

# SCHOTT Memorandum on Solar Thermal Power Plant Technology





# Solar Thermal Power Plants: Proven and ready for market

## Europe must seize its opportunity in the world market

The international technology concern SCHOTT decided back in the 1990's to focus on solar energy. Today SCHOTT is the only company worldwide that offers products and solutions for all solar technologies. SCHOTT delivers solar thermal tube collectors for water heating, photovoltaic modules for decentralized power generation, and receivers for parabolic trough power plants for centralized generation of electricity.

SCHOTT employs outstanding solar experts. They are convinced of the great future prospects for solar energy. That is why we want to help a technology make a breakthrough, which, like no other, can develop the unlimited potential of solar energy: solar thermal power plant technology. This technology is proven and ready for the market - yet remains virtually unknown.

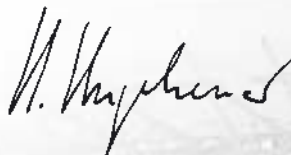
Now it is time to convince politicians and potential investors of its capabilities. SCHOTT would like to make a contribution to achieving this goal: the "SCHOTT Memorandum on Solar Thermal Power Plant Technology" is designed to familiarize decision makers in politics and economy with the technology and to initiate the necessary steps for market launch.

With high efficiency and the lowest energy production costs of all kinds of solar power plants, the parabolic trough solar thermal power plant represents the goals of profitability, reliable power supply, and environmental protection. Parabolic trough power plants are suitable for industrial scale applications in the range of 50 to 200 MW of electrical power. They can replace conventional power plants designed for medium-load operation - and without any qualitative change in the network structure.

The countries of the Mediterranean area alone could generate many times the total European energy demand. That makes solar thermal power plant technology an important technology option for a sustainable energy mix in the future.

In the area of solar thermal power plant technology, European companies are the worldwide market and technology leaders. With parabolic trough technology, Europe has the potential for an extraordinary success in the world market.

Now is the time to seize this opportunity.



Dr. Udo Ungeheuer  
Chairman of the Board of Management  
SCHOTT AG







## Solar Thermal Power Plants: The future belongs to parabolic trough technology

Of the various solar thermal power plant technologies, only parabolic trough technology has yet achieved market maturity. Therefore the statements on solar thermal power plant technology in this memorandum are based on this technology. They have been reinforced through operational practice.

- In the solar field of a parabolic trough power plant, parabolic mirrors placed in long rows concentrate solar irradiation 80 times upon an absorber tube, in which a heat transfer fluid is heated. In the central generation unit, a heat exchanger produces steam to power the turbines.

Research is currently under way on the following other solar thermal power plant technologies:

- **Solar towers** consisting of a central receiver tower, which is surrounded by a mirror field that concentrates the irradiation on the tip of the tower. In the receiver a heat transfer medium is used to transfer the ener-

gy to a heat exchanger in order to produce steam.

- In **Fresnel technology**, horizontal flat mirror facets track the sun. Here, too, the energy is transferred to a heat exchanger using a heat transfer medium.
- With the **Dish-Stirling system**, parabolic dishes capture the solar radiation and transfer it to Stirling motors.
- With the **solar chimney**, the sun heats air beneath gigantic, greenhouse-like glass roofs. The air then rises in a tower and drives the turbines.

In contrast to these technologies, parabolic trough technology is completely ready for use. It is mature and, compared to the other forms of solar thermal power plant technologies, has a head start in development of at least twenty years.



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## Towards sustainable energy: time is running out

- The next few years will be the decisive window of opportunity for conversion of energy systems. According to the International Energy Agency, by 2030 the investment needed for the electricity business worldwide will be 7.5 trillion euro. In Germany alone, half the current power plant capacity will be off grid by that time.
- Planning and constructing a power plant takes up to ten years. With a predicted operating time of about 50 years, we are now deciding the energy structure through 2060.
- Foreseeable shortages and today's already unreliable and distinctly expensive fossil resources are forcing a diversification of energy sources. The limit of CO<sub>2</sub> emissions in our atmosphere has already been exceeded.
- Solutions can no longer be put on the 'back burner': we must not engage in a one-sided pursuit for technologies that may not be ready for market for decades. We must take advantage of renewable energy resources that are available and affordable today.
- National energy cartels are retarding the necessary rethinking process. Today, questions of energy infrastructure must be thought of in European terms. The establishment of powerful, international energy transmission structures and a really workable EU domestic energy market are more urgent than ever.
- Protection of the climate is not just a necessity, but also a future market, which Europe must exploit through specific, coordinated strategies.

## The solar age can start tomorrow

- Solar thermal power plants are ready for the market and suitable for large-scale use at up to 200 MWel. They can replace conventional power plants operated in the medium load range - and without any qualitative changes in the grid structure.
- The turnaround in energy can be initiated today. Parabolic trough power plants are based on a proven technology and can be "delivered". They are among the lowest-cost renewable energies and in the mid-term will stand up to a profitability comparison with medium-load fossil fuel systems.
- Solar thermal power plants can be operated profitably in the Earth's sunbelt - which includes Southern Europe and especially the Southern Mediterranean. Transmission to Central Europe could be handled at a favorable cost using high-voltage DC transmission, a technology that is already available today. In Europe and in the Mediterranean area, appropriate power line capacity should be constructed quickly.
- Europe gets gas from Russia and petroleum from the Middle East - 'ignoring' questions of supply reliability. The risks of transport through politically unstable regions and across distances of several thousand kilometers seem to bother no one. When it is a question of routing solar power from Southern Spain to Central Europe, 'small-statism' reigns victorious. In the area of power generation and infrastructure, we must get beyond thinking in national terms.
- Solar thermal power plant technology is a future technology, in which European science is the world's best, and European companies are the market leaders. If European industrial policy is serious about its Lisbon strategy, then it must pave the way for solar thermal power plant technology. **Now.**





## Outstanding prospects for the future

Solar thermal power plants use the energy from the sun to generate heat, which is converted into electricity via turbines. With their high efficiency and the lowest power production costs of all solar technologies, the technologically mature parabolic trough power plants in particular have outstanding prospects for the future. The technology is market-ready; it now needs the support of policy makers and the confidence of potential investors.

Whereas photovoltaics is the right technology for decentralized utilization of solar energy, the strength of solar thermal power plant technology (CSP) is centralized energy generation. The uninhabited deserts of North Africa alone could generate many times the European power requirements. This makes concentrating solar power technology a significant technological option for a sustained energy mix in the future. It will also contribute directly to the CO<sub>2</sub> reduction strategy of the European Union. According to a Greenpeace study, the use of CSP can prevent 154 million tons of CO<sub>2</sub> emissions worldwide by 2020.

Solar thermal power plant technology is particularly efficient at high solar irradiation. Therefore it offers very good options for development not only for the southern member states of the EU, but also in many economically disadvantaged regions in the Earth's sunbelt.

In the face of the threatening climate change, CSP opens the door to a substantially increased share of renewables in power production, especially in these countries.

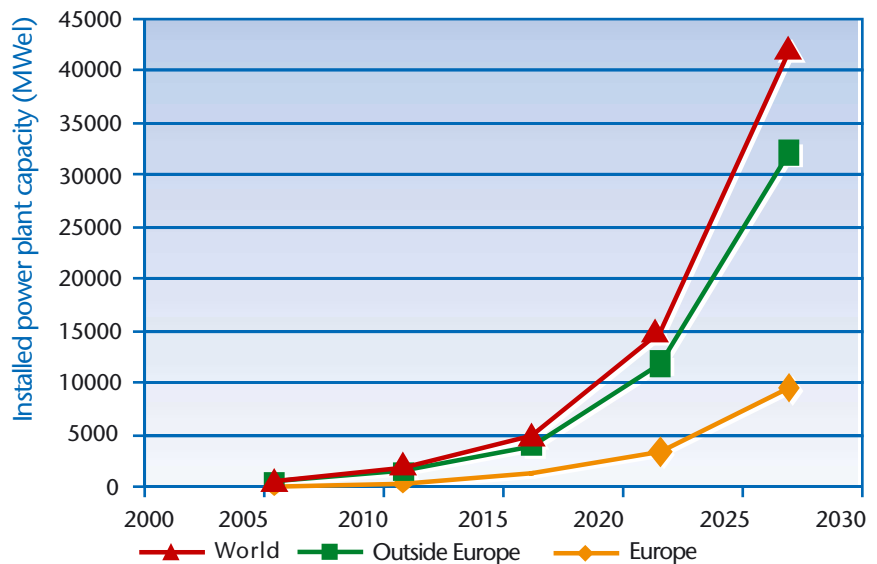
As steam power plants, solar thermal power plants can be combined with fossil energy sources: parabolic trough solar fields can be linked to conventional power plants. Particularly in the Earth's sunbelt, solar thermal power plants can thus be the first step toward a reasonable supplement to



fossil power plants. Solar thermal power plants of 100 to 200 MWeI can replace conventional power plants operating in the medium load range - and without any qualitative changes in the grid structure.

Although solar thermal power plants of the first generation have been operating successfully for more than 20 years in California, solar thermal power plant technology is still a widely unknown technology. Therefore it now needs the support of the public, the media, and the corresponding political decision makers. We must provide the beginning of a secure solar thermal power plant market with stable growth and, in particular, break down the financing reservations of the partners involved. Not until confidence in the new technology has developed among banks and potential investors will the risk premiums drop and projects be easier to finance - in the mid-term even without public subsidies.

#### Future opportunities for solar thermal power plant technology



*The scenario of the German Aerospace Center (DLR) for expansion in the world*

Thoroughly in line with the Lisbon strategy, solar thermal power plant technology puts Europe in a top position in a future-oriented technology with great growth potential. European companies are the worldwide market and technology leaders. The solar thermal power plant technology now urgently needs industrial-scale reference projects, which can illuminate their value for the energy mix of the future. With parabolic trough technology, Europe has the potential for an extraordinary success in the world market.

*Parabolic trough power plants have been providing a reliable power supply to 200,000 households in California for 15 years.*



## How parabolic trough power plants work

**Solar thermal power plants** are basically power plants, which generate electricity from high-temperature heat. The difference between them and conventional power plants: not gas, coal, or oil, but the sun provides the energy that drives the turbines. In the solar field of the power plant, parabolic mirrors lined up in long rows concentrate the solar irradiation 80 times on an absorber tube, in which a special oil used as heat transfer medium is heated to about 400 °C. In the central generating unit, a heat exchanger then generates steam, which powers the conventional steam turbines.



*In the solar field, parabolic mirrors concentrate solar irradiation 80 times on an absorber tube.*

**Modern storage technology** makes solar power available during unfavorable weather and at night: the millions of liters of heat transfer fluid circulating in the solar field already represent a considerable storage capacity, which can bridge short-term cloudy phases. Molten salt storage tanks provide for additional reliable power supply around the clock. Applying storage technology ensures that the turbines can always run at full load and thus with optimal efficiency. That makes the power plant more profitable. Molten salt storage tank technology is proven and has been rated as reliable by common carriers. The Spanish national carrier has therefore given the power plant setup described here the same reliability status as fossil fuel power plants. It sees no problem in integrating such power plants in existing networks.

The construction of **hybrid power plants** is possible: since solar fields feed their heat energy into a conventional steam turbine, they can, for example, be integrated with ease in the relatively clean natural-gas-fired combined-cycle power plants of the latest generation. It is also possible to retrofit existing conventional steam power plants with parabolic trough solar fields as an additional solar steam generator. Hybrid technology means:

- ➔ Improved utilization of the turbines and thus optimal operation of the entire power plant block,
- ➔ Favorable power prices based on a mixed calculation,
- ➔ In comparison to molten salt storage technology, a more cost-effective buffering of fluctuations in the solar radiation by using of auxiliary heating with fossil fuels,
- ➔ Gentler entry into the power plant park consisting predominantly of fossil power plants,
- ➔ The opportunity for ecological enhancement of fossil power plants.



*In a central power plant block, a heat exchanger then produces the steam, which powers the turbines.*

Hybrid technology leads to a great improvement in competitiveness against conventional power plants. Substantial cost advantages result even from auxiliary heating with fossil fuels at SEGS power plants (solar energy generating system), as operated at the California power plants. The power

production costs are cut in half for ISCCS power plants (integrated solar combined-cycle system). In ISCCS power plants, parabolic trough fields are combined with modern gas-fired combined-cycle power plants. Here the power production costs are just slightly higher than those of conventional power plants, even without subsidies. Solar thermal hybrid power plants are thus an important link between today's fossil fuel and tomorrow's solar power supply.

These advantages have moved the Global Environmental Facility (GEF) to provide subsidies in the amount of 200 million US dollars exclusively for gas and steam/solar hybrid power plants. The ability to be combined with conventional power plants substantially increases the market opportunities also in the USA. Currently large-scale investments are being made there in new generation gas power plants. In Algeria, too, plans call for the use of auxiliary solar power as an enrichment for gas-generated power systems.

Parabolic trough power plants can be operated in cogeneration plants for heat and power, for example to produce drinking water with a sea water desalination system. In cogeneration systems, solar efficiencies of up to 55 percent are achievable.

Solar thermal power plant technology is available in Europe: substantial solar resources are usable on the southern edge of the EU (Andalusia, Sicily, Malta, the Greek islands, Cyprus); and practically inexhaustible resources are available at technically feasible distances in North Africa. The transmission costs from this area to Central Europe are around 2 cent per KWh.

**Proven technology:** nine of the power plants of the first generation built in California in the 1980's have proven their long-term capabilities and reliability: 200,000 households have been supplied continuously with electricity for over 15 years. So far, they have generated about fifty percent of the solar power generated worldwide.

Parabolic trough technology has now entered a phase of constant optimization. The operating costs have dropped from originally 8 cent/KWh to just over 3 cent/KWh. Experience provided the basis for development of a new generation of parabolic trough components with substantially improved performance. Due to the inexhaustible energy potential of the sun, technical performance, and environmental friendliness, solar thermal power plant technology is in a position to make an essential contribution to future power supply. **It is ready for worldwide use.**



*High-voltage DC transmission makes electricity available across very long distances.*



## Advantages of solar thermal power plant technology

**Centralized power generation  
in systems up to 200 MWe**

**No qualitative change  
in the grid structure**

**Reliable, plannable, stable grids**

**Can be combined  
with fossil fuel heating**

**In the mid-term competitive  
with medium-load fossil fuel plants**

**Independent of fuel prices,  
low operating costs**

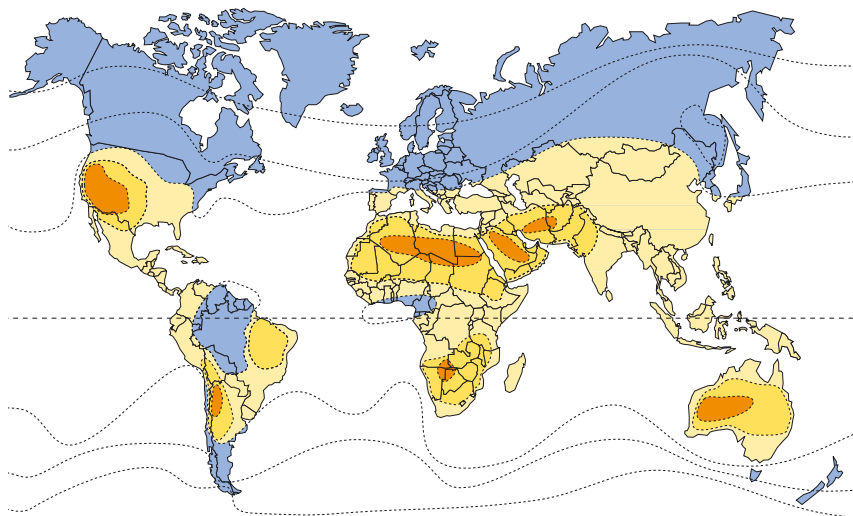
**Already competitive  
for peak loads**

**High-voltage DC transmission  
permits cost-effective conduction  
of electricity over long distances**

**Proven technology**

- ➔ Parabolic trough power plants are suitable for large-scale use in the range of 10 to 200 MWe electrical output. The modular character of the solar field makes it possible to start at any power level. Currently the optimal size is 150 - 200 MWe. Parabolic trough power plants can replace conventional thermal power plants - and without any qualitative changes in the grid structure.
- ➔ Due to the option of thermal storage, the turbines of solar thermal power plants can also produce power in low-radiation periods and at night. Solar thermal power plants can deliver power reliably, on a planned schedule, and in a way that keeps the grids stable.
- ➔ Solar thermal power generation can be combined with conventional thermal power plants. Combined utilization leads to substantial cost reductions and thus facilitates entry into the use of renewable energies, particularly for threshold countries.
- ➔ Depending on local irradiation, parabolic trough power plants can now produce cost-effective solar power at prices between 10 and 20 cent/KWh. The high costs of the investment phase are balanced by low operating costs of currently only 3 cent/KWh. By 2015 the power production costs will be comparable to those of medium-load power plants using fossil fuels.
- ➔ The use of solar energy means reliable planning. The independence of the operating costs from fluctuating fuel prices and unlimited availability permit reliable calculation throughout the entire investment period.
- ➔ Particularly in the sunbelt when most power is needed for cooling, solar thermal power plant technology is most effective. These power peaks are already covered competitively today by the nine solar thermal power plants in California.
- ➔ High-voltage DC transmission lines, which are currently state-of-the-art, can conduct the power over long distances - for example from North Africa to Central Europe. The costs are around 2 cent/KWh.
- ➔ Parabolic trough power plants are a proven technology. In the USA, the power plants of the first generation are running reliably with a total capacity of 354 MWe. With nearly 12 terawatt hours of solar power produced at a value of 1.6 billion dollars, parabolic trough technology has demonstrated its potential impressively. In nearly 20 years of operation, no disadvantageous effects on the social or the fragile natural environment have become known.





Suitability for solar thermal power plants:

■ Excellent ■ Good ■ Suitable ■ Unsuitable

*California and North Africa are ideal solar thermal power plant sites. The large industrial conglomerations in the north can be reached by high-voltage DC lines.*

- ➔ Solar thermal power plants use low-cost, recyclable materials that are available worldwide: steel, glass, and concrete. Local companies handle a great share of the construction work. The modular structure of the solar field facilitates entry into mass production with substantial potential for increased efficiency.
- ➔ Solar thermal power plants have a very good ecological balance. The energy payback time of five months is low - even in comparison to other regenerative energies. Parabolic trough technology has the lowest material requirements of all solar thermal power plant technologies.
- ➔ The land use of solar thermal power plants is substantially lower than for biomass, wind energy, or water power - not to mention dams in mountains. In addition, since they are erected only in the dry zones of the Earth, there is hardly any competition for land utilization. Solar thermal power plants can be used in the Earth's sunbelt between 35° northern and southern latitude.
- ➔ Parabolic trough power plants are ideally suited for "Joint Implementation" (JI) and "Clean Development Mechanism" (CDM) projects under the Kyoto Agreement. Industrial and developing countries can work together on parabolic trough power plant projects to make power generation decisively more environmentally friendly and thus protect our planet's climate.
- ➔ The waste heat of solar thermal power plants can be used for sea water desalination as well as for electricity generation. Particularly countries in North Africa and the Middle East, which are outstanding locations for solar thermal power plant technology, could improve their water supply by this means.

**Great proportion of added value is local**

**Good ecological balance**

**Lower land use than other renewable energies**

**Kyoto projects for environmental protection**

**Sea water desalination as added benefit**

## Concrete need for action

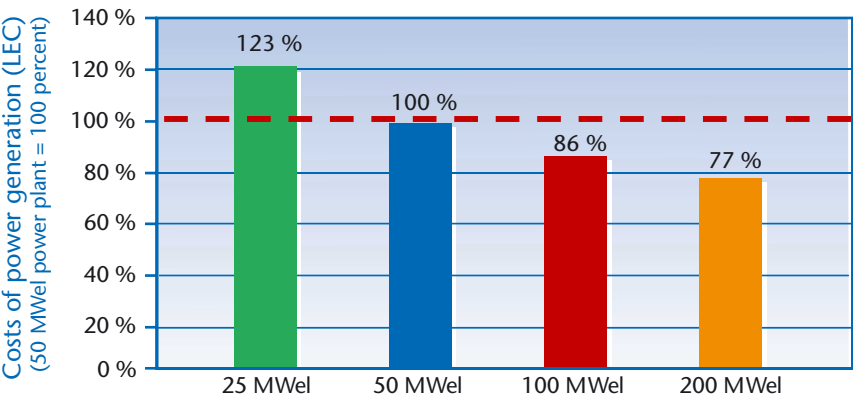
Whether hydro power, coal, or wind energy - in the past, too, each step toward a new type of energy production was promoted by corresponding changes in conditions and constraints. Above all, solar thermal power plant technology needs open markets and international cooperation on energy policy. To promote a rapid start for reference projects, European energy policy should provide help:

**Solid financing through long-term power purchasing guarantees:** the financing of the high initial investments represents the greatest obstacle for the construction of new solar thermal power plants. To overcome this hurdle, CSP needs long-term power purchasing guarantees. The regulations in Spain regarding the premium for solar power supplied to the grid are a step in the right direction. In addition, in the market launch phase, public financial institutions must be involved in a way that can also increase the confidence of private investors in the new technology. Solar thermal power plant technology now needs the decisive support of decision makers in politics and business.

**Trans-European and Mediterranean power grids:** very large solar resources are unused in the Mediterranean area and North Africa. To exploit this energy resource for Central Europe, too, unimpeded power transmission must be guaranteed by the potential transfer countries (Spain, France, Italy, Greece). The EU must not allow large national carriers to block international power transmission. Furthermore, the power transmission fees must not be substantially higher than the technology-based costs of a maximum of 2 cent/KWh. The theoretical opening as part of the liberalization of the European electricity market must now be followed by concrete steps in the construction of high-voltage DC transmission lines.

**No limit on power plant size in laws regarding the supply of energy to the grid:** one legal obstacle is the current general practice of limiting power plant size. It is far below the commercially reasonable capacity and,

Power plant size: lowest costs at 200 megawatt



(Source: U.S. Department of Energy)

for instance, forces Spanish projects, instead of one 200 MWel power plant, to construct four 50 MWel power plants of the same type at the same site. This makes power production up to 30 percent more expensive. Such restrictions must be eliminated.

**European regulations regarding power from renewable energies:** the generation of “green power” should be rewarded, irrespective of country boundaries. The current rigid alignment toward a national basis for renewable energies should be broken down.

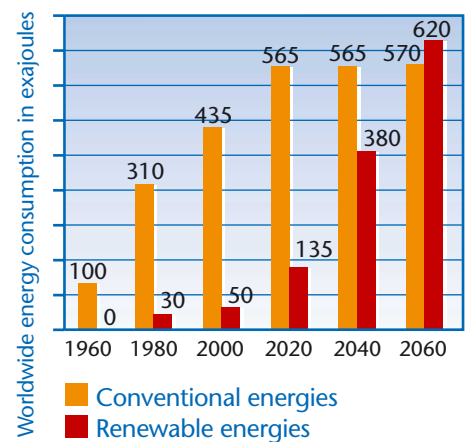


**Mediterranean program of the EU:** solar power production is an obvious choice as a component of the EU Mediterranean partnership. The goal should be a strategic energy partnership between North Africa and the European Union, in order to integrate the possibilities of using solar energy in the European power supply system in a way that is profitable for both sides. It promotes the economic power of the neighboring states, creates jobs in both regions, and opens up a new and reliable energy source for the EU. To accomplish this, in addition to direct subsidies, an integrated power grid must be created for the entire Mediterranean area.

**End tax disadvantages:** unlike power plants using fossil fuels, 80 percent of whose costs are caused by fuel and only 20 percent by initial investments and corresponding debt service, in solar power plants the investment ratio is 80 percent. Creating a legal and tax framework attuned to solar thermal power plant technology would facilitate its market launch substantially.

**Technology quota:** solar thermal power plant technology is still in the early stages of industrial development. In areas where there is intense competition with other renewables - such as wind power - development could be promoted by a fixed-term technology quota that sets a specific share of electricity to be generated by solar thermal power plants.

### Development potential for renewable energies



*From 2000 to 2060 worldwide energy consumption will rise by more than 140%.*

*(Source: Shell 1998)*



*Reliable power supplier:  
The Californian parabolic trough  
power plants*

## Questions and Facts

### Is concentrating solar power technology a proven and reliable technology?

Solar thermal power plants exist not just on paper. The Carter administration, which, due to the oil crises of the 1970's, was open to the topic of sustainability and renewable energies, supported the construction of parabolic trough power plants in the USA. They were built between 1984 and 1991 in California's Mojave Desert - 160 kilometers from Los Angeles - with a total output of 354 MWel.

To compensate for the fluctuations in solar radiation, these power plants are permitted to generate up to 25 percent of their annual energy production from natural gas. The premium for energy supplied to the grid was pegged to the oil price. As it sank again in the mid-1980's, the incentive for construction of additional commercial power plants also dissipated. However, the power plants constructed till that time are still running reliably: nine solar fields with 2.5 million square meters of concentrating reflector surface have fed more than 12 billion kilowatt hours into the California grid, earning nearly 1.6 billion US dollars.

The positive construction and operating experience in California is the basis for current project planning in Southern Europe and in the developing countries of the Earth's sunbelt. The performance of the power plant components has proven to be very reliable. The technical availability of the solar fields has always been over 98 percent.



This experience leads to the conclusion that the lifetime of the parabolic trough field will far exceed the planned technical life cycle of 25 years. The positive development of the privately operated California power plants shows that, for locations with suitable conditions, operation can be economical without extensive public subsidies. The prospects are improved further, when the operating costs after the end of debt service drop to only 3 cent/KWh.

The increasing significance of renewable energies for the European energy mix has led to a “rediscovery” of solar thermal power plant technology. Above all the research and development work under the support program of the German federal government promoted the build-up of Europe's own parabolic trough technology. This work was planned, co-financed, and implemented essentially by the German solar thermal industry. The German Aerospace Center (DLR) and the European test system “Plataforma Solar de Almería” also provided important support.

The result: a new, European generation of parabolic trough technology, which has been tested successfully as a demonstration project in one of the Californian solar energy generating systems (SEGS) and is now ready for market. Integrating the experience of the past 20 years in operations and technical development has resulted in a learning curve that opens up the justifiable prospect of competitiveness with medium-load fossil fuel power plants within the next 10 years.

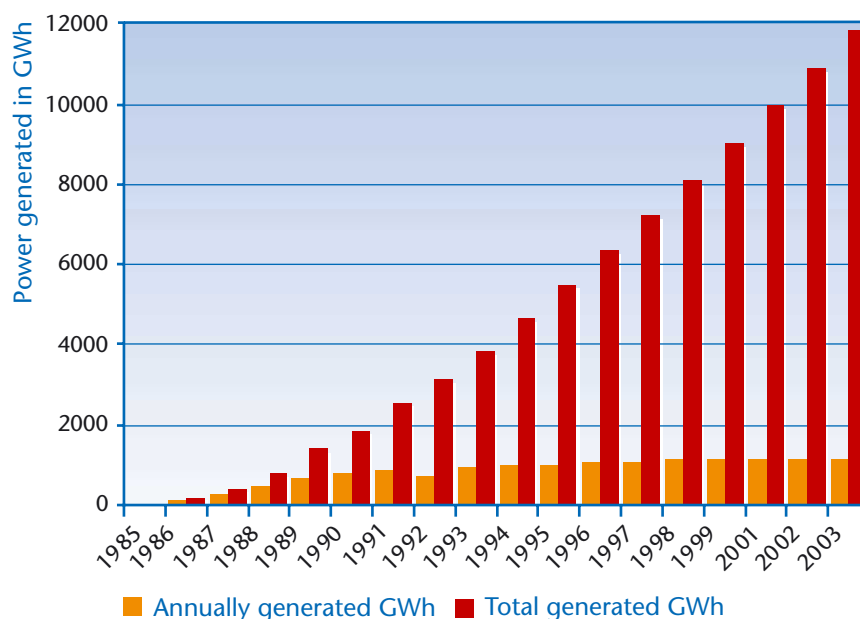
## The nine power plants built in California

SEGS I	14 MWel	since 1984
SEGS II	30 MWel	since 1985
SEGS III	30 MWel	since 1986
SEGS IV	30 MWel	since 1986
SEGS V	30 MWel	since 1987
SEGS VI	30 MWel	since 1988
SEGS VII	30 MWel	since 1988
SEGS VIII	80 MWel	since 1989
SEGS IX	80 MWel	since 1990
Total output		354 MWel

(SEGS: solar energy generating system)

### Reliable power supplier:

#### The Californian parabolic trough power plants



(Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)

## How is power generated when the sun doesn't shine?

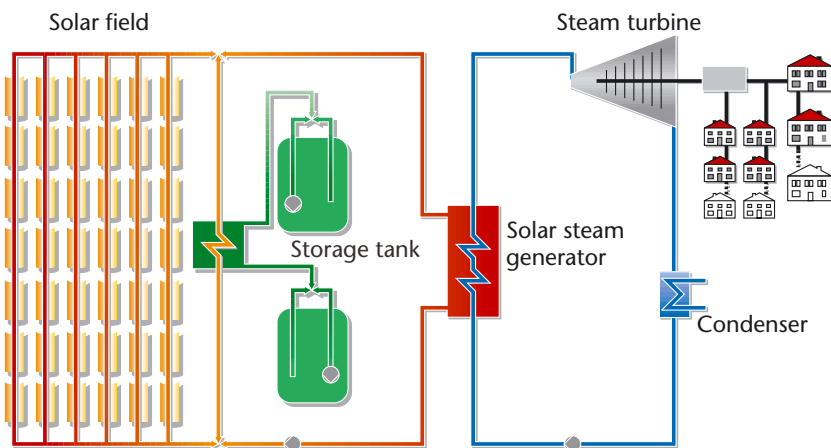
Of course, in a solar power plant, producing heat depends on solar irradiation. To generate electricity “around the clock”, two methods have been developed, each of which has been technologically proven.

**Hybridization:** the total compatibility of solar thermal power plant technology with steam generation from fossil fuels makes it possible to combine solar and fossil components in any ratio in a hybrid power plant. In the first-generation California power plants, the fossil component is used primarily to cover occasional cloudy and stormy phases. It is limited to 25 percent of annual power generation and provides great security for breaks in radiation. Combination with modern gas and steam ISCCS power plants (integrated solar combined-cycle system) makes it possible to produce electricity very cost-effectively; however, the solar function is limited to 15 percent.

**Heat storage systems** also make solar power available in unfavorable weather and at night: the millions of liters of heat transfer fluid already represent a considerable storage capacity, which can cover short cloudy phases. Storage on the basis of molten salt makes it possible to produce electricity around the clock. Molten salt storage technology is proven and is rated as reliable by carriers. The Spanish national carrier has given this kind of power plant system the same reliability status as power plants using fossils.

The output of solar thermal power plants is thus available continuously. Solar thermal power plants can deliver their output reliably and in a way that is plannable and guarantees network stability. They are thus excellently suited for reliable coverage of peak loads during midday, but - if necessary - by using storage technology, they can also handle evening supply peaks and, in the long term, can even be used to supply base load.

### Parabolic trough power plant with heat storage system



### SEGS power plant

For auxiliary heating in **SEGS power plants** (solar energy generating system) a parallel steam generation unit is powered by fossil fuel (as a rule natural gas) and can thus provide additional thermal energy as needed. The California power plants, which have already been connected to the grid for years, use up to 25 percent natural gas in order to cover sunless periods.

### Parabolic trough power plant with heat storage system

In Spain's AndaSol power plant, a mixture of 25,000 tons of sodium and potassium nitrate is heated to 384 degrees Celsius. Fully loaded, this suffices for power plant operation for well over 6 hours.

*Diagram of a solar thermal power plant with heat storage system:  
In the solar field, transfer fluid is heated, and then flows to a heat exchanger. There steam is produced, which powers the turbines. If needed, a heat storage tank can be added to the cycle.*

*(Source: Solar Millennium AG)*



## ISCCS power plant

In **ISCCS power plants** (integrated solar combined-cycle system) a solar parabolic field is integrated in a modern gas and steam power plant. In this case, the waste heat boiler is modified in such a way that additional steam generation can be provided by a solar steam generator. The power production costs here, even without subsidies, are just slightly higher than those of conventional power plants. For combination with gas and steam power plants of the ISCCS type, for technical reasons, the solar fraction should not exceed one-third, which corresponds to 15 percent of the total capacity of a combined-cycle power plant.



(Source of the graphic: KJC Operating Company, U.S. Department of Energy)

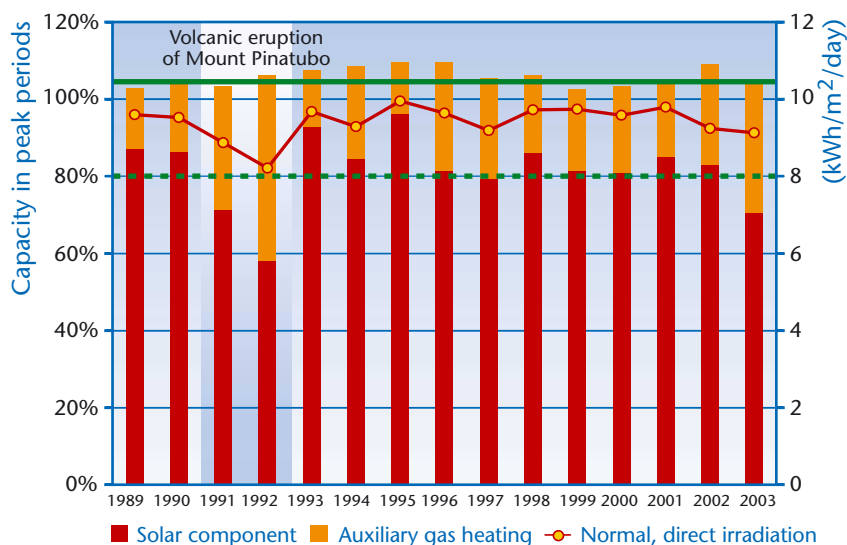
## What are the advantages of hybrid power plants?

Hybrid solar thermal power plants can use fuel in addition to solar energy to generate heat. Since solar fields feed their heat energy into a conventional generation unit with a steam turbine, they can be combined without any problem with fossil fuel hybrid power plants. Solar thermal hybrid power plants are thus a connecting link between fossil fuel and solar energy supply. They utilize conventional power plant processes in combination with solar technologies. The mixture of fossils and renewables takes place not on the level of the electrical grid but in the power plant itself.

The occasional fluctuations in radiation are buffered by the fossil component. Partial load states with reduced efficiency are avoided. Thus hybrid technology provides better utilization of the turbines and optimized operation of the shared generation unit. For the carrier that means less problematic integration in existing grids. Hybrid technology greatly improves competitiveness against conventional power plants. It is also possible to retrofit existing conventional steam power plants with parabolic trough solar fields. That means a smooth entry into the existing conventional power plant park and greater ecological value for the fossil power plants.

The ability to combine with conventional power plants increases the market opportunities in the USA substantially. Currently large scale investments are being made in gas power plants of the new generation. In Algeria, too, plans are in the works to supplement electricity generated from their own huge gas reserves by an additional solar component - for this purpose Algeria has passed the first laws regarding the sale of electricity to the grid for any country that is not a member of the Organisation for Economic Co-operation and Development (OECD).

## Output in peak periods







## Is solar thermal power plant technology a sustainable technology?

The solar irradiation on the Earth is about 10,000 times world energy demand. The use of only the suitable areas in the countries bordering the southern Mediterranean would suffice by far to supply those countries themselves and all the northern European industrialized countries with power.

According to a study by Greenpeace, the use of CSP can prevent the emission of 154 million tons of CO<sub>2</sub> by 2020. Just one 50 MWel parabolic trough power plant can cut annual heavy oil consumption by 30 million liters and thus eliminate 90,000 tons of CO<sub>2</sub> emissions.

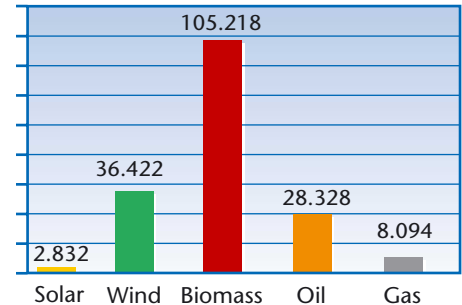
The energy balance is outstanding: the payback period for the energy expended in production of the components is 5 months. The materials used (concrete, steel, glass) can be recycled. The specific land use is quite low at 2 hectares per MWel. The property needed has a very low value. There are no social or ecological problems associated with its use. There are no hidden social costs in the form of environmental pollution, additional social services, or other resulting economic effects. Solar thermal power plants use construction materials that are available and affordable worldwide. For the most part they can be constructed and operated by local labor.

The German Advisory Council on Global Change (WBGU), which advises the German federal government, projects that world energy consumption will triple by the year 2050. "In the long term the rising demand for primary energy can be covered only through decisive use of solar energy", writes the WBGU in its report "World in Transition - Towards Sustainable Energy Systems".



*SCHOTT receivers being built into a mirror segment.*

### Land use of various fuels based on the example of Texan electricity requirements of 270 TWh in km<sup>2</sup>



(Source: State Energy Conservation)

### Energy amortization time

The energy amortization time describes the time the system needs to recover the energy used for production, operation, and waste removal. Power plants based on exhaustible fuels never amortize the energy expended, because they always need more fuel than the energy they produce.

Wind power	4 to 7 months
Hydro power	9 to 13 months
CSP in Morocco	5 months
Polycrystalline silicon (Central Europe)	3 to 5 years
Gas power plant	never
Coal power plant	never
Nuclear power plant	never

(Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)

## Why is solar thermal power plant technology so important for the energy mix of the future?



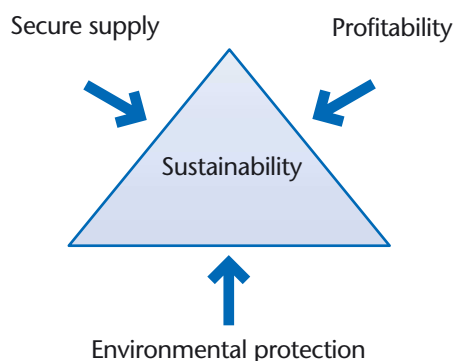
The foreseeable shortages in fossils require a broad range of measures to secure the energy supply. The times now call for diversification. The energy mix of the future will therefore be marked by a higher proportion of renewable energies, which will also become increasingly competitive due to the rising scarcity of fossil energies. In the long term solar will probably become the most important energy source.

In its Green Book "Towards an European Strategy for a Secure Energy Supply" (2000), the EU Commission recommends an energy mix balanced and diversified by fuels and geographic zones. The sooner politics and business react, the more smoothly we can accomplish the transition.

The International Energy Agency gives a figure of 7.5 trillion euro for the worldwide investment requirements for modernization and expansion of the power supply infrastructure through 2030. In Germany alone half the entire power plant park will be off the grid by then. Even by 2010 we are threatened by the "technical end" of many fossil power plants and the "political end" of nuclear power plants.

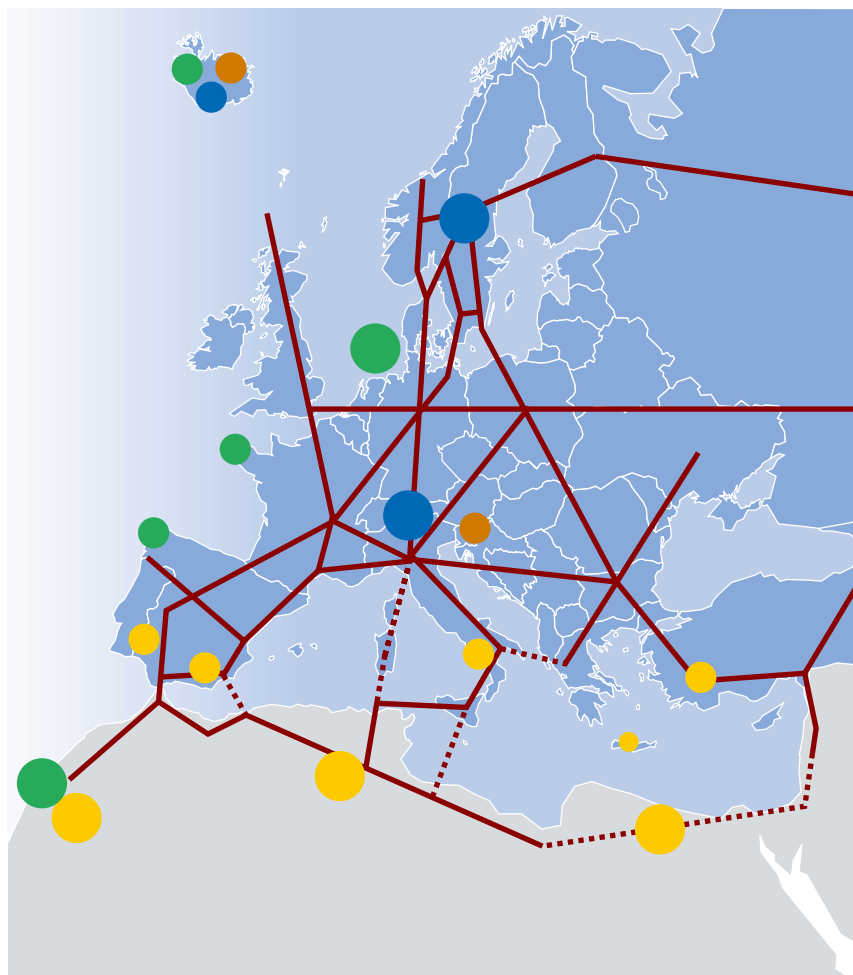
The omens for decisions regarding power plant expansion have changed: in recent decades the business side was clearly given too much weight in the triangle of energy policy goals (secure supply, profitability, environmental protection). The great blackouts of recent years in the USA, Italy, and Scandinavia; the political instability of many energy exporting countries; the drastically rising energy demands especially in China and India; and the pressing questions of environmental protection have now clearly outlined the significance of a secure supply and environmental protection.

### Triangle of goals in energy policy



A substantial expansion in the share of solar thermal power generation means positive prospects for all three dimensions of the energy triangle: it improves the security of supply through production in Europe and bordering areas; it is an environmentally friendly technology that conserves resources; and it is already competitive with fossil fuel power plants in peak load. Finally, solar thermal power plant technology is actually able to cover the need for new plants through the construction of large scale power plants. Particularly the ability to combine with modern combined-cycle systems opens up economical prospects for the transition from the fossil to the solar age.

Both in Europe and in the United States, a mix of renewable energies will ensure a reliable energy supply. Currently there is a danger that wind energy, thanks to its developmental head start and the associated cost advantages will inhibit other renewable energies. In particular, in California, where legislators want to use a so-called portfolio standard to initiate the



### Energy potentials

- Sun
- Wind
- Hydro
- Geothermal

### Power grid

- Existing
- ⋯ Planned

*Sun, wind, hydro, geothermal and bio-mass: Central elements of the European energy mix of the future.*

*(Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)*

energy turnaround, many utilities are pressing into the currently favorable area of wind energy. A technology quota in favor of solar thermal power plant technology could help during a ten-year introductory phase.

Of the greatest importance is probably the future attitude of the USA toward climate protection. In the face of the great potential of solar energy in the USA, there will be a race to develop solar energy know-how, as soon as an altered consciousness has been achieved there regarding this topic. The first signs of this can already be seen at the state level: in the summer of 2004 the Western Governors Association - WGA, under the leadership of governors Schwarzenegger (California) and Richardson (New Mexico) approved an energy program running through 2020, which plans for 7,000 to 10,000 MWeI from renewable power generation technologies, of which CSP alone will reach a share of 3,000 MWeI.

If this trend takes hold, then a global mass market beckons the new technologies. Promotion of research and development in this area is thus of great significance to industrial policy. CSP will become a big hit among exports. Precisely these worldwide prospects for the future constitute an important motive for the construction of powerful European reference power plants.

### It depends on the energy mix

On 7 September 2004, a very hot day without any wind, all the Californian wind farms together, with a capacity of 2,100 MWeI, produced only 63 MWeI (3 percent). The high level of solar irradiation on that day enabled the solar thermal power plant in Kramer Junction (normal capacity at full utilization: 150 MWeI) to produce 172 MWeI - or 115 percent output.

## Is electricity from solar thermal power plant technology available in Europe, too?



*500-kV DC conversion plant (above)  
and control center (below)  
of a high-voltage DC transmission line  
in China.*



Economic operation of solar thermal power plants requires solar radiation of at least 1900 KWh/m<sup>2</sup> per year. That means: solar thermal power plants can be operated in the Earth's sunbelt on both sides of the equator to 35 degrees latitude. For Europe the sunbelt encompasses the entire Mediterranean area, including the southern edge of the EU, North Africa, and the Sahara. The solar energy available in this area alone is sufficient not only to supply the provider countries, but also the entire European continent with power.

Modern high-voltage DC transmission is a low-loss and low-cost method that makes it possible to transport electricity for distances of 2000 to 3000 kilometers. For such distances, the grid costs are around 2 cent/KWh. Thus the possible solar thermal power plant sites are within the transmission range of both the developing demand in the third world and that in the industrial nations in the temperate zones.

Some connections through the Mediterranean are in the planning or construction stage. There are already power lines between Gibraltar and Morocco with a transmission capacity of 2000 MWel; as well as between southern Italy and Tunisia. In the long term the EU-Northern-African electrical power grid must be expanded comprehensively.

### High-voltage DC transmission technology

Great distances can be covered by a very efficient form of energy transmission: high-voltage DC transmission technology. In this method alternating current produced by a power plant is converted to direct current by a converter station at the start of the transmission route, is transported, and is then reconverted to alternating current at the receiving station. As a result, electrical energy of up to 3000 MWel can be transported for long distances at low loss and low cost. This technology is always in demand when conventional AC transmission reaches its technological limits. For instance when distances are very long, as is common in China. There the hydro power plants that generate electricity are located in the country's interior; the major cities along the coast - often over 1000 kilometers away. In the Indian East-South high-voltage DC transmission link, the two power converter stations are separated by 1400 kilometers. The hydroelectric power plants in the American state of Oregon are connected to the Los Angeles area by high-voltage DC transmission technology. High-voltage DC transmission technology is also used in maritime cable transmission - such as between Northern Ireland and Scotland, or Tasmania and the Australian continent.



## How important is the question of access to the grid?

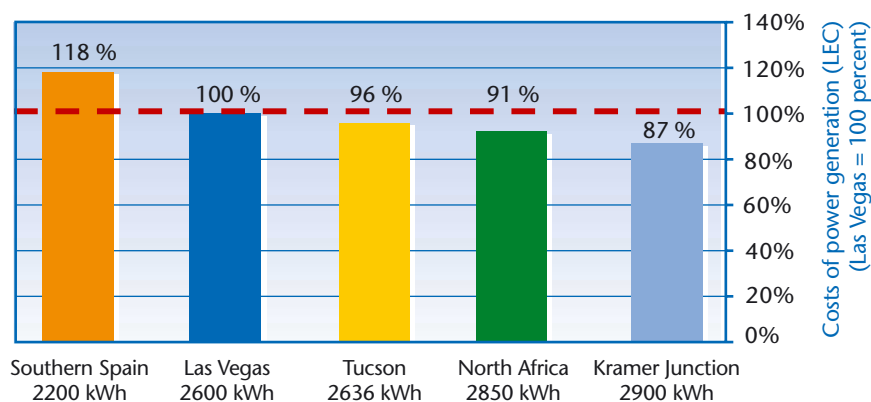
Very large solar resources are today unutilized in the Mediterranean area and in North Africa. To exploit these energy sources for Central Europe, unimpeded grid connection must be guaranteed by the potential transfer countries (Spain, France, Italy, Greece). The grid access fees must not be substantially higher than the technology-based costs of around 2 cent/KWh.

The EU must prevent carriers with large numbers of fossil and nuclear power plants from impeding or even preventing power transmission across national borders. Europe can achieve a turnaround in the energy sector only if the EU ensures free access on the entire continent.

To develop a future energy partnership of the EU with the entire Mediterranean area to the benefit of all, the planning and construction of powerful high-voltage DC transmission lines should begin. Large networks like

### It depends on the location:

#### Costs of power generation by location



KWh/m<sup>2</sup>/year (Source: U.S. Department of Energy, SCHOTT's calculations)



the "Euro-Mediterranean Power Pool" as well as the already operational high-voltage DC line between Spain and Morocco could be used until that time.

The directive 2001/77/EG for promotion of power generation from renewable energy sources in the interior electricity market should also be used to promote cross-border trading in renewable energies. The call for unimpeded trading in the interior electricity market also entails the corresponding expansion of the grid. The guideline even calls for priority grid access for renewable energies. Since solar thermal power plants produce electricity based on a principle very similar to that of conventional fossil fuel power plants, their integration in existing grids requires no additional restructuring or grid stabilization measures. Thus, even on the grid level, solar thermal power plant technology facilitates a smooth transition to the age of renewable energies.

## Can solar thermal power plants be operated profitably?

Power production costs (levelized energy cost = LEC) for the currently operating Californian power plants, depending on their location, are 10-15 cent/KWh; for the planned Spanish, purely solar AndaSol parabolic trough power plants - solar power plants with molten salt storage systems and 20 percent less irradiation - they are correspondingly higher. Experts agree that these costs can be reduced to 6 cent/KWh in the next 15 years if capacity is expanded to 5000 MWe. Thus they will become competitive with medium load conventional power plants.

The cost structure of electricity produced by solar thermal power plant technology is marked by high costs for initial investment. Over the entire life cycle that means: 80 percent of the costs are expenditures for construction and the associated debt service; only 20 percent are operational costs. This is why the confidence of financial institutions in the new technology is of such great importance. Only when they make funds available without high risk surcharges a solar thermal power plant technology project can be financed and in the future become competitive with fossil fuel medium load power plants.

Once the plant has been paid for after 25 or 30 years, only operating costs remain, which are currently about 3 cent/KWh. The electricity will then be cheaper than any competition, comparable to that today from hydro power plants that have long since been written off. The Californian power plant operators will have reached this point by 2018.

Even in the current market launch phase, the energy feed-in tariff for the power grid is far below that required for photovoltaics, and can provide an adequate impulse for constructing large scale power plants. Thus the Spanish decision to set the sale of energy to the grid for solar thermal power plants at 18 cent plus market price per kilowatt hour is an adequate market launch incentive. At that rate, solar thermal power plants can be operated profitably at good sites in the southern part of the Iberian Peninsula. This incentive is limited to a capacity of max. 50 MWe per power plant.

In the view of the International Energy Agency and the World Bank, solar thermal power plant technology is the most economical way to generate electricity from solar energy. The International Energy Agency (IEA) in Paris foresees a potential cost reduction to less than 6 cent/KWh by 2020. The U.S. Department of Energy (DOE) developed a plan for solar thermal power generation back in 1996, which envisions an installed capacity of 20,000 MWe by 2020 with electricity costs of less than 6 cent/KWh. On the basis of economies of scale and the learning curve, the World Bank also expects that electricity production costs for solar thermal power plants will drop to less than 6 cent/KWh by the year 2020.



*Construction of the drive pylon for a parabolic trough collector in California.*

## Where will future cost reductions come from?

**Technical progress:** the Californian power plants of the first generation are between 15 and 20 years old. During this time, progress in materials and measurement technology have led to a new generation of parabolic trough components, which have been undergoing testing for some years in demonstration projects, such as SKAL ET in California, and have demonstrated substantial increases in efficiency.

**Parabolic trough collector:** an innovative metal structure - SKAL ET (scaled EuroTrough) leads to improvements in torsion resistance and in the adjustment of mirrors and receiver. It is supported by a new solar field control system and enables the collectors to track the sun more precisely.

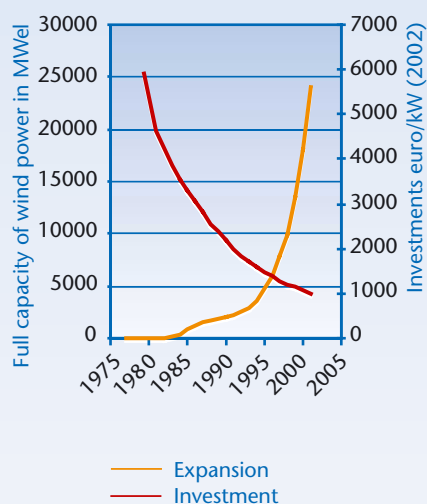
**Mirror elements:** suppression of existing residual waviness of the mirror surface through improved forming processes.

**Receiver:** greater active length through optimized design of the SCHOTT receiver, distinctly improved optical key values for selective absorber tube

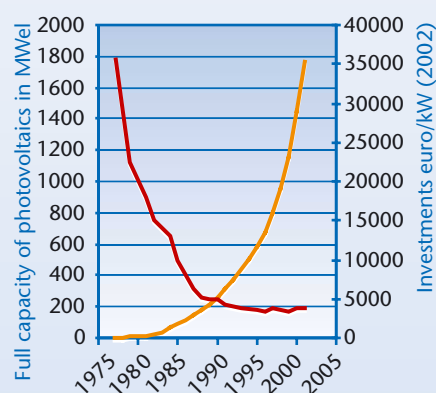
*The increasing expansion of worldwide power plant output for wind power and photovoltaics led to a substantial reduction in costs. A comparable learning curve began for parabolic trough technology in the 1980's with the construction of the Californian power plants. When additional power plants are constructed, we can expect a development comparable to that of wind power and photovoltaics.*



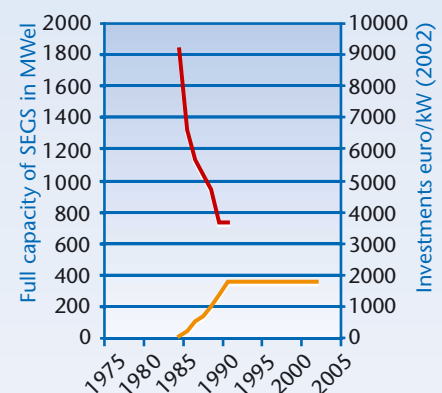
Learning curve wind power



Learning curve photovoltaics



Learning curve CSP



(Source: German Aerospace Center, DLR)

## Future development of parabolic trough technology

### Thermo oil

- Heat transfer fluid, operation at 290 to 390 °Celsius, 80 bar, with downstream steam generator
- Mature technology (Californian power plants)
- Heat storage possible with an overall efficiency of around 14 percent

### Direct steam generation

- Operation currently at 400 °Celsius, 100 bar
- In development
- Heat storage still not solved
- Goal: 550 °Celsius, overall efficiency of 23 percent

### Molten salt

- Operation: 290 to 550 °Celsius  
In the study phase
- Integrated heat storage
- Unsolved: freezing of the molten salt
- Goal: overall efficiency of above 20 percent

coating, abrasion-resistant anti-reflective coating, if needed greater absorber diameter to capture lost radiation.

**Break rate of the receiver:** the simultaneous distinct drop in the break rate from currently 4 percent to less than 1 percent through a new kind of glass-metal seal has a favorable effect on current operations (greater availability of the solar field) and on future operating costs (lower spare part demand).

**Higher working temperature:** an increase in working temperature to over 400 °C is associated with more effective utilization of the heat. Currently the limiting factor is the thermal stability of the heat transfer fluid. Alternatives (direct steam generation, molten salt as heat transfer medium) are being worked on.

**Progress in operation and maintenance:** constant improvements in control and monitoring technology and increased power plant size will cut operating and maintenance costs even further. This process will be flanked by the long-lasting new parabolic trough elements (torsion-resistant trough, break-resistant receiver, abrasion-resistant anti-reflective coating).

**Power plant size:** the transition to power plants with the optimal size of 150 - 200 MWel will result in a number of specific advantages:

- Higher efficiency of the power plant block,
- Reduction in specific project development effort,
- Reduction of operating and logistical costs.

**Mass production:** the increase in annually installed power plant capacity means entry into a period of distinctly more cost-efficient mass production of components. Engineering costs will also be lowered through standardization.

**Location:** in principle, locations in North Africa have about 20-30 percent better irradiation than those in Southern Europe. In addition construction costs can be cut through the use of local companies to construct the solar field, which makes up about 50 percent of the added value.

**Legal and tax conditions:** if there are no limitations on power plant size and if a tax framework attuned to solar thermal power plant technology is created, further significant cost benefits can be achieved.







## SCHOTT: technology leader in parabolic trough receivers

The heart of parabolic trough power plants is comprised of receivers from SCHOTT, which are manufactured at the Mitterteich site in Bavaria. Hundreds of parabolic mirrors arranged in a trough shape, which continuously track the sun during the day and focus the sun's direct beam on the receivers, which are placed along the focal line.

A SCHOTT receiver consists of a specially coated absorber tube, which is embedded in an evacuated glass envelope tube. The absorbed solar radiation heats the fluid pumped through the absorber tube to nearly 400 degrees Celsius. This is conducted along a heat exchanger in which steam is produced. In the downstream turbines the steam generates electricity. The following improvements have been achieved in the new generation of receivers:

- ➔ High-quality glass envelopes with highly transparent anti-reflective coating, transmittance of at least 96 percent, great abrasion resistance
- ➔ Design with shortened bellows: thanks to compact design. Aperture length more than 96 percent, absorbers made from steel with highly efficient coating, absorbance at least 95 percent, emittance at most 14 percent
- ➔ Durable glass-to-metal seal: through new combinations of materials with matched coefficients of thermal expansion
- ➔ Improved vacuum insulation



*Employees of SCHOTT in Mitterteich during manufacturing and quality control of parabolic trough receivers*



With our know-how as the world market leader in glass tube manufacturing and with subsidies from the ZIP-Program of the German federal government, SCHOTT has advanced to the technology leader in the area of receivers for solar thermal power plants. While still at the "renewables 2004" conference in Bonn, Solar Millennium AG, Erlangen, and SCHOTT signed a frame contract: SCHOTT will deliver a total of 48,000 receivers to the project developer Solar Millennium for the two first solar thermal power plants in Europe, which will be built starting at the end of 2004 in the vicinity of Granada, Andalusia (Spain).

## What part does R&D play in the new solar thermal power plant technology generation?

The great potential of solar thermal power plant technology was recognized early by the scientific community. The development of new, more efficient components for parabolic trough power plants was marked by outstanding cooperation between the scientific community and research organizations as part of the PARASOL project subsidized by 7 million euro from the German Environmental Ministry. Project PARASOL was used to develop a new, more efficient generation of parabolic trough elements that would be ready for industrial use. It was carried out and concluded successfully in the years 2001-2004.

SCHOTT developed the heart of every parabolic trough system, a new receiver with a distinctly longer lifetime and higher efficiency. Project partners included the company FlagSol (Cologne), German Aerospace Center (DLR, Cologne), the Fraunhofer Institute for Solar Energy Systems (ISE, Freiburg), and the University of Clausthal-Zellerfeld.

Secondly, at the same time, under the leadership of Solar Millennium AG (Erlangen), in collaboration with FlagSol, the engineering company Schlaich, Bergermann and Partner, and the DLR, a new torsion-resistant mirror trough design (Skaled-up EuroTrough, SKALET) was developed with substantially improved focusing characteristics.

Thirdly, FlagSol developed a highly precise collector control unit, and the DLR the accompanying measurement technology to optimize the manner in which the captured radiation is directed.

Under the aegis of the International Energy Agency (IEA), scientists from eighteen countries collaborated in the government-sponsored cooperative project "SolarPACES", to further optimize solar thermal power plant technology, to support its market launch, and to promote public awareness.

The result of the efforts of science and industry is a mature technology whose goal must be an early market launch through the construction of power plants. Recently, studies commissioned by the U.S. Department of Energy and the World Bank confirmed the positive assessments of the scientific community: after overcoming the market launch threshold, solar thermal power plant technology has the potential to compete with fossil fuel power plants even without subsidies.

*An innovative metal structure - SKAL ET (scaled Euro-Trough) - a joint development of Solar Millennium, FlagSol, and the engineering company Schlaich, Bergermann and Partner - leads to improvements in torsion resistance and in the adjustment of the mirrors and receivers.*





## Do governments and financial institutions support solar thermal power plant technology?

An important framework for international efforts to expand solar thermal power generation is the global market initiative for solar thermal power plants known as the Global Market Initiative for Concentrating Solar Power (GMI). At the world climate summit in Johannesburg in September 2002, this initiative was recognized by UNEP (United Nations Environment Programs) as an official public-private partnership program.



The goal of the GMI is to create suitable conditions for worldwide implementation of solar thermal power plants by pooling the efforts of governments and financial institutions as well as those of science and business. A bridge must also be built between the industrial nations and the countries of the Earth's sunbelt: the one has the financial resources and technological know-how; the other has the energy resources.

The elimination of existing obstacles on electricity markets in the appropriate countries in the Earth's sunbelt is part of the initiative, as is the provision of financial resources for implementation of concrete projects. The goal is to have about 5,000 MWel of installed solar thermal power plant output by the year 2015.

At the "renewables 2004" conference in Bonn, the governments of the host country Germany as well as Algeria, Egypt, Morocco, Jordan, Italy, and Spain all signed bilateral agreements to promote solar thermal power plant technology. The Global Environmental Facility of the UN (GEF) and the German KfW-Group are participating in the initiative. Of all the projects, a planned power plant project in Morocco has progressed furthest. The corresponding call for bids is expected. The GEF is also supporting projects in Egypt, India, and Mexico.



*Parabolic trough segment  
at "renewables 2004" in Bonn*

## Solar thermal power plant technology at "renewables 2004" in Bonn

At the international conference "renewables 2004" in Bonn, government representatives from 154 countries signed an "International Action Program" (IAP). Part of the program is the "Global Market Initiative" (GMI), which is designed to promote and support the construction of solar thermal power plants in the Earth's sunbelt. The initiative was signed by German Federal Minister for the Environment Jürgen Trittin as well as the energy ministers from Algeria, Morocco, Egypt, and Jordan. Spain, Israel, and Italy also agreed to support the GMI.



## Why is financing a decisive question?

In a study, the DLR dealt with the question of financing for solar thermal power plants. Result: from an economic perspective, solar thermal power plant technology is a profitable investment in a sustainable and cost-effective power supply. However, at the same time, private investors must overcome very big hurdles for a market launch. Important risk factors include the high investment amounts, which have to be provided as equity capital or bank loans. 80 percent of the costs for construction and operation of a power plant are incurred in the initial investments and their financing. For fossil fuels this is exactly the opposite. 20 percent goes for investment; 80 percent for later operation of the power plant.

Only long-term power purchase agreements (PPA) in hard currency enable private investors to provide the funds at reasonable terms and conditions. The example of wind energy shows: if the feed-in-tariff guarantees premiums for twenty years, internal, reasonable project interest rates of 6 to 7 percent are accepted. If such favorable conditions do not exist, the interest expectations of investors can rise to 15 percent and more. The estimate of project risk is actually decisive for the ability to get financing and thus for the market launch of solar thermal power plants. If we can succeed in lowering the risk for all participants to a reasonable level, substantial capital costs can be saved, and the market launch of solar thermal power plants can be accelerated.



## Which power plants are currently planned?

The groundbreaking for a 50-MW<sub>el</sub> power plant in Spain on the plateau of Guadix near Granada is planned for mid-2005. A second plant will follow the next year at the same location. The two of them together are designed to cover the power demands of a half million people. In the meantime, a big Spanish power utility has announced that it also wants to invest in solar thermal power plants with 50-megawatt output. The capacity limit is prescribed by Spain's legislators.

Construction using the new technology is also scheduled to begin in 2005 for a 50-MW<sub>el</sub> power plant in Eldorado Valley, Nevada in the USA. Two regional power utilities, which are legally obligated to generate a certain share of their power from renewable sources (Renewable Portfolio Standard - RPS) have signed a long-term contract to purchase this electricity. Italy, Israel, and South Africa are also studying entry into the area of solar thermal power plants. In addition, supported by the GEF, there are also concrete plans to build parabolic trough fields to support gas-fired power plants in Mexico, Morocco, Egypt, and India. Algeria also plans to build a 150-MW<sub>el</sub> hybrid power plant.

## How does a power plant work with integrated sea water desalination?

Considering the scarcity of water due to industrialization and increased population growth in the predominantly arid zones, desalination plants could become increasingly important, especially in North Africa, Southern Europe, and Latin America. Thermal distillation processes produce fresh water of very high quality, but require great amounts of thermal and electrical energy.

The combination of distillation and power generation therefore entails considerable energy savings compared to direct water desalination. Nevertheless the energy consumption of these systems is still relatively high. In solar thermal power plants, the combination of power generation and sea water desalination could be designed in such a way that the excess thermal energy, which occurs especially at midday, could be used for sea water desalination.



It is to be expected that solar thermal power plants with sea water desalination will be used only in the base load operations of hybrid power plants, because the substantial investments for the power generation unit and the desalination plant would not pay off. In principle the solar fraction could be increased substantially thanks to thermal storage capacities; however this would also be during base load operations.

The construction of such plants is conceivable only on locations near the coast. At present there is still no practical experience in the operation of this combination of solar thermal power plant technology and sea water desalination.

## What is the significance of the Mediterranean policy of the EU for solar thermal power plant technology?

The partnership between the EU and the Mediterranean states encompasses 34 states: the 25 EU states as well as Egypt, Algeria, Israel, Jordan, Lebanon, Libya, Morocco, Syria, Tunisia, and Turkey. The Palestinian Self-Administration is also involved. The MEDA Program is the most important instrument for financial support for the southern and eastern Mediterranean area. In 2004 subsidies amounting to 709 million euro were awarded. Of that amount, 14 million went for improvement of energy cooperation among the Mediterranean countries.

In the Association Agreements with Algeria (Art. 61), Morocco (Art. 57), Tunisia (Art. 57), Egypt (Art. 53), Israel (Art. 51), Jordan (Art. 74), Lebanon (Art. 54), and the Palestinian Administration (Art. 48), the promotion of renewable energies is mentioned expressly. Now these agreements have to be filled with life.

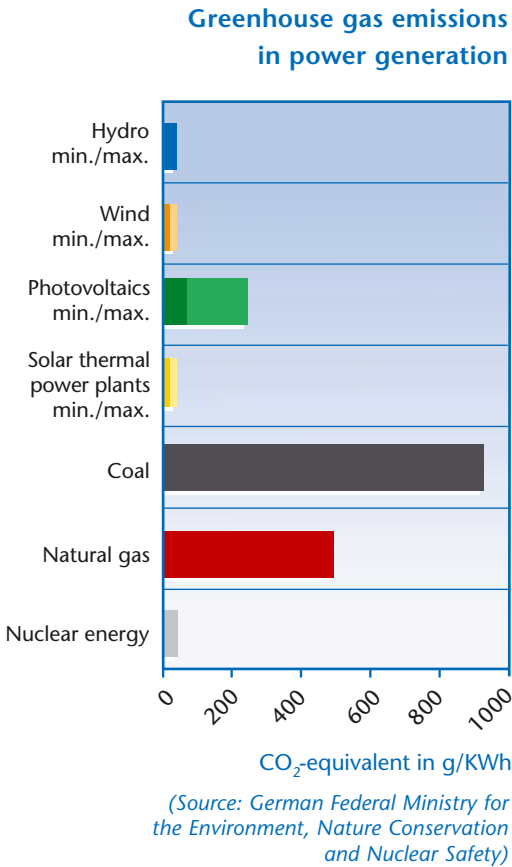


*Goal: strategic energy partnership between the southern and eastern Mediterranean states and the EU.*

Solar power generation is an obvious choice as an element of the partnership between the EU and the Mediterranean. The goal should be a strategic energy partnership between the southern and eastern Mediterranean states and the European Union, in order to integrate options for using solar energy into the European power supply system to the benefit of both sides. It promotes the economic power of the neighboring states, creates jobs, and opens up a new and reliable energy base for the EU.

In addition to the direct promotion of investment, the creation of a power grid around the Mediterranean is also of outstanding significance. The contracts concluded between Germany, Spain, Italy, Morocco, Algeria, Egypt, Jordan, and Israel in connection with the "Global Market Initiative for Concentrating Solar Power" (GMI) at the "renewables2004" conference in Bonn represent an important step in this direction.

### What does Kyoto certificate trading mean for the solar thermal power plant technology?



In 1997, the member states of the Kyoto Agreement obligated themselves to reduce CO<sub>2</sub> emissions. Each industrial country was assigned a country-specific obligation to limit or reduce emissions. The EU agreed to a reduction goal of 8 percent, which in turn was divided among the individual member states. As part of the implementation of the Kyoto Protocol, emission trading began within the European Union on 1 January 2005. Each affected plant was first given an emission certificate and concrete reduction goals. Unneeded certificates can be traded. Whoever does not reach the reduction goal must purchase additional certificates on the market. Emission trading is also possible between countries.

International solar thermal power plant technology projects can also profit from the Kyoto Agreement: in connection with "Joint Implementation" (JI) (among industrialized countries) CO<sub>2</sub> certificates can be transferred to the Investor country. In the "Clean Development Mechanism" (CDM), projects are carried out between an industrialized country and a developing country. Goal: to develop the affected states economically and simultaneously to reduce environmental pollution.

Developing countries under the Kyoto Agreement are not subject to any reduction obligation. Reduced emissions achieved through the project can however be transferred to the investor country as "Certified Emission Reductions" (CER). These can also be traded. The official emission trading is not scheduled to begin until 2008.

Due to the lower avoidance costs for CO<sub>2</sub> emissions in developing countries, CDM projects are always very cost-effective for industrialized countries. Experts estimate the ratio of avoidance costs between developing and industrialized countries at up to 1:10. One of the essential requirements for CDM projects is additionality, which means that reductions must be achieved that would not have occurred without the CDM project. Regarding this criterion, too, there are no argumentation difficulties for solar thermal power plant technology. In this way, the Kyoto Agreement also promotes environmental protection in those countries that are not obligated to reduction and offers potential investors financial incentives. A mechanism that solar thermal power plant technology should exploit.

The call by KfW-Bankengruppe for submission of projects for the KfW Carbon Fund, which can provide emission certificates from projects in developing countries, has generated a positive response. At the end of the submission period at the end of October 2004, KfW-Bankengruppe had about 30 project proposals with a potential of about 6.5 million tons of CO<sub>2</sub> per year. Cautious estimates place the income potential of solar thermal power plant technology power plants from the Kyoto mechanisms initially on the order of 0.5 cent pro KWh. The increasing scarcity of emission rights can lead to a substantial increase in this income over the long term.



## What are the long-term prospects for solar thermal power plant technology?

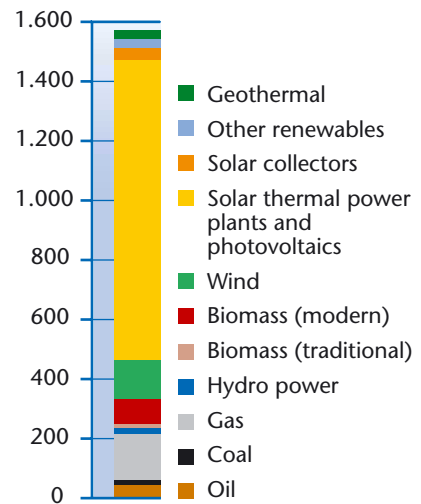
According to a report published by Greenpeace and the "European Solar Thermal Power Industry Association" (ESTIA) in 2003, the solar thermal power plant industry could become a new dynamic growth sector with a market volume of 7.6 billion euro by 2020. The study "Solar Thermal Power 2020" demonstrates how solar thermal power plants in the sunny areas of the world could develop into an important energy source within fewer than two decades, which would then supply over 100 million people with clean electricity. The study calculates that solar thermal power plant technology could supply an output of 21,000 MWel by the year 2020; by 2040 as much as 630,000 MWel - that would be more than five percent of global power consumption, even if it were to increase 2.5 times by then. According to the study, solar thermal power plants could save the atmosphere about 154 million tons of carbon dioxide by the year 2020.

The global market launch initiative for solar thermal power plants (Global Market Initiative for Concentrating Solar Power, GMI) expects an expansion of worldwide installed output of solar thermal power plants to 5000 MWel by the year 2015; then further growth of about 20-25 percent per year. This includes a continuous expansion of hybrid solar thermal steam power plants with at least 75 percent solar fraction with successive expansion of thermal storage capacity and operating time from initially 2000 full load hours per year to 6500 hours per year in the year 2025. At 136 TWh/a, annual power generation from solar thermal power plants will reach an order of market share of about 1 percent of worldwide power generation in the year 2025.

The International Energy Agency (IEA) in Paris foresees a total potential of 20 - 40,000 MWel by the year 2020 at costs of less than 6 US cent/KWh. Back in 1996, the U.S. Department of Energy (DOE) developed a plan for solar thermal generation of electricity, which envisions an installed capacity of 20,000 MWel by 2020 at power production costs of under 6 US cent/KWh. The World Bank also expects that the power production costs of solar thermal power plants will drop to under 6 US cent/KWh by the year 2020 due to economies of scale and learning curves.

### Global energy mix in the year 2100

Primary energy used [EJ/a]



(Source: German Advisory Council on Global Change, WBGU, 2004)





## References

The Concentrating Solar Power. Global Market Initiative (GMI), Washington 2004, download: <http://www.solarpaces.org/GMI.HTM>

Greenpeace, European Solar Thermal Power Industry Association (ESTIA): Solar Thermal Power in 2020, Birmingham/Amsterdam 2003, download: <http://archive.greenpeace.org/docs/SolarThermalPower.pdf>

German Advisory Council on Global Change (WBGU): World in Transition - Towards Sustainable Energy Systems, Berlin 2003, download: [http://www.wbgu.de/wbgu\\_jg2003.pdf](http://www.wbgu.de/wbgu_jg2003.pdf)

Sokrates, Solarthermische Kraftwerkstechnologie für den Schutz des Erdklimas, Forschungsprojekt zur STKT, download: <http://www.dlr.de/sokrates>

SCHOTT memorandum on solar thermal power plant technology, Mainz 2005, download: <http://www.schott.com/solar/>

## CSP Internet links

International partnership for solar thermal power plant technology (with the support of the International Energy Agency, IEA): <http://www.solarpaces.org>

German-language website on solar thermal power plant technology (VDI/VDE Innovation+Technik GmbH): <http://www.solar-thermie.org>

TroughNet. Parabolic Trough Solar Power Network (financed by the U.S. Department of Energy): <http://www.eere.energy.gov/troughnet/>

German Aerospace Center: <http://www.dlr.de/Energie>, <http://www2.dlr.de/TT/solartherm>

Plataforma Solar di Almería, European solar thermal power plant technology research site: <http://www.psa.es/>

Solar Millenium AG, responsible for the AndaSol power plant project: <http://www.solarmillennium.de>

Business Unit Solar at SCHOTT AG: <http://www.schott.com/solar>

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Contact:

Solar

**SCHOTT AG**

Hattenbergstraße 10

55122 Mainz

Germany

Tel.: +49 9633/80-291

Fax: +49 9633/80-757

E-mail: [info.solar@schott.com](mailto:info.solar@schott.com)

[www.schott.com/solar](http://www.schott.com/solar)

Concept and Copywriting:

**SCHOTT AG**

Corporate Public Relations

Hattenbergstraße 10

55122 Mainz

Germany

Tel.: +49 6131/66-2411

Fax: +49 6131/66-4011

E-mail: [info.cpr@schott.com](mailto:info.cpr@schott.com)

[www.schott.com](http://www.schott.com)