, the EUROTROUGH, which aims to achieve better performance and cost by enhancing the trough structure.
We are developing a cost effective single parabolic concentrating trough collector SPC-24, the working prototype of which is shown in the following figures:

Figure: SPC-24 Prototype Model being tested

Figure: The Accuracy of the Focal point of SPC-24 being evaluated. The Temperature at the focus was around 365 degree Celsius.

How the SPC-24 System Works

Figure shows the working principle of the SPC-24 collector.

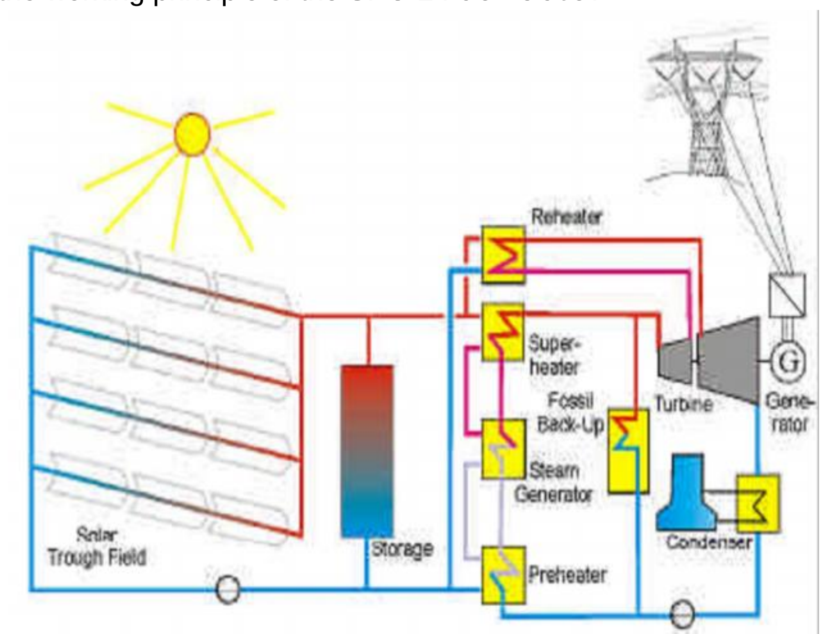


Fig. Schematic of the SPC-24 Solar Thermal Power Plant

By tracking the sun from sunrise to sunset, the parabolic SPC-24 collectors concentrate the sun's radiation with their parabolic mirror facets on the absorber tubes along their focal line. Through these absorber tubes circulates a heat transfer fluid (HTF), usually synthetic oil, which is heated to a temperature of nearly 400°C. This heat transfer oil circulates in the boiler tubes, which produces a steam of approx. 350 degree Celsius. The steam runs a conventional steam turbine and consequently the generator (Fig. Shown).

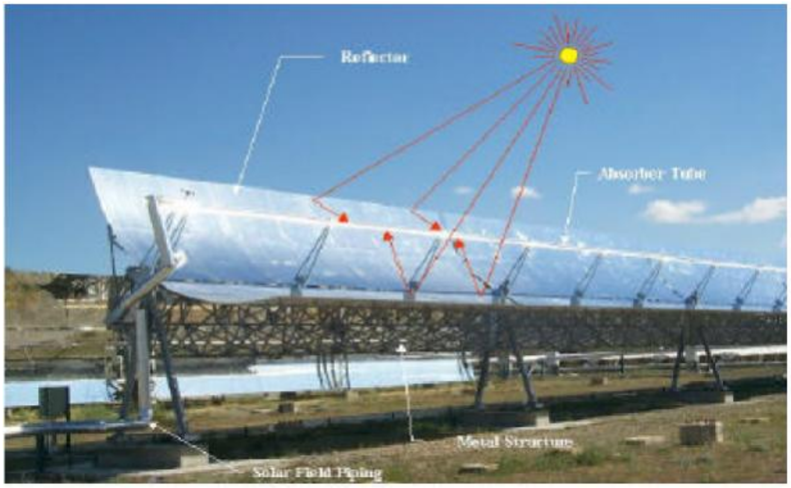


Figure : Working Principle of the SPC-24 Collector

This system works on the Conventional Rankine Cycle. The SPC-24 converts the Solar Radiations into Electricity through the following major components;

1) Parabolic Trough Solar Concentrator
2) Receiver(Evacuated Tubes)
3) HTF (Heat Transfer Oil)
4) Storage
5) Boiler
6) Steam Turbine
7) Electrical Generator

Parabolic Trough Solar Concentrator

The SPC-24 collectors are made up of identical 12 m long collector modules. Each module comprises 32 parabolic mirror panels - 8 along the horizontal axis between pylons and 4 in a vertical cross-section. Each mirror is supported on the structure at four points on its backside. This permits the glass to bend within the range of its flexibility without effect on the focal point. The SPC-24 has 8 collector modules and an aperture area of $499.2m^2$.

The torque-box design has been selected for the SPC-24, with less weight and less deformations of the collector structure due to dead weight. The design reduces torsion and bending of the structure during operation and results in increased optical performance and wind resistance.
The central element of the box design is a 12-m long steel space-frame structure having a squared cross section that holds the cantilever arms for the parabolic mirror facets. The torque box consists of only 4 steel parts which enables easy manufacturing, reduces transportation problems, decreases erection time and thus reduces overall cost.

The Schematic of the whole module is and the main parts of SPC-24 are shown in the figure below:
The main parts of the SPC-24 are shown below:

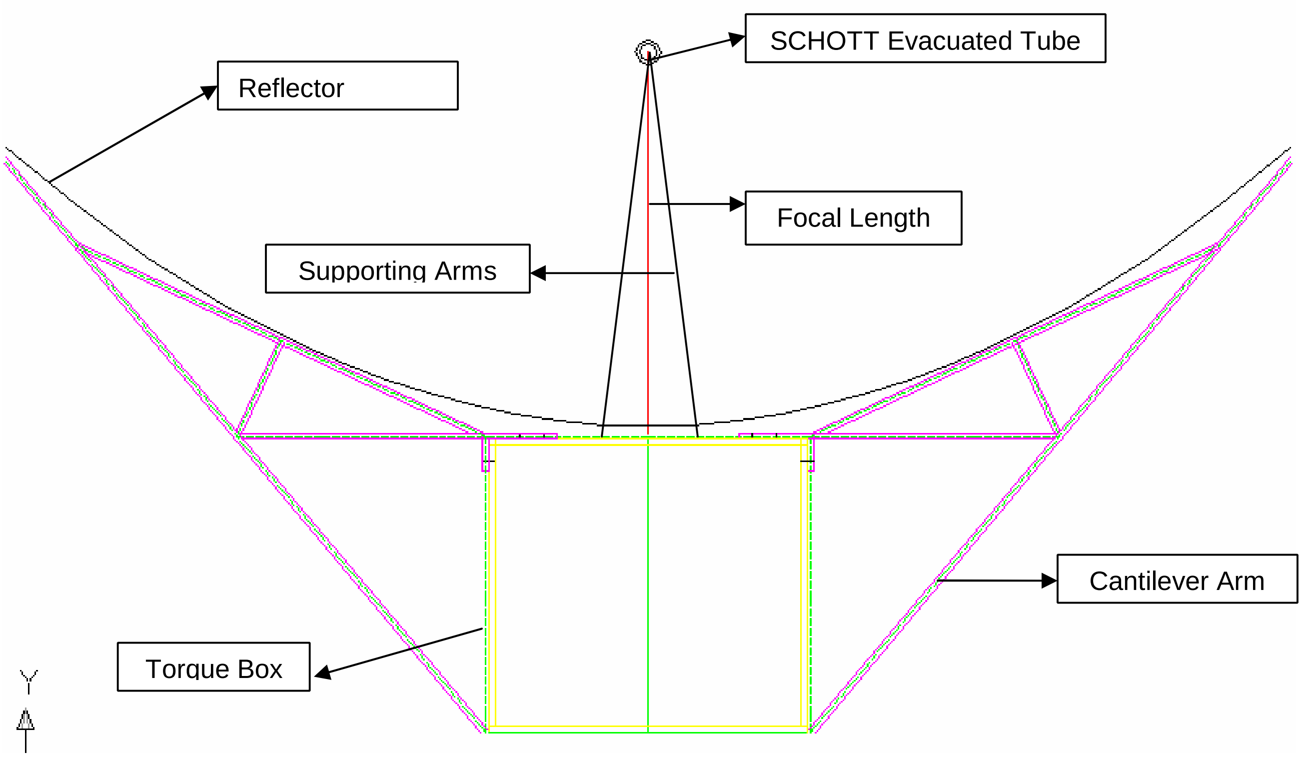


Figure: Main Parts of SPC-24 Trough

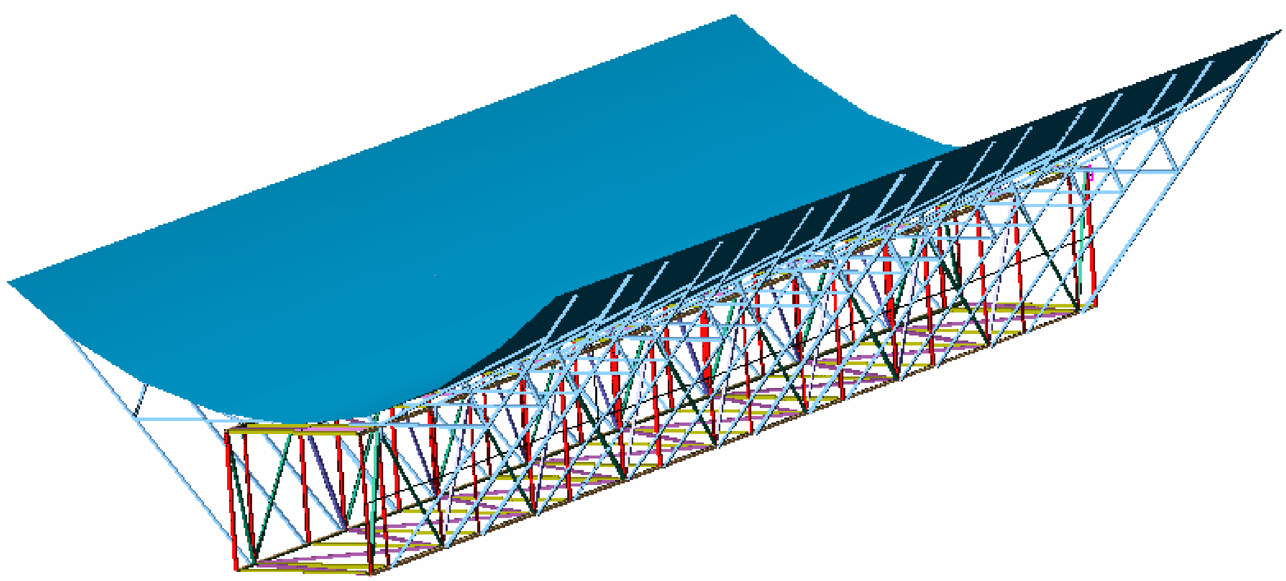


Figure: Schematic of Complete SPC-24 Trough Module

TABLE: SPC-24 Module Description

SPC Trough Model	**SPC 24**
Focal Length	1.5 m
Absorber Radius	3.5 cm
Aperture Width	5.2 m
Aperture Area	124.8 m²
Collector Length	24 m
Number of Modules per Drive	2
Number of Glass Facets	64
Number of Absorber Tubes (4.1 m)	6
Mirror reflectivity	94%
Weight of steel structure and pylons, per m2 aperture area	20.0 kg

DISH STIRLING SYSTEM

System Description
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. Like all concentrating systems, they can additionally be powered by fossil fuel or biomass, providing firm capacity at any and expected future achievements time. Because of their size, they are particularly well suited for decentralised power supply and remote, stand-alone power systems. Their size typically ranges from 5 to 10 m of diameter for 5 to 25 kW of power, respectively. A cost effective 10 kW Dish for decentralised electric power generation is being developed which will run a 10kW Stirling Engine.

The system consists of the following components:

- Parabolic solar concentrator (Dish)
- Tracking system
- Receiver (Stirling engine with generator)

How the System Works

The parabolic dish reflects the incoming solar radiation onto a receiver which is located at the concentrator's focal point. The solar radiation is absorbed by the heat exchanger (receiver) and thus heats the working gas (helium or hydrogen) of the Stirling engine to temperatures of about 650^{o}C. This heat is converted into mechanical energy by the Stirling engine. An electrical generator, directly coupled to the crankshaft of the engine, converts the mechanical energy into electricity (440V AC). A sun-tracking system rotates the solar concentrator continuously about two axes to follow the daily path of the sun.

Parabolic Solar Concentrator (Dish)

The parabolic solar concentrator consists of 12 segments and each segment is further divided into four parts to facilitate ease of construction. These segments are made up of fibre glass and are supported on a steel structure of hollow cross-section. The design of the parabolic concentrator is very sensitive because it delivers the fuel to the receiver (Stirling Engine).

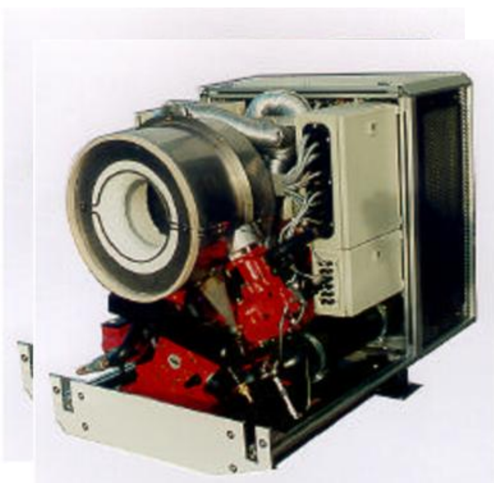
For the operation of the Stirling engine, temperatures as high as possible are desired. This is achieved by dividing the parabolic shell into 12 equal segments and thus forming a perfect parabolic shape. The rim of the shell is stiffened by a ring truss to which later on the bearings and the Stirling support structure are attached. Thin anodised, electro-plated, mirror finished, 0.4 mm thick Aluminium foil sheets will be fitted onto the front side of the segments and will have a reflectivity of around 94%.

Tracking System

The parabolic concentrators always require the orientation towards the sun. So, a horizontal (Polar) and vertical (Azimuthal) tracking system is required. Therefore a simple movable steel construction standing on six wheels has been developed for Polar and the vertical orientation of the concentrator are done by a small servomotor.

Receiver (Stirling Engine)

The SOLO Stirling Engine, Germany will be used as receiver.



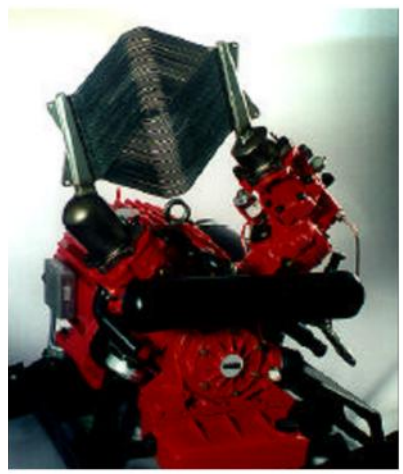


Figure: SOLO Stirling Engine in Conjunction with the DS-9 Parabolic Dish

TABLE: Specifications of Dish Stirling Model DS 9

Dish Stirling Model	**DS 9**
Focal Length	4.5 m
Aperture Width	9.0 m
Projected Area	63.62 m²
Number of Glass Facets	48
Number of segments	12
Mirror reflectivity	94%
Receiver	Stirling Engine