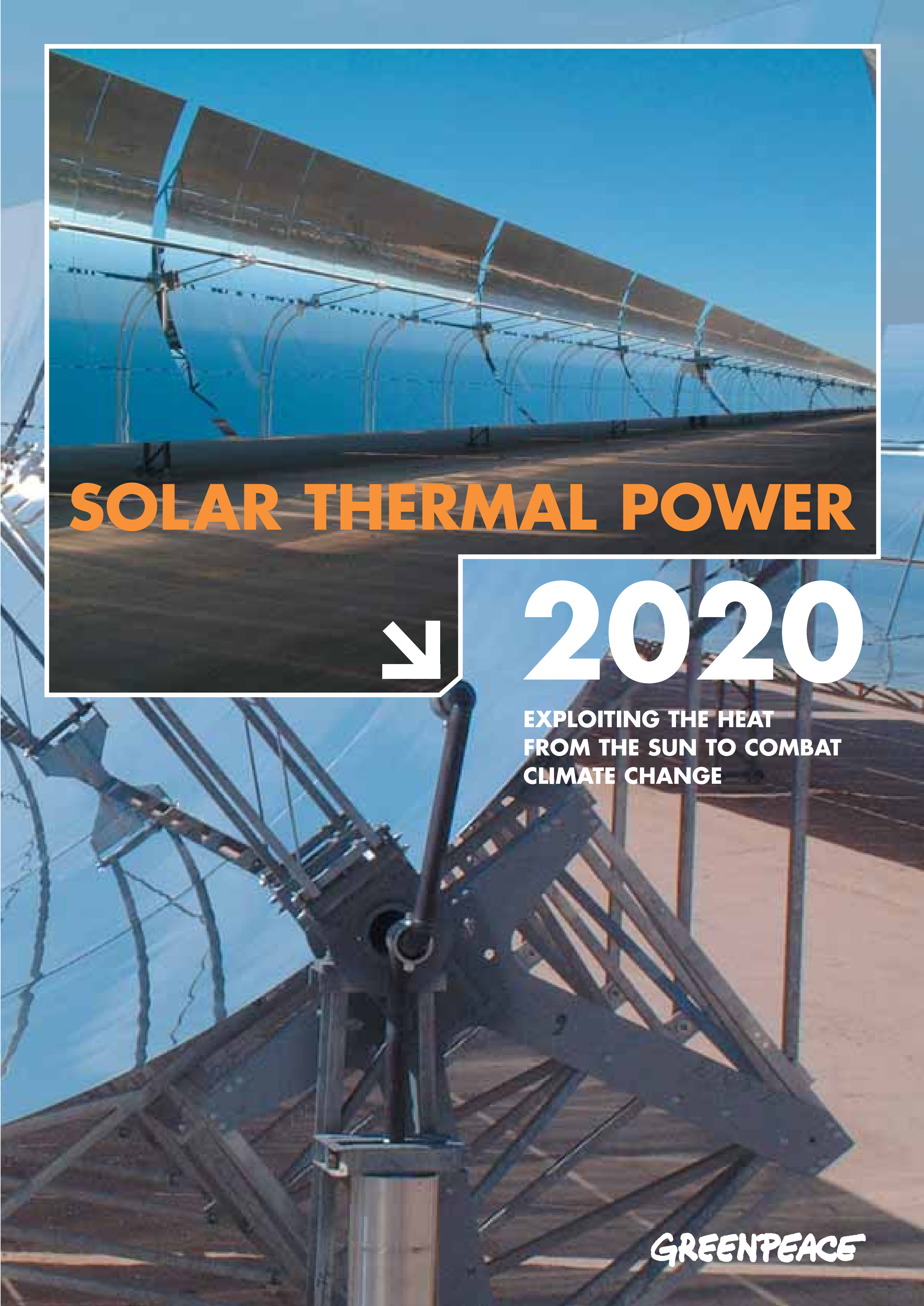


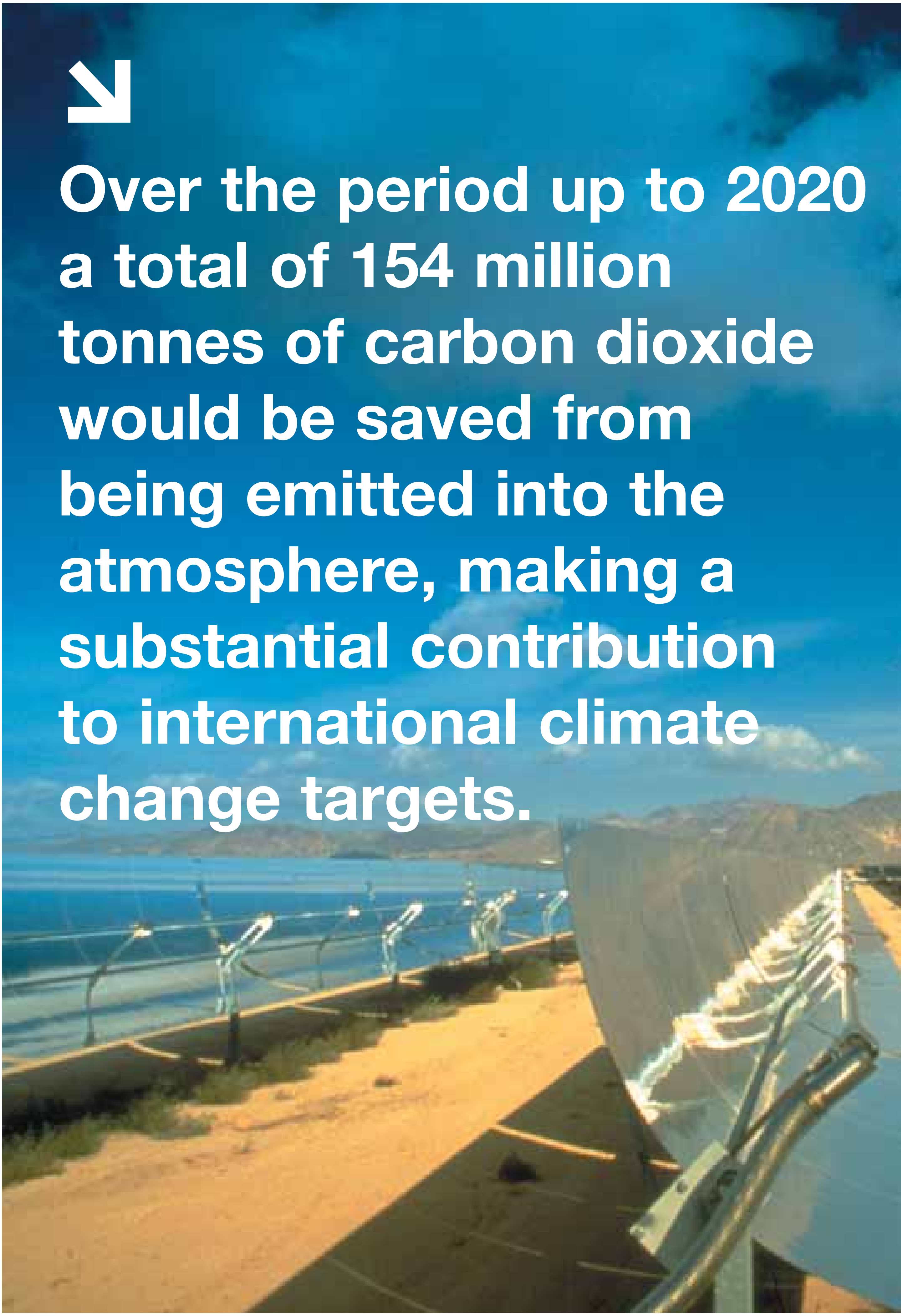
SOLAR THERMAL POWER

2020

EXPLOITING THE HEAT FROM THE SUN TO COMBAT CLIMATE CHANGE

GREENPEACE

Over the period up to 2020 a total of 154 million tonnes of carbon dioxide would be saved from being emitted into the atmosphere, making a substantial contribution to international climate change targets.



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FOREWORD

THE VISION IS CLEAR: SOLAR THERMAL POWER PLANTS CAN BECOME THE OFFSHORE WIND FARMS OF THE DESERT – EXPLOITING THE HEAT FROM THE SUN TO COMBAT CLIMATE CHANGE.

This report demonstrates that there are no technical, economic or resource barriers to supplying 5% of the world's electricity needs from solar thermal power alone by 2040 – even against the challenging backdrop of a projected more than doubling in global electricity demand. The solar thermal industry is capable of becoming a dynamic, innovative €15 billion annual business within 20 years, unlocking a new global era of economic, technological and environmental progress.

The benefits of solar power are compelling: environmental protection, economic growth, job creation, diversity of fuel supply and rapid deployment, as well as the global potential for technology transfer and innovation. The underlying advantage of solar energy is that the fuel is free, abundant and inexhaustible. The total amount of energy irradiated from the sun to the earth's surface is enough to provide for annual global energy consumption 10,000 times over.

On climate change, a solid international consensus now clearly states that business-as-usual is not an option and the world must move swiftly towards a clean energy economy. Solar thermal power is a prime choice in developing an affordable, feasible, global energy source that is able to substitute for fossil fuels in the sunbelts around the world.

Electricity for 100 million people

Greenpeace and the European Solar Thermal Power Industry Association (ESTIA) have together produced this report in order to update our understanding of the contribution that solar thermal power can make to the world's energy supply. The report is a practical blueprint to show that solar thermal power is capable of supplying electricity to more than 100 million people living in the sunniest parts of the world within two decades.

Modern solar thermal power plants provide bulk power equivalent to the output from conventional power stations and can be built in a matter of months. The aim of this blueprint is to push further forward the boundaries of technological progress and unlock the benefits that will follow. Solar thermal power does not need to be invented, nor is there a need to wait for any magical 'breakthrough'; it is ready for global implementation today.

The vision is clear: solar thermal power plants can become the offshore wind farms of the desert – exploiting the heat from the sun to combat climate change.

Urgent political commitment

The solid industrial and political commitment to the expansion of the solar thermal power plant industry outlined in this report shows clearly that the current surge of activity in the solar electricity sector represents merely a foretaste of the massive transformation and expansion it is capable of over the coming decades. But although reports are a useful guide, it is people who change the world by their actions. We encourage politicians and policy-makers, global citizens, energy officials, companies, investors and other interested parties to support solar thermal power by taking concrete steps which will help ensure that hundreds of millions of people will receive their electricity from the sun, harnessing its full potential for our common good.

Following last year's Earth Summit, the Johannesburg Renewable Energy Coalition was formed, with more than 80 countries proclaiming that their goal is to "substantially increase the global share of renewable energy sources" on the basis of "clear and ambitious time-bound targets". Political declarations mean little if not put into practice. This report is a blueprint for action that governments can implement, and shows what is possible with just one renewable technology.

Solar thermal power is a global scale technology that has the capacity to satisfy the energy and development needs of the world without destroying it.

Note: Figures are given in this report in both US dollars and Euros. Readers should note that the two currencies have a similar value.

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EXECUTIVE SUMMARY

Power from the Sun

Solar thermal power is a relatively new technology which has already shown enormous promise. With few environmental impacts and a massive resource, it offers an opportunity to the sunniest countries of the world comparable to the breakthrough offshore wind farms are currently offering European nations with the windiest shorelines.

Solar thermal power uses direct sunlight, so it must be sited in regions with high direct solar radiation. Among the most promising areas of the world are the South-Western United States, Central and South America, Africa, the Middle East, the Mediterranean countries of Europe, Iran, Pakistan and the desert regions of India, the former Soviet Union, China and Australia.

In many regions of the world, one square kilometre of land is enough to generate as much as 100-200 Gigawatt hours (GWh) of electricity per year using solar thermal technology. This is equivalent to the annual production of a 50 MW conventional coal or gas-fired power plant. Worldwide, the exploitation of less than 1% of the total solar thermal potential would be enough to stabilise the world climate through massive CO_2 reductions.

Turning Solar Heat into Electricity

Producing electricity from the energy in the sun's rays is a relatively straightforward process. Direct solar radiation can be concentrated and collected by a range of Concentrating Solar Power (CSP) technologies to provide medium to high temperature heat. This heat is then used to operate a conventional power cycle, for example through a steam or gas turbine or a Stirling engine. Solar heat collected during the day can also be stored in liquid, solid or phase changing media like molten salts, ceramics, concrete, or in the future, phase changing salt mixtures. At night, it can be extracted from the storage medium to run the steam turbine.

Solar thermal power plants can be designed for solar-only generation, ideally to satisfy demand during daylight hours, but with future storage systems their operation can be extended to almost base load requirements.

Electricity from solar thermal power is also becoming cheaper to produce. Plants operating in California have already achieved impressive cost reductions, with generation costs ranging today between 10 and 13 US cents/kWh. However, costs are expected to fall closer to 5 US cents in the future. Advanced technologies, mass production, economies of scale and improved operation will together enable a reduction in the cost of solar electricity to a level competitive with fossil power plants within the next 10 to 15 years.

Technology, Costs and Benefits

Four main elements are required to produce electricity from solar thermal power: a concentrator, a receiver, some form of a heat transport, storage and power conversion equipment much the same as for a fossil fuel-based plant. The three most promising solar thermal technologies are the parabolic trough, the central receiver or solar tower, and the parabolic dish.

Parabolic trough systems use trough-shaped mirror reflectors to concentrate sunlight on to receiver tubes through which a thermal transfer fluid is heated to roughly 400°C and then used to produce superheated steam. They represent the most mature solar thermal power technology, with 354 MWe of plants connected to the Southern California grid since the 1980s and more than two square kilometres of parabolic trough collectors. These plants supply an annual 800 million kWh – enough for more than 200,000 households – at a generation cost of about 10-13 US cents/kWh.

Further advances are now being made in the technology, with utility scale projects planned in Greece, Spain, Egypt, Mexico, India, Morocco, Iran, Israel, Italy, the United States and Algeria. Electricity from trough plants combined with gas-fired combined cycle plants – ISCC (Integrated Solar Combined Cycle) systems – is expected to cost 6 €cents/kWh today and 5 €cents in medium terms.

Central receiver (solar tower) systems use a circular array of large individually-tracking mirrors (heliostats) to concentrate sunlight on to a central receiver mounted on top of a tower, with heat transferred for power generation through a choice of transfer media. After an intermediate scaling up to 30 MW capacity, solar tower developers now feel confident that grid-connected tower power plants can be built up to a capacity of 200 MWe solar-only units. Use of thermal storages will increase their flexibility.

Although central receiver plants are considered to be further from commercialisation than parabolic trough systems, solar towers have good longer term prospects for high conversion efficiencies. Projects are in various stages of development (from assessment to implementation) in Spain, South Africa and the United States. In the future, central receiver plant projects will benefit from similar cost reductions to those expected from parabolic trough plants. The anticipated evolution of total electricity costs is that they will drop to 5 cents/kWh in the mid to long term.

Parabolic dish systems are comparatively small units which use a dish-shaped reflector to concentrate sunlight, and heated gas or air to generate power in a small engine at the focal point of the reflector. Their potential lies primarily in decentralised power supply and remote, stand-alone power systems. Projects are currently planned in the United States, Australia and Europe. In terms of electricity costs, an attainable mid-term goal is a figure of less than 15 cents/kWh.

Current trends show that two broad pathways have opened up for large scale delivery of electricity using solar thermal power. One is the ISCC-type hybrid operation of solar collection and heat transfer combined with a conventional state-of-art combined cycle gas-fired power plant. The other is solar-only operation, with a conventional steam turbine, increasing use of a storage medium such as molten salt. This enables solar energy collected during the day to be stored and then dispatched when demand requires.

A major benefit of solar thermal power is that it has little environmental impact, with none of the polluting emissions or safety concerns associated with conventional generation technologies. There is no pollution in the form of exhaust gases during operation. Decommissioning a system is unproblematic.

Each square metre of surface in a solar field is enough to avoid the annual production of 200 kilograms (kg) of carbon dioxide. Solar power can therefore make a substantial contribution towards international commitments to reduce emissions of greenhouse gases which contribute to climate change.

The Global Solar Thermal Market

New opportunities are opening up for solar thermal power as a result of the global search for clean energy solutions. Both national and international initiatives are supporting the technology, encouraging commercialisation of production. A number of countries have introduced legislation which forces power suppliers to source a rising percentage of their supply from renewable fuels. Bulk power high voltage transmission lines from high insulation sites, such as in northern Africa, could encourage European utilities to finance large solar plants whose power would be used in Europe.

These and other factors have led to significant interest in constructing plants in the sunbelt regions. In addition, interest rates and capital costs have drastically fallen worldwide, increasing the viability of capital intensive renewable energy projects. Examples of specific large solar thermal projects currently planned around the world, evidence of the “race to be first”, include:

- **Algeria**: 140 MW ISCC plant with 35 MW solar capacity.
- **Australia**: 35 MW CLFR-based array to pre-heat steam at a coal-fired 2,000 MW plant.
- **Egypt**: 127 MW ISCC plant with 29 MW solar capacity.
- **Greece**: 50 MW solar capacity using steam cycle.
- **India**: 140 MW ISCC plant with 35 MW solar capacity.
- **Israel**: 100 MW solar hybrid operation.
- **Italy**: 40 MW solar capacity using steam cycle.
- **Mexico**: 300 MW ISCC plant with 29 MW solar capacity.
- **Morocco**: 230 MW ISCC plant with 35 MW solar capacity.
- **Spain**: 2 x 50 MW solar capacity using steam cycle and storage.
- **USA**: 50 MW Solar Electric Generating Systems.
- **USA**: 1 MW parabolic trough using ORC engine

The Future for Solar Thermal Power

A scenario prepared by Greenpeace International and the European Solar Thermal Power Industry Association projects what could be achieved by the year 2020 given the right market conditions. It is based on expected advances in solar thermal technology coupled with the growing number of countries which are supporting projects in order to achieve both climate change and power supply objectives.

KEY RESULTS FROM GREENPEACE-ESTIA SCENARIO 2002 TO 2020

Capacity of Solar Thermal Power in 2020	21,540 MW
Electricity Production in 2020	54,600,000 MWh (54.6 TWh)
Cumulative Investment	US$ 41.8 billion
Employment Generated	200,000 jobs
Carbon Emissions Avoided 2002 – 2020	154 million tonnes CO_2
Annual Carbon Emissions Avoided in 2020	32.7 million tonnes CO_2
Projection 2021 to 2040	
Capacity of Solar Thermal Power in 2040	630,000 MW
Electricity Production in 2040	1573 TWh
Percentage of Global Demand	5%

Over the period of the scenario, solar thermal technology will have emerged from a relatively marginal position in the hierarchy of renewable energy sources to achieve a substantial status alongside the current market leaders such as hydro and wind power. From a current level of just 354 MW, by 2015 the total installed capacity of solar thermal power plants will have reached 5,000 MW. By 2020 additional capacity would be rising at a level of almost 4,500 MW each year.

- By 2020, the total installed capacity of solar thermal power around the world will have reached 201,540 MW.

- Solar thermal power will have achieved an annual output of more than 54,600,000 MWh (54.6 TWh) This is equivalent to the consumption of over one third of Australia's electricity demand.

- Capital investment in solar thermal plant will rise from US$ 375 million in 2005 to almost US$ 7.6 billion in 2020. The total investment over the scenario period would amount to US$ 41.8 bn.

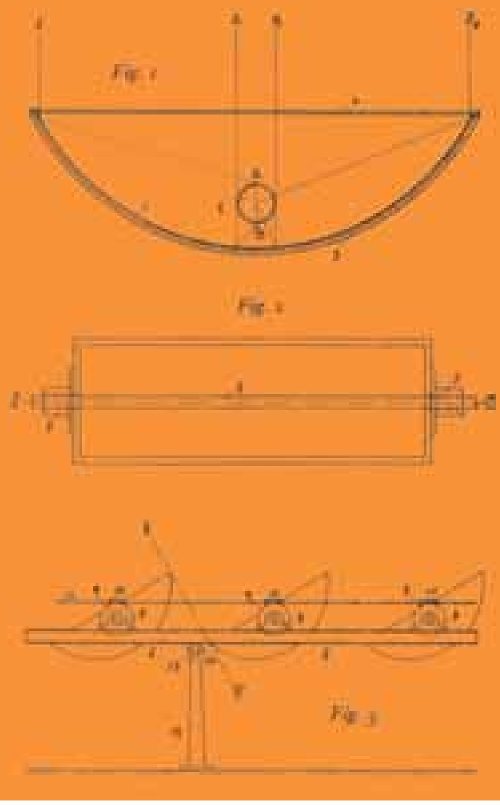
- Expansion in the solar thermal power industry will result in the creation of 200,000 jobs worldwide, even not counting those involved in production of the hardware.

- The five most promising countries in terms of governmental targets or potentials according to the scenario, each with more than 1,000 MW of solar thermal projects expected by 2020, are Spain, the United States, Mexico, Australia and South Africa.

- Over the period up to 2020 a total of 154 million tonnes of carbon dioxide would be saved from being emitted into the atmosphere, making an important contribution to international climate protection targets.

A further projection is also made for the potential expansion of the solar thermal power market over another two decades up to 2040. This shows that by 2030 the world-wide capacity will have reached 106,000 MW, and by 2040 a level of almost 630,000 MW. Increased availability of plants because of the greater use of efficient storage technology will also increase the amount of electricity generated from a given installed capacity.

The result if that by 2040 more than 5% of the world's electricity demand could be satisfied by solar thermal power.



Patent for first parabolic trough collector in 1907 to Dr. W. Maier of Aalen and A. Remshardt Stuttgart. These early designs formed the basis for R&D developments in the late 1970s and early 1980s, when solar thermal projects were undertaken in a number of industrialised countries, including the United States, Russia, Japan, Spain and Italy (see Table 1). Many of these plants, covering the whole spectrum of available technology, failed to reach the expected performance levels, and subsequent R& D has continued to concentrate on technology improvement and increasing the size of unit.

PART 1

SOLAR THERMAL POWER – THE BASICS

1. Power from the Sun

Solar thermal power is a relatively new technology which has already shown enormous promise. With few environmental impacts and a massive resource, it offers an opportunity to the sunniest countries of the world comparable to that which offshore wind farms are currently offering to European and other nations with the windiest shorelines.

Solar thermal power uses direct sunlight, so it must be sited in regions with high direct solar radiation. Suitable sites should offer at least 2,000 kilowatt hours (kWh) of electricity per m^2 of sunlight annually, whilst the best sites offer more than 2,500kWh/m^2. Typical locations, where the climate and vegetation do not offer high levels of atmospheric humidity, include steppes, bush, savannah's, semi-deserts and true deserts, ideally located within ±40 degrees of latitude. Among the most promising areas of the world are therefore the South-Western United States, Central and South America, Africa, the Middle East, the Mediterranean countries of Europe, Iran, Pakistan and the desert regions of India, the former Soviet Union, China and Australia.

In many regions of the world, one square kilometre of land is enough to generate as much as 100-200 Gigawatt hours (GWh) of solar electricity per year using solar thermal technology. This is equivalent to the annual production of a 50 MW conventional coal or gas-fired power plant. Over the total life cycle of a solar thermal power system, its output would be equivalent to the energy contained in 16 million barrels of oil. Worldwide, the exploitation of less than 1% of the total solar thermal potential would be enough to meet the recommendations of the United Nations' Intergovernmental Panel on Climate Change (IPCC) for the long-term stabilisation of the climate.

This large solar power potential will only be used to a limited extent, however, if it is restricted by regional demand and by local technological and financial resources. If solar electricity is exported to regions with a high demand for power but few indigenous solar resources, considerably more of the potential in the sunbelt countries could be harvested for the protection of the global climate. Countries such as Germany are already seriously considering the import of solar electricity from North Africa and Southern Europe as a way of contributing to the long-term sustainable development of their power sector. However, priority should still be given to supply for legitimate indigenous demand.

2. Turning Solar Heat into Electricity

Producing electricity from the energy in the sun's rays is a relatively straightforward process. Direct solar radiation can be concentrated and collected by a range of Concentrating Solar Power (CSP) technologies to provide medium to high temperature heat. This heat is then used to operate a conventional power cycle, for example through a steam or gas turbine or a Stirling engine. Solar heat collected during the day can also be stored in liquid, solid or phase changing media like molten salts, ceramics, concrete, or in the future, phase changing salt mixtures. At night, it can be extracted from the storage medium to run power generation plant.
Solar thermal power plants can be designed for solar-only generation, ideally to satisfy day-time peak load demand, but with future storage systems operation can be extended until base load coverage. During the technology's market development phase, hybrid plant concepts which back up the solar output by fossil firing are likely to be the favoured option. This would involve, for example, Integrated Solar-Combined Cycle (ISCC) plants for mid-load or base-load operation.

Combined generation of heat and power by CSP has particularly promising potential, as the high value solar energy input is used to the best possible efficiency, exceeding 85%. Process heat from combined generation can be used for industrial applications, district cooling or sea water desalination.

Current CSP technologies include parabolic trough power plants, solar power towers and parabolic dish engines (see Part Two). Parabolic trough plants with an installed capacity of 354 MW have been in commercial operation for many years, whilst solar towers and dish engines have been tested successfully in a series of demonstration projects.

3. Why Concentrate Solar Power?

Concentrating solar power to generate bulk electricity is one of the best suited technologies to help mitigate climate change in an affordable way, as well as reducing the consumption of fossil fuels.

Environmental Sustainability

Life cycle assessment of the emissions produced, together with the land surface impacts of CSP systems, shows that they are ideally suited to the task of reducing greenhouse gases and other pollutants, and without creating other environmental risks or contamination. Each square metre of CSP solar field surface, for example, is enough to avoid the annual emisson of 200 kilograms (kg) of carbon dioxide. The energy payback time of concentrating solar power systems is in the order of just five months. This compares very favourably with their lifespan of approximately 25 to 30 years. Most of the CSP solar field materials e.g. steel and glass can be recycled and used again for further plants.

Economic Sustainability

The cost of solar thermal power is falling. Experience from the Solar Electric Generating Systems (SEGS) in California (see Part Two) shows that impressive cost reductions have already been achieved, with generation costs ranging today between 10 and 13 US cents/kWh. However, most of the learning curve is still to come.

Table 1: Early Solar Thermal Power Plants

Name	Location	Size (MWe)	Type, Heat Transfer Fluid & Storage Medium	Start–up Date	Funding
Aurelios	Adrano, Sicily	1	Tower, Water-Steam	1981	European Community
SSPS/ CRS	Almeria, Spain	0.5	Tower, Sodium	1981	8 European countries & USA
SSPS/ DCS	Almeria, Spain	0.5	Trough, Oil	1981	8 European countries & USA
Sunshine	Nio, Japan	1	Tower, Water-Steam	1981	Japan
Solar One	California, USA	10	Tower, Water-Steam	1982	US Dept. of Energy & utilities
Themis	Targasonne, France	2.5	Tower, Molten Salt	1982	France
CESA-1	Almeria, Spain	1	Tower, Water-Steam	1983	Spain
MSEE	Albuquerque, USA	0.75	Tower, Molten Salt	1984	US Dept. of Energy & utilities
SEGS-1	California, USA	14	Trough, Oil, Oil Storage	1984	Luz (private company)
Vanguard 1	USA	0.025	Dish, Hydrogen	1984	Advanco Corp.
MDA	USA	0.025	Dish, Hydrogen	1984	McDonnell-Douglas
C3C-5	Crimea, Russia	5	Tower, Water-Steam	1985	Russia

Advanced technologies, mass production, economies of scale and improved operation will together enable a reduction in the cost of solar electricity to a level competitive with other power sources within the next 10 to 15 years. This will reduce dependency on fossil fuels and avoid the risk of future electricity cost escalation. Hybrid solar-fossil fuel plants, making use of special finance schemes at favourable sites, can already deliver competitively priced electricity.

Competition with the economics of solar thermal power plants comes mainly from conventional grid-connected fossil fuel-fired power plants, particularly the modern natural gas-fired combined cycle plants in mid-load or base-load operation mode. In small-scale off-grid generation systems, such as islands or developing countries, the competition comes from gas oil or heavy fuel oil-powered diesel engine generators. However, a mixture of factors, including reform of the electricity sector, the rising demand for ‘green power’, the possibility of gaining carbon credits from pollution-free generation and direct support schemes for renewable energy in some countries, are all increasing the viability of such projects.

4. A Brief History

Efforts to design devices for supplying renewable energy through use of the sun’s rays began some 100 years before the oil price crisis of the 1970s triggered the modern development of renewables. Experiments started in the 1860s, with Auguste Mouchout’s first solar-powered motor producing steam in a glass-enclosed iron cauldron, then continued in the early 1900s with Aubrey Eneas’ first commercial solar motors. In 1907 a patent was granted to Dr. Maier from Aalen and Mr. Remshardt from Stuttgart for a device to directly use solar irradiation for steam generation. This was based on the solar parabolic trough technology. In 1912 Frank Shuman used this technology to build a 45kW sun-tracking parabolic trough plant in Meadi, Egypt.

These early designs formed the basis for R&D developments in the late 1970s and early 1980s, when solar thermal projects were undertaken in a number of industrialised countries, including the United States, Russia, Japan, Spain and Italy (see Table 1). Many of these plants, covering the whole spectrum of available technology, failed to reach the expected performance levels, and subsequent R& D has continued to concentrate on technology improvement and increasing the size of units.

A major breakthrough came in the early 1980s when the American-Israeli company Luz International commercialised the technology by building a series of nine Solar Electric Generating Stations in the Californian Mojave desert. The SEGS plants range from 14 up to 80 MWe in capacity and accumulates 354 MW capacity for the Southern Californian grid.

Arial View of five 30MW SEGS plants in Kramer Junction, California

PART 2

SOLAR THERMAL POWER: TECHNOLOGY, COSTS AND BENEFITS

1. Technology Overview

Solar thermal power plants produce electricity in much the same way as conventional power stations. The difference is that they obtain their energy input by concentrating solar radiation and converting it to high temperature steam or gas to drive a turbine or engine. Four main elements are required: a concentrator, a receiver, some form of heat transport media or storage, and power conversion. Many different types of systems are possible, including combinations with other renewable and non-renewable technologies, but the three most promising solar thermal technologies are:

Figure 1: Parabolic Trough

Parabolic trough-shaped mirror reflectors are used to concentrate sunlight on to thermally efficient receiver tubes placed in the trough focal line. In these tubes a thermal transfer fluid is circulated, such as synthetic thermal oil. Heated to approximately 400°C by the concentrated sun’s rays, this oil is then pumped through a series of heat exchangers to produce superheated steam. The steam is converted to electrical energy in a conventional steam turbine generator, which can either be part of a conventional steam cycle or integrated into a combined steam and gas turbine cycle.

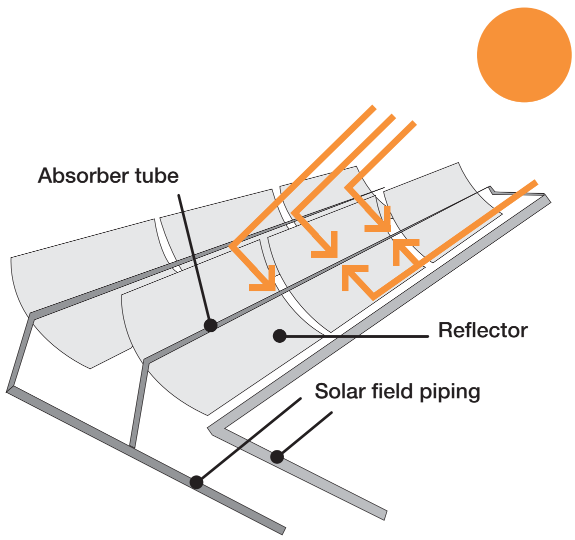


Figure 2: Central Receiver/Solar Tower

A circular array of heliostats (large individually-tracking mirrors) is used to concentrate sunlight on to a central receiver mounted at the top of a tower. A heat transfer medium in this central receiver absorbs the highly concentrated radiation reflected by the heliostats and converts it into thermal energy to be used for the subsequent generation of superheated steam for turbine operation. Heat transfer media so far demonstrated include water/steam, molten salts, liquid sodium and air. If a gas or even air is pressurised in the receiver, it can be used alternatively to drive a gas turbine (instead of producing steam for a steam turbine).

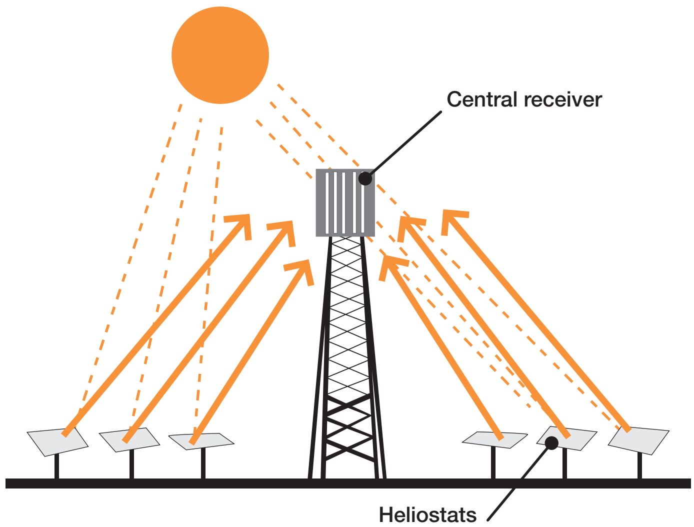
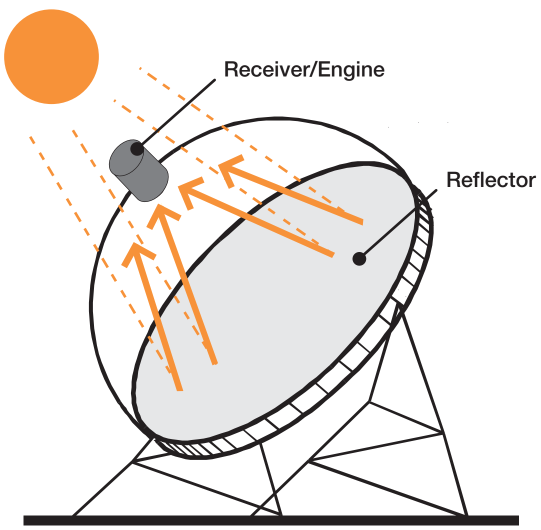


Figure 3: Parabolic Dish

A parabolic dish-shaped reflector is used to concentrate sunlight on to a receiver located at the focal point of the dish. This absorbs energy reflected by the concentrators, enabling fluid in the receiver to be heated to approximately 750°C. This is then used to generate electricity in a small engine, for instance Stirling engine or a micro turbine, attached to the receiver.



Each technology has its own characteristics, advantages and disadvantages, some of which are shown in Table 2.

Table 2: Comparison of Solar Thermal Power Technologies

	Parabolic Trough	Central Receiver	Parabolic Dish
Applications	Grid-connected plants, process heat (Highest solar unit size built to date: 80 MWe)	Grid-connected plants, high temperature process heat (Highest solar unit size built to date: 10 MWe)	Stand-alone applications or small off-grid power systems (Highest solar unit size built to date: 25 kWe)
Advantages	• Commercially available – over 10 billion kWh operational experience; operating temperature potential up to 500°C (400°C commercially proven) • Commercially proven annual performance of 14% solar to net electrical output • Commercially proven investment and operating costs • Modularity • Best land use • Lowest materials demand • Hybrid concept proven • Storage capability	• Good mid-term prospects for high conversion efficiencies, with solar collection; operating temperature potential up to 1000°C (565°C proven at 10MW scale) • Storage at high temperatures Hybrid operation possible	• Very high conversion efficiencies – peak solar to electric conversion of about 30% • Modularity • Hybrid operation possible • Operational experience of first prototypes
Disadvantages	• The use of oil based heat transfer media restricts operating temperatures to 400°C, resulting in moderate steam qualities • Land availability, water demand	• Projected annual performance values, investment and operating costs still need to be proved in commercial operation	• Reliability needs to be improved • Projected cost goals of mass production still need to be achieved

2. Parabolic Trough Systems

Technology Developments

Parabolic trough systems represent the most mature solar thermal power technology, with 354 MW connected to the Southern California grid since the 1980s and over 2 million square meters of parabolic trough collectors operating with a long term availability of over 99%. Supplying an annual 800 million kWh at a generation cost of about 10 to 12 US cents/kWh, these plants have demonstrated a maximum summer peak efficiency of 21% in terms of conversion of direct solar radiation into grid electricity (see box "The California SEGS Power Plants" on page 14).

But although successful, they by no means represent the end of the learning curve. Advanced structural design will improve optical accuracy and at the same time reduce weight and costs. By increasing the length of the collector units, end losses can be further reduced and savings in drive systems and connection piping achieved. Next generation receiver tubes will also further reduce thermal losses and at the same time increase reliability. Improvements to the heat transfer medium will increase operating temperature and performance. Low cost thermal bulk storage will increase annual operating hours and thereby reduce generation costs. Most important for further significant cost reductions, however, is automated mass production in order to steadily increase market implementation. New structural collector designs are currently being developed in Europe and the US, whilst work on improved receiver tubes is under way in Israel, Germany and the US.

What promises to be the next generation of parabolic collector technology has been developed at the Plataforma Solar in Spain since 1998 by a European consortium. Known as EuroTrough, this aims to achieve better performance and lower costs by using the same well tried key components – parabolic mirrors and absorber tubes – as in the commercially mature Californian plants, but significantly enhancing the optical accuracy by a completely new design of the trough structure. With funding from the European Union, a 100m and a 150m prototype of the EuroTrough were successfully commissioned in 2000 and 2002 respectively at the Plataforma Solar Research Centre.

Figure 4: Electricity generation at Californian plants using parabolic trough collectors, 1985 to 2001

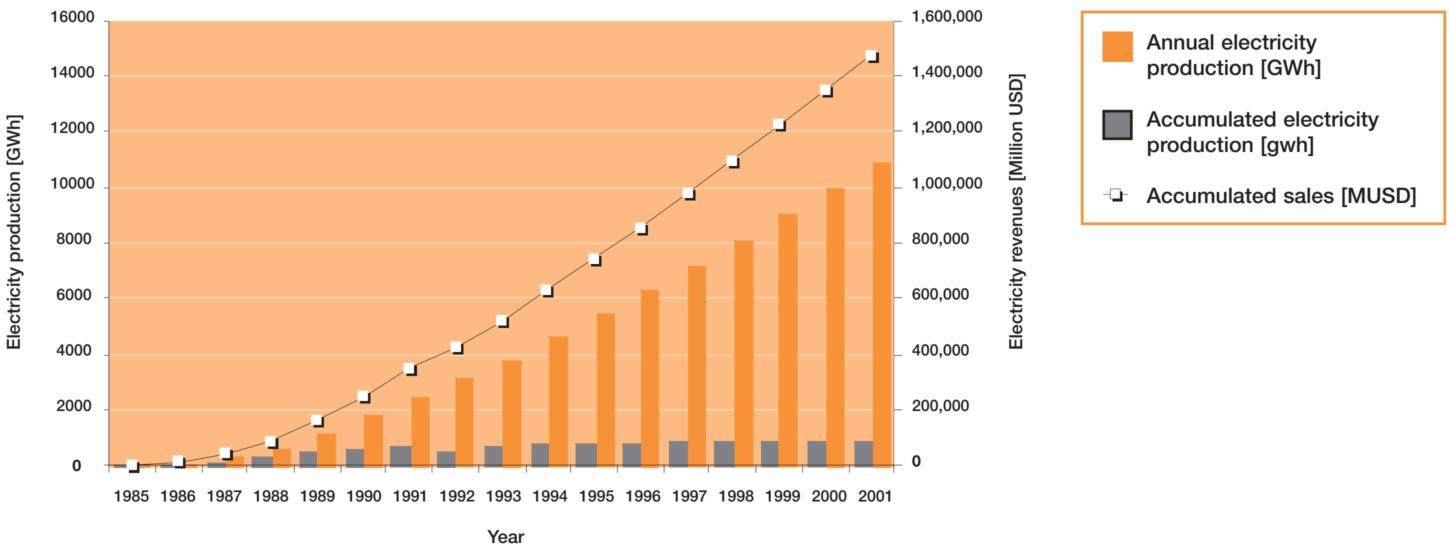


Figure 5: Daily summer output pattern at the SEGS VI plant in Kramer Junction, California

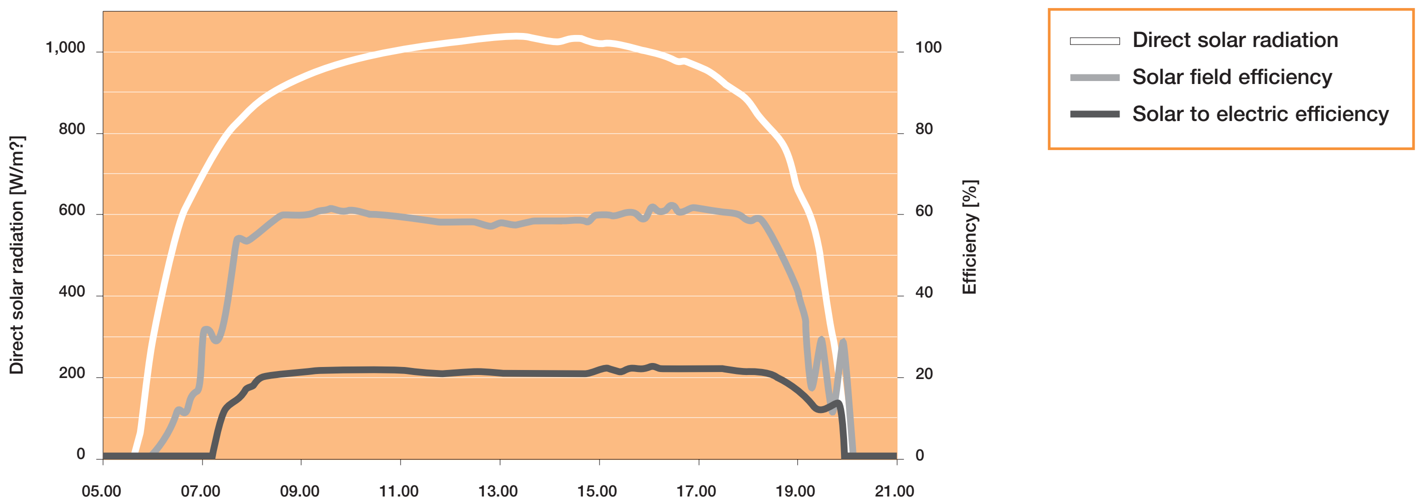


Figure 6: Operating principles and daily tracking of a parabolic trough collector

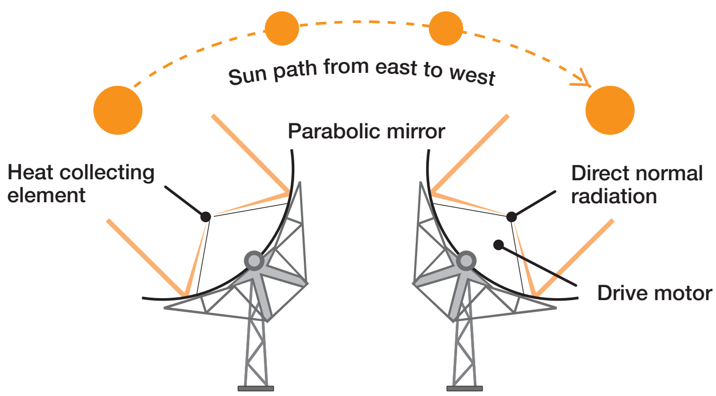
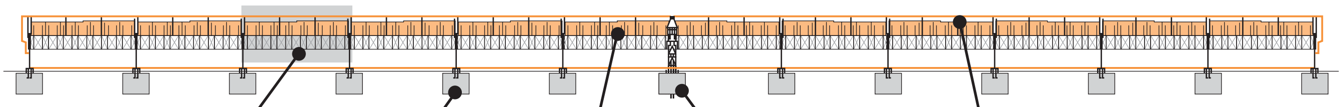


Figure 7: Side view of a EuroTrough ET150 collector unit (150m length)



An extended 4,360m² loop of advanced EuroTrough collectors with both 100m and 150m units is now fully commercially operational, as part of the the so-called PARASOL project, at the SEGS V plant in Kramer Junction, California in April 2003. Developed by Solar Millenium AG, Germany this has received financial support from the German Ministry for Environment. Other new designs for parabolic troughs are under development in the US and in Belgium.

While the commercial plants in California use a synthetic oil as the heat transfer fluid, because of its low operating pressure and storability, R&D efforts are under way at the Plataforma Solar – through the DISS (Direct Solar Steam) and INDITEP projects sponsored by the European Commission – to achieve direct steam generation within absorber tubes and to eliminate the need for an intermediate heat transfer. This increases efficiency and could reduce costs by as much as 30%. In the first DISS pilot plant, direct solar steam has been generated at 100bar and 375°C. Following this success, the current R&D effort from the INDITEP project is focused on increasing the steam temperature beyond 400°C. The issue of a feasible phase change storage medium for direct steam systems will be the future focus of R&D activities.

Another potential technology under investigation is a parabolic line focusing concept with segmented mirrors, employing the Fresnel principle (see below). Although this will reduce efficiency, the developers expect a considerable potential for cost reduction, since the closer arrangement of the mirrors requires less land and provides a partially shaded, useful space underneath.

An alternative to mechanical trackers is being developed in Australia, known as Yeoman's Floating Solar Concentrators. These are designed as a low-tech, low-cost solution and use 5m² concrete flotation modules and strips of low-iron glass mirrors set in the top surface in a Fresnel structured parabolic trough. To protect them from impact damage a simple high-flow irrigation pump can flood the top surface of the modules in minutes, sinking them in half a metre of water. Steam can be produced at high temperatures and pressures at 60% efficiency. Final efficiency will depend on turbine operation and other factors. Full scale ponds are planned to be 110 meters in diameter and contain 340 individual modules. They would have an estimated peak output of 1.5 MW, and an estimated capital cost of AU$ 1 million/MW.

Fresnel Principle Solar Collectors

A Linear Fresnel Reflector (LFR) array is a line focus system similar to parabolic troughs in which solar radiation is concentrated on an elevated inverted linear absorber using an array of nearly flat reflectors. With the advantages of low structural support costs, fixed fluid joints, a receiver separated from the reflector system, and long focal lengths allowing the use of conventional glass, LFR collectors have attracted increasing attention. The technology is seen to be a lower cost alternative to trough technology for the production of solar steam for power generation.

An LFR can be designed to have similar thermal performance to that of a parabolic trough per aperture area, but recent designs tend to use less expensive reflector materials and absorber components which reduce optical performance. However, this lower performance is outweighed by lower investment and operation and maintenance costs. Fresnel collectors also have other advantages, such as allowing use of the land below the mirror fields for other economic purposes, such as horticulture.

In 1999 the Belgian Company Solarmundo erected the largest prototype of a Fresnel collector, with a collector width of 24 m and a reflector area of 2500 m². The next step should be a pilot plant to demonstrate the technology in a large scale system under commercial operational conditions. Most convenient and cost-effective would be a plug-in solution of a Fresnel collector connected to an existing power plant. The Australian company Solar Heat and Power is planning a 24,000 m² pilot CLFR array for attachment to a coal-fired station in late 2003.

To date, as a result of the regulatory framework prevailing in California during implementation of the SEGS plants (see below), all existing commercial parabolic trough plants use a steam cycle, with a back-up natural gas-fired capability to supplement the solar output during periods of low radiation, up to an annual maximum of 25% of primary thermal heat input. From SEGS-II onwards, however, the SEGS plants can be operated in solar only mode. Parabolic trough plants can be built in unit sizes up to 200 MW.

Current Projects

Due to its commercial maturity, parabolic trough technology is the preferred choice of industrial bidders and investors in proposed utility scale projects in Europe and the South-western United States (although only pure solar operation is eligible under the renewable electricity incentive programmes of Spain, Greece and Italy), while in the proposed Integrated Solar Combined Cycle Systems being sponsored by the Global Environment Facility in India, Mexico, Morocco and Egypt. The following utility scale parabolic trough projects are currently being planned:

Spain

Following introduction of a solar thermal incentive premium of 12€cents/kWh in Spain in September 2002, Solar Millennium AG completed land acquisition and planning for the first two 50 MW AndaSol plants in Andalusia. With 510,120 m² of solar field and 6 hours of storage capacity, each plant will feed an annual 157 GWh of solar electricity into the Spanish grid and have an annual efficiency of 14.7%. The EPC-specification documents for the power block have been prepared by Fichtner Solar GmbH. Detailed engineering and permitting documents are being prepared by the German company Flagsol GmbH. The AndaSol-1 project has been granted €5 million financial support from the 5th Framework Programme of the European Union. At the same time, the Spanish EHN group and Duke Solar (now Solargenix Energy) are pursuing a 15 MW parabolic trough project in the region of Navarra.

Egypt

The Egyptian New and Renewable Energy Agency published a Request for Pre-qualification Statements in March 2000 for a 120 – 140 MW Integrated Solar Combined Cycle System to be built near Kuraymat, 100km south of Cairo, in which the choice of solar technology was left to the bidders. Eighteen of the 20 responding consortia offered parabolic trough technology. In August 2003 the NREA changed the approach to implementation by an EPC cum O&M consortium and assigned Fichtner Solar GmbH with the preparation of the conceptual design and the request for Proposal (RfP).

The California SEGS Power Plants

Constructed over the period 1984-91, and ranging in size from 14 MWe up to 80 MWe, the nine separate parabolic trough systems in the Californian Mojave desert (with a total capacity of 354 MWe) are known collectively as the Solar Electricity Generating Systems (SEGS). For power generation they use a highly efficient steam turbine fed with steam from the solar field. The gas-fired back-up burners are used to maintain the temperature of the heat transfer fluid in hours of insufficient sunshine. However, the power purchase conditions restrict gas use to an annual maximum of 25% of the total heat input. With more than two million square meters of glass mirrors the plants have generated over 10 billion kWh of solar electricity since 1985.

The five 30HWe raised to build these plants came from private risk capital and, with increasing confidence in the maturity of the technology, from institutional investors. Although backed originally by tax incentives and attractive power purchase contracts, these have since been withdrawn, whilst a fall in fuel prices in the late 1980s led to a 40% reduction in electricity sales revenue. Nonetheless, significant cost reductions were achieved over the construction period through increased size, performance and efficiency. All nine SEGS plants are still in profitable commercial operation.

The 30 MWe SEGS plants at Kramer Junction, with an annual insolation of over 2,700 kWh/m2, have generating costs of 15 US cents/kWh during high-priced daytime slots (mainly for peak load air conditioning), including an allowance to generate up to 25% of the annual output by supplementary natural gas firing. The equivalent pure solar costs would be 20 US cents/ kWh. The 80 MWe SEGS plants at Harper Lake, with the same annual insolation, have generating costs of 12 US cents/kWh. The equivalent pure solar costs would be 16 US cents/ kWh).

In terms of efficiency, the SEGS plants have achieved daily solar-to-electric efficiencies close to 20%, and peak efficiencies up to 21.5%. The annual plant availability has exceeded 98% and the collector field availability more than 99%. The five plants at Kramer Junction have achieved a 30% reduction in operation and maintenance costs between 1995 and 2000.

The improvements gained in the performance of the Kramer Junction SEGS plants have been the result of successful adaptations to the design of the solar collectors, absorber tubes and system integration by a number of companies. Ongoing development work continues in Europe and the US to further reduce costs in a number of areas, including improvements in the collector field, receiver tubes, mirrors and thermal storage.

Solar Costs

"For the current state of technology and at very good sites a solar kWh can be generated for about 15 US cents/kWh. This generation cost will be reduced when more projects will be implemented. The CSP industry anticipates reducing solar power generation costs by 20%, once 400 MWe of new solar capacity has been implemented. Upon reaching 5,000 MWe of new solar capacity, solar electricity generation cost will be fully competitive with fossil-based grid-connected power generation costs."

Declaration of Berlin, June 2002

Mexico
Mexico's Comisión Federal de Electricidad issued a Request for Proposals in March 2002 for a 198 – 242 MW gas-fired combined cycle plant with an optional integrated parabolic trough solar field of at least 25 MW electrical output under design conditions. The additional solar costs will be covered by a grant from the Global Environment Facility.

India
Rajasthan Renewable Energy Corporation published a Request for Proposals in June 2002 for a combined cycle system of about 140 MW incorporating a parabolic trough solar thermal field with a collection area of 220,000 m^2 to support a 35 to 40 MWe solar thermal plant. The additional solar costs will be covered by soft loans from the German KfW bank and grants from India, Rajasthan and the Global Environment Facility. Fichtner Solar GmbH has prepared the initial feasibility study, the conceptual design as well as the Request for Proposal for an EPC cum O&M contract.

The collector size should be changed to: 220 000 m^2.

Morocco
A grant of US$ 50 million from the Global Environment Facility has been offered to Morocco for a 230 MW ISCC project with 30-50 MW equivalent solar capacity. Fichtner Solar GmbH is now preparing for the national electricity utility ONE the Request for Proposals, with the choice of technology being left to the bidding investors.

Iran
The government of Iran is interested in the implementation of a 200,000-400,000 m^2 parabolic trough field in a 300 MW natural gas-fired combined cycle plant in the Luth desert in the area of Yazd. A detailed feasibility study had been prepared jointly by Fichtner Solar GmbH and Flagsol (formally Pilkington Solar International GmbH).

Israel
The Israeli Ministry of National Infrastructure, which is also responsible for the energy sector, decided in November 2001 to introduce concentrating solar power as a strategic ingredient in the Israel electricity market from 2005, with an initial parabolic trough plant of 100 MWe. The Israeli company Solel is currently preparing the engineering side of this project.

Italy
In 2001, the Italian parliament allocated €110 million for a CSP development and demonstration programme. Since then, several parabolic trough plants have started development.

United States
Sierra Pacific Resources announced in January 2003 that its two Nevada-based utility subsidiaries had signed long-term contracts with Solargenix Energy (formerly Duke Solar Energy) to supply 50 MW of electricity generated by solar power using parabolic troughs from a plant to be located in Eldorado Valley, near Boulder City, Nevada.

Algeria
This is the most recent country to have announced interest in implementing an Integrated Solar Combined Cycle System with parabolic trough technology.

Australia
A 35 MWe CLFR-based array will be used for pre-heating steam at the large coal-fired 2,000 MW Liddell power station in Hunter Valley, New South Wales. Rather than being a coal replacement technology, this system increases the electrical output for a given coal input. The use of existing infrastructure reduces costs compared to a stand-alone plant. Promoters Solar Heat and Power expect construction to start during 2003.

Cost Trends
The installed capital costs of the Californian SEGS Rankine-cycle trough systems with on-peak power operation fell from US$ 4,000/kWe to under US$ 3,000/kWe between 1984 and 1991, mainly due to the increase in size from 30 to 80 MWe units and series experience.

The investment cost of parabolic trough fields has dropped to €210/m^2 for enhanced collectors like the SKALET Euro Trough design with large solar fields and to €130-110/m^2 for high production runs in the long term. A 15% reduction in US/European price levels can be expected in developing countries due to lower labour costs.

Table 3: Cost Reductions in Parabolic Trough Solar Thermal Power Plants

	Near-Term (Next Plant	Near-Term (Next Plant	Near-Term (Next Plant	Mid-Term (~ 5 Years)	Long-Term (~ 10 Years)	Long-Term (~ 10 Years)
Power Cycle	Rankine	Rankine	ISCC	Rankine	Rankine	Rankine
Solar Field (,000 m²)	193	1210	183	1151	1046	1939
Storage (hours)	0	0	0	0	0	9-12
Solar Capacity (MW)	30	200	30	200	200	200
Total Capacity (MW)	30	200	130	200	200	200
Solar Capacity Factor	25%	25%	25%	25%	25%	50%
Annual Solar Efficiency	12.5%	13.3%	13.7%	14.0%	16.2%	16.6%
Capital Cost ($/kW)						
US Plant	3500	2400	3100	2100	1800	2500
International	3000	2000	2600	1750	1600	2100
O& M Cost ($/kWh)	0.023	0.011	0.011	0.009	0.007	0.005
Solar LEC ($/kWh)	0.166	0.101	0.148	0.080	0.060	0.061

According to a World Bank assessment of the US/European solar thermal power plant market ("Cost Reduction Study for Solar Thermal Power Plants", Final Report, May 1999), the installed capital costs of near-term trough plants are expected to be in the range of €3,500-2,440/kWe for 30-200 MWe Rankine-cycle (SEGS type) plants and about €1,080/kWe for 130 MWe hybrid ISCC plants with 30 MWe equivalent solar capacity. The projected total plant electricity costs range from 10 to 7 €cents/kWh for SEGS type plants and less than 7 €cents/kWh for ISCC plants.

The expected further fall in the installed capital costs of grid-connected ISCC trough plants should result in electricity costs of 6 €cents/kWh in the medium term and 5 €cents/kWh in the long term. The promising long term potential is that Rankine-cycle trough plants can compete with conventional peaking Rankine-cycle plants (coal or oil-fired) at good solar sites. The cost reduction potential of direct steam generation trough technology is even greater in the longer term. In Australia, the CLFR total plant electricity costs have been estimated to be about AU$ 0.045/kWh when used in conjunction with coal fired plant, and AU$ 0.07/kWh to AU$ 0.09/kWh as a stand-alone solar thermal plant.

Table 3 shows how substantial cost reductions could be achieved over the next five to ten years, especially for plants with the largest solar fields. Similarly, the analysis shows that projects could be built cheaper outside the developed world. In a pre-feasibility study for a plant in Brazil, for example, it was estimated that the construction cost of a 100 MW Rankine-cycle plant would be US$ 2,660/kW, 19% lower than in the US, with savings in labour, materials and to some extent equipment. A number of companies interested in building GEF projects have indicated that using local labour and manufacturing capabilities in India, Egypt, Morocco and Mexico will be key to their bidding at a low cost.

A US initiative called the Parabolic Trough Technology Roadmap, developed jointly by industry and the US Department of Energy's SunLab, identified a number of potential improvements. The initiative suggests that further cost reductions and performance increases of up to 50% are feasible for parabolic trough technology.

3. Central Receiver/Solar Tower Systems

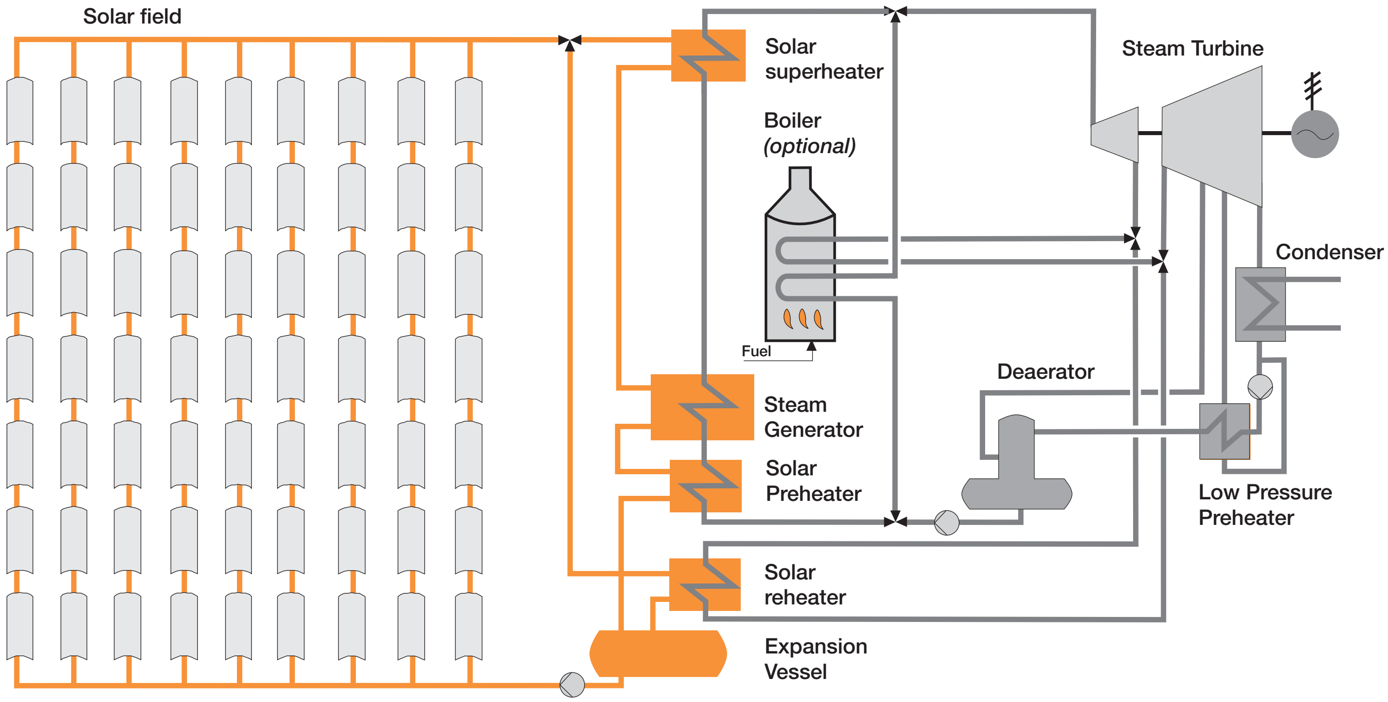
Technology Developments

Concentrating sunlight by up to 600 times, solar tower technology has the potential advantage of delivering high temperature solar heat in utility scale quantities at temperatures from 500°C for steam cycles and beyond 1,000°C for gas turbines and combined cycles power plants.

The technical feasibility of central receiver technology was first proved during the 1980s by the operation of six research power plants ranging from 1 to 5 MWe capacity, and by one demonstration plant with a water/steam receiver, connected to the Southern California grid. Their total net electrical capacity was 21.5 MWe, with an installed heliostat mirror area of about 160,000 m². Commercial solar tower operation has still to be demonstrated, however. After an intermediate scaling up to 30 MW systems, solar tower developers now feel confident that grid-connected tower power plants can be built up to a capacity of 200 MWe solar-only units. Conceptual designs of units with more than 100 MWe have also been drawn up for ISCC plants.

For gas turbine operation, the air to be heated must first pass through a pressurised solar receiver with a solar window. Combined cycle power plants using this method will require

Figure 8: Parabolic Trough Power Plant with Hot and Cold Tank Thermal Storage System and Oil Steam Generator



30% less collector area than equivalent steam cycles. At present, a first prototype to demonstrate this concept is being built as part of the European SOLGATE project, with three receiver units coupled to a 250kW gas turbine.

Various central receiver heat transfer media have been investigated, including water/steam, liquid sodium, molten salt and ambient air. The 10 MWe Solar One pilot demonstration plant operated in California from 1982 to 1988 with steam as the heat transfer medium. Rebuilt as the 10 MWe Solar Two plant, it was successfully operated from 1997 to 1999 with a molten salt-in-tube receiver system and a two-tank molten salt storage system, accumulating several thousand hours of operating experience and delivering power to the grid on a regular basis.

As already explained, the molten salt storage system allows solar energy to be collected during daylight hours and dispatched as high value electric power at night or when demanded by the utility. In the sunbelt regions of the US a plant could therefore meet demand for the whole of the summer peak periods (afternoon, due to air conditioners, and evening). In developing countries, this storage capability could be even more important, with peak times occurring only during the evening.

Today, the most promising storage systems are considered to be the European volumetric air technology and the US molten salt-in-tube technology. The latter is now close to being commercially viable, and a joint venture between Ghersa (Spain) and Bechtel (US), with further subcontracting work from Boeing (US), is hoping to build the first commercial central receiver plant with the help of EU and Spanish grants. This proposed 15 MWe Solar Tres plant in Cordoba, Spain will utilise a 16 hour molten salt storage system to run on a 24-hour basis.

The European system involves irradiating fine wire mesh or ceramic foam structures, transferring the energy by convection at a temperature range of 700-1,200°C. Tests conducted in the joint German/Spanish Phoebus project between 1993 and 1995 with a German 2.5 MWth pilot plant demonstrated the feasibility of the volumetric air receiver system concept with a ceramic energy storage system. Spanish and German companies are now involved in commercialising this technology through the Planta Solar (PS10) 10 MWe project near Seville.

As with parabolic troughs, efforts are underway to develop commercial central receiver plants using solar/ fossil fuel hybrid systems, especially in the ISCC mode. One concept undergoing demonstration in Israel involves a secondary reflector on the tower top which directs solar energy to ground level for collection in a high temperature air receiver for use in a gas turbine. Coupling the output of the high temperature solar system to a gas turbine could allow a

higher efficiency than current steam turbine applications, as well as faster start-up times, lower installation and operating expenses, and perhaps a smaller, more modular system.

Since heliostats represent the largest single capital investment in a central receiver plant, efforts continue to improve their design with better optical properties, lighter structure and better control. Activities include the 150 m^2 heliostat developed by Advanced Thermal Systems (USA), the 170 m^2 heliostat developed by Science Applications International Corporation (USA), the 150 m^2 stretched-membrane ASM-150 heliostat from Steinmüller (Germany), and the 100 m^2 glass/metal GM-100 heliostat from Spain. Initiatives to develop low cost manufacturing techniques for early commercial low volume builds are also underway, whilst prices for manufacture in a developing country could be roughly 15% below US/European levels. As with many solar thermal components, the price should fall significantly with economies of scale in manufacture.

Although central receiver plants are considered to be further from commercialisation than parabolic trough systems, solar towers have good longer term prospects for high conversion efficiencies. Meanwhile, more scaled-up demonstration projects are needed.

Current Projects

Spain

The first two commercial solar tower plants in the 10-15 MW range are currently being planned within the Spanish feed-in-law for CSP. The Spanish Abengoa group is promoting a 10 MW solar tower with air receiver technology, known as PS-10. With a 90,000 m^2 heliostat field, the PS-10 plant will feed an annual 19.2 GWh of solar electricity into the grid and will achieve a 10.5% annual net efficiency. In spite of the high receiver temperatures, the system is handicapped by its small turbine size. The Spanish Ghersa group, together with its US partners Boeing and Bechtel, is planning a 15 MW molten salt system with 16 hours of storage based on the Californian Solar Two model. With its 240,000 m^2 heliostat field the Solar Tres plant will feed an estimated annual 80 GWh of electricity into the Spanish grid. Both the PS-10 and Solar Tres projects have each been granted €5 million in financial support from the 5th Framework R&D Programme of the European Union.

South Africa

The South African national electricity utility ESKOM has taken a strategic decision to assess the feasibility of molten salt solar tower technology within its programme on bulk renewable electricity, considering a possible 100 MW demonstration plant.

Cost Trends

Installed capital costs for central receiver pilot plants are still too high, and no electricity generation costs for commercially scaled-up plants are yet available. Central receiver plants can take credit, however, for their potential use with high temperature energy storage systems. This will increase plant performance and capacity factor, although not necessarily reduce electricity costs.

Promoters of new near-term tower projects in Spain, such as the 10 MW PS-10 plant with 3 hours of storage, have indicated their installed plant capital costs to be roughly €2,700/kWe, with Rankine-cycle turbines and a small energy storage system, and with the range of predicted total plant electricity costs from 20 to 14 €cents/kWh. The total capital cost for the 15 MW Solar Tres plant, with 16 hours of storage, is estimated to be €84 million, with annual operating costs of about €2 million.

For installing the heliostat field, expected costs range from €180 to €250/m^2 for small production runs in the USA, and from €140 to €220/m^2 in Europe. A 15% discount on the US/ European price level can be projected for developing countries due to lower labour costs. Heliostat field costs are expected to drop below €100/m^2 at high production runs in the long term.

In the future, central receiver plant projects will benefit from similar cost reductions to those expected from parabolic trough plants. The expected evolution of total electricity costs, according to the World Bank, is that they will drop to 8 to 7 €cents/kWh in the medium term (100 MWe Rankine-cycle plant or 100 MWe ISCC, both with storage) and to 5 €cents/kWh in the long term period (200 MWe Rankine-cycle plant with storage) for high insolation sites with an annual DNI of more than 2,700kWh/m^2.

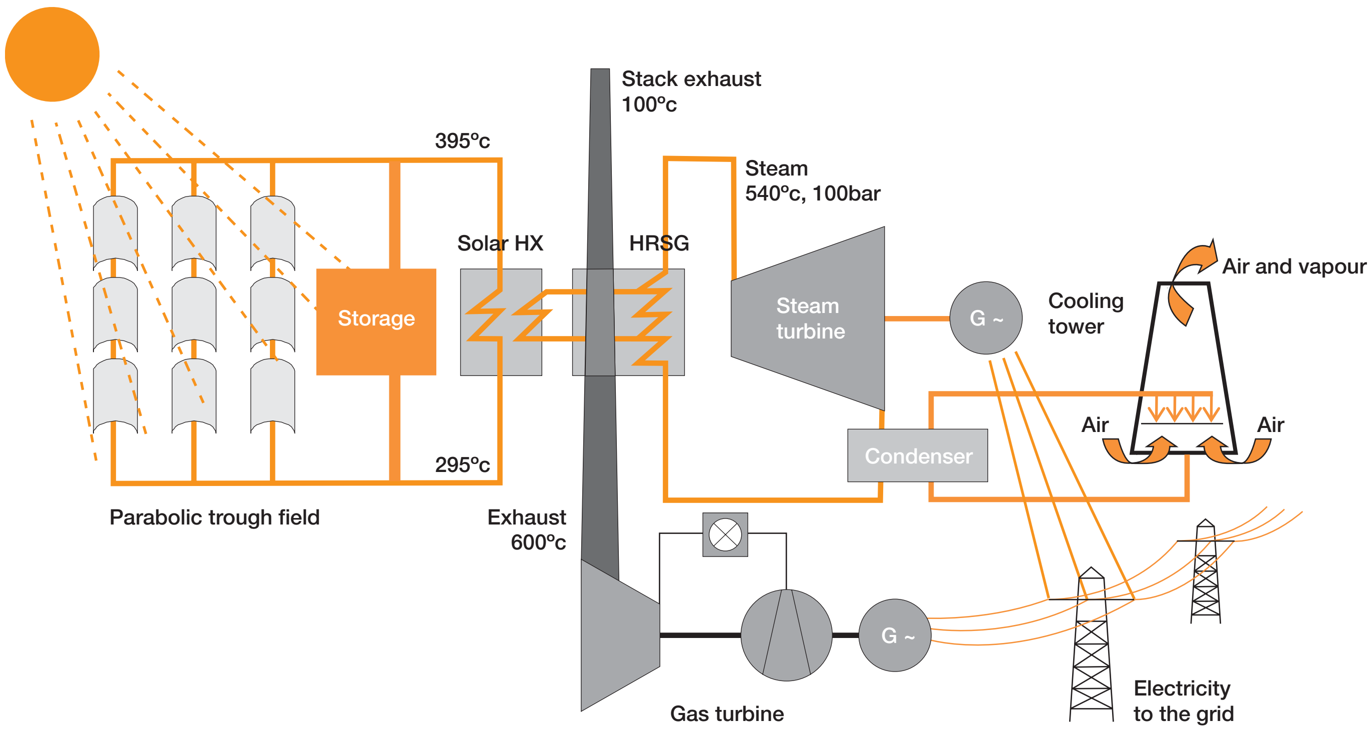
4. Parabolic Dish Engines

Technology Status

Parabolic dish concentrators are comparatively small units with a motor-generator at the focal point of the reflector. Overall size typically ranges from 5 to 15 meters in diameter and 5 to 50kW of power output. Like all concentrating systems, they can be additionally powered by natural gas or biogas, providing firm capacity at any time.

Due to their ideal point focusing parabolic optics and their dual axis tracking control, dish collectors achieve the highest solar flux concentration, and therefore the highest performance of all concentrator types. For economic reasons, systems are currently restricted to unit capacities of about 25kWe, but multiple dish arrays can be used in order to accumulate the power output

Figure 9: Integrated Solar/Combined Cycle System (ISCC)



upwards to the MWe range. Because of its size, the future for dish technology lies primarily in decentralised power supply and remote, stand-alone power systems.

Several small off-grid power systems with parabolic dish units in the range of 5 to 50kWe have proved their technical feasibility in experimental projects around the world since the 1970s. Dish/Stirling engine systems in particular have an excellent potential for high conversion efficiencies because of the high process temperatures in the engine. The record energy yield so far has been from a 25kWe US dish/Stirling system with a solar-to-electric peas efficiency of 30%.

Dish/engine prototypes which have successfully operated over the last 10 years include 7 to 25kW units developed in the United States by Advanco, the McDonnell Douglas Corporation, the Cummins Engine Company and others, although large scale deployment has not yet occurred. In Spain, six units with a 9 to 10kW rating are currently operating successfully. These were developed by the German company Schlaich, Bergermann and Partners (SBP) in collaboration with Mero (suppliers of the collector system) and SOLO Kleinmotoren (Stirling engine). Three of these dishes have been continually operated with great success since 1992, accumulating more than 30,000 hours of operating experience.

The new EuroDish development, supported by the European Union, will advance this technology further. At the same time, two industrial teams working in the United States – Stirling Energy Systems/Boeing Company and Science Applications International Corporation/STM Corp – have installed several second generation 25kW dish/Stirling prototypes for extended testing and evaluation. Finally, WG Associates have demonstrated the first unattended, remote operation of an advanced technology 10kW dish/Stirling prototype. Turnkey dish/Stirling systems, with the option of hybrid operation with gas combustion, are currently under development and expected to be available soon for initial demonstration projects.

Current Projects

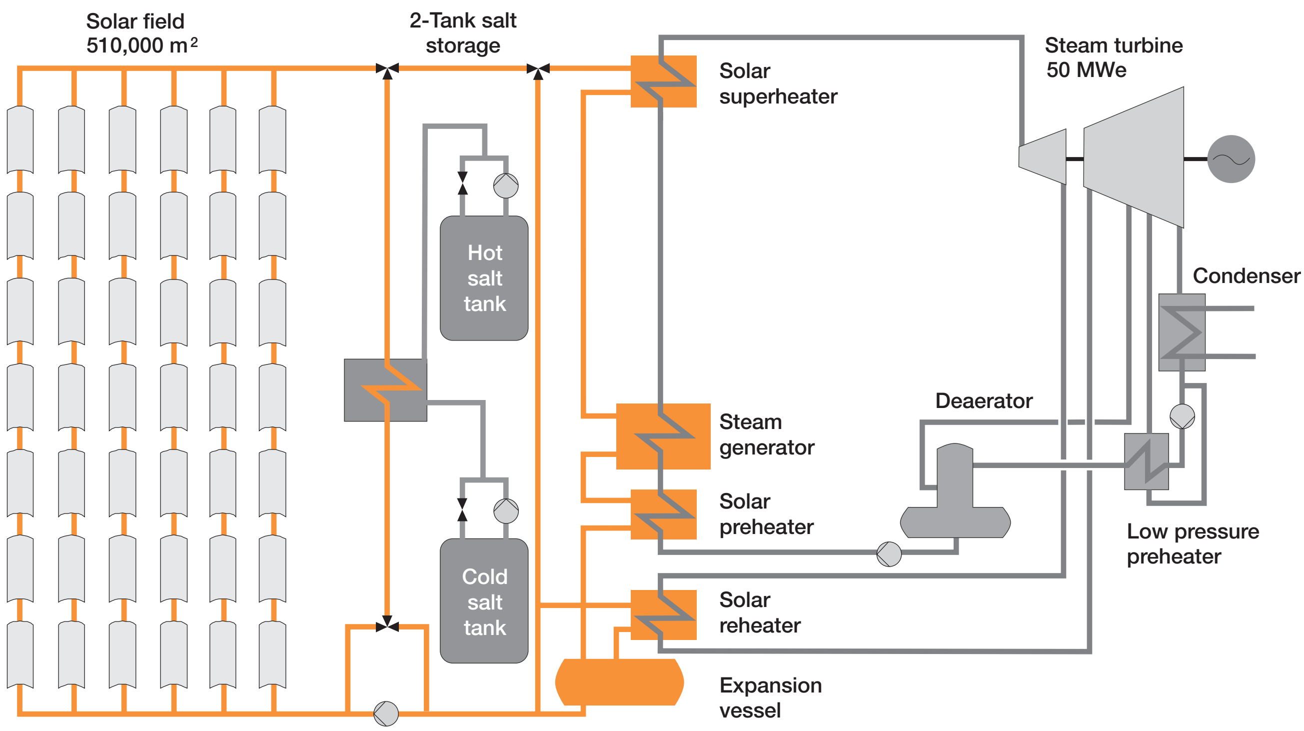
United States

In July 2002, the US Department of Energy's Concentrating Solar Power Program issued a request for proposals for a project to deploy 1 MW or more of dish-engine systems at a site in Southern Nevada. This field validation scheme is known as the Nevada Solar Dish Power Project.

Europe

A demonstration project at the PSA in Spain involves six German dish/Stirling pre-commercial units with 9 to 10kWe capacity. Over 30,000 operating hours have been accumulated

Figure 10: AndaSol Configuration diagramatic scheme of the solar field, storage system and steam cycle at the AndaSol-1 project, southern Spain



by the earliest system. Promising advanced heat pipe receivers and Stirling engines are currently under development with the aim of reducing costs.

Australia

The first 400 m² pilot "big dish" project with a capacity of up to 150kWth has been undergoing testing at the Australian National University since 1994. An alternative to the small unit philosophy, this is designed for power generation using a 50kWe steam engine generator or for co-generation applications with solar steam production.

Cost Trends

The cost trend for dish collectors has already shown a sharp reduction, from €1,250/m2 in 1982 (40 m² array, Shenandoah, USA) to €150/m2 in 1992 (44 m² array, German SBP stretched-membrane dish).

Overall installed plant capital costs for a first stand-alone 9 to 10kWe dish/Stirling unit currently range from €10,000 to €14,000/kWe. If a production run of 100 units per year was achieved, this could fall to €7,100/kWe. In terms of electricity costs, an attainable near-term goal is a figure of less than 15 €cents/kWh. In the medium to long term, with series production, dish/Stirling systems are expected to see drastically decreasing installed system costs.

The goal of the European EuroDish project is for a reduction from €7,100/kWe, at a production rate of 100 units per year, to €3,700/kWe (1,000 units/year) to €2,400/kWe (3,000 units/year) and eventually to €1,600/kWe (10,000 units/ year). Prices are unlikely to fall below that level due to the inherently highly modular technology. Medium to long-term installed dish collector costs are predicted to be in the range of €125 to €105/m² for high production rates. Advanced dish/Stirling systems are expected to compete in the medium to long term with similar sized diesel generator units at sunny remote sites such as islands.

A 1999 US study on the utility market potential for dish systems concluded that costs will need to fall to between US$ 2,000 and US$ 1,200/kWe in order to achieve any significant market uptake. For initial market sectors, such as distributed generation, reliability and O&M costs will be crucial factors. Parabolic dish system commercialisation may well be helped by hybrid operation, although this presents a greater challenge with Stirling engines. Gas turbine based systems may present a more efficient alternative.

5. Future Trends and Costs

Two broad pathways have opened up for large scale delivery of electricity using solar thermal power. One is to combine the solar collection and heat transfer process with a conventional power plant. The most favoured current combination is the Integrated Solar Combined Cycle System (ISCC).

Essentially, the ISCC system uses the CSP element as a solar boiler to supplement the waste heat from a gas turbine in order to augment power generation in the steam Rankine bottoming cycle (see Figure 9). Although yet to be built, studies have shown that efficiency would be improved and operating costs reduced, cutting the overall cost of solar thermal power by as much as 22% compared with a conventional SEGS plant (25% fossil) of similar size.

These systems could still have an equivalent solar capacity of 30 to 40 MWe, and promise to be extremely attractive as a way of introducing the technology to the market. They would also have the advantage of allowing mid-load to base-load operation, as opposed to the peak load use which is the primary market of the SEGS plants.

Increasing attention is being paid, however, to entirely solar-based systems. This is reflected, for instance, in the incentive programmes currently available in both Spain and Nevada, USA, for which only 100% solar operation is eligible, whilst the UN and the World Bank-backed Global Environment Facility, an important source of funding, is focussing on supporting hybrid ISCC systems.

The market for 100% solar only operation will broaden still further with the use of thermal storage as a way of storing the sun's heat until required for power generation. A recent study, part of the USA Trough Initiative, evaluated several thermal storage concepts, with the preferred design using molten salts as the storage medium, as already chosen for the Solar Two pilot plant in California. Such a storage system will also be implemented in the first 50 MW AndaSol plant now being planned in southern Spain.

Solar energy collected by the solar field during the day will be stored in the storage system and then dispatched after sunset. To charge the storage system, the salt is heated up to approx. 384°C, to discharge the system, it is cooled down again to about 291°C. At both temperatures the salt is in a liquid state. Cold and hot salt are stored in separate tanks, giving the system its "two-tank" label. A thermal storage system with separate cold and hot tanks has the advantage that charging and discharging occur at constant temperatures.

Figure 10 shows a process flow diagram of the AndaSol-1 plant, with a two-tank molten salt storage system. In this configuration, hot thermal fluid from the solar field is diverted to a heat exchanger, where its thermal energy passes to the salt flow arriving from the cold tank. This heats up and accumulates in the hot tank. During the night or at times of reduced radiation, the charging process is reversed, and salt from the hot tank is pumped to the heat exchanger, where the salt returns its thermal energy to the cold thermal fluid. The thermal fluid heats up to keep producing steam for the turbine, while the cooled salt accumulates again in the cold tank.

In terms of costs, commercial experience so far has been exclusively from parabolic trough systems, such as the Californian SEGS. For current trough systems with 100% solar operation, costs are in the range of 12-15 US cents/kWh. This could fall to about 8.5 US cents/kWh after 2006 for projects in southern Europe or the Sahara Desert.

6. Environmental Benefits

Solar thermal power involves none of the polluting emissions or environmental safety concerns associated with conventional generation technologies. There is no pollution in the form of exhaust fumes or noise during operation. Decommissioning a system is unproblematic.

Most importantly, in terms of the wider environment, there are no emissions during the operation of a solar thermal plant of carbon dioxide – the main gas responsible for global climate change (see panel "Climate Change and Fuel Choices"). Although indirect emissions of CO_2 occur at other stages of the life-cycle (construction and decommissioning), these are significantly lower than the avoided emissions.

Solar power can therefore make a substantial contribution towards international commitments to reduce the steady increase in the level of greenhouse gases and their contribution to climate change (see panel "The Climate Change Imperative").

Climate Change and Fuel Choices

Carbon dioxide is responsible for more than 50% of the man-made greenhouse effect, making it the most important contributor to climate change. It is produced mainly by the burning of fossil fuels. Natural gas is the least dirty of the fossil fuels because it produces roughly half the quantity of carbon dioxide as coal, and less of other polluting gases. Nuclear power produces very little CO_2, but has other major pollution problems associated with its operation and waste products.

The consequences of climate change already apparent today include:

- The proportion of CO_2 in the atmosphere has risen by about 30% since industrialisation began.
- The number of natural disasters has trebled since the 1960s. The resulting economic damage has increased by a factor of 8.5.
- The seven warmest years over the last 130 were recorded during the past 11 years.
- The mass of inland glaciers has been halved since industrialisation began.
- Rainfall and temperate in northern latitudes has increased by 5% since 1950. Average wind speed has also increased significantly.
- Sea level has risen by 10-20 centimetres in the last 100 years, 9-12 cm of this in the last fifty.

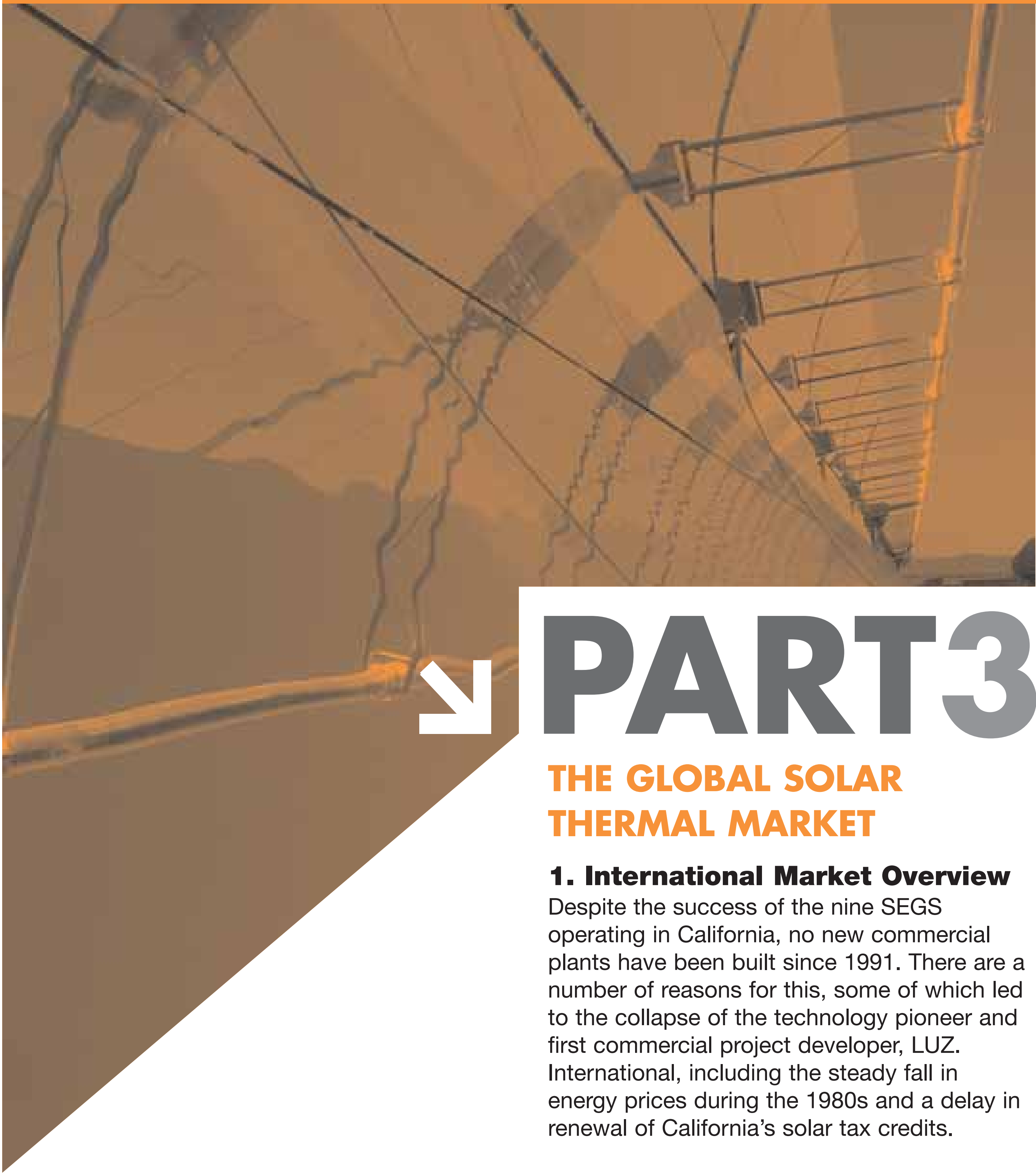
Because of the time lapse between emissions and their effects, the full consequences of developing climate change have still to emerge over the coming decades, bringing increased danger to the stability of the world's ecosystems, economy and lifestyle.

To effectively stem the greenhouse effect, emissions of CO_2 must therefore be greatly reduced. Scientists believe that only a quarter of the fossil fuel reserves which can be developed commercially today ought to be allowed to be burned if ecosystems are not to go beyond the point at which they are able to adapt.

The Climate Change Imperative

The growing threat of global climate change resulting from the build-up of greenhouse gases in the earth's atmosphere has forced national and international bodies into action. Starting with the agreement of the UN Framework Convention on Climate Change at the Rio Earth Summit in 1992 a series of targets has been set for reducing greenhouse gas emissions and has prompted national and regional measures for increasing the take-up of renewable energy, including solar power.

- The 1997 **Kyoto Protocol**, brokered by the United Nations, committed the world's developed countries to reduce their emissions of greenhouse gases by an average of 5% from their 1990 level. Most of the industrialised nations have taken up this challenge.
- The **European Union** has set a target to double the proportion of energy in the 15 member states provided from renewable sources. The aim is for 12% renewable energy by 2010. A specific target for solar thermal power plants is under discussion.



PART3

THE GLOBAL SOLAR THERMAL MARKET

1. International Market Overview

Despite the success of the nine SEGS operating in California, no new commercial plants have been built since 1991. There are a number of reasons for this, some of which led to the collapse of the technology pioneer and first commercial project developer, LUZ. International, including the steady fall in energy prices during the 1980s and a delay in renewal of California's solar tax credits.

Progress on developing the market has been further hampered by the worldwide liberalisation of the electricity sector. This has significantly affected the viability of large, capital intensive generating plants. Lack of either firm market prices or long-term power purchase agreements has increased uncertainty and shortened the depreciation times for capital investments. The result has been a shift towards low capital cost plant like gas fired combined cycles, with quick build times, installed costs falling to below $ 500/kW and generation efficiencies of over 50%. In this climate, solar thermal plant will need to scale up to larger unit capacities in order to compete successfully for the generation of bulk electricity.

Against this trend has been the growing pressure from international agreements, often translated into national targets and support mechanisms, for the accelerated development of power systems which do not pollute the environment and produce little or no carbon dioxide emissions. But although 'green power markets' have been advancing in both Europe and North America, with premiums paid by customers or state funds for electricity generated from renewable sources, solar thermal has generally not been included in the list of qualifying technologies.

Even so, new opportunities are opening up as a result of the global search for clean energy solutions. Some of the main sponsors of energy investments in the developing world, including the UN and the World Bank's Global Environment Facility (GEF), the German Kreditanstalt für Wiederaufbau (KfW) and the European Investment Bank (EIB), have recently been convinced of the environmental promise and economic prospects for solar thermal. Funding has also been made available for demonstration and commercialisation projects through the European Union's 5th Framework Programme, with particular interest in the sunbelt northern Mediterranean region. Projects are already planned in Spain, Italy and Greece.

Other national initiatives will significantly advance solar thermal development. Spain, for example, as part of its CO_2 emissions limitation target, intends to install 200 MWe of capacity by 2010. Supported by the Spanish national pricing mechanism (see below), this could generate an annual power production of 628 GWh. Similarly, the Italian government's ENEA energy/environment agency has produced a strategic plan for mass development of solar energy. This recommends bringing thermal-electric solar technology to the market within three years. Commercial ventures would be encouraged through financial incentives to show the advantages of large scale schemes and reduce costs to competitive levels.

Bulk power transmission from high insolation sites (up to 2,750kWh/m^2) in southern Mediterranean countries, including Algeria, Libya, Egypt, Morocco and Tunisia, may also offer opportunities for European utilities to finance solar plants for electricity consumption in Europe.

In the United States, the Solar Energy Industry Association (SEIA) and the Department of Energy have helped create Solar Enterprise Zones in sunbelt states. These zones are aimed at assisting private companies to develop large scale solar electric projects of 1,000 MWe over a seven year period. Projects in Nevada (50 MW) and Arizona (10-30 MWe) are in the planning stage and will benefit both from Renewable Portfolio Standards, which require a certain percentage of electricity supply to come from renewable sources, and green pricing. Interest from the Australian government has resulted in Renewable Energy Showcase Grants being provided for two projects being integrated with existing coal-fired plants.

How Spain Supports Solar Thermal Power

Law 54/1997, which introduced competition into the Spanish electricity sector, also made this principle compatible with the achievement of other objectives such as improving energy efficiency, reducing consumption and protecting the environment, all vital to meet Spanish commitments to reduce greenhouse gases. The Spanish Royal Decree 2818 of 1998 followed this by establishing a special legal framework which allowed for favourable treatment towards energy systems which contributed most efficiently to those objectives. This decree established specific premiums for the electricity generated from different renewable sources, all of them (with the exception of solar PV) of up to 90% of the average electricity price.

In 2000 a further national law allowed for an incentive premium payment to exceed 90% of the average electricity price to be paid for the output from solar thermal installations. The premium for solar thermal plants is currently set at 12 €cents/kWh. This and parallel incentives for other renewable energy sources have been established in order to enable them to contribute to a target for a minimum of 12% of Spanish energy demand to be supplied by renewables in the year 2010.

In the "Plan for Promotion of Renewable Energies in Spain", approved by the Council of Ministers in December 1999, the installation of 200 MW of solar thermal plants is planned by 2010.

Table 4: Solar Thermal Projects in Development

Name/ Location	Total Capacity (MWe)	Solar Capacity (MWe)	Cycle	Companies/ Funding
Parabolic Troughs				
Algeria	140	35	ISCC	New Energy Algeria
Stanwell Power Station, Queensland, Australia	1440	35	Compact Linear Fresnel Reflector	Austa Energy & Stanwell Corp + Australian government grant
Kuraymat, Egypt	127	29	ISCC	Open for IPP bids GEF grant
THESEUS – Crete, Greece	50	50	Steam cycle	Solar Millennium Fichtner Solar, OADYK, EU FP5 grant
Mathania, India	140	35	ISCC	Open for IPP bids GEF grant, KfW loan
Israel	100	100	Steam Cycle with hybrid fossil firing	Israeli Ministry of National Infrastructure Solel
Italy	40	40	Steam Cycle	ENEA
Baja California Norte, Mexico	300	29	ISCC	Open for IPP bids GEF grant
Ain Beni Mathar, Morocco	230	26	ISCC	Open for IPP bids GEF grant
ANDASOL1 and ANDASOL-2 – Granada Province, Spain	2x50	2x50	Steam Cycle with 6h storage for solar only operation	Solar Millennium Group Spanish premium EU FP5 grant
Navarra, Spain	15	15	SEGS	EHN and Duke Solar Spanish premium Navarra Government's fiscal allowances
Nevada, USA	50	50	SEGS	Solargenix (formerly Duke Solar) Solar Port ofolio – Nevada
Central Receivers				
Planta Solar (PS-10), Seville, Spain	10	10	Volumetric air receiver/ small energy storage	Abengoa (Spain) group EU/ Spanish premium grants/ subsidy
Solar Tres, Cordoba, Spain	15	15	Molten-salt/ direct-steam with 12-16h storage solar only	Ghersa (Spain) and Bechtel/ Boeing (US) EU/ Spanish premium grant/ subsidy
Parabolic Dishes				
SunCal 2000, Huntingdon Beach, California, USA	0.4	0.4	8-dish/ Stirling system	Stirling Energy Systems

In other countries with a large solar thermal potential, especially in the Middle East, Southern Africa and South America, interest is being shown by both governments and national utilities. The attraction comes both from the availability of post-Kyoto clean energy funding and, for countries with oil-based electricity production, the desire to exploit indigenous renewable resources. Apart from the four countries which have received GEF grants (see Table 5), a number of technology assessments and feasibility studies have been carried out in Brazil, South Africa, Namibia, Jordan, Malta and Iran. Many of these countries are currently undergoing electricity sector reform, in the process encouraging independent power producers, seen as the most appropriate vehicle for solar thermal projects.

These factors have led to recent but significant interest in constructing plants in the sunbelt regions from private sector turnkey suppliers. In addition, interest rates and capital costs have drastically fallen worldwide, increasing the viability of capital intensive renewable projects.

Overall, it is clear that parabolic trough plants are the most economic and most mature solar thermal technology available today, although there are still significant areas for improvement and cost cutting. Central receivers, with low cost and efficient thermal storage, promise to offer dispatchable, high capacity factor solar-only plants in the near future, and are very close to commercialisation. Whilst the modular nature of parabolic dish systems will allow them to be used in smaller high value and off-grid remote applications for deployment in the medium to long term, further development and field testing is still needed, but with significant potential for cost cutting through mass production.

Upscaling of the size of projects will also produce economies of scale. Studies have shown that doubling the size of a plant reduces the capital cost by approximately 12-14%, both through increased manufacturing volume and reduced O& M costs. A number of projects are now in various stages of development (see Table 4) which, if successful, will give valuable learning experience and a clear indication of the potential for cost reduction in the next generation.

2. Market Breakthrough: The Race to be First

India

After many years of planning, a 140 MW ISCC plant using parabolic trough collectors is now scheduled to be constructed at Mathania village near Jodhpur in Rajasthan, north-west India. Funding has come from a mixture of development agency (GEF and KfW) and state finance. Unlike other GEF supported projects, which are IPPs, the plant is being commissioned by the Rajasthan State Power Corporation.

The technical feasibility of a 35 MW demonstration project was first established in the early 1990s by German engineering consultants Fichtner, with assistance from the KfW. Following a full feasibility study completed in 1995 by Engineers India Ltd, EIL and Fichtner came up with the option of integrating the solar thermal unit with a fossil fuel based combined cycle power plant with a total capacity of 140 MW. The cost was estimated at US$ 200 million.

Eventually, an agreement was reached between the World Bank/GEF and the German KfW development bank to co-fund the project. The GEF commitment is US$ 49 million, KfW's a US$ 150 million loan, whilst the Indian government will contribute about $10 million.

Morocco

This project has been developing rapidly following a four year pre-feasibility study by Pilkington Solar International. Funded by the EU, this provided an economic analysis of 11 designs at different sites.

The eventual design involves the construction and operation of a solar/fossil fuel hybrid station of around 230 MW, with the site expected to be Ain Beni Mathar, in the north-eastern Jerada province. A parabolic trough collector field will be integrated with a natural gas-fired combined cycle plant, and sited close to the new gas pipeline from Algeria to Spain.

The Moroccan state utility Office National de l'Electricite has assigned Fichtner Solar to conduct the bidding, and negotiations of the power purchase, fuel supply and implementation agreements with the selected Independent Power Producer (IPP). The IPP will be secured through either a Build Own Operate Transfer (BOOT) or Build Own Operate (BOO) contract, with the final design and choice of technology left relatively open. For a BOOT contract, takeover costs for the whole power plant are required, for a BOO contract a fixed tariff is needed for a number of years. The exact configuration and size will be chosen by the project sponsors after competitive bidding. This should help to ensure that the resulting design is more likely to be replicated by the private sector in the future.

Table 5: GEF Supported Solar Thermal Power Projects

Location	Expected Technology	Size	Project Type	Cost (US$)	Status – Aug 2003	Anticipated date of commissioning
Mathania, India	Natural gas-fired ISCC with Parabolic Trough solar field	140 MW Solar component: 35 MW, Solar field: 220 000 m^2	Greenfield: EPC cum O&M (5 yrs)	Total 200 million: 49.75 m (GEF); 125 m loan (KfW); 26 m (Indian and Rajasthan government)	GEF grant approved, RFP published June 2002	2006
Ain Beni Mathar, Morocco	Natural gas-fired ISCC;Technology choice left to bidder	180 MW. Solar component: 35 MW	Merchant IPP: BOO/ BOOT	Total 220 million: 43.9 m (GEF); Balance from private IPP	GEF grant approved, RFP under preparation	2006
Kuraymat, Egypt	Natural gas-fired ISCC; Technology choice left to bidder	120-140 MW. Solar component: 29 MW	Merchant IPP: BOO/ BOOT	Total 228 million 41 m (GEF); balance from private IPP; risk guarantee -IRBD	GEF grant approved	2006
Baja California Norte, Mexico	Natural gas-fired ISCC with Trough solar field	300 MW. Solar component: 29 MW	Merchant IPP: BOO	Total 178 million: 50 m (GEF); balance from private IPP	GEF grant approved; RFP published March 2002	2006

The power output from the solar-based component of this project will be monitored by expert consultants throughout the project life.

Egypt

The Egyptian government has endorsed the National Renewable Energy Authority's long-term solar thermal programme, with planning underway for two subsequent 300 MW hybrid solar/fossil plants following from an initial 137 MW plant (see Table 5). These are expected to be on line in 2007 and 2009. Key to the success of these projects so far has been the firm commitment of NREA and the support of the Egyptian Electrical Authority (EEA) and Ministry of Energy. NREA has successfully conducted a series of studies investigating the national solar thermal potential, technology capacity and industrial resources, and their implications for the national energy plan, as well as the support of international development agencies. In August 2003 the NREA changed the approach for the Kuraymat Solar Hybrid Power Plant to implementation by an EPC cum O&M consortium and has assigned Fichtner Solar GmbH with the preparation of the conceptual design and the Request for Proposal (RfP).

Mexico

A solar thermal project is being considered as part of an expansion plan proposed by the national Comisión Federal de Electricidad. This would involve construction of up to 500 MW of hybrid solar/combined cycle gas turbines spread across two sites, either Laguna or Hermosillio during 2004, followed by Cerro Prieto in 2005.

Spencer Management Associates, working on behalf of the World Bank and CFE, have since conducted a study on the economic viability and technical feasibility of integrating a solar parabolic trough with a Combined Cycle Plant at the Cerro Prieto, Baja California Norte site owned by CFE. This has resulted in approval of GEF part funding for the scheme. The project has been delayed, however, both by restructuring of the power sector in Mexico and changes in the national government, putting political support for the project at risk.

In March 2002, however, CFE issued a Request for Proposals (RFP) for a 198 – 242 MW gas-fired combined cycle with an optional integrated parabolic trough solar field of at least 25 MW electrical output under design conditions. The additional solar costs are covered by a grant from the Global Environment Facility.

Table 6: Solar Thermal Power Targets in Spain by Region

Regions	Solar Thermal power targets in Spain by Regions Government's Plan by 2010 (MW)	Existing plans from companies (MW)	Greenpeace scenario by 2010 (MW)
Andalusia	50	125	125
Balearic Islands	0	-	10
Canary Islands	25	-	25
Castilla-La Mancha	50	-	50
Extremadura	25	-	25
Madrid	25	-	25
Murcia	25	-	25
Navarra	0	15	15
Total	**200**	**140**	**300**

One advantage of this project is that Mexico has a well developed industrial base and skilled labour force with the potential to manufacture domestically most of the plant's equipment and components. This would lower the total cost and possibly develop an industry supplying solar thermal components for other plants around the world. Mexican companies have already been manufacturing parabolic collectors for US installations and have demonstrated their ability to meet international quality standards.

Spain

In September 2002, Spain was the first European country to introduce a "feed-in tariff" funding system for solar thermal power. This means that the generation output from solar thermal plants is guaranteed a premium payment of 12 € cents/kWh on top of the electricity pool price which oscillated between 2-8 cents per kilowatt hour. The official target is to connect 200 MW of solar thermal power to the grid by 2010.

On this basis, several solar thermal project developments have been proposed in Spain, the most prominent being:

- 10 MWe solar-only power tower plant project **Planta Solar** (PS-10) at Sanlúcar near Sevilla promoted by Solucar S.A., part of the Abengoa Group. The PS-10 project has received a €5 million grant from the 5th Framework Programme of the European Union. All permits had been received by late 2002 and negotiations started with the financing banks.

- 15 MWe solar-only power tower plant **Solar Tres** project in the province of Cordoba promoted by the Spanish company Ghersa and Bechtel/Boeing employing US molten-salt technologies for receiver and energy storage. Together with Ghersa, Nexant and Boeing have formed a company called Solar Tres to finance and build a fully commercial 15 MWe solar power tower plant that can deliver this power around the clock. The Solar Tres project has received a €5 million grant from the EU's 5th Framework Programme.

- 15 MWe solar trough power plant **EuroSEGS** at Montes de Cierzo near Pamplona promoted by the Spanish EHN group in cooperation with SOLARGENIX (former Duke solar), USA.

- Two 50 MWe solar trough power plants, **AndaSol-1 and 2**, are being promoted by the Millennium Solar AG group and its industrial partners in the region of Andalucia with a 510,120 m^2 SKALET solar collector field and six hours thermal storage. The AndaSol-1 project has received a €5 million grant from the EU's 5th Framework Programme and financial support from the German Ministry for Environment. All permitting documents had been submitted by the end of 2002.

Table 6 shows the Spanish government's plans (by region) for solar thermal power development, together with current plans from private companies. The third column shows a very conservative Greenpeace scenario where all proposed private projects succeed (and thus surpass the official targets for those regions) and the remaining regional governments stick to their respective targets; a new target is added for the Balearic Islands. This Greenpeace scenario can be met, provided there is political will both to support private initiatives and to meet public targets. In fact, Greenpeace considers that a more ambitious target of 1,000 MW by 2010 is feasible and necessary, and thus the modest existing target should be raised, leading to a new more active policy of legislative, economic and fiscal measures in support of solar thermal power.

Iran

With a rapidly expanding population, an urgent need to increase the production of electricity, and concern about the build-up of greenhouse gases in the atmosphere, the Islamic Republic of Iran has shown a growing interest in renewable energy technology, including solar power. Keen to exploit its abundant solar resource, specifically by means of CSP technology, the government also wants to diversify its power production away from the country's oil and natural gas reserves.

In 1997, the Iranian Power Development Company contracted the Electric Power Research Centre (now the NIROO Research Institute), Pilkington Solar International (now Flagsol) and Fichtner (now Fichtner Solar) to execute a comprehensive feasibility study on an Integrated Solar Combined Cycle with trough technology. The best regions for installing solar thermal power plants in Iran are Esfahan, Fars, Kerman and Yazd, but Yazd was eventually selected for implementing the first plant. The entire high plateau of the Yazd region is characterised by an annual direct normal radiation of 2,511kWh/m^2.

The government of Iran is now discussing potential funding with the Global Environment Facility.

Israel

The Israeli Ministry of National Infrastructure, which is also responsible for the energy sector, decided in 2001 to make CSP technology a strategic element in the Israel electricity market in the period up to 2005, with an initial aim for a unit of 100 MWe. There is an option to increase the CSP contribution up to 500 MWe at a later stage, after the successful operation of the first unit.

The investment cost of the first unit is expected to be US$ 200 million, with an estimated production cost of 9 ¢/kWh for the electricity output, and an expected reduction to 7 ¢/kWh when the 500 MWe unit is completed. Construction and operation of the first unit will create around 1,000 jobs during the construction period and 120 permanent jobs in operation and maintenance. The Ministry of National Infrastructure has now designated a team to locate a suitable site, with the likely location in the Yamin Plain near Arad in the south of the country. The technology will probably be parabolic troughs, although a final decision may depend on the company which builds the plant.

Construction of a 100 MWe solar power plant at a cost of US$ 250 million was officially agreed by the Israel Electric Company (IEC) in February 2002, with the option to increase the capacity up to 500 MWe. The IEC approved establishment of the plant on the condition that the Israel Electric Authority takes account of the higher cost of the electricity through its national tariff policy. This will mean a slight increase in the price of electricity to the public.

Jordan

Jordan has a long-standing interest in large-scale solar thermal power generation. Nearly ten years ago a European-based industrial consortium known as Phoebus proposed the construction of a 30 MW volumetric-type solar power tower. The consortium carried out site and feasibility studies, collected weather data and identified financing. Further project development, however, was delayed by the onset of the Gulf war. In 1997 a START (Solar Thermal Analysis, Review and Training) team composed of IEA/SolarPACES representatives from Egypt, Germany, Israel, Spain, Switzerland and the US, with guest observers from the European Union, also visited Jordan, with the mission hosted by the Jordanian National Electric Power Company.

In 2001, a request for solar plant proposals was published by the government. Solar Millennium AG (Germany) submitted a proposal to build a solar hybrid plant in the Quwairah area of southern Jordan (35km north of Aqaba) to generate 100-150 MW of electricity and to be implemented on a Build, Own and Operate (BOO) basis. The solar element will be backed up by gas or heavy fuel generation. The project will create at least 100 jobs in Quwairah, and will be linked to the national electricity grid. The Jordan government now intends to conduct a detailed feasibility study and seeks for financial sources.

South Africa

By 2007, South African power utility Eskom could be operating the world's largest CSP plant. Eskom is currently in the final stages of a feasibility assessment of the molten salt central receiver technology The study included the possibility of manufacturing key components locally. Ultimately, a decision will be made on a variety of factors, including cost, and which plant can be constructed with the largest local content.

United States

Several paths towards CSP market development have gained momentum over the last year, all focused on projects in the US South-west states, and encouraged by both the excellent direct beam solar resource and growing demand for power.

In 2002, the US Congress asked the Department of Energy (DOE) to develop and scope out an initiative to fulfil the goal of having 1,000 MW of new parabolic trough, power tower and dish/engine solar capacity supplying the south-western United States by 2006. The US CSP industry and SunLab collaborated on development of this report.

The key findings were:

- The solar resource in the US South-west is comparable in scale to the hydropower resource of the North-west.
- CSP is clean, large-scale power that could provide a very significant contribution to South-west US electricity needs.
- CSP could be scaled up rapidly, although it might take 6-8 years to achieve 1,000 MW because of initial project development time.
- CSP costs are not yet competitive with conventional power, requiring financial support for the first 1,000 MW.
- Overall cost of a programme would be $1.8 billion, equivalent to $1.40/watt installed for troughs, $2.00/watt installed for towers and $2.60/watt installed for dishes.

Solargenix Solar is now carrying out a planning project funded by the California Energy Commission, and in cooperation with Californian municipal utilities. This aims to develop the reference PPA terms and conditions for 1,000 MW of trough plants over ten years which will satisfy municipal utility goals as well as industry needs. The project will also identify sites, transmission line issues, the resource mix for utilities and the expected cost of electricity.

Two other projects are meanwhile progressing in Nevada. A 50 MW plant using parabolic trough technology is to be built in Eldorado Valley by SOLARGENIX, with its output supplied to utility subsidiaries of Sierra Pacific Resources. This was made possible by legislation requiring utilities to supply a percentage of electricity from renewable sources. Contracts are also being finalised for the Nevada Solar Dish Power Project, a 1 MW demonstration plant (funded by the US Department of Energy's Concentrating Solar Power Program) designed to validate the operation of a dish-engine system. A project for a 1 MW parabolic trough using an ORC engine is also in progress in Arizona. This is being implemented by Solargenix.

A recent technical evaluation of US solar thermal power by Sargent and Lundy, commissioned by the Department of Energy, the most thorough technical analysis to date, shows a declining cost curve towards 3.5-6 US cents perkWh – based on continued technology improvements, mass production efficiencies and larger plant sizes.

Algeria

As Algeria takes its place within the IEA/SolarPACES programme, the country's emerging interest in CSP technology could lead to exciting developments in the future – including solar power exports to Europe.

The trigger which has provided the framework for new investment opportunities is liberalisation of the Algerian power market, created following a new law passed in February 2002. Two major objectives, to be achieved by 2010, are to build a number of power plants with a total capacity of 2,000 MW, and secondly, to construct two power export cables (Algeria-Spain and Algeria-Italy) with an export capacity of 1,200 MW. Meanwhile, both the Algerian government and the private sector are aware of Europe's commitment to renewable energy sources, in particular the European Union's aim to have 12% of renewable energy by 2010.

Algeria has now taken on its own domestic commitment, with the aim of increasing the solar percentage in its energy mix to 5% by 2010. But beyond this Algeria is looking for a close partnership with the European Union so that Algerian plants can help deliver the green energy needed for Europe to meet its targets. To bring these plans to reality, and to enhance the participation of the private sector – both local and international – a new company has been created. New Energy Algeria (NEAL) brings together Sonatrach, the Algerian hydrocarbon producer, Sonelgaz, the Algerian power producer and distributor, and SIM, a privately owned company.

NEAL is to promote renewables in Algeria by helping to develop firstly, cost effective power plants which will enable access to energy for the whole population, secondly, the technical, economic and financial support for plant development, and thirdly, more efficient use of the country's gas reserves. NEAL's specific interest in solar thermal power is the result of an analysis of national strengths, since Algeria benefits not only from abundant solar radiation but also a ready gas supply.

NEAL's first initiative is to build a new 140 MW ISCC power plant with 30 MW of solar output. With the expected political support, the aim is to have this ready for operation by 2006. But while preparing for the near-term supply of solar thermal power, NEAL is also working closely with the Ministry of Energy to have a law adopted that will provide proper incentives for renewable energy sources, underpinning their economic viability. Part of this will involve establishing a green certificate market.

US Policy Priorities

Three trends are giving solar thermal power some market momentum in the US. Firstly, a deregulated power generation system has inspired state-mandated Renewable Energy Portfolio Standards, the right of interconnection and the sale of green power. Secondly, concerns about implementing the Clean Air Act and implementing climate change emissions reductions are driving use of cleaner technologies, including renewable energy. And thirdly, the private sector has been advancing solar thermal technologies on its own, with a bare minimum of federal support and some at a state and local government level.

Emerging technologies need sustained orderly development, however, to attract further private capital, scale-up manufacturing and establish installation and service capabilities to meet expanding market demand. Six policies are required to expand the market for solar thermal and to achieve the economies-of-scale required in manufacturing, system integration and deployment.

1. National or Regional Solar Portfolio Standard – Establishing minimum set asides based on relative renewable energy resource availability, including solar thermal power alongside other clean distributed generation, is an essential tool to create market based mechanisms.

2. Production and investment tax credits – With energy costs slightly higher than geothermal and wind, solar thermal power needs investment credits for its first two years of initial plant construction (with accelerated depreciation) and then production credits (1.8 cents per kWh) for the following eight years, with waivers for investors from the Alternative Minimum Tax (AMT).

3. Encouragement for solar electric power can come via mandated green power purchases for federal agencies and other public and municipal bodies.

4. Expanded federal support for a solar thermal power R&D program is required to support the market expansion envisaged for the Southwestern United States. A recent study by Sargent & Lundy concluded that further technology improvements will result in approximately a 50% reduction in the cost of electricity from trough plants and 25% from power tower plants.

5. Federal loan guarantees – As proposed for emerging coal and nuclear technologies, these should first be applied to CSP installations to “prove out” these federal tools in the cleanest, lowest emission technology available to displace higher cost, higher emissions midday peak power.

6. Formal federal support to existing federal-to-state programs could yield a significant number of megawatts in both larger central CSP generating facilities and distributed CSP generation.

There is no question that the United States has some of the world’s best high-value solar radiation, which is optimal for concentrated solar power. There now exists a critical mass of private companies and private investment along with a range of technologies that could play a meaningful role in the US and global markets. Policy trends relating to deregulation and environmental protection bode well for establishing a maturing industry.

Italy

In 2001, the Italian parliament allocated €110 million for a CSP development and demonstration programme. Since then, several parabolic trough plant concepts have been under development.

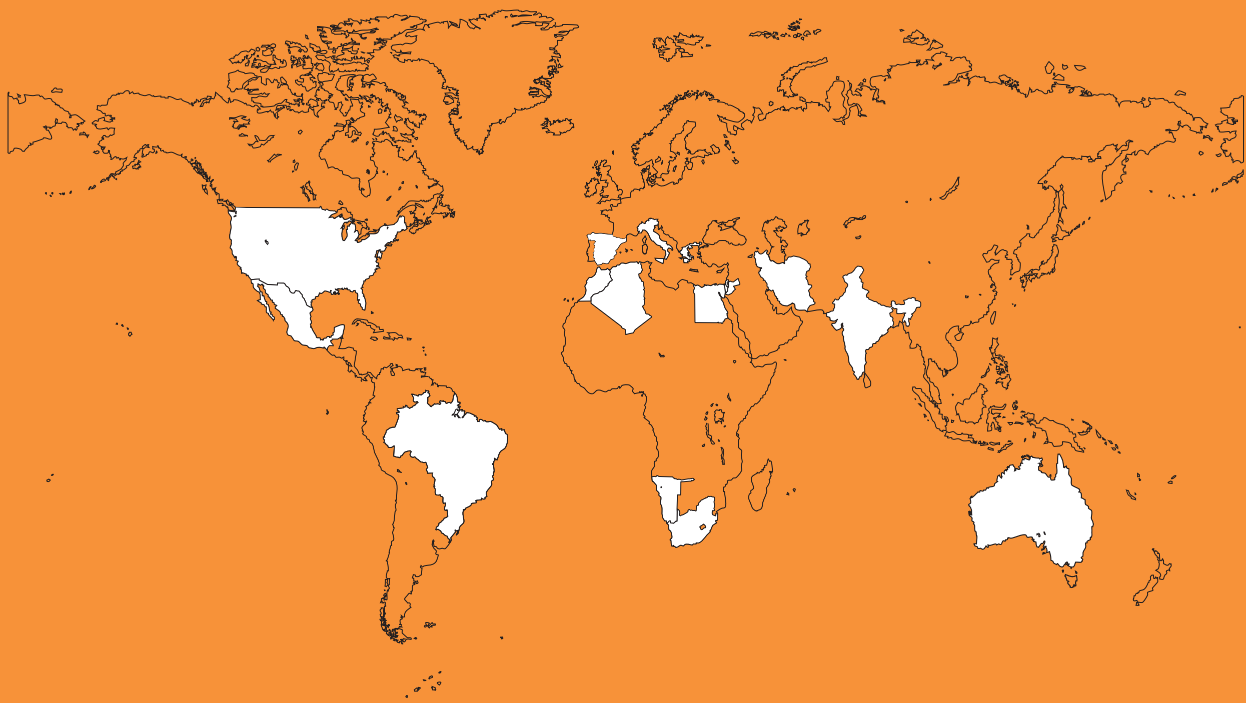
Brazil

Brazil applied in 1997 through the UNDP for a GEF-supported Project Development Fund to conduct a study on “Reducing the Long-term Cost of Solar Thermal Power Generation”. The application was approved by GEF in early 1998 and an implementation agreement signed with UNDP. After a period of project reorganisation, work was started by CEPEL in December 2001. The study is due to be published in 2003.

Australia

There are three main areas of solar thermal electricity generation in Australia. The most commercially advanced of these is the 35 MW CLFR system to be incorporated into an existing coal-fired power station, with construction already underway. The initial plant is being constructed by the company Solar Heat and Power for approximately US$ 500 per kWe (peak) without direct subsidy. This low cost is achieved because the project uses existing turbines and electrical infrastructure. It has no storage and a relatively low capacity factors, but it is approximately competitive with advanced wind generation. Further CLFR plant proposals using storage are now being discussed with utilities having an annual output equal to 4% of the NSW electricity supply. Including storage for a 56% capacity factor and using a moderate pressure turbine and generator, these will cost about US$1400 per kWe peak according to SHP. Other analysis suggests that large systems such as CLFR plants will be more cost effective with a much more rapid uptake over the early years. However, unlike trough technology, the CLFR technology will have to be proven and thus represents a more optimistic scenario than the European Solar Thermal Power Industry Association approach.

The next most developed system is the 50kW parabolic dish prototype at the Australian National University, but although the dish is being refurbished, there is as yet no commercial project announced. A 1.5 MW version of the Yeoman?s Floating Solar Concentrator is currently being built. Research is also being conducted into MTSA beam splitting technology that would both power a photovoltaic array and provide heat to operate a Brayton cycle micro-turbine, and a single tower prototype is being proposed by a consortium the CSIRO, the University of Sydney, and SHP Pty Ltd.



PART4

THE FUTURE FOR SOLAR THERMAL POWER

The Greenpeace – ESTIA Scenario for 2020 and Projection to 2040

This scenario was prepared by Greenpeace International and the European Solar Thermal Power Industry Association in order to project what could be achieved given the right market conditions. Its core assessment looks forward 18 years from the base year of 2002 to the end of the second decade of the 21st century. It is not a prediction, but a scenario based on expected advances in solar thermal technology coupled with the growing number of countries which are supporting CSP projects in order to achieve both climate change and power demand objectives.

KEY RESULTS FROM GREENPEACE-ESTIA SCENARIO 2002-2020

Capacity of Solar Thermal Power in 2020	21,540 MW
Electricity Production in 2020	54.6 TWh
Cumulative Investment in Plant Construction	41.8 billion
Employment Generated	200,000 jobs
Carbon Emissions Avoided 2002 – 2020	154 million tonnes CO_2
Carbon Emissions Avoided in 2020	32.7 million tonnes CO_2
Projection 2021 to 2040	
Capacity of Solar Thermal Power in 2040	630,000 MW
Electricity Production in 2040	1573 TWh
Percentage of Global Demand	5%

Over the period of the scenario, solar thermal technology will have emerged from a relatively marginal position in the hierarchy of renewable energy sources to achieve a substantial status alongside the current market leaders such as hydro and wind power. From a current level of just 354 MW, by 2015 the total installed capacity of solar thermal power plants will have passed 5,000 MW. By 2020 additional capacity would be rising at a level of almost 4,500 MW each year.

At the end of the scenario period, the total installed capacity around the world will have reached the impressive figure of 21,540 MW.

The scenario also shows how much electricity would be produced by solar thermal power plants. This is based on the assumption that 1 MW of capacity produces 2,500 MW hours of electricity per annum.

By 2020 solar thermal power will have achieved an annual output of more than 54,000,000 MWh, or 54 TWh.

In terms of capital investment, it is assumed in the scenario that during the initial years, solar field investment costs are at a level of US$ 2,500/kW installed, slightly lower but close to the US$ 3,000/kW level of the SEGS plants in California during the early 1990s. These specific investment costs then fall gradually over the timescale of the scenario, and are cut by half in 2020. This means that the investment volume in solar thermal power plants will rise from US$ 375 million in 2005 to almost US$ 7.6 billion in 2020.

The total investment over the scenario period would amount to more than US$ 41.8 bn.

A substantial level of employment would be an important by-product of this expansion in the solar thermal power industry. At the end of the scenario period, more than 20,000 highly qualified jobs will have been created just in plant operation and maintenance. More than 40,000 jobs would be created in plant construction, and a further 40,000 in plant component manufacture.

By 2020, about 200,000 people will be permanently employed in the solar thermal power industry worldwide.

The final benefit from realisation of the Greenpeace-ESTIA scenario would be to the environment.

Over the period up to 2020 a total of 154 million tonnes of carbon dioxide would be saved from being emitted into the atmosphere, making a substantial contribution to international climate change targets.

The assumption here is that 1 MWh of installed solar thermal power capacity results in the saving of 600 kilograms of carbon dioxide. The total annual savings of 32.7 million tonnes CO_2 in 2020 is equivalent to 20 coal fired power plants.

The scenario is also broken down by region of the world and into the main country markets. By 2020, the leading regions will be Europe. The most promising countries according to the scenario, each with more than 1,000 MW of solar thermal projects expected by 2020, are Spain, the United States, Mexico, Australia and South Africa.

Table 7: Solar Thermal Power – Global Projection 2002 to 2020

Year	Total MW	Total MWh	Total tCO_2	Total investment	Total Jobs
2002	354	708,000	424,800	0	0
2005	505	1,058,000	634,800	375	9,900
2010	1,550	6,095,500	3,657,300	1,280	11,929
2015	5,990	15,208,000	9,124,800	2,056	72,294
2020	21,540	54,583,000	32,749,800	7,687	198,774
Total 2000 to 2020			154,003,500	40,804	

Finally, a further projection is made for the potential expansion of the solar thermal power market over another two decades up to 2040. This shows that by 2030 the worldwide capacity will have reached 106,000 MW, and by 2040 a level of almost 630,000 MW. Increased availability of plant because of the greater use of efficient storage technology will also increase the amount of electricity generated from a given installed capacity.

This means that by 2040 the proportion of global electricity demand which could be satisfied by solar thermal power will have reached a share of 5%. This is on the assumption that global electricity demand doubles by that time, as projected by the International Energy Agency. Long before that point, however, solar thermal power will already be a mature, well-established and market-orientated source of electricity supply.

Table 8: Solar Thermal Power by 2020 – Key Results by Region: OECD Europe

Year	OECD-Europe MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	100	250,000	150,000	250	1,300
2010	470	1,800,000	1,080,000	310	1,950
2015	1,620	4,050,000	2,430,000	426	3,250
2020	3,970	9,925,000	5,955,000	775	7,150
Total 2000 to 2020				6,834	

Table 9: Case Study: Greece

Year	Greece MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	100	375,000	225,000	103	650
2015	250	625,000	375,000	164	1,300
2020	750	1,875,000	1,125,000	141	1,300
Total 2000 to 2020				1,272	

Table 10: Case Study: Spain

Year	Spain MW	MWh	tCO_2	Market volume in MUS$ 0	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	60	150,000	90,000	150	780
2010	335	1,237,500	742,500	207	1,300
2015	1,145	2,862,500	17,175,500	341	2,600
2020	2,645	6,612,500	3,967,500	423	3,900
Total 2000 to 2020				4,579	

Table 11: Solar Thermal Power by 2020 – Key Results by Region: OECD North America

Year	OECD-N-America MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	354	708,000	424,800	0	0
2005	405	808,000	484,800	125	5,265
2010	1,350	2,258,000	1,354,800	413	2,600
2015	2,400	6,483,000	3,889,800	853	6,500
2020	6,400	16,983,000	10,189,800	1,409	13,000
Total 2000 to 2020				9,646	

Table 12: Case Study: USA

Year	USA MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	708,000	424,800	0	0
2005	50	808,000	484,800	125	650
2010	350	1,908,000	1,144,800	413	2,600
2015	2,400	5,508,000	3,304,800	853	6,500
2020	6,400	13,508,000	8,104,800	1,409	13,000
Total 2000 to 2020				10,631	

Table 13: Case Study: Mexico

Year	MEXICO MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	90	350,000	210,000	103	33,800
2015	1,290	975,000	585,000	85	84,500
2020	1,390	3,475,000	2,085,000	423	169,000
Total 2000 to 2020				2,255	

Table 14: OECD-Pacific

Year	OECD-Pacific MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	50	125,000	75,000	107	650
2015	250	625,000	375,000	177	1,300
2020	2,250	5,625,000	3,375,000	845	7,800
Total 2000 to 2020				3,472	

Table 15: Case Study: Australia

Year	Australia MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	50	125,000	75,000	107	650
2015	250	625,000	375,000	177	1,300
2020	2,250	5,625,000	3,375,000	845	7,800
Total 2000 to 2020				3,472	

Table 16: Latin America

Year	OECD-Latin America MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	90	350,000	210,000	103	650
2015	390	975,000	585,000	85	650
2020	1,940	4,850,000	2,910,000	705	6,500
Total 2000 to 2020				3,070	

Table 17: Case Study: Brazil

Year	Brazil MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	45	175,000	105,000	52	325
2015	195	487,500	292,500	43	325
2020	970	2,425,000	1,455,000	352	3,250
Total 2000 to 2020				1,535	

Table 18: Case Study: Chile

Year	Chile MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	45	175,000	105,000	52	325
2015	195	487,500	292,500	43	325
2020	970	2,425,000	1,455,000	352	3,250
Total 2000 to 2020				1,535	

Table 19: Case Study: Russia

Year	OECD-Russia (south) MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	0	0	0	0	0
2015	0	0	0	0	0
2020	250	625,000	375,000	141	1,300
Total 2000 to 2020				371	

Table 20: South Asia (Pakistan and India)

Year	OECD-South Asia MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	70	300,000	180,000	103	650
2015	420	1,050,000	630,000	171	1,300
2020	1,670	4,175,000	2,505,000	493	4,550
Total 2000 to 2020				2,684	

Table 21: Case Study: India

Year	India MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	35	212,500	127,500	103	650
2015	335	837,500	502,500	85	650
2020	1,335	3,337,500	2,002,500	423	3,900
Total 2000 to 2020				2,143	

Table 22: Case Study: China

Year	OECD-China MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	50	125,000	75,000	103	650
2015	100	250,000	150,000	164	1,300
2020	1,100	2,750,000	1,650,000	423	3,900
Total 2000 to 2020				1,690	

Table 23: Middle East

Year	OECD-Middle East MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	335	837,500	502,500	215	1,300
2015	405	1,012,500	607,500	62	455
2020	2,455	6,137,500	3,682,500	916	8,450
Total 2000 to 2020				3,947	

Table 24: Case Study: Israel

Year	Israel MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	100	125,000	75,000	114	195
2015	130	200,000	120,000	27	195
2020	705	1,637,500	982,500	282	2,600
Total 2000 to 2020				1,024	

Table 25: Africa

Year	OECD-Africa MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	185	300,000	180,000	248	455
2015	405	762,500	457,500	520	455
2020	1,505	3,512,500	2,107,500	1,980	3,250
Total 2000 to 2020				2,532	

Table 26: Case Study: Morocco

Year	Morocco MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	50	125,000	75,000	107	650
2015	100	250,000	150,000	89	650
2020	250	625,000	375,000	146	1,300
Total 2000 to 2020				421	

Table 27: Case Study: South Africa

Year	South Africa MW	MWh	tCO_2	Market volume in MUS$	Jobs excl. Manufaction
2002	0	0	0	0	0
2005	0	0	0	0	0
2010	0	0	0	0	0
2015	125	125,000	75,000	96	650
2020	325	625,000	375,000	146	1,300
Total 2000 to 2020				403	

PART 5

POLICY RECOMMENDATIONS

1. The Political Challenge

Energy is considered to be a vital ingredient for any economic development. The history of industrialisation in today's developed nations is also a history of massive fossil energy exploitation, with its associated benefits of rapid availability, high energy density, and – at least initially – low generation costs. Over the past three decades, however, the harmful environmental impact of fossil fuels on the regional and global climate has been brought into sharp focus.

For those nations still in development, energy is even more vital as they have to make up for, and keep pace with, the mature energy infrastructure of the industrialised nations in an increasingly globalised economy. Furthermore, it is widely accepted in the developing world that these countries should not just copy the historical energy patterns of the developed world, but should consider building up a sustainable energy infrastructure which avoida long term detriments.

Although history has shown that building up such an infrastructure is most efficiently managed by the private sector, governments do have a public responsibility to ensure fair market rules, level playing fields for the market participants and, most importantly, sustainability of living conditions for the generations to come. Hence they face many challenges in formulating current and future energy policies. They have to respond to the need for security of energy supply, economic growth, sustainable development, employment and technological development and to combat the growing effects of climate change. Renewable energy technologies are considered to have a positive impact on all these parameters.

This study clearly demonstrates that solar thermal power plants, up to now not widely known as an energy technology, are one of the most promising renewable sources – capable of meeting 5% of future global electricity demand by the year 2040. The developing world in particular, with its abundant and evenly distributed solar resource, can contribute in a cost-effective way to the bulk power supply of mega-cities, where decentralised or fluctuating power supply would be inadequate. This strategic power supply advantage has already motivated development banks, such as the World Bank, European Investment Bank and the German Kreditanstalt für Wiederaufbau to support the implementation of solar thermal power plants.

Without initial political and financial support, however, solar thermal power remains at a competitive disadvantage, largely because of inadequate price information in the world's electricity markets resulting from decades of massive financial and structural support to traditional polluting fuels and power plant technologies.

Solar thermal power plants have to compete in a well established, very competitive energy market segment where older nuclear and fossil fuel power stations produce electricity at marginal cost because the interest payments and depreciation on their investment costs have already been paid by consumers and taxpayers. Political action is therefore needed to overcome those distortions and create a level playing field in which the economic and environmental benefits of solar thermal power can be fully exploited.

2. Successful Market Creation Policy Measures

A clear, visible market for solar thermal power must be defined in order for a project developer to seriously consider getting involved. Just as with any other investment, the lower the risk to the investor, the lower the costs can be for supplying the product. The most important measures for establishing new solar power markets are therefore those where the market for solar electricity is clearly embedded in national laws, providing a stable and long term investment environment with relatively low investor risks and sufficient returns.

As already outlined, a key benefit of a growing solar thermal energy market is job creation. It is estimated that direct and indirect employment in the industry worldwide, not including the production of components and equipment, could rise to about 100,000 jobs by 2020. In order to attract solar thermal power plant suppliers to establish manufacturing facilities, markets need to be strong, stable and reliable, with a clear commitment to long term expansion.

• Legally Binding Targets for Renewable Electricity in the EU and US

In recent years an increasing number of countries have established targets for renewable energy as part of their greenhouse gas reduction policies. These are either expressed as specific quantities of installed capacity or as a percentage of energy consumption.

Renewable energy targets are most effective if they are based on a percentage of a nation's total electricity consumption. This creates an incentive to optimise renewable technologies in the supply mix, and provides a guide to where immediate policy changes are required in order to achieve the anticipated targets. But targets have little value if they are not accompanied by policies to achieve a level playing field in electricity markets, to eliminate market barriers and to create an economic framework environment that will attract investment.

The most ambitious target has been set by the European Union. In 2001 the European Council and the European Parliament adopted a Renewable Energy Directive establishing national targets for each member state. Although these are not at present legally binding, the Directive aims at doubling the share of renewable energy sources in the primary energy mix from 6% to 12% by 2010, equivalent to 22% of Europe's total electricity consumption. If this non-binding approach appears not to be working, then the Directive allows the European Commission to submit proposals to the European Parliament and Council for mandatory renewable energy targets.

Table 28: European Union Targets for Renewable Electricity in 2010

Country	RES-E in 1997 (%)	RES-E 2010 Target (%)
Belgium	1.1	6.0
Denmark	8.7	29.0
Germany	4.5	12.5
Greece	8.6	20.1
Spain	19.9	29.4
France	15.0	21.0
Ireland	3.6	13.2
Italy	16.0	25.0
Luxembourg	2.1	5.7
Netherlands	3.5	9.0
Austria	70.0	78.1
Portugal	38.5	39.0
Finland	24.7	31.5
Sweden	49.1	60.0
United Kingdom	1.7	10.0
Community	**13.9**	**22.1**

Source: Directive 2001/77/EC on the Promotion of Electricity Produced from Renewable Energy Sources

The table below shows the national targets for supply from renewable energy expected in the 15 current EU member countries, expressed as a percentage of gross national electricity consumption.

The majority of current supply comes from large hydro stations, although this technology is already widely exploited and will not represent a major new renewable source in Europe. Most of Europe's renewable energy supply increase will therefore come from biomass plants, wind energy parks, small hydro and solar thermal power plants.

In the US, Renewable Portfolio Standards have been established to gradually increase the contribution of clean, renewable power in the supply mix of some of its federal states. If utility companies are failing to reach certain agreed targets, they will be penalised through compensation payments. This mechanism, with initial targets for 2-5% of a state's total electricity demand by 2005 and 2010, respectively, already starting to work. As a result, Nevada and Arizona are both negotiating long-term power purchase contracts for their first new solar thermal power plants.

- **Specific Policy Mechanisms – the Case of European "Feed-In Laws"**

A specific European policy mechanism which has enabled the achievement of renewable energy supply targets is the fixed tariff system, where a specific tariff rate or premium is allocated to particular renewable technologies. These rates and premiums reflect the relative cost difference of the specific renewable technology compared to the price offered by the liberalised power market for bulk power. Utility companies are obliged to buy all renewable power produced at the rates established in the specific feed-In law. The differential cost of renewable power compared to the market price of bulk fossil or nuclear generated electricity is borne by the electricity ratepayer.

The most successful feed-in law schemes have been established in Austria, Denmark, Germany and Spain, with the most remarkable result that about 20,000 MW of wind power is currently on stream. Biomass and small hydro power plants are also increasing.

Surprisingly, considering its cost-effectiveness amongst solar power technologies, solar thermal power had not been included in any feed-in tariff system until Spain published its "Prima" in September 2002.

3. Public-Private Partnerships for Introducing Solar Thermal Power

• The GEF-BMU-KfW-ESTIA/SEIA Approach

At the International Executive Conference on Concentrating Solar Power, held in Berlin, Germany in 2002, the Global Environmental Facility, the German Kreditanstalt für Wiederaufbau bank, the German Federal Ministry for the Environment, and both the European and American Solar Thermal Power Industry Associations discussed a Global Market Initiative for Concentrating Solar Power and defined strategies for its rapid and large-scale market introduction. This strategy was published as the Declaration of Berlin.

The participants included politicians, senior government executives, the financial community, donor organisations, the CSP industry, independent power project developers and potential plant owners from 16 countries. The participating stakeholder groups supported the launching of a CSP Global Market Initiative to be further substantiated at the follow-up conference in Palm Springs, California in October 2003.

GLOBAL MARKET INITIATIVE
TO DEVELOP AND EXPAND THE GLOBAL MARKET FOR CONCENTRATING SOLAR POWER (CSP)

Solar energy is the most evenly distributed and readily available renewable energy resource on the planet. Solar thermal power plants, which make use of this concentrating solar power (CSP) technology have the capability to meet a significant percentage of the future global electricity demand without technological, economic or resource limitations, specifically in sun-belt regions such as the south-west U.S., southern Europe and parts of the developing world.

This capability and the ability of solar thermal power plants to dispatch power as needed during peak demand periods has motivated development banks, such as the World Bank, the European Investment Bank and the German Kreditanstalt für Wiederaufbau (KfW), as well as the Global Environmental Facility (GEF), the European Union and the U.S. Department of Energy, to support the implementation of this technology.

At the First International Executive Conference on Concentrating Solar Power in June 2002 in Berlin, Germany, the GEF, the KfW, the German Federal Ministry for the Environment (BMU), the European Solar Thermal Power Industry Association (ESTIA) and the American Solar Energy Industries Association (SEIA) discussed a Global Market Initiative (GMI) for CSP, and defined strategies towards the rapid and large-scale market introduction of the technology. This commitment was published as the Declaration of Berlin, which was registered as a UNEP Market Facilitation WSSD Type-II Partnership for Concentrating Solar Power Technologies.

The participating stakeholder groups of the Declaration of Berlin are now urging the implementation of this Global Market Initiative to accelerate the entry of CSP into the market. However, a visible, reliable and growing market for solar thermal power with normal risk levels must be established in order for many project developers and CSP equipment suppliers to make the needed long-term investments to achieve lower costs.

There are three basic policy areas that will significantly impact the increased use of concentrated solar power

I. Political and technological targets to trigger new power markets

Establish a consistent basis of national laws and regulations, such as feed-in tariffs specifically also applicable for CSP, to pave the way for reaching the anticipated renewable supply targets committed in Kyoto.

Establish Renewable Portfolio Standards that encourage actual "portfolios" of electricity and heat generation from renewables, and insure that the locally available energy resources are evenly utilized and encouraged.

Make green tariff schemes available for electricity imports from high insolation areas in neighboring states and/or countries.

II. Regulatory improvements

Avoid limitations on capacity or operating strategies that make the energy production introduction more costly thus hindering introduction of CSP technology.

Remove restrictive laws to interconnection which will allow concentrated solar plants to more easily hook into the electric grid at the end user (customer), distribution or transmission points.

III. Improve financing mechanisms

Ensure that the Kyoto instruments (emission trading) are made applicable to CSP and that the mechanisms are bankable. Institute Production Tax Credits (PTCs) as wind energy now enjoys and which catapulted the technology globally. Maintain investment tax credits to assist in the initial capital investments before CSP plants begin to produce power.

Establish loan guarantee programs via existing windows at multilateral banks, existing US national lending programs such as SBA, RUS, FmHA, Regional Power Administrations, and global environmental programs such as GEF, UNEP, and UNDP. These programs allow private sector banking institutions to do the necessary project due diligence while providingthem with some extra insurance to loan on new technology projects which are inherently more risky.

The Global Market Initiative (GMI): 5000 MW till 2015

Recent activities indicate that CSP technologies are at the threshold of very extensive commercial deployment. One of the primary market barriers is a lack of knowledge about the current technology and near-term potential of CSP by energy policy makers, regulators, general contractors and would-be owners and users. With increased awareness of the numerous benefits of using the solar thermal energy resources around the world, it is anticipated that new CSP projects will soon come on stream. There are about 10 advanced projects underway around the world, totalling over 1000 MW of new solar capacity.

With the understanding that these projects would come online faster and be more commercial viable if there was a forum for collaboration among interested countries and states, an international public-private partnership has been proposed to meet this need. The goal of this partnership, called the CSP Global Market Initiative, is to facilitate the building of 5,000 MW of CSP power world-wide over the next 10 years. Participation is open to governments in countries or states with adequate solar thermal resources or that have an industrial capability in CSP, but lack the adequate solar thermal resources, and who accept the framework proposed below.

Different Strategies for Different Regions

Today's CSP technologies require a minimum direct normal solar radiation level of 1,900 kWh/m^2/a. This can be found in many countries around the Sunbelt of the world. However, adequate solar radiation is just the beginning. Successful CSP projects require adequate tariffs, long-term power contracts with credit worthy off-takers, access to commercial financing and where needed, subsidies and supportive policies. To take advantage of the different situations and needs of both developed and developing countries, the GMI will use three different strategies.

(1) Region I

In southern Europe, Israel, and the south-western US, most of the essential elements of the GMI (described below) already exist or could reasonably be expected. In these countries, existing CSP-specific targets or portfolio standards will create market-based demand and a feed-in law or system benefit charge, both of which rely on the ratepayers to cover the price gap. In Region I, political support is primarily needed to make targets, policies and tariffs stable and predictable so that commercial financing can be secured. Tariffs should reflect different levels of solar radiation intensity so that each region, country or state with radiation patterns above 1,900 kWh/m^2/a has the chance to built-up this strategic backstop technology.

Eventually, tariff harmonisation schemes may help to ensure that the resource is more evenly built. Capacity restrictions for individual projects should be removed to make best use of economies of scale to help drive prices lower. Alternatively, the demand may be aggregated to assure that CSP plants are built in sizes of 50 MW or larger.

(2) Region II
For developing countries that are or will soon be connected to Region I countries by a power grid, such as Mexico and North Africa, power generated from CSP plants built in these countries may be sold to Region I countries and could receive a premium price. As a result of excellent solar radiation resources and good grid connections, the south-western US and northern Mexico as well as southern Europe and North Africa are two such regions. In Region II, political initiative is primarily needed for formulating a fair scheme that accounts for both improved tariffs for clean energy generated in the Region II countries allowing a benefit from enhanced feed-in tariffs for such energy that is imported into their service territory. To avoid large tariff differences between cheap bulk fossil-based energy and solar power generation, access to favourable Region I tariffs should only be offered when subsidies are no longer available on fossil power production in Region II. The tariff difference can be further reduced through a blend of CDM (i.e., carbon tax credits), and preferential financing, such as theEU´s energy sector infrastructure support MEDA Program for Region II.

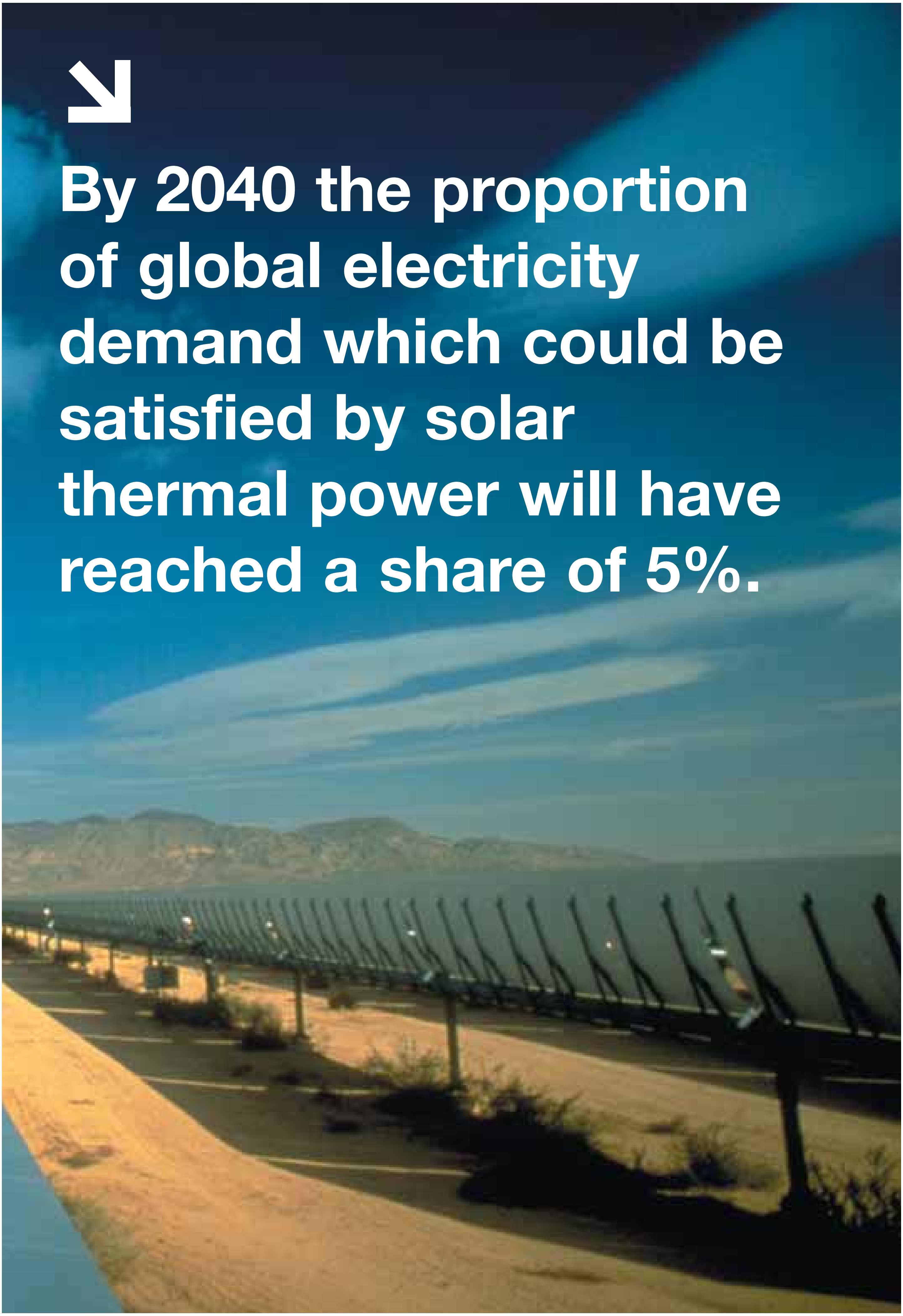
(3) Region III
For other developing countries, not interconnected to the grid of Region I countries, such as Brazil, India, Iran, Jordan and South Africa, preferential financing in the form of subsidies (could be grants, soft loans, carbon credits, CDM, green premiums, etc.) provided by Region I sources will be required to support the Region III group of countries desire for development of clean CSP power plants. An example of such sources is the $0.5 billion dollars for renewable energy that was announced by German Chancellor, Mr. Gerhard Schroeder, in his UN Environmental Summit speech in Johannesburg in September 2002. In the medium term, the Region III countries will profit from closing the price gap as a result of growing installed CSP capacity in Regions I and II. Recognising that financial resources are limited, Region II and III countries, therefore, must contribute something to help reduce the cost of the CSP plants, such as free or low cost land, infrastructure and grid access, etc.

Organization, Structure and Management
The Global Environment Facility (GEF) has agreed to endorse and sponsor the CSP Global Market Initiative (GMI). The GEF and the CSP industry will jointly form a CSP GMI Advisory/Management Board initially consisting of 2-3 highly respected and well-known business leaders from Region I plus 1 board member representing Region II and 1 board member from Region III.

In order to represent the participating countries and states, an Executive Committee will be formed to support the Advisory Board, to provide input and to assure the effective and successful implementation of the Initiative.

This Executive Committee will consist of senior people, representing power project development, power project finance, industry and government. Each participating country and state will be entitled to one Executive Committee seat. The Executive Committee is envisioned to include representatives from the following countries and states:

Algeria
Jordan
Arizona
Mexico
California
Morocco
Egypt
Nevada
Germany
New Mexico
Greece
South Africa
Iran
Spain
Israel
Turkey
Italy


By 2040 the proportion of global electricity demand which could be satisfied by solar thermal power will have reached a share of 5%.

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