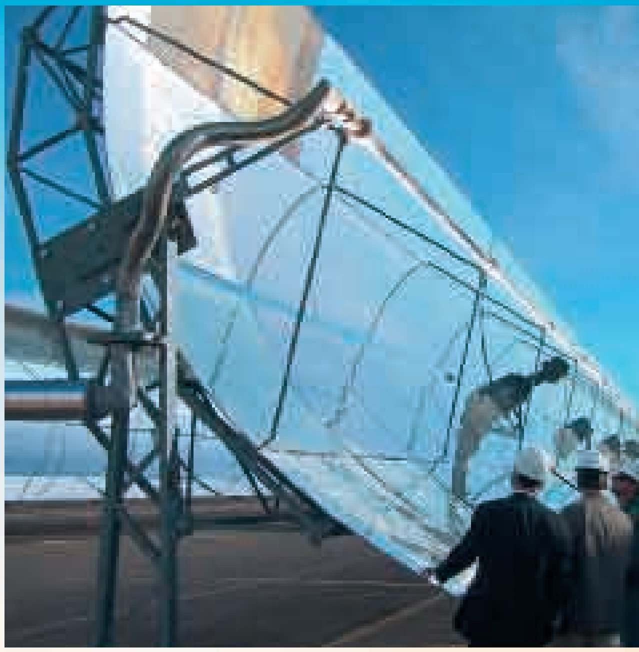
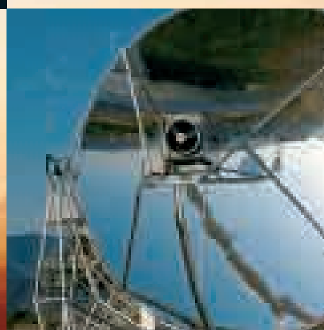
EXPLOITING THE HEAT FROM THE SUN TO COMBAT CLIMATE CHANGE





CONCENTRATED SOLAR THERMAL POWER – NOW!

SEPTEMBER 2005

CONTENTS

Note: The currency used in this report is mainly the Euro (€) with the US dollar in some sections on non-European countries. It is assumed that, averaged over long timescales, the two currencies have an exchange rate of 1:1.

FOREWORD

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 by 2040 – even against the challenging backdrop of a projected doubling in global electricity demand. The solar thermal industry is capable of becoming a dynamic, innovative € 16.4 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 can be a substitute for fossil fuels in the sun belts around the world.

Every day we damage our climate by using fossil fuels (oil, coal and gas) for energy and transport. Climate change already has an impact on our lives and eco systems and it will get worse. We need to reduce our greenhouse gas emissions significantly. We have already experienced a global mean temperature rise of 0.6° C during the last century and, as a result of the greenhouse gases we have already pumped into the atmosphere, we are already committed to 1.2° or 1.3°C warming, even if all emissions were stopped tomorrow. The goal of responsible climate policy should be to keep global mean temperature rise to less than 2°C above pre-industrial levels. Above 2°C, damage to ecosystems and disruption to the climate system increases dramatically. We have a very short time window, i.e. no more than one to two decades, within which we can change our energy system to meet these targets.

Electricity for 100 million people

Greenpeace, the European Solar Thermal Power Industry Association (ESTIA), and the International Energy Agency's (IEA) SolarPACES Programme have produced this report to improve understanding of the solar thermals contribution to world energy supply. The report,a practical blueprint, shows that solar thermal power is capable of supplying electricity to more than 100 million people[1)] living in the sunniest parts of the world, within two decades.

Modern solar thermal power plants can provide bulk power equivalent to the output and firm load characteristics of conventional power stations. This blueprint aims to accelerate market introduction and push the boundaries of technological progress , unlocking many subsequent benefits. Solar thermal power already exists; There is no need to wait for a magical 'breakthrough'; Solar thermal power is ready for global implementation today.

A clear vision: Solar thermal power plants as the offshore wind farms of the desert – exploiting the heat from the sun's heat to combat climate change.

Urgent political commitment

The solid industrial and political commitment to the expansion of the solar thermal power plant industry shows that the current surge of activity in the solar electricity sector is only a foretaste of the potential, massive transformation and expansion over the coming decades. Although reports are a useful guide, it is people who change the world by their actions. We encourage politicians and policy-makers, citizens worldwide, energy officials and regulators, utility companies, development banks and private 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 the 2002 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". In June 2004, an International Action Plan was adopted by even more countries during the Renewables'2004 Conference in Bonn, including a specific Global Market Initiative for Concentrated Solar Power.

Political declarations, however, mean little if they are 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.

Georg Brakmann
President / European Solar Thermal Industry Association

Rainer Aringhoff
Secretary-General / European Solar Thermal Industry Association

Dr. Michael Geyer
Executive Secretary / IEA SolarPACES

Sven Teske
Renewables Director / Greenpeace International

1. *Solar Electricity production in 2025 = 95.8 TWh/a; average per capita consumption in Africa, Asia, China and Latin America 955 kWh/a;*

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 a comparable opportunity to the sunniest countries of the world as offshore wind farms are currently offering to European nations with the windiest shorelines.

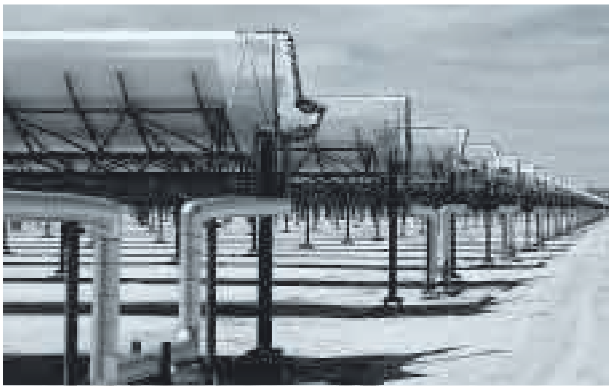
Solar thermal power uses direct sunlight, so it must be sited in regions with high direct solar radiation. Among the most promising areas of the world are the South-Western United States, Central and South America, North and Southern Africa, the Mediterranean countries of Europe, the Middle East, Iran, and the desert plains of India, Pakistan, 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 -120 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 mid-load power plant.

TURNING SOLAR HEAT INTO ELECTRICITY

Producing electricity from the energy in the sun's rays is a 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 turbine or a Stirling engine. Solar heat collected during the day can also be stored in liquid or solid media like molten salts, ceramics, concrete or, in the future, phase-changing salt mixtures. At night, it can be extracted from the storage medium and, thus, continues turbine operation.

Solar thermal power plants can be designed for solar-only or hybrid operation, as in California where some fossil fuel is used in case of lower radiation intensity to secure reliable peak-load supply. Thermal energy storage systems are extending the operation time of solar thermal power plants up to a 100% solar share. For example, in Spain the 50 MWe AndaSol plants are designed with six to 12 hours thermal storage, increasing annual availability by about 1,000 to 2,500 hours.



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 14 and 17 US cents/kWh. However, costs are expected to drop closer to 7-8 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-fueled peak- and mid-load power stations within the next ten 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 transport or storage, and power conversion. 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 400oC 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 2 million square metres of parabolic trough collectors. These plants supply an annual 800 million kWh at a generation cost of about 14-17 US cents/kWh.

Further advances are now being made in the technology, with utility-scale projects planned in Spain, Nevada (USA), Morocco, Algeria, Italy, Greece, Israel, Egypt, India, Iran, South Africa and Mexico. Electricity from trough plants are thus expected to fall to 7-8 € cents/kWh in the medium term. Combined with gas-fired combined cycle plants – so-called ISCC (Integrated Solar Combined Cycle) systems – power generation costs are expected to be in the order of 6-7 € cents/kWh in the medium term and 5 € cents/kWh in the long term.

Central receiver (solar tower) systems use a circular array of large individually tracking plain 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. Following completion of the first 10 MWe PS-10 demonstration tower plants, currently under construction in Spain, and with further scaling up to 30-50 MW capacity, solar tower developers feel confident that grid connected tower power plants can be built up to a capacity of 200 MWe solar-only units with power generation costs then comparable to those of parabolic troughs. Use of thermal storage will also increase their flexibility.

Although central receiver plants are considered to be further away from commercialisation than parabolic trough systems, solar towers have good longer-term prospects for high conversion efficiencies. Projects are under construction in Spain and under preparation in South Africa. In 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 7 € cents/kWh in the medium term and to 5 € cents/kWh in the long term.

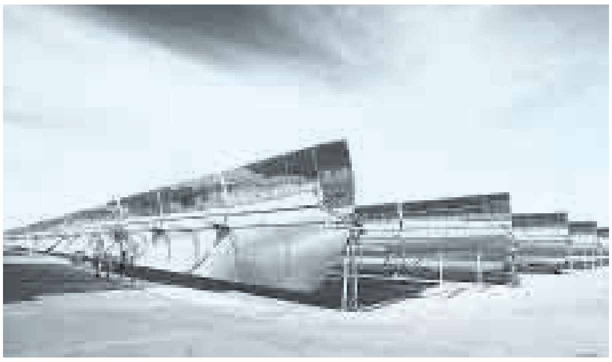
Parabolic dish systems are comparatively small units which use a dish-shaped reflector to concentrate sunlight, with super-heated fluid being used to generate power in a small engine at the focal point of the reflector. Their potential lies primarily in decentralised power supply and remote, stand-alone power systems. Projects are currently planned in the United States, Australia and Europe. In terms of electricity costs, an attainable near-term goal is a figure of less than 15-20 € cents/kWh, depending on the solar resource.

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 power plant. The other is solar-only operation, with increasing use of a storage medium such as molten salt. This enables solar energy collected during the day to be stored then dispatched when demand requires.

BENEFITS OF SOLAR THERMAL POWER

A major benefit of solar thermal power is that it has little adverse environmental impact, with none of the polluting emissions or safety concerns associated with conventional generation technologies. There is hardly any pollution in the form of exhaust fumes or noise during operation. Decommissioning a system is not problematic.

Each square metre of reflector surface in a solar field is enough to avoid the annual production of 150 to 250 kilograms (kg) of carbon dioxide. Solar thermal 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.



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 offers attractive tariffs for project developers or forces power suppliers to source a rising percentage of their supply from renewable fuels. Bulk power transmission lines from high-insolation sites, such as in northern Africa, could encourage private project developers or European utilities to finance large solar plants whose power would be used for consumption in Europe.

These and other factors have led to significant interest in constructing plants in the sun belt regions from private-sector project developers and turnkey contracting firms. In addition, interest rates and capital costs have drastically fallen worldwide, increasing the viability of capital-intensive renewable projects.

EXECUTIVE SUMMARY

Examples of specific large solar thermal projects currently under construction or in advanced permitting and development stage around the world include:

- *Algeria: 140-150 MW ISCC plant with 25 MW solar capacity (trough)*
- *Egypt: 150 MW ISCC plant with 30 MW solar capacity (trough)*
- *Greece: 50 MW solar capacity using steam cycle (trough)*
- *India: 140 MW ISCC plant with 30 MW solar capacity (trough)*
- *Italy: 40 MW solar capacity integrated into existing combined cycle plant (trough)*
- *Mexico: 291 MW ISCC plant with 30 MW solar capacity (trough)*
- *Morocco: 220 MW ISCC plant with 30 MW solar capacity (trough)*
- *Spain: over 500 MW solar capacity using steam cycle (4 x 10-20 MW solar tower and 12 x 50 MW parabolic trough)*
- *USA: 50 MW solar capacity with parabolic trough in Nevada using steam cycle, preceded by a 1 MW parabolic trough demonstration plant using ORC turbine in Arizona*
- *USA: 500 MW Solar Dish Park in California, preceded by a 1 MW (40 x 25 kW) test and demo installation*

THE FUTURE FOR SOLAR THERMAL POWER

A scenario prepared by Greenpeace International, the European Solar Thermal Industry Association and IEA SolarPACES projects what could be achieved by the year 2025 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 demand objectives.

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 total installed capacity, the rate of annual installation by 2015 will have reached 970 MW, thus reaching a total installed capacity of 6454 MW . By 2025, 4 600 MW will come on steam each year.

- *By 2025, the total installed capacity of solar thermal power around the world will have reached over 36,000 MW.*
- *By 2025, solar thermal power will have achieved an annual output of almost 100 million MWh (95.8 TWh). This is equivalent to the consumption of over one half of Australia's electricity demand, or the total combined electricity consumption of Denmark and Belgium or Israel, Morocco, Algeria and Tunisia.*
- *Capital investment in solar thermal plant will rise from US$ 60 million in 2006 to almost US$ 16.4 billion in 2025.*
- *Expansion in the solar thermal power industry will result in the creation of over 50,000 jobs worldwide, without even counting those involved in production of the hardware.*
- *The five most **promising regions,** in terms of governmental targets or potentials according to the scenario, **each with more than 1,000 MW** of solar thermal projects expected by 2025, **are the Mediterranean, especially Spain, the countries of the Middle East and North Africa, the southern states of the USA, and Australia.***
- *During the period up to 2025, the emission into the atmosphere of a total of 395 million tonnes of carbon dioxide would be avoided, 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 1 1/2 decades up to 2040. This shows that, by 2030, the worldwide capacity will have reached 100,000 MW and, by 2040, a level of almost 600,000 MW. The increased availability of plant resulting from the greater use of efficient storage technology will also increase the amount of electricity generated from a given installed capacity.

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

Key results from Greenpeace-ESTIA Scenario 2002-2025	
Capacity of solar thermal power in 2025	36,850 MW
Electricity production in 2025	95.8 TWh/year
Employment generated	54,000 jobs
Investment Value	16.4 billion $ per year
Carbon emissions avoided	362 million tonnes CO_2
Annual carbon emissions avoided in 2025	57.5 million tonnes CO_2
Projection 2025 to 2040	
Capacity of solar thermal power in 2040	600,000 MW
Electricity production	16,000 TWh
Percentage of global demand	5%

PART ONE

SOLAR THERMAL POWER – THE BASICS

PART ONE: SOLAR THERMAL POWER – THE BASICS

POWER FROM THE SUN

The principles of solar thermal power conversion have been known for more than a century; its commercial scale-up and exploitation, however, has only taken place since the mid 1980s. With these first large-scale 30-80 MW parabolic trough power stations, built in the California Mojave desert, the technology has impressively demonstrated its technological and economic promise. With few adverse environmental impacts and a massive resource, the sun, it offers an opportunity to the countries in the sun belt of the world comparable to that currently being offered by offshore wind farms to European and other nations with the windiest shorelines.

Solar thermal power can only use direct sunlight, called 'beam radiation' or Direct Normal Irradiation (DNI), i.e. that fraction of sunlight which is not deviated by clouds, fumes or dust in the atmosphere and that reaches the earth's surface in parallel beams for concentration. Hence, it must be sited in regions with high direct solar radiation. Suitable sites should receive at least 2,000 kilowatt hours (kWh) of sunlight radiation per m^2 annually, whilst best site locations receive more than 2,800 kWh/m^2/year. Typical site regions, where the climate and vegetation do not produce high levels of atmospheric humidity, dust and fumes, include steppes, bush, savannas, semi-deserts and true deserts, ideally located within less than 40 degrees of latitude north or south. Therefore, the most promising areas of the world include the South-Western United States, Central and South America, North and Southern Africa, the Mediterranean countries of Europe, the Near and Middle East, Iran and the desert plains of India, Pakistan, 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 100-130 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 mid-load power plants. Over the total life cycle of a solar thermal power system, its output would be equivalent to the energy contained in more than 5 million barrels of oil[2)].

However, this large solar power potential will only be used to a limited extent 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 sun belt countries could be harvested to protect the global climate. Countries such as Germany are already seriously considering importing 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 be given primarily to supply for legitimate indigenous demand.

TURNING SOLAR HEAT INTO ELECTRICITY

Producing electricity from the energy in the sun's rays is a 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 turbine or a Stirling engine. Solar heat collected during the day can also be stored in liquid or solid media such as molten salts, ceramics, concrete or, in the future, phase-changing salt mixtures. At night, it can be extracted from the storage medium thereby continuing turbine operation.

Solar thermal power plants designed for solar-only generation are ideally suited to satisfying summer noon peak loads in wealthy countries with significant cooling demands, such as Spain and California. Thermal energy storage systems are capable of expanding the operation time of solar thermal plants even up to base-load operation. For example, in Spain the 50 MWe AndaSol plants are designed with six to 12 hours thermal storage, increasing annual availability by about 1,000 to 2,500 hours.

During the market introduction phase of the technology, hybrid plant concepts which back up the solar output by fossil co-firing are likely to be the favoured option, as in commercially operating parabolic trough SEGS plants in California where some fossil fuel is used in case of lower radiation intensity to secure reliable peak-load supply. Also, Integrated Solar-Combined Cycle (ISCC) plants for mid- to base-load operation are best suited to this introduction phase. 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 in the California Mojave desert, whilst solar towers and dish engines have been tested successfully in a series of demonstration projects.

WHY CONCENTRATE SOLAR POWER?

Concentrating solar power (CSP) to generate bulk electricity is one of the technologies best suited to helping to 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, without creating other environmental risks or contamination. Each square metre of CSP concentrator surface, for example, is enough to avoid annual emissions of 200 to 300 kilograms (kg) of carbon dioxide, depending on its configuration. The energy payback time of concentrating solar power systems is of 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 can be recycled and used again for further plants.

Economic sustainability

The cost of solar thermal power will fall with higher volumes. Experience from the Solar Electric Generating Systems (SEGS) in California (see Part Two) shows that today's generation costs are about 15 US cents/kWh for solar generated electricity at sites with very good solar radiation. However, most of the learning curve is still to come.

Together, advanced technologies, mass production, economies of scale and improved operation will enable a reduction in the cost of solar electricity to a level competitive with conventional, fossil-fueled peak and mid-load power stations within the next ten years. This will reduce dependency on fossil fuels and, thus, avoid the risk of drastic electricity costs escalation in future. Hybrid solar-fossil fueled CSP plants, making use of special finance schemes at favourable sites, can already deliver competitively priced electricity.

Basically, solar thermal power plants compete with conventional, grid-connected fossil fuel-fired power stations – in particular, modern, natural-gas-fired combined cycle plants in mid-load or base-load operation mode. For small-scale, off grid solar power generation, such as on islands or in rural hinterlands of developing countries, competition stems basically from gas oil or heavy-fuel-oil-powered diesel engine generators.

However, a mixture of factors, including reform of the electricity sector, rising demand for 'green power', and the possibility of gaining carbon credits from pollution-free power generation as well as direct support schemes – e.g. feed-in laws or renewable portfolio standards for renewable power in some countries – are all increasing the economic viability of such projects.

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, and 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. Remshalden from Stuttgart for a parabolic trough-shaped collector to use solar irradiation directly for steam generation. In 1912, Frank Shuman used a similar concept to build a 45 kW sun-tracking parabolic trough plant in Meadi, near Cairo, Egypt.

These early designs formed the basis for R&D development 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 1.1*). Many of these pilot plants, covering the whole spectrum of available technology, failed to reach the expected performance levels. In the following decades, activities concentrated on further R&D for technology improvements.

In the mid 1980s, the American/Israeli company Luz International achieved a major technology breakthrough when they started to build parabolic trough power stations in series. Each of the nine Solar Electric Generating Stations (SEGS) plants built between 1984 and 1991 in the California Mojave desert was bigger by far than any of the research pilot plants built shortly before. The SEGS plants started its success story with an initial 14 MW, followed by six plants of 30 MW, finally reaching a capacity of 80 MWe in the last two units built between 1989 and 1991. In total, they provide 354 MW of reliable capacity which can be dispatched to the Southern California grid. In contrast to the early R&D plants listed below, all SEGS plants have been developed, financed, built and are still operated on a purely private basis.

Table 1.1: 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	1984	Private Project Financing – Luz
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

PART TWO

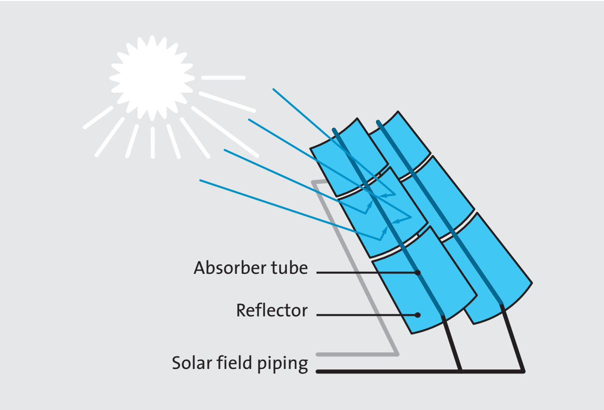
SOLAR THERMAL POWER – TECHNOLOGY, COSTS AND BENEFITS

PART TWO: SOLAR THERMAL POWER – TECHNOLOGY, COSTS AND BENEFITS

TECHNOLOGY OVERVIEW

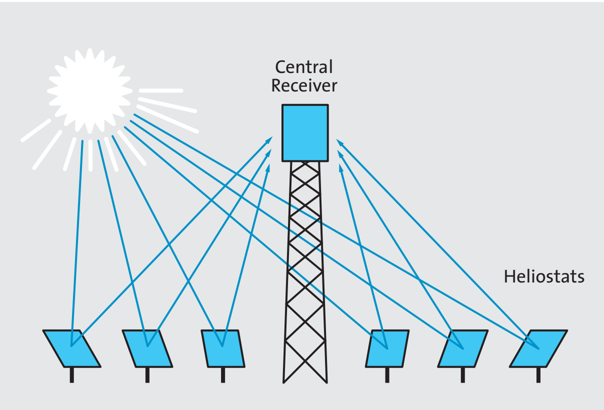
Solar thermal power plants, often also called Concentrating Solar Power (CSP) plants, produce electricity in much the same way as conventional power stations. The difference is that they obtain their energy input by concentrating solar radiation and converting it to high-temperature steam or gas to drive a turbine or motor engine.

Four main elements are required: a concentrator, a receiver, some form of 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:



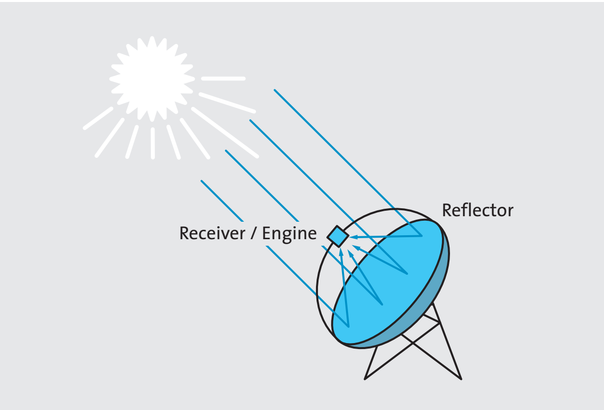
Parabolic trough

Parabolic trough-shaped mirror reflectors are used to concentrate sunlight on to thermally efficient receiver tubes placed in the trough's focal line. A thermal transfer fluid, such as synthetic thermal oil, is circulated in these tubes. 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.



Central receiver or 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. To date, the heat transfer media demonstrated include water/steam, molten salts, liquid sodium and air. If pressurised gas or air is used at very high temperatures of about 1,000°C or more as the heat transfer medium, it can even be used to directly replace natural gas in a gas turbine, thus making use of the excellent cycle (60% and more) of modern gas and steam combined cycles.



Parabolic dish

A parabolic dish-shaped reflector is used to concentrate sunlight on to a receiver located at the focal point of the dish. The concentrated beam radiation is absorbed into the receiver to heat a fluid or gas (air) to approximately 750°C. This fluid or gas is then used to generate electricity in a small piston or 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 2.1*.

Table 2.1: Comparison of solar thermal power technologies			
	Parabolic Trough	**Central Receiver**	**Parabolic Dish**
Applications	Grid-connected plants, mid- to high-process heat (Highest single unit solar capacity to date: 80 MWe.) Total capacity built: 354 MW	Grid-connected plants, high temperature process heat (Highest single unit solar capacity to date: 10 MWe, with another 10 MW currently under construction.)	Stand-alone, small off-grid power systems or clustered to larger grid-connected dish parks (Highest single unit solar capacity to date: 25 kWe; recent designs have about 10 kW unit size.)
Advantages	• Commercially available – over 12 billion kWh of operational experience; operating temperature potential up to 500°C (400°C commercially proven) • Commercially proven annual net plant efficiency of 14% (solar radiation to net electric output) • Commercially proven investment and operating costs • Modularity • Best land-use factor of all solar technologies • Lowest materials demand • Hybrid concept proven • Storage capability	• Good mid-term prospects for high conversion efficiencies, operating temperature potential beyond 1,000°C (565°C proven at 10 MW scale) • Storage at high temperatures • Hybrid operation possible	• Very high conversion efficiencies – peak solar to net electric conversion over 30% • Modularity • Hybrid operation possible • Operational experience of first demonstration projects
Disadvantages	• The use of oil-based heat transfer media restricts operating temperatures today to 400°C, resulting in only moderate steam qualities	• Projected annual performance values, investment and operating costs still need to be proven in commercial operation	• Reliability needs to be improved • Projected cost goals of mass production still need to be achieved

PARABOLIC TROUGH SYSTEMS

Technology developments

Parabolic trough systems represent the most mature solar thermal power technology, with 354 MWe connected to the Southern California grid since the 1980s and over 2 million square metres of parabolic trough collectors operating with a long term availability of over 99%. Supplying an annual 924 million kWh at a generation cost of about 12 to 15 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").

Figure 2.1: Generation of solar thermal electricity at Californian plants using parabolic trough collectors, 1985 to 2004

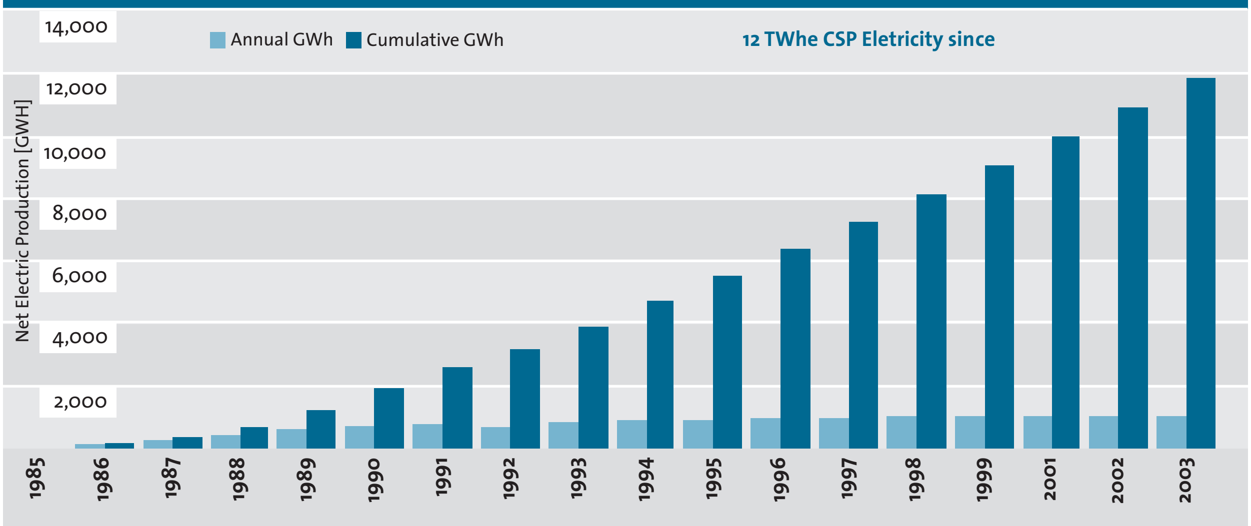


Figure 2.2: Measured daily output on July 1st 1997 at SEGS VI plant in Kramer Junction, California

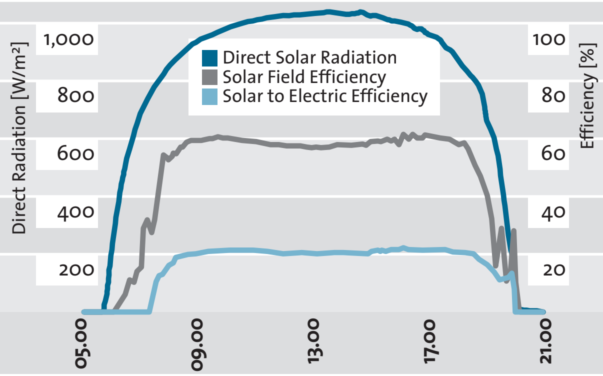
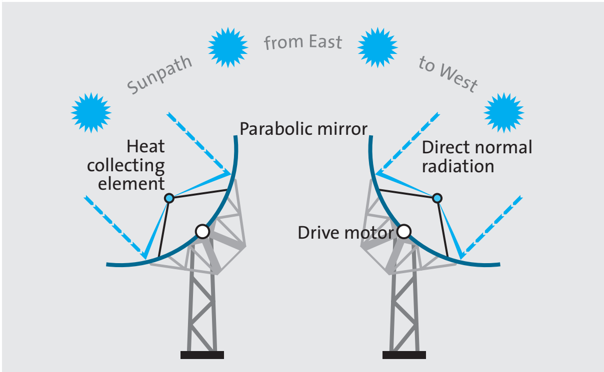
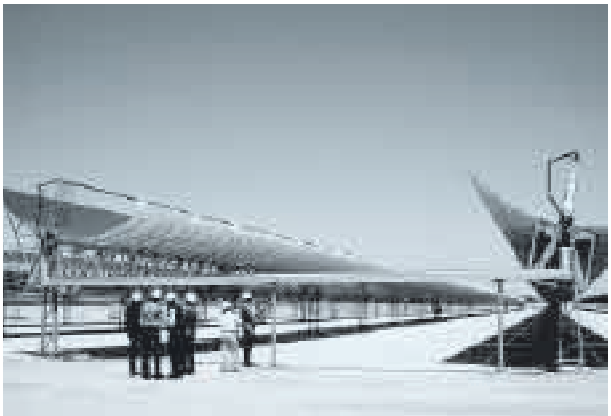


Figure 2.3: Operating principles and daily tracking of the SKAL ET-EuroTrough collector



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, thus resulting in higher thermal output. By increasing the length of the collector units, investment savings can be achieved in drive systems and connection piping. Next-generation receiver tubes will also further reduce thermal losses while, at the same time, improving 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 have recently been developed in Europe and the USA and are currently in their test phase, whilst work on improved receiver tubes is under way in both Israel and Germany.

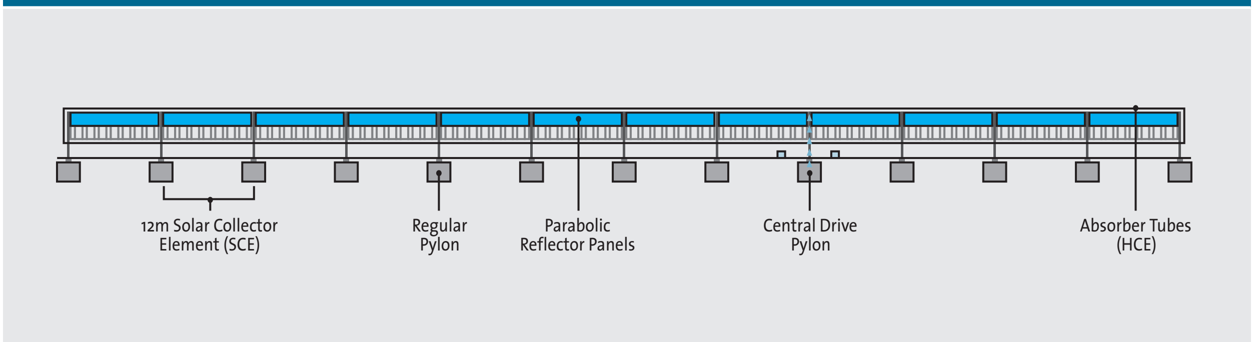


SKAL ET Parabolic Trough Collector loop, built by Solar Millennium AG and FlagSol into the operating SEGS V plant at Kramer Jct., California.

What promises to be the next generation of parabolic collector technology has been under development at the European solar thermal research centre, the Plataforma Solar in Spain, since 1998 by a European R&D consortium. Known as EuroTrough, it 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 for the trough structure. With funding from the European Union, both a 100m and a 150m prototype of the EuroTrough were successfully commissioned in 2000 and 2002 respectively at the Plataforma Solar.

An extended 4,360m² loop of an advanced EuroTrough design, the SKAL ET collector loop with both 100m and 150m collector units has been built into and is in operation at the SEGS V plant in Kramer Junction, California since spring 2003 and has operated continually ever since. The cost of this demonstration loop was shared between the German SKAL ET consortium and the German Federal Ministry for the Environment (BMU).

Figure 2.4: EuroTrough ET 150 collector



In the USA, an advanced-generation trough concentrator design that uses an all-aluminium space frame is currently being implemented in a 1 MW pilot plant in Arizona. The design is patterned on the size and operational characteristics of the LS-2 collector, but is superior in terms of structural properties, weight, manufacturing simplicity, corrosion resistance, manufactured cost, and installation ease. Also in Israel, an upgraded version of the LS2 parabolic trough has now become the fifth generation of this well-known and proven technology.

The commercial plants in California use a synthetic oil as the heat transfer fluid, because of its low operating pressure and storability. However, 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 will further reduce costs. 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 cost-effective phase change storage medium for direct steam systems is at the focus of the European R&D project DISTOR.

For the Spanish 50 MW AndaSol 1, 2 and 3 projects, the German project developer Solar Millennium, in full collaboration with an American engineering company, designed a six to 12 full load hours thermal storage system operating with molten salt, which was successfully tested in the 10 MW USA Solar Two solar tower pilot plant. Similarly, this endeavour was cost shared by the industry developer and the BMU.

Another option under investigation is the development of the parabolic-line-focusing concept with segmented mirrors, according to the Fresnel principle (see box). 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.

To date, as a result of the regulatory framework prevailing in California during implementation of the SEGS plants (see box), 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.

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 and reflector 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 as a lower-cost alternative to trough technology for the production of solar process heat and steam. For power generation, where higher steam temperatures are needed, LFR must still prove its cost effectiveness and system reliability.

An LFR can be designed to have similar thermal performance to that of a parabolic trough per aperture area, although recent designs tend to use less expensive reflector materials and absorber components which reduce optical performance and thus, thermal output. However, this lower performance seems to be outweighed by lower investment and operation and maintenance costs.

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 2,500 m^2. The next step should be a pilot plant to demonstrate the technology in a larger-scale system under commercial operational conditions.

Most convenient and cost-effective would be a plug-in solution for a Fresnel collector connected to an existing power plant. In 2003, the Australian company Solar Heat and Power constructed a test field for its new Fresnel collector concept, equivalent to 1 MW electric capacity, and tested it. This year (2005) has seen the start of the enlargement of the Fresnel solar field, comprising 20,000 m which will be connected to the large coal-fired Liddell power station using solar steam as feed-water addition. The final stage will be a roll out to 135,000 m.

Solar costs

"For the current state of parabolic trough CSP technology, and at very good sites, a solar kWh can be generated for about 15-17 US cents/kWh. This generation cost will be reduced when more projects are implemented. CSP industry anticipates reducing solar power generation costs by 20-25%, once 1,000 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 mid-load power generation."

Global Market Initiative, June 2004

The California SEGS power plants

Designed, developed and constructed by the American/Israeli company LUZ over the period 1984-91, and ranging in size from an initial 14 MWe up to the last-built 80 MWe, the nine parabolic trough power plants in the California Mojave desert (total capacity of 354 MWe) are known collectively as the Solar Electricity Generating Systems (SEGS). They use a highly efficient steam turbine fed with steam from the solar field for power generation. 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 2 million square metres of glass mirrors, the plants have generated over 12 billion kWh of solar electricity since 1985.

The US$ 1.2 billion 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 during 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/m^2, have generating costs of about 17 US cents/kWh (expressed in 2005 US$) and operate predominantly during high-priced summer daytime peak demand hours (mainly to cover California peak load caused by air conditioning). They have an allowance to generate up to 25% of the annual thermal output by supplementary natural gas firing. The equivalent pure solar costs would be 20 US cents/ kWh. The two 80 MWe SEGS plants at Harper Lake, with the same annual insolation, have generating costs of 15 US cents/kWh (in 2005 US$). The equivalent "solar-only" costs would be 17 US cents/ kWh).

In terms of efficiency, the SEGS plants have achieved daily solar-to-net electric efficiencies close to 20%, and peak efficiencies up to 21.5%. The annual plant availability constantly exceeds 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 USA to further reduce costs in a number of areas, including improvements in the collector field, receiver tubes, mirrors and thermal storage.

Current projects

Due to its commercial maturity, parabolic trough technology is the preferred choice of industrial developers of and investors in large-scale CSP projects in Europe and the South-western United States. This also applies to Integrated Solar Combined Cycle (ISCC) projects in Algeria, Egypt, India, Iran, Mexico and Morocco, some of which are currently out for international bidding, either with financial support of the Global Environment Facility (GEF) or through national tariff or R&D incentive schemes. The following large-scale parabolic trough projects are currently at an advanced development stage:

Algeria

Without additional support from GEF's CSP portfolio, Algeria has set up a national programme for the promotion of renewable energy sources in the frame of its Sustainable Energy Development Plan for 2020. Algeria, as the first non-OECD country, published a feed-in law in March 2004 with elevated tariffs for renewable power production, including solar thermal power for both hybrid solar-gas operation in steam cycles, as well as integrated solar, gas- combined cycle plants. In June 2005, the first Request for Proposals (RfP) was published by the New Energy Algeria (NEAL) Agency for a 150 MW ISCC plant with parabolic trough technology to be privately financed and operated.

Australia

Having passed the successful pre-qualification step of a 1 MWe equivalent pilot installation at the large, coal-fired 2,000 MW Liddell power station in Hunter Valley, New South Wales, a further demonstration step for such Compound Linear Fresnel (CLFR) solar field expansion to 5 MWe has recently been awarded to the promoters, Solar Heat and Power, by the off taking utility company. After successful demonstration, the next steps will include a 35 MWe CLFR-based array which will be used for pre-heating steam. This system increases the electrical output for a given coal input rather than being simply a coal-replacement technology. The use of existing infrastructure reduces costs when compared to a stand-alone plant.

Egypt

In August 2003, the New and Renewable Energy Agency (NREA) changed the GEF-sponsored, formerly structured as an Independent Power Project (IPP) approach to a national utility owned implementation – and assigned the preparation of the conceptual design and the Request for Proposal (RfP) to Fichtner Solar GmbH. In February 2005, the Egyptian authorities decided to change the previous RfP, which was structured on a turnkey basis for the complete ISCC of 150 MWe capacity (with a solar contribution of 30 MWe), into RfPs for two distinct lots, one for Solar Island and one for the Combined Cycle Island. New pre-qualification and bid documents were developed in 2004, while NREA secured the required co-financing. It is expected that the contracts for the Solar Island and the Combined Cycle Island will be awarded by mid 2006 and the plant will start operations by the end of 2008.

India

Rajasthan Renewable Energy Corporation (RREC) published a Request for Proposals (RfP) in June 2002 for an ISCC (Integrated Solar Combined Cycle Power Plant) of 140 MWe capacity, incorporating a parabolic trough solar field of about 220,000 m^2 to provide an approximately 30 MWe solar thermal contribution. The incremental solar costs were to be covered by a grant from Global Environment Facility (GEF) and with further soft loan financing from the German KfW bank and loans from India and the state of Rajasthan. Fichtner Solar GmbH had prepared the initial feasibility study, the conceptual design as well as the Request for Proposal for an EPC cum O&M contract. Limited competition, high risks on uncertain fossil fuel supply and some administrational disputes delayed the project. After extensive review of the underlying technical and project implementation concept, GEF is now seeking re-affirming of the commitment from all Indian participants to continue the project.

Iran

Since 1997, the government of Iran has been interested in the implementation of a 200,000–400,000 m^2 parabolic trough field into a 300 MW natural-gas-fired combined cycle plant in the Luth desert in the area of Yazd. For that reason, Iran had approached GEF with a request to finance the incremental cost of the solar field. As GEF was not in the position to allocate any additional resources for this request, in 2005, Iran has changed the plant configuration and now intends to build a solar field, equivalent to about 17 MWe, also to power the envisaged upgrade of installed gas turbines at a 467 MW combined cycle plant.

Israel

In November 2001, the Israeli Ministry of National Infrastructure, also responsible for the energy sector, decided to introduce CSP as a strategic ingredient for Israel's electricity market. A feasibility study, identifying necessary incentive premiums for CSP, was completed in late 2003 and is under review by the Israel Public Utilities Authority for the drawing up of an adequate feed-in law. Recent Israeli information suggests that a national CSP programme is currently under way, encompassing about 500 MW of CSP capacity by 2010 and another 1,000 MW by 2015.

Italy

In 2001, the Italian Parliament allocated € 55 million for CSP development and a national demonstration programme. In early 2004, a co-operation agreement between the National Environmental and Renewable Research centre, ENEA and ENEL, one of Italy's and Europe's biggest utility companies, was signed to develop the Archimede project in Sicily as the first Italian solar plant integrated with an existing combined cycle plant with advanced parabolic trough technology, using new collector design, new absorber tubes and molten salts as heat transfer and thermal storage fluid.

Mexico

Mexico's Comisión Federal de Electricidad (CFE) issued a RfP in March 2002 for a 250 MW gas-fired combined cycle plant with an optional integrated parabolic trough solar field of at least 25 MW electrical output. The incremental solar costs should be covered by a grant from GEF. As investor's response to this concept was very limited, it was decided in 2003 that an EPC scheme with CFE as the GEF grant recipient should be pursued. The solar field would no longer be an option but compulsory. In 2005, the plant location was changed to Sonora State and it was suggested by CFE that the combined cycle size be doubled from 250 to 500MW.

Morocco

In 1999, a grant of US$ 50 million from the GEF was committed to Morocco for a 220 MW ISCC project with 30 MW equivalent solar capacity. On behalf of the national utility company, Office National de l'Electricité (ONE) and GEF, Fichtner Solar GmbH prepared the RfP with the choice of technology being left to the bidding investors. When investor interest in a merchant Independent Power Project appeared non-existent, the approach was changed to a national utility-owned project. In August 2004, industry response to that new RfP concept was significant, leading to the pre-qualification of four international consortia. In February 2005, bid preparation documents were submitted to the World Bank for "Non-Objection". Additional financing has already been committed by the African Development Bank. The contract award is expected early in 2006, and the start of operations at the end of 2008.

Spain

Today, Spain is probably the hottest spot on earth for CSP project development. In August 2002, the first European feed-in law, explicitly regulating CSP for a solar resource-wise sufficiently appropriate region, initiated early CSP project developments, such as those of Solar Millennium for the 50 MWe parabolic trough AndaSol projects in Andalusia. Following an increase in the Spanish solar thermal incentive premium from 12 to 18 € cents/kWh in March 2004, over a dozen further 50 MWe solar thermal parabolic trough project developments were started. Developers include general contractors such as Abengoa and ACS/Cobra, the Spanish industry partner of Solar Millennium for the AndaSol plants, as well as utility companies like EHN, the partner of the American CSP developer Solargenix, Iberdrola, Hidrocantabrico-Genesa and others. It is expected that about 500 MW of CSP capacities could be installed by 2010.

United States

In 2003, Nevada Power signed a long-term power purchase agreement (PPA) with Solargenix Energy (formerly Duke Solar) for a 50 MW parabolic trough power plant to be built in Eldorado Valley near Las Vegas. This plant is designed to operate in solar-only mode. In 2005, the envisaged capacity has been increased to 64 MW. Financial closure is expected to take place by the end of 2005 or early 2006 and construction should start immediately after. Prior to the start of the construction of this 64 MW plant, a 1 MW parabolic trough test plant with organic rankine-cycle turbine, also designed and built by Solargenix, will be put into operation in September 2005. In August 2005, the American solar dish developer SES and Southern California Edison, Southern California's biggest utility company have announced the signature of a long-term power purchase agreement (PPA) for a huge, 500 MW dish park with, with an option for further 350 MW. This PPA will be exercised once a first 1 MW dish park, consisting of 40 individual 25 kW dish-sterling systems, has been successfully built and tested by SES.

With the positive recommendations of Governor Schwarzenegger's Solar Task Forces in California, the Western Governors Association´s and New Mexico's CSP Task Force, a revival of solar thermal power is expected in the USA soon. This is underlined by intensified project development activities by a variety of companies.

Cost trends

Between 1984 and 1991, 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 mainly due to the increase in size from 30 to 80 MWe units and series experience.

The investment cost of parabolic trough fields has currently dropped to € 210/m^2 for enhanced collectors like the SKAL ET EuroTrough design with large solar fields, and will fall to about € 110-130/m^2 for high-production runs in the long term. A 15% solar field investment cost reduction can be expected in developing countries, compared to USA/European price levels, due to lower labour costs.

According to a World Bank assessment of the USA/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 power generation costs range from 10 to 7 € cents/kWh for SEGS type plants and less than 7 € cents/kWh for ISCC plants.

The expected further drop in 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 to mid-load 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 plants, and AU$ 0.07/kWh to AU$ 0.09/kWh as a stand-alone solar thermal plant.

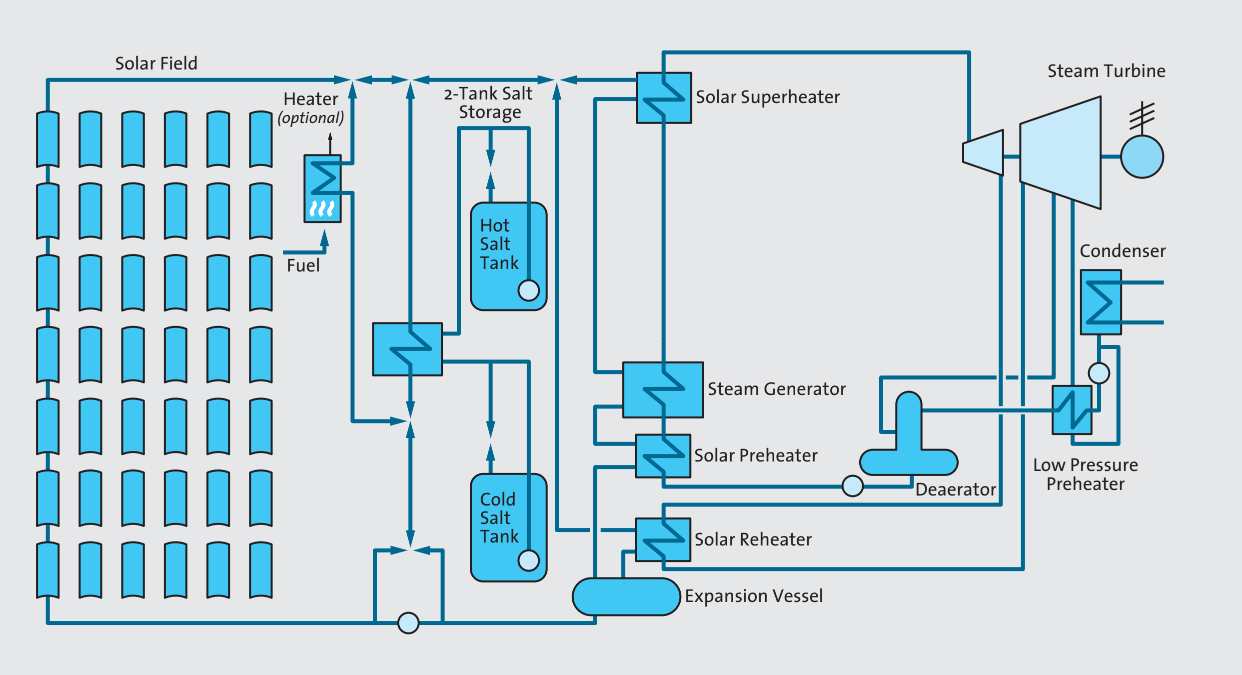
Table 2.3 shows how substantially these cost reductions could be achieved over the next five to ten years, especially for plants with very large solar fields. Similarly, the analysis shows that projects could be built cheaper outside the developed world. In a pre-feasibility study for a CSP plant in Brazil, for example, it was estimated that the construction cost of a 100 MW Rankine-cycle plant would be just US$ 2,660/kW today, 19% lower than in the USA, 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 the key to their competitive bidding at a low cost.

An American 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.

Table 2.3: Cost reductions in parabolic trough solar thermal power plants

	Near-Term (Next Plant Built)	Near-Term (Next Plant Built)	Near-Term (Next Plant Built)	Mid-Term (~ 5 Years)	Long-Term (~ 10 Years)	Long-Term (~ 10 Years)
Power Cycle	Rankine	Rankine	ISCC	Rankine	Rankine	Rankine
Solar Field (,000 m^2)	193	1,210	183	1,151	1,046	1,939
Storage (hours)	0	0	0	0	0	0
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 ($/kW)						
US Plant	3,500	2,400	3,100	2,100	1,800	2,500
International	3,000	2,000	2,600	1,750	1,600	2,100
O& M Cost ($/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

Figure 2.5: Parabolic trough power plant with hot and cold tank thermal storage system and oil steam generator



CENTRAL RECEIVER/SOLAR TOWER SYSTEMS

Technology developments

The average sunlight concentration of tower systems varies with the process temperature from about 500 times for 540°C steam cycles to several thousand times concentration for applications at 1,000°C and beyond for gas turbine or combined cycles electricity, and thermo chemical cycles for production of industrial materials or synthetic fuels like hydrogen.

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 10 MWe 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, although 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 sealing window. Integrated Solar Combined Cycle power plants using this method will require 30% less collector area than equivalent steam cycles. At present, a first prototype to demonstrate this concept is being built as part of the European SOLGATE project, with three receiver units coupled to a 250 kW gas turbine.

Various central receiver heat transfer media have been investigated, including water/steam, liquid sodium, molten salt and ambient air. Those storage systems allows solar energy to be collected during daylight hours and dispatched as high-value electric power at night or when required by the utility. Therefore, in the USA sun belt regions, a plant could 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 only occurring during the evening.

Today, the most promising storage systems are considered to be the European volumetric air technology and the USA molten-salt technology. The latter is now ready to be commercially demonstrated, and a project led by Sener (Spain) is promoting the first commercial central receiver plant with support of EU and Spanish grants. This proposed 15 MWe Solar Tres plant in Spain will utilise a 16-hour molten-salt storage system to run on a 24-hour basis in summertime. Molten-salt storage coupled with central receiver/tower technology is unique among all renewable energy technologies in that the addition of storage[3] reduces energy cost and increases its value by enabling dispatch to peak demand periods.

The European system involves irradiating fine wire mesh or ceramic foam structures, and 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.

As with parabolic troughs, efforts are under way to develop commercial central receiver plants using solar/fossil fuel hybrid systems. Although the ISCC configuration, where solar

1. up to about 13 hours yielding a 70% capacity factor at a high solar resource location heat is added to the bottoming steam cycle, favours the lower temperature of the trough designs, high-temperature air receivers for tower technology allow heat addition to the topping gas turbine cycle at much higher conversion efficiency. Coupling the output of the high temperature solar system to a gas turbine also has the potential for 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 m² heliostat developed by Advanced Thermal Systems (USA), the 170 m² heliostat developed by Science Applications International Corporation (USA), the 150 m² stretched-membrane ASM-150 heliostat from Steinmüller (Germany), and the 100 m² glass/metal GM-100 heliostat from Spain. Initiatives to develop low-cost manufacturing techniques for early commercial low-volume builds are also under way, whilst prices for manufacture in a developing country could be roughly 15% below USA/European levels. As with many solar thermal components, the price should fall significantly with economies of scale in manufacture.

Central receiver plants have reached commercial status with the erection of PS10 plant, 11MW solar tower which is the first of the new wave of CSP projects in Spain. Potential for improvement is already high, as solar towers have good longer term prospects for high conversion efficiencies.

Current solar tower projects

Spain

The first two commercial solar tower plants in the 10-15 MW range are currently being prepared for or are already under construction within the Spanish solar thermal incentive programme.

The Spanish company Solucar, belonging to the Abengoa group, is currently constructing a 11MW solar tower plant with saturated steam receiver technology, known as PS10. With a 75.000m² heliostat field, the PS10 will feed an annual 23 GWh of solar electricity to the grid, and will achieve a 17.0% annual conversion efficiency from solar radiation to electricity (without cosine effect), thanks to the high efficiency of the cavity geometry and the low temperature of its receiver. The system includes the use of a small turbine, which makes the concept interesting for modular distributed electricity generation systems. Solucar has already given permission for a further two 20MW solar tower plants of the same type.

The Spanish company SENER is promoting the 15MW solar tower project Solar Tres with molten-salt receiver and storage technology for 24-hour round-the-clock operation.

South Africa

The South African national electricity utility Eskom has taken a strategic decision to pursue molten-salt solar tower technology within its programme on bulk renewable electricity, aiming for a series of 100 MW commercial solar towers. The project is currently assessing the feasibility of a 100MW pilot project.

Cost trends

Installed capital costs for central receiver pilot plants are still too high, and no electricity generation costs from commercially scaled-up plants are yet available. Central receiver plants will take credit, however, for their potential for the favourable application of high-temperature energy storage systems. This will increase the plant capacity factor, reduce electricity costs, and increase the value of power by enabling dispatch to peak demand periods.

Promoters of new near-term tower projects in Spain, such as the 10 MW PS10 plant with three 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 predicted total plant electricity costs ranging 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. The expected costs for installing the heliostat field range from € 180 to € 250/m² for small production runs in the USA, and from € 140 to € 220/m² in Europe. A 15% discount on the USA/ European price level can be projected for developing countries because of lower labour costs. Heliostat field costs are expected to drop below € 100/m² 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. According to the World Bank, the expected evolution of total electricity costs 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 (200 MWe Rankine-cycle plant with storage) for high insolation sites with an annual DNI of more than 2,700kWh/m².

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 metres in diameter and 5 to 50 kW of power output. Like all concentrating systems, they can be additionally powered by natural gas or biogas, providing reliable capacity at any time.

As a result of 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 25 kWe, but multiple dish arrays can be used in order to accumulate the power output 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.

Since the 1970s, several small off-grid power systems with parabolic dish units in the range of 5 to 50 kWe have proved their technical feasibility in experimental projects around the world. 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 25 kWe USA dish/Stirling system with a solar-to-electric efficiency of 30%.

Dish/engine prototypes which have successfully operated over the last ten years include 7 to 25 kW 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 10 kW rating are currently operating successfully. These were developed by the German company Schlaich, Bergermann und Partner (sbp), working with Mero (suppliers of the collector system) and SOLO Kleinmotoren (Stirling engine). Three of these dishes have been operated continually 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 25 kW dish/Stirling prototypes for extended testing and evaluation. Finally, WG Associates have demonstrated the first unattended, remote operation of an advanced technology 10 kW dish/Stirling prototype. Turnkey dish/Stirling systems, with the option of hybrid operation with gas combustion, are currently under development and are 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. Last year, SES, an American dish developer, has built 5 dish-sterling systems of 25 kW, each, at the American National Solar Research test facility, Sandia, Albuquerque. In August 2005, SES announced conclusion of a 500 MW power purchase agreement (PPA) with Southern California Edison utility, with a future option of another 350 MW. The PPA is conditional upon SES's successful implementation and operation of an initial 1 MW solar dish park test facility consisting of 40 dish-sterling systems with 25 kW, each.

Europe

A demonstration project at the PSA in Spain involves six German dish/Stirling pre-commercial units with 9 to 10 kWel capacity each. Over 30,000 operating hours have been accumulated by the earliest system. Promising advanced heat pipe receivers and Stirling engines are currently under development with the aim of reducing costs. A further six demonstration dishes have been implemented, with financial support from the German Ministry for Environment, by the German company SBP in Germany, Spain, France, Italy and India. The Spanish one at Seville University's Engineering Department is the first CSP system to sell solar thermal electricity under the new Spanish feed-in law.

Cost trends

The cost trend for dish collectors has already shown a sharp reduction from € 1,250/m^2 in 1982 (40 m^2 array, Shenandoah, USA) to € 150/m^2 in 1992 (44 m^2 array, German SBP stretched membrane dish). Overall installed plant capital costs for a first stand-alone 9 to 10 kWe dish/Stirling unit currently range from € 10,000 to € 14,000/kWe. If a production run of 100 units per year were 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 a drastic decrease in 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/m^2 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.

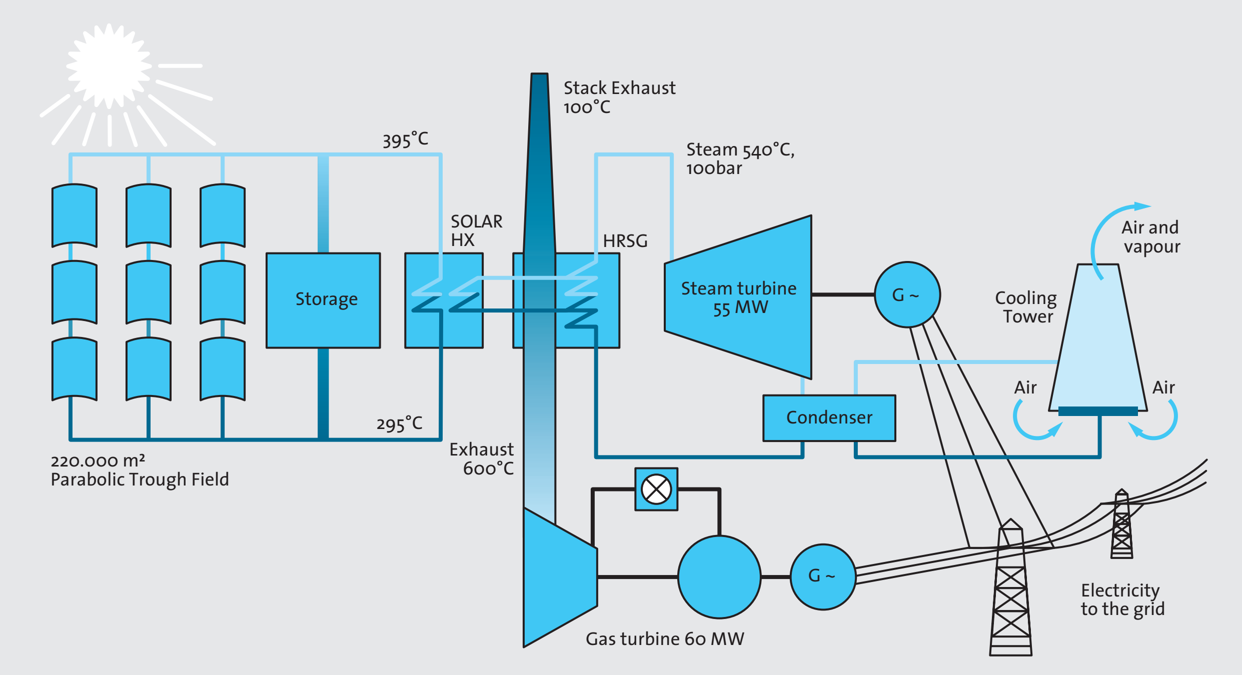
A 1999 American study on the utility market potential for dish systems concluded that costs will need to fall to between US$ 2,000 and US$ 1,200/kWe in order to achieve any significant market uptake. For initial market sectors, such as distributed generation, reliability and O&M costs will be crucial 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.

In 2005, the USA dish developer SES announced, that the company might be able to offer electricity from dish/Stirling engines in California for about the cost of a conventional generated peaking kWh, if power purchase agreements of 500-1,000 MW were available. These context has been achieved with the recent publication of a PPA for 500 MW with SCE.

Future trends and costs

Two broad pathways have opened up for the 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).

Figure 2.6: 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 2.6*). 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 quite 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 for 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 85-100% solar operation is eligible, whilst the World Bank-backed Global Environment Facility, an important source of funding, is supporting hybrid ISCC systems with a low solar share.

Current drastically increasing fuel prices and power shortages for summer daytime peaking power in South-west USA and Southern Spain suggest that CSP systems will today find their prime market segment in this summer on peaks. Here, power generation cost differences, compared to typically used gas turbine operation, are smallest.

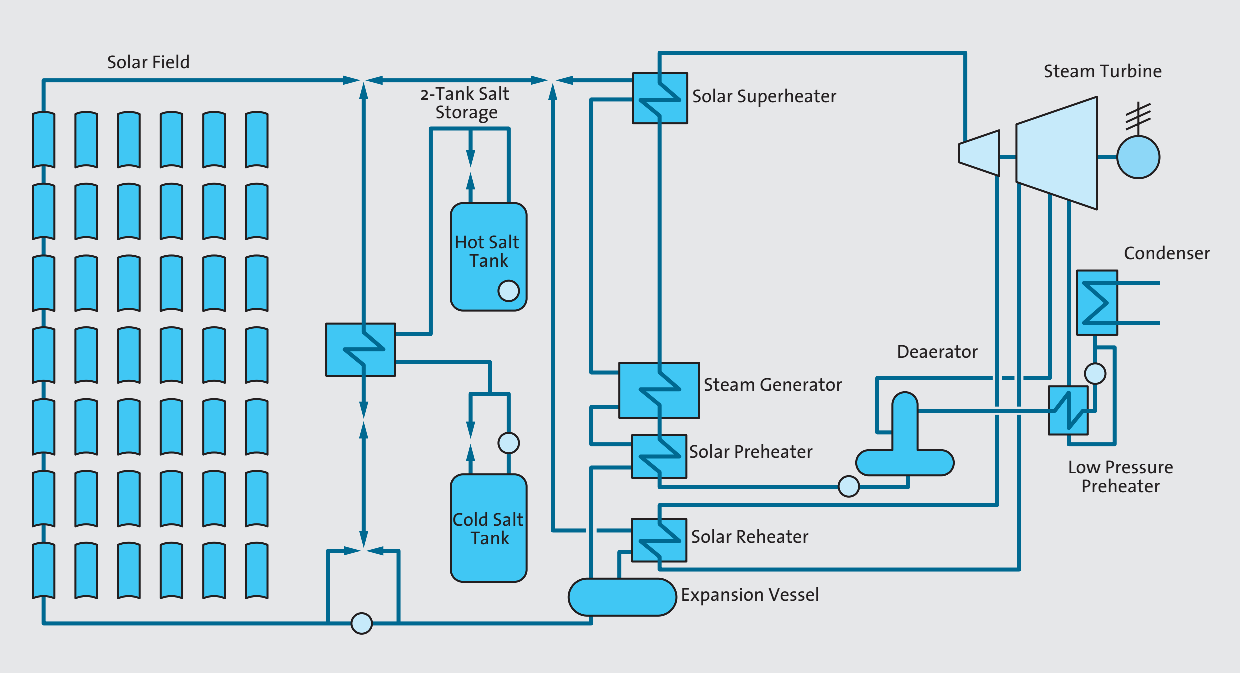
The market for 100% solar only operation will broaden still further with the use of thermal storage as a way of storing the sun's heat until required for power generation. A recent study, part of the USA Trough Initiative, evaluated several thermal storage concepts, with the preferred design using molten 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 most of the 50 MW parabolic trough plants now being promoted in 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 approximately 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 2.7 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, experience so far has been almost exclusively from parabolic trough systems, such as the Californian SEGS plants. For current trough systems with 100% solar operation, costs are in the range of 15-17 US cents/kWh in high solar radiation areas of the US South-west and about 20 euro cents/

Figure 2.7: Flow diagram of solar field, storage system and steam cycle at the AndaSol-1 project, southern Spain



kWh in the medium solar radiation areas of the Mediterranean. These costs can be cut down by 30-50% through the implementation of the first 5,000 MW within the market introduction concept of the Global Market Initiative for CSP.

ENVIRONMENTAL BENEFITS

Solar thermal power involves hardly any of the polluting emissions or environmental safety concerns associated with conventional, fossil or nuclear-based power generation. There is very little pollution in the form of exhaust gases, dust or fumes. Decommissioning a system is not problematic. Most importantly, in terms of the wider environment, there are no emissions of carbon dioxide in solar-only operation of a solar thermal plant – the main gas responsible for global climate change (see panel "Climate change and fuel choices"). If additional fossil fuel is used to back peak-load operation, in proportion to the solar share achieved, emissions are still significantly lower. Although indirect emissions of CO_2 occur at other stages of the life cycle, these are negligible compared to the emissions avoided from power generation.

Solar power can therefore make a substantial contribution towards international commitments to reducing 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 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 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 in temperate and 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 50.*

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 economy and lifestyle.
Therefore, to effectively stem the greenhouse effect, emissions of CO_2 must 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.

Greenpeace calls for:

- *An early start and rapid conclusion of negotiations for the second commitment period (2013-2017) of the Kyoto Protocol, continuing the absolute emission-reduction caps for industrialized countries and increasing them to at least 30% overall reductions for the third commitment period (2018-2022). This must include improving and strengthening the so called 'flexible mechanisms' of the Protocol, using the price of carbon to drive the development and diffusion of the clean technologies the world so desperately needs. The countries covered by these caps should be broadened somewhat, and all efforts must be made to bring the US and Australia back into the system, but must move ahead regardless of what the US does;*

- *A new 'decarbonisation' track, engaging rapidly industrializing countries such as China, India and Brazil in major programs to 'decarbonise' their economies, to increase their progress to low and no-carbon technologies faster than 'business-as-usual' while, at the same time, respecting their legitimate aspirations for economic growth and a better standard of living for their citizens. The industrialized countries must help to accelerate the dissemination of low- and no-carbon technology at home and in rapidly industrializing countries in the developing world. Renewable energy, energy efficiency and fuel switching to less carbon-intensive fuels – these are the ways to 'engage' the large emitters in the industrializing world in the global effort to protect the climate;*

- *Serious, concerted global action to help the world's poorest and most vulnerable countries adapt to the impacts of climate change which are already upon us, and which will get much worse in the coming decades. The developed world has a legal, political and moral responsibility to assist these countries to deal with the floods, droughts, storms, disease and famine which are being exacerbated by climate change; on top of the overriding responsibility to limit these impacts as much as is humanly possible. But whatever happens, millions of people will be displaced by climate change, their livelihoods will be disrupted or destroyed, and the tens of thousands who die annually from climate change impacts today will no doubt grow to hundreds of thousands and perhaps millions per year until we get this problem under control.*

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 from the Rio Earth Summit in 1992, a series of targets have been set both for reducing greenhouse gas emissions and increasing the take-up of renewable energy, including solar power. Ten years later, however, the World Summit for Sustainable Development in Johannesburg still failed to agree on legally binding targets for renewables, prompting the setting up of a "coalition of the willing". The European Union and more than a dozen nations from around the world expressed their disappointment with the Summit's inaction by issuing a joint statement called "The Way Forward on Renewable Energy". Later renamed the Johannesburg Renewable Energy Coalition, more than 85 countries had joined by the time of the Renewables 2004 conference in Bonn.

The Kyoto Protocol

The Kyoto Protocol is the world's only international agreement with binding targets to reduce greenhouse gas emissions. As such, it is the primary tool governments of the world have to address climate change. Specifically, the Protocol requires a nominal 5 percent reduction in emissions by developed countries world-wide relative to 1990 levels, by 2008-2012. To meet this world-wide target, each country is obligated to its individual target - the European Union (EU[15]) 8 percent, Japan 6 percent, etc. These individual targets are derived from past greenhouse gas emissions. In addition to legally binding national emissions targets, the Kyoto Protocol includes various trading mechanisms.

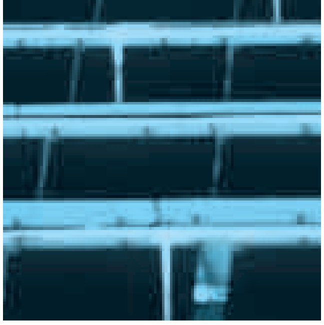
Now that the Protocol is law, formal preparations will begin to create a 'global' carbon market for emissions trading by 2008, and the so-called 'flexible mechanisms' - the Clean Development Mechanism (CDM) and Joint Implementation (JI) - will become operational.

The Kyoto Protocol was originally agreed on in 1997 - although many crucial details were left to later talks. In order to enter into force (become law) the Protocol required ratification by at least 55 countries accounting for at least 55 percent of the carbon dioxide emissions from Annex B (industrialised) nations. So far, 129 countries have ratified or acceded to the Protocol. It passed the number of countries test in 2002, and finally passed the second hurdle with ratification by the Russian Federation in late 2004.

Notably absent from the Protocol is the US; which shows no signs of ratifying the treaty, at least not as long as the Bush administration is in power - even though the US is the world's biggest greenhouse gas polluter. Australia, Liechtenstein, Croatia and Monaco also have yet to complete the ratification process.

The international issue now is what objectives for reduction in greenhouse gases will follow on from the present 2008-12 target period. The EU Heads of states meeting in March recommended that "reduction pathways... in the order of 15- 30% by 2020, compared to the baseline envisaged in the Kyoto Protocol...should be considered." Furthermore, it is critical that the next round of emissions reductions be agreed soon, so that the market is clear that the strong system sent by the entry into force of the Kyoto Protocol continues beyond 2012.

PART THREE

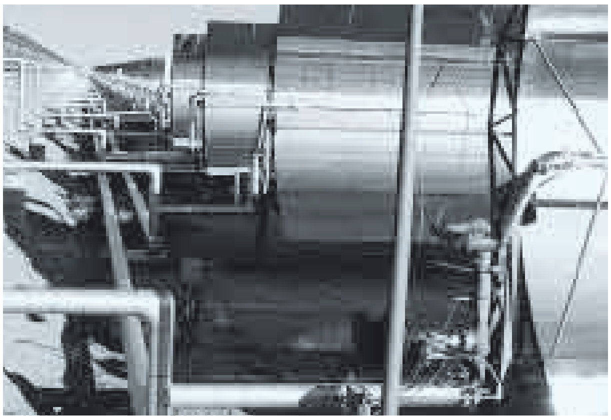


THE GLOBAL SOLAR THERMAL MARKET

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 project's sponsors, Luz International, including the steady fall in energy prices during the 1980s, and a delay in renewing California's solar tax credits. Others stem from the fact that solar thermal plants still generate electricity at a higher cost than fossil-fueled plants.

Progress in 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 lowered the depreciation times for capital investments. The result has been a shift towards low capital cost plant like combined cycle gas firing, 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 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 of and economic prospects for solar thermal. Funding has also been made available for demonstration and commercialisation projects through the European Union's Fifth and Sixth Framework Programmes, with particular interest in the sun belt northern Mediterranean region. Projects are already planned in Spain, Italy and Greece.

Other national initiatives will progress solar thermal development significantly. Spain, for example, as part of its CO_2 emissions limitation target, intends to install 500 MWe of capacity by 2010. Supported by the recent Spanish feed-in law for renewable electricity, with attractive incentive premiums for solar thermal plants (see panel), this could generate an annual power production of 1500 GWh. Similarly, the Italian government's ENEA energy/environment agency has produced a strategic plan for mass development of solar energy. Interest for solar thermal projects is reawakening in Greece. This recommends bringing thermal-electric solar technology to the market well before 2010. 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 2,750 kWh/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.

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 granted favourable, technology dependent feed-in premiums for renewable electricity generation. However, only the incentive premiums for photovoltaic electricity generation were allowed to exceed the limit of 90% of the average sales price. In 2000, any solar electricity generation was exempted from this limit, treating PV and CSP equally. In 2002, a first incentive premium for solar thermal plants of 12 € cents/kWh was introduced, which did not cover the costs of the first plants.

Therefore, the solar thermal premium was increased in 2004 by 50% to 18 € cents/kWh under Spanish Royal Decree 436 which, for the first time since the vintage Standard Offers of California in the late eighties, made solar thermal power projects bankable and attractive for investors through the following factors:

- *It grants the same tariffs for PV and solar thermal from 100 kW to 50 MW*
- *A premium on top of the electricity pool price of 0.18 €/kWh for the first 200 MW of solar thermal plants, which roughly equates to a total price of 0.21 €/kWh*
- *Bankable with 25-year guarantee*
- *Annual adaptation to electricity price escalation*
- *12-15% natural gas back-up allowed to grant 'dispatchability' and reliable capacity*

After implementation of first 200 MW tariff it will be revised for subsequent plants to achieve cost reductions.
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.

This last incentive finally covers the costs and has motivated prominent players in the Spanish power market to launch over a dozen 50 MW solar thermal projects, so that raising the 200 MW limit to 500 MW was approved by the Government in August 2005 under the new Renewable Energy Plan 2005-2010.

In the USA, the Solar Energy Industry Association and the Department of Energy have helped create Solar Enterprise Zones in sun belt 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 at 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.

During 2004 and in 2005, a remarkable revival of CSP has been observed in the USA South-west. With the election of Governor Schwarzenegger in October 2003, California has increased its Renewable Portfolio Standard (RPS) to 20% in 2012 and 30% in 2020. Governor Schwarzenegger mandated a Solar Task Force aiming to define the rules to implement 3,000 MW of new solar power by 2015. A similar task force has been set-up by the Western Governor's Association, resulting in a goal of 30 GW of clean power technology, including 7 GW of renewable power by 2015. New Mexico has even mandated a CSP specific task force to outline the way towards the first commercial plants.

All this is very rational if the USA South-west's peaking power profile is considered: during recent years, California experienced several summer on-peak brown- and black-outs. Gas prices have quadrupled during the last three years. Today, Southern California's peaking power costs anywhere between US cent 10-18/kWh, i.e. CSP is already cost-effective without any subsidies or enhanced tariff schemes.

Interest from the Australian government has resulted in Renewable Energy Showcase Grants being provided for two projects being integrated with existing coal-fired plants.

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 3.1*), 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, and in the process encouraging independent power producers which are seen as the most appropriate vehicle for solar thermal projects.

These factors have led to recent and significant interest in constructing plants in the sun belt regions from private-sector turnkey suppliers. In addition, interest rates and capital costs have fallen drastically 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, with the first commercial plants coming on line in Spain. 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.

Table 3.1: Solar thermal projects under development

Name/Location	Total Capacity (MWe)	Solar Capacity (MWe)	Cycle	Companies/Funding
Parabolic Troughs				
Algeria	140	35	ISCC	New Energy Algeria
Liddell Power Station, NSW, Australia	2,000	50	Compact Linear Fresnel Reflector	Macquarie Generation and Solar Heat and Power
Kuraymat, Egypt	150	30	ISCC	NREA / GEF grant, JBIC loan
THESEUS – Crete, Greece	50	50	Steam cycle	Solar Millennium, Flabeg Solar Int., Fichtner Solar, OADYK
Mathania, India	140	30	ISCC	RREC (Rajasthan Renewable Energy Authority) / GEF grant, KfW loan
Yazd / Iran	467	17	ISCC	Mapna / Iranian Ministry of Energy
Israel	100	100	Steam Cycle with hybrid fossil firing	Israeli Ministry of National Infrastructure with Solel
Italy	40	40	Steam Cycle	ENEA
Baja California Norte, Mexico	291	30	ISCC	Open for IPP bids GEF grant
Ain Beni Mathar, Morocco	220	30	ISCC	ONE / GEF grant, African Development Fund
Spain	12x50	12x50	Steam Cycles with 0.5 to 12 hours storage for solar-only operation with 12-15% hybrid firing	Abengoa, ACS-Cobra, EHN-Solargenix, Iberdrola, HC-Genesa, Solar Millennium
Nevada, USA	50	50	SG -1 SEGS	Green pricing, consortium for renewable energy park Sierra Pacific Resources with SolarGenix
Central Receivers				
Spain Solar Towers with Steam Receivers PS10 and PS20	10 + 2x20	10 + 2x20	Steam Cycle with saturated steam receiver and steam drum storage	Abengoa (Spain) group
Spain Solar Towers with molten-salt receivers	15	15	Molten-salt/direct-steam	SENER (Spain)
Parabolic Dishes				
SunCal 2000, Huntington Beach California, USA	0.4	0.4	8-dish/Stirling system	Stirling Energy Systems
EuroDish Demonstrations	0.1	0.1	6-dish/Stirling system	SBP and Partners

Scaling-up the size of the 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 3.1*) which, if successful, will give valuable learning experience and a clear indication of the potential for cost reduction in the next generation.

MARKET BREAKTHROUGH: THE RACE TO BE FIRST

At the time of the first edition of this brochure, the race for the connection of the first solar thermal plant after SEGS plants seemed to be headed by the four ISCCS projects of the GEF solar thermal portfolio in Egypt, India, Mexico and Morocco. Three years later this perception has changed. The struggle of those countries, with the volatility of their local currencies and the international increase in oil prices after the Iraq war, forced them to abandon the independent power plant concept with private project finance and to return to national utility ownership. This change not only required lengthy re-negotiations with the multilateral sponsors and financing institutions but also demanded the rewriting of the bidding document and restart of the tendering process.

Meanwhile, hand-in-hand with the economic and job-creation success of wind energy in industrialised countries like Germany, Spain and the USA, the need for reliable, renewable, and dispatchable peaking power coverage became more and more visible. This convinced governments in Spain and the

Table 3.2: GEF-supported solar thermal power projects						
Location	**Expected Technology**	**Size**	**Project Type**	**Financing**	**Status**	**Anticipated date of operation**
Mathania, India	Natural gas-fired ISCC with Parabolic Trough solar field	140 MW. Solar component: 30 MW, Solar field:	Owned by RREC	50 m$ (GEF); 128 m€ (KfW); 20 m$ (Indian and Rajasthan government)	Project under review	
Ain Beni Mathar, Morocco	Natural gas-fired ISCC with Parabolic Trough solar field	220 MW. Solar component: 30 MW	Owned by ONE	50 m$ (GEF); Balance credit from ADB and ONE	GEF grant approved, RFP modified for turnkey EPC contract	2008
Kuraymat, Egypt	Natural gas-fired ISCC with Parabolic Trough solar field	150 MW. Solar component: 30 MW	Owned by NREA	50 m$ (GEF); balance credit from JBIC and NREA	GEF grant approved RFP modified for EPC contracts for Solar Island and for Combined Cycle Island	2008
to be defined Mexico	Natural gas-fired ISCC with Parabolic Trough solar field	500 MW Solar component: 30 MW	Owned by CFE	50 m$ (GEF); balance financing from CFE	GEF grant approved;	2008

South-western USA to launch incentive programmes to attract private investment in solar thermal independent power projects.

An outstanding example is the publication of the Royal Decree 436 in Spain in March 2004, which improved the solar thermal feed-in premium by 50% from 12 to 18 € cents/kWh and made solar thermal power projects bankable again, as they were during the time of California's Standard Offers in the late 1980s. These are the main elements of Spain's Royal Decree:

- *To grant the same tariffs for PV and solar thermal from 100 kW to 50 MW with a premium on top of the electricity pool price of 0.18 €/kWh, which roughly equates to a total price of 0.21 €/kWh*
- *Bankable with 25-year guarantee*
- *Annual adaptation to electricity price escalation*
- *12-15% natural gas back-up allowed to grant 'dispatchability' and reliable capacity*

Since this tariff may be revised after implementation of the first 200 MW, a race has started in Spain to be among those first.

India
The technical feasibility of a 35 MW demonstration project was first established in the early 1990s by Fichtner, a German engineering consultant, with assistance from the KfW. Following further evaluations, together with Engineers India Ltd, an Indian engineering consultant, Fichtner came up with the option of integrating the solar thermal unit with a gas-fired combined cycle power plant with a total capacity of 140 MW. The project cost was estimated at around 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$ 50 million (to cover the additional solar costs), KfW wanted to provide a € 128 million loan, whilst the Indian and Rajasthan governments wanted to contribute about $10 million each. Rajasthan Renewable Energy Corporation (RREC) published a Request for Proposals in June 2002 for a combined cycle of about 140 MW incorporating a parabolic trough solar thermal field of some 220,000m^2 equivalent to 30MWe solar capacity. Limited competition, high risks, uncertain fuel supply and administrational disputes delayed the project. The sponsors of the Global Environmental Facility are now seeking a firm commitment of all Indian participants to continue the project.

Morocco
In 1992, a EU-funded pre-feasibility study provided a first analysis of implementing solar thermal plants in Morocco.

In 1999, the GEF provided the national electric utility ONE with a grant of 700 000 US$ for the development of technical specifications for an 220 MWe Integrated Solar/Combined Cycle system with a solar field of some 220,000m^2 equivalent to 30MWe, the establishment of the bid documents and evaluation of offers. A grant of US$ 50 million has been made available by the Global Environmental Fund to cover the incremental cost of the solar element. In December 2000, Fichtner Solar GmbH was selected to assist ONE in the establishment of the technical specifications, evaluating offers and negotiating the contracts. In May 2002, invitations for expression of interest were launched in order to attract investors for implementation as an

Independent Power Project with private financing. Following the lack of response, ONE took the decision to carry out the project within the framework of a turnkey contract for construction, operating and the maintenance of the power plant during the first five years. Concurrence with this new structure was given by GEF in August 2003. At the same time, the local authorities gave their approval to use the selected land at Ain Beni Mathar for the ISCC power plant. In December 2003, topographic surveys and a geotechnical study of the site were carried out. In January 2004, negotiations were initiated for a natural gas supply contract. In April 2004, a General Procurement Notice was published. Industry response to such a "Request for Prequalification" in 2004 was significant, leading to the prequalification of four international consortia. In February 2005, the bid document was submitted to the World Bank for "Non-Objection". Financing has been committed by the African Development Bank. The contract award is expected for early in 2006 and the start of operations at the end of 2008.

Egypt

In 1995, two pre-feasibility studies were conducted based on parabolic trough and central tower technologies, followed by a SolarPACES START mission in 1996. It was agreed to implement the first solar thermal power plant as a 150 MW ISCC with a 30 MW parabolic trough solar field. GEF granted the project consultancy services and expressed the willingness to cover the incremental cost. In 1998, the conceptual design and project concept paper were prepared. The consultancy services were divided into two phases. In 2000, the first phase was conducted, resulting in a detailed feasibility study report. A shortlist of qualified and interested developers was set up in 2001. Due to the unexpectedly high rate of the US$ exchange against the Egyptian Pound, and to avoid the lack of foreign currency in 2002, the government issued regulations for new independent power projects to reduce the burden on the national treasury, requiring their financing either in local currency or in foreign currency, on condition that the annual repayments be made from export revenues achieved by the project. In May 2003, a study was conducted by the World Bank to assess the level of interest of international developers and investors under the new framework. No interest was found. In June 2003, NREA and the World Bank agreed to change the approach of the project into a governmental one. The private sector could participate in the O&M through a contract limited to five years.

A general Procurement Notice was published in February 2004. Thirty-five firms expressed their interest. The new pre-qualification and the bid documents were developed in 2004, while NREA secured the required co-financing. It is expected that the contracts for the Solar Island and the Combined Cycle Island will be awarded by the middle of 2006 and that the plant will begin operation by the end of 2008.

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 CCGT at the Cerro Prieto, Baja 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 the restructuring of Mexico's power sector and changes in the national government, putting political support for the project at risk.

Mexico's Comisión Federal de Electricidad (CFE) issued a Request for Proposals in March 2002 for a 250 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 incremental solar costs will be covered by a grant from the Global Environment Facility (GEF). Since investor response to this structure was very limited, it was decided in 2003 that an EPC scheme with CFE as GEF grant recipient should be pursued. The solar field would no longer be an option but compulsory. In 2005, the plant location was changed to Sonora state and CFE suggested doubling the combined cycle size from 250 to 500 MW.

Spain

In September 2002, Spain was the first European country to introduce a "feed-in tariff" funding system for solar thermal power. This granted a premium payment of 12 € cents for each kWh output of a solar thermal plant between 100 kW and 50 MW capacity, which could be changed every four years. It turned out that this was not bankable and that the amount did not cover the cost and risks to make the first projects feasible.

Therefore, the solar thermal premium was increased in 2004 by 50% to 18 € cents/kWh under Spanish Royal Decree 436, and guaranteed for 25 years, with annual adaptation to the average electricity price increase. This removed the concerns of investors, banks and industrial suppliers and launched a race of the major Spanish power market players to be among the first 200 MW, the most prominent being:

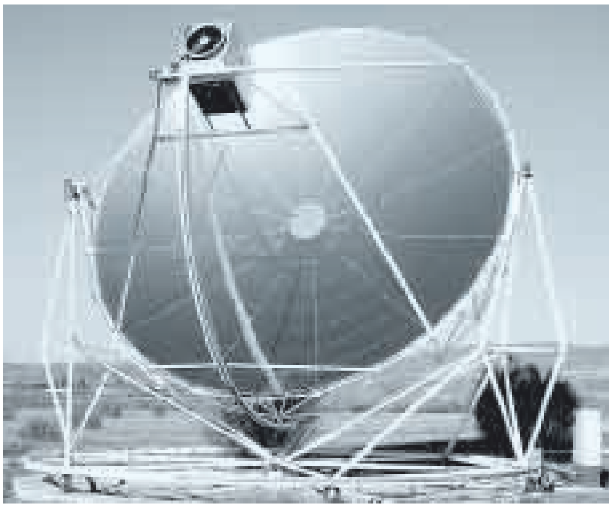
- *10 MWe solar-only power tower plant project* ***Planta Solar (PS10)*** *at Sanlúcar near Sevilla, promoted by Solucar S.A., part of the Abengoa Group, together with partners, and employing saturated steam receiver technology. The PS10 project has received a € 5 million grant from the European Union's Fifth Framework Programme. Construction started in summer 2004 and will be completed in 2006. Project development of the following two 20 MW power tower plants PS20 of the same type has started. Abengoa has also started to develop various 50 MW parabolic trough plants.*
- *15 MWe solar-only power tower plant* ***Solar Tres*** *project is promoted by the Spanish company SENER employing US molten-salt technologies for receiver and energy storage. Solar Tres will have a 16-hour molten-salt storage system to deliver this power around the clock. The Solar Tres project has received a € 5 million grant from the EU's Fifth Framework Programme.*
- *15 MWe solar trough power plant* ***EuroSEGS*** *at Montes de Cierzo near Pamplona, promoted by the Spanish EHN group in co-operation with SolarGenix.*
- *Two 50 MWe solar trough power plants,* ***AndaSol-1 and 2****, are being promoted jointly by ACS Cobra and the Solar Millennium group in the region of Andalucia, with a 510,120 m^2 SKAL ET solar collector field and six hours' thermal storage. The AndaSol-1 project has received a € 5 million grant from the EU's Fifth Framework Programme and financial support from the German Ministry for Environment. Construction will start in autumn 2005 and will be completed in 2007. ACS Cobra and Solar Millennium have started development of various 50 MW follow-up plants in Southern Spain.*
- *National electric utility companies, such as Iberdrola and Hidrocantabrico-Genesa, have started promotion of over a dozen 50 MW parabolic trough plants all over Southern Spain.*

Greenpeace Spain and the Spanish national association of solar thermal project developers, Protermosolar, joined forces to increase the objective of 200 MW to 1,000 MW in the next revision of the national plan for promotion of renewable energies, in order to increase Spain's capacity of dispatchable clean peak power for the summer dry seasons. In August 2005, the Spanish Government approved a new Renewable Energy Plan, setting a new target of 500 MW by 2010.

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 (IPDC) contracted its Electric Power Research Centre and the German engineering consulting firm Fichtner 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 irradiation larger than 2,500 kWh/m^2/a.



As a result, the IPDC was interested in the implementation of a 200,000-400,000 m^2 parabolic trough field into a 300 MW natural gas-fired combined cycle plant in the Luth desert, near Yazd. For that purpose, Iran had approached GEF with a request to finance the incremental cost of the solar field. As GEF was not in the position to allocate any additional resources for this request, in 2005, Iran has changed the plant configuration and now intends to build a solar field, equivalent to about 17 MWe, to also power the envisaged upgrade of installed gas turbines to a 467 MW combined cycle plant.

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 being 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 the 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. A feasibility study about the necessary incentive premiums for CSP in Israel was completed in 2003 and is being evaluated by the Israel Public Utilities Authority for the formulation of a feed-in law. Greenpeace published a cost-benefit analysis for solar energy in Israel. The reports indicates a great economic benefit for the state's economy from a gradual growth in solar thermal utilization up to 2,000MW in 2025.

Jordan

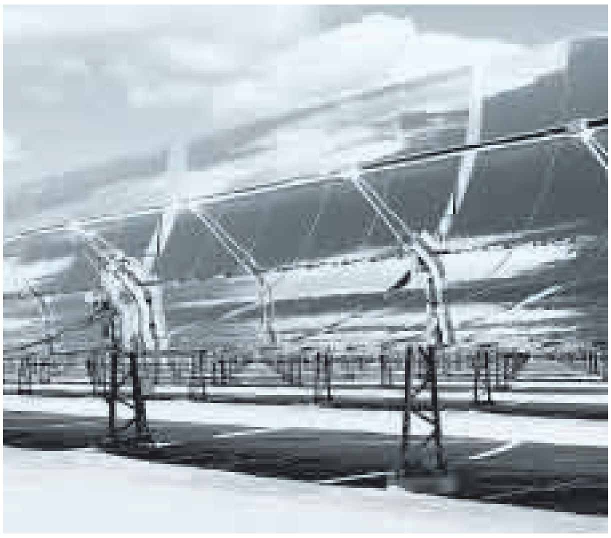
Jordan has a long-standing interest in large-scale solar thermal power generation. Nearly ten years ago, a European-based industrial consortium known as Phoebus proposed the construction of a 30 MW volumetric-type solar power tower. The consortium carried out site and feasibility studies, collected weather 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, the mission being hosted by the Jordanian National Electric Power Company.

In 2001, an informal request for solar plant proposals was published by the government. Based on a first project sketch for a solar hybrid plant in the Quwairah area of southern Jordan (35 km north of Aqaba) to generate 100-150 MW of electricity, Jordan is seeking international support to execute a feasibility study and preferred financing.

With Jordan joining the Global Market Initiative for CSP, that support may become available sooner than expected. Jordan's need for renewable power alternatives is obvious as previously available oil contracts on a preferred supply basis with Iraq have expired and, consequently, fuel costs will rise in their oil-fired steam plants at Aqaba.

South Africa

By 2010, South African power utility Eskom could be operating the world's largest central receiver-type CSP plant. Eskom studied both parabolic trough and central receiver technology to determine which is the cheaper of the two. The national utility is also looking at manufacturing the key components through local suppliers and is gathering estimates from local glass and steel manufacturers. Ultimately, a decision will be made on a variety of factors, including cost, and which plant can be constructed with the largest local content. The project is currently assessing the feasibility of a 100 MW pilot project.



United States

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

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 USA CSP industry and SunLab collaborated on the development of this report..

The key findings were:

- *The solar resource in the USA's South-west is comparable in scale to the hydro-power resource of the North-west.*
- *CSP is clean, large-scale power that could make a very significant contribution to South-west USA electricity needs.*
- *CSP could be scaled up rapidly, although it might take six to eight 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 US$1.8 billion, equivalent to US$1.40/watt installed for troughs, US$2.00/watt installed for towers, and US$2.60/watt installed for dishes.*

Solargenix is now carrying out a planning project funded by the California Energy Commission, and in co-operation 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.

Meanwhile, two other projects are progressing in Nevada. A 50 MW plant using parabolic trough technology is to be built in Eldorado Valley by Solargenix, with its output being 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.

During 2004 and in 2005, a remarkable revival of CSP has been observed in the USA's South-west. With the election of Governor Schwarzenegger in October 2003, California increased its Renewable Portfolio Standard (RPS) to 20% in 2012 and 30% in 2020. Governor Schwarzenegger mandated a Solar Task Force aiming to define the rules to implement 3,000 MW of new solar power by 2015. A similar task force has been set up by the Western Governor's Association, resulting in a goal of 30 GW for clean power technology, including 7 GW of renewable power by 2015. New Mexico has even mandated a CSP specific task force to outline the way towards its first commercial plants.

All this is very rational considering the American South-west's peaking power profile. During recent years, California has experienced several summer on-peak brown- and black-outs. Gas prices have quadrupled during the last three years. Southern California peaking power today costs anywhere between 10-18 US cent/kWh, i.e. CSP is already cost-effective without any subsidies or enhanced tariff schemes.

Algeria

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

The trigger which has provided the framework for new investment opportunities is liberalisation of the Algerian power market, which resulted from 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 fruition, 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. In order to promote the production of solar electricity with integrated solar combined cycles, on 28 March 2004, the Algerian Government published the Decret Executif 04-92 in the Official Journal of Algeria Number 19, relating to the diversification of electricity production costs. This decree establishes a premium for total electricity production by an ISCCS project, depending on the achieved solar share, ranging from a 100% premium for a 5-10% solar share up to a 200% premium for a solar share beyond 200%.

NEAL is to promote renewables in Algeria by helping to develop, primarily, 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 supply of gas.

NEAL's first initiative is to build a new 150 MW ISCC power plant with 25 MW of solar output. Following the identification of the project site at Hassi R'Mel, NEAL published the tender in June 2005.

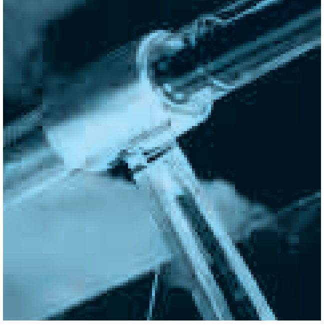
Italy

In 2001, the Italian parliament allocated € 110 million for a CSP development and demonstration programme. Since then, several parabolic trough plants have been under development. In early 2004, a co-operation agreement between ENEA and ENEL was signed to develop the Archimede project in Sicily – the first Italian solar plant integrated with a thermoelectric combined cycle plant with advanced troughs using molten salts as heat transfer fluid.

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. The initial plant is being constructed by the Solar Heat and Power company for approximately US$ 500 per kWe (peak) without direct subsidy. This low cost can be 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. Work started in July 2003. The first MW was completed and tested by September 2004. A second step was awarded in spring 2005 by the coal power plant operator. Solar Heat and Power is also developing a stand-alone 240 MW design with its own turbine for various sites around the world. Further CLFR plant proposals using storage are now being discussed among utilities with an annual output equal to 4% of the NSW electricity supply. According to SHP, these will cost about US$1400 per kWe peak, including storage for a 56% capacity factor and using a moderate pressure turbine and generator. Other analysis suggests that large systems such as CLFR plants will be more cost-effective with a much more rapid take-up 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 50 kW parabolic dish prototype at the Australian National University – although the dish is being refurbished, as yet no commercial project has been announced.



PART FOUR

THE FUTURE FOR SOLAR THERMAL POWER

PART FOUR: THE FUTURE FOR SOLAR THERMAL POWER

THE GREENPEACE-ESTIA SCENARIO FOR 2025 AND PROJECTION TO 2040

This scenario was prepared by Greenpeace International and the European Solar Thermal Industry Association in order to project what could be achieved given the right market conditions. Its core assessment looks forward 20 years from the base year of 2005 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.

This is the second edition of the Greenpeace/ESTIA scenario. The first was published in 2003. Since than, several things have changed as this a very young industry. Some projects experienced delays with the tendering and/or financing. But the main results remain the same.

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 355 MW, the total installation by 2015 will have passed 6400 MW – 18 times more than today. By 2025, the annual installation rate will be 4600 MW/a. At the end of the scenario period, the total installed capacity around the world will have reached the impressive figure of 36,850 MW.

The scenario also shows how much electricity would be produced by solar thermal power plants. This is based on the assumption that the first installations will have an annual output of 2,500 megawatt hours (MWh). However, the later installations will have internal storage systems which increase the output per Megawatt to 3,500 hours per year in 2030 and 5,000 hours per year in 2040. To achieve this, the collector field must be enlarged to produced more steam, which will not be used to produce electricity straight away, but to store it for the night.

By 2025, solar thermal power will have achieved an annual output of more than 95,000 MWh or 95 terawatt hours (TWh).

In terms of capital investment, it is assumed in the scenario that during the initial years, solar field investment costs – including all system costs – are at a level of US$ 6,000/kW installed. These specific investment costs then fall gradually over the timescale of the scenario, and are cut by almost half in 2025. This means that the investment volume in solar thermal power plants will rise from US$ 60 million in 2006 to US$ 16.4 billion in 2025.

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 54,000 highly qualified jobs will have been created in plant construction, operation and maintenance.

The final benefit from the realisation of the Greenpeace-ESTIA scenario would be for the environment. During the period up to 2025, the emission into the atmosphere of a total of 362 million tonnes of carbon dioxide would be avoided, 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 57.5 million tonnes of CO_2 in 2025 is equivalent to that of 35 coal-fired power plants.

The scenario is also broken down by regions of the world and into the main country markets. By 2025, the leading regions will be Europe and the Mediterranean. According to the scenario, the most promising countries, each with more than 1,000 MW of solar thermal projects expected by 2025, are Spain, the United States, and North Africa/Middle East.

Key results from Greenpeace-ESTIA Scenario 2002-2025	
Capacity of solar thermal power in 2025	36,850 MW
Electricity production in 2025	95.8 TWh/year
Employment generated	54,000 jobs
Investment Value	16.4 billion $ per year
Carbon emissions avoided	362 million tonnes CO_2
Annual carbon emissions avoided in 2025	57.5 million tonnes CO_2
Projection 2025 to 2040	
Capacity of solar thermal power in 2040	600,000 MW
Electricity production	16,000 TWh
Percentage of global demand	5%

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 100,000 MW, and by 2040 a level of almost 600,000 MW. Increased availability of plant resulting from 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 4.1: Solar Thermal Power Plant Market by Regions – Key Results					
Year	OECD-Europe / MW	MWh	tCO_2	Market volume in MUS$	
2005					
2010	600	1.500.000	900.000	1.125	
2015	1.200	3.000.000	1.800.000	400	
2020	2.400	6.000.000	3.600.000	1.125	
2025	4.500	11.250.000	6.750.000	2.100	
Total 2000 till 2025			**49.470.000**		
Year	Spain / MW	MWh	tCO_2	Market volume in MUS$	
2005					
2010	500	1.250.000	750.000	900	
2015	1.000	2.500.000	1.500.000	400	
2020	1.500	3.750.000	2.250.000	375	
2025	2.000	5.000.000	3.000.000	350	
Total 2000 till 2025			**30.795.000**		
Year	OECD North America / MW	MWh	tCO_2	Market volume in MUS$	
2005	354	885.000	531.000		
2010	1.054	2.635.000	1.581.000	2.025	
2015	3.354	8.385.000	5.031.000	2.000	
2020	8.054	20.135.000	12.081.000	4.125	
2025	15.354	38.385.000	23.031.000	5.950	
Total 2000 till 2025			**158.445.000**		
Year	California / MW	MWh	tCO_2	Market volume in MUS$	
2005	354	885.000	531.000		
2010	854	2.135.000	1.281.000	1.350	
2015	2.354	5.885.000	3.531.000	1.200	
2020	4.854	12.135.000	7.281.000	1.875	
2025	7.354	18.385.000	11.031.000	1.750	
Total 2000 till 2025			**93.195.000**		
Year	OECD Pacific/Australia / MW	MWh	tCO_2	Market volume in MUS$	
2005	1	2.500	1.500	3	
2010	100	250.000	150.000	225	
2015	500	1.250.000	750.000	320	
2020	1.000	2.500.000	1.500.000	375	
2025	2.000	5.000.000	3.000.000	700	
Total 2000 till 2025			**20.734.500**		
Year	Latin America / MW	MWh	tCO_2	Market volume in MUS$	
2005					
2010	20	50.000	30.000	90	
2015	100	250.000	150.000	80	
2020	800	2.000.000	1.200.000	1.125	
2025	3.000	7.500.000	4.500.000	1.750	
Total 2000 till 2025			**18.855.000**		

(continued on p.38)

Table 4.1: Solar Thermal Power Plant Market by Regions – Key Results *(continued from p. 37)*

Year	South Asia / India / MW	MWh	tCO_2	Market volume in MUS$	
2005					
2010	30	75.000	45.000	135	
2015	100	250.000	150.000	160	
2020	500	1.250.000	750.000	100	
2025	1.500	3.750.000	2.250.000	700	
Total 2000 till 2025			**11.040.000**		
Year	**China / MW**	**MWh**	**tCO_2**	**Market volume in MUS$**	
2005					
2010	50	125.000	75.000	225	
2015	200	500.000	300.000	200	
2020	700	1.750.000	1.050.000	375	
2025	1.500	3.750.000	2.250.000	700	
Total 2000 till 2025			**13.125.000**		
Year	**Middle East / MW**	**MWh**	**tCO_2**	**Market volume in MUS$**	
2005					
2010	200	500.000	300.000	405	
2015	800	2.000.000	1.200.000	520	
2020	2.100	5.250.000	3.150.000	1.500	
2025	5.000	12.500.000	7.500.000	2.100	
Total 2000 till 2025			**44.055.000**		
Year	**Africa / MW**	**MWh**	**tCO_2**	**Market volume in MUS$**	
2005					
2010	100	250.000	150.000	360	
2015	200	500.000	300.000	200	
2020	1.300	3.250.000	1.950.000	1.500	
2025	4.000	10.000.000	6.000.000	2.100	
Total 2000 till 2025			**27.600.000**		
Year	**Total / MW**	**Total / MWh**	**Total / tCO_2**	**Total / Investment**	**Total / Jobs**
2005	355	887.500	532.500	888	
2010	2.154	5.635.000	3.381.000	4.815	12.036
2015	6.454	17.385.000	10.431.000	4.200	18.880
2020	16.854	44.635.000	26.781.000	10.875	33.040
2025	36.854	95.885.000	57.531.000	16.450	54.280
Total 2000 till 2025			**361.804.500**		

PART FIVE

CSP SPECIAL – SOLAR THERMAL POWER PLANTS IN THE MEDITERRANEAN

PART FIVE: CSP SPECIAL – SOLAR THERMAL POWER PLANTS IN THE MEDITERRANEAN

PART FIVE: CSP SPECIAL – SOLAR THERMAL POWER PLANTS IN THE MEDITERRANEAN

Any renewable energy supply strategy aiming to take over the major part of electricity supply in the decades to come has to consider Concentrated Solar Power (CSP) as this technology option is capable of contributing with reliable, dispatchable power, specifically for daytime-demand peaks.

The stress on today's energy economies are already visible: Southern Spain as well as the USA's South-west states are experiencing peaking power black-outs, mainly associated with their huge demand for air-conditioning. As, at the same time, this market segment offers the highest compensation for peaking power supply, CSP's initial cost gaps are smallest, relative to conventional gas- and oil-based peaking power production.

It is also clear that southern Europe, at least, is not capable of generating all of its required reliable peaking power alone through its own renewable resources. Therefore, energy co-operation with its neighbouring countries is mandatory and has already become day-by-day practice. There are gas and power interconnections between Italy, Tunisia and Algeria, as well as between Morocco and Spain. As these southern neighbours also have a much greater solar resource, it is logical to intensify this co-operation for CSP.

The Global Market Initiative for CSP has already structured the way for regional co-operation:

Region II includes those countries that are or will soon be connected to Region I countries for transnational power exchange. Countries in Region II include Algeria, Morocco and Mexico. Solar power generated from CSP plants in these countries could be exported to Region I countries at a much more attractive price than generating it from the inferior solar resource in Region I. As a result of their excellent solar radiation resources and good grid connections, the southwestern USA and northern Mexico, as well as southern Europe and North Africa, offer such cross-border possibilities.

The Region II participants will take the **political initiative** to formulate a fair scheme that accounts for both improved tariffs for clean energy generated in the Region II countries and allows a benefit from enhanced feed-in tariffs for energy that is imported into Region I.

In this chapter, we would like to feature an interesting study published in April 2005 from the German Aerospace Centre (DLR) called "Concentrating Solar Power for the Mediterranean Region". The basic findings strongly support the Greenpeace/ESTIA position, that solar thermal power pants have huge technical and economical potential. This study also suggests that the Greenpeace/ESTIA market forecast up to 2025 is just a foretaste of how important solar thermal power plants can be.

One of the most promising areas for solar thermal power plants is the Mediterranean region. This region, although blessed with intense solar radiation, currently exports mainly fossil fuels. Fossil fuels, however, cause dangerous climate change effects and are, as currently being observed, subject to volatile price escalations.

To help prevent the European economy from further fuel price dependencies and keep global warming in a tolerable frame, the Scientific Council of the German Government for Global Environmental Change (WBGU), in its latest study based on a scenario of the IPCC (Intergovernmental Panel for Climate Change), recommends reducing CO_2 emissions on a global level by 30% until 2050. According to this scenario, developing countries and countries in transition may increase their transmissions by about 30% in consideration of their still growing infrastructure, while industrialised countries will have to reduce their emissions by about 80%.

To achieve those CO_2 reduction targets, WBGU recommends establishing a type of highly visible 'lighthouse' projects to introduce renewable energies on a large scale as a strategic lever for global change in energy policies. A strategic partnership between the European Union (EU), the Middle East (ME) and North Africa (NA) is a key element within such a policy for the benefit of both sides: MENA has vast resources of solar energy for its economic growth and as a valuable export product, while the EU can provide the technologies and finance to activate those potentials and to cope with its national and international responsibility for climate protection – as documented in the Johannesburg agreement to increase considerably the global renewable energy share as a priority goal.

In order to establish appropriate instruments and strategies for the market introduction of renewables in the European and MENA countries, well-founded information on demand and resources, technologies and applications are essential. It must further be investigated if the expansion of renewables energies would imply unbearable economic constraints on the national economies of the MENA region.

MAIN RESULTS OF THE MED-CSP STUDY

The MED-CSP study focuses on the electricity and water supply of the regions and countries in Southern Europe (Portugal, Spain, Italy, Greece, Cyprus, Malta), North Africa (Morocco, Algeria, Tunisia, Libya, Egypt), Western Asia (Turkey, Iran, Iraq, Jordan, Israel, Lebanon, Syria) and the Arabian Peninsula (Saudi Arabia, Yemen, Oman, United Arab Emirates, Kuwait, Qatar, Bahrain). The results of the MED-CSP study can be summarised in the following statements:

- *Environmental, economic and social sustainability in the energy sector can only be achieved with renewable energies. Present measures are insufficient to achieve that goal.*
- *A well-balanced mix of renewable energy technologies can displace conventional peak-, intermediate and base-load electricity, thereby prolonging the global availability of fossil fuels for future generations in an environmentally compatible way.*

Figure 5.1: Countries of the EU-MENA region analysed within the MED-CSP Study/DLR 2005

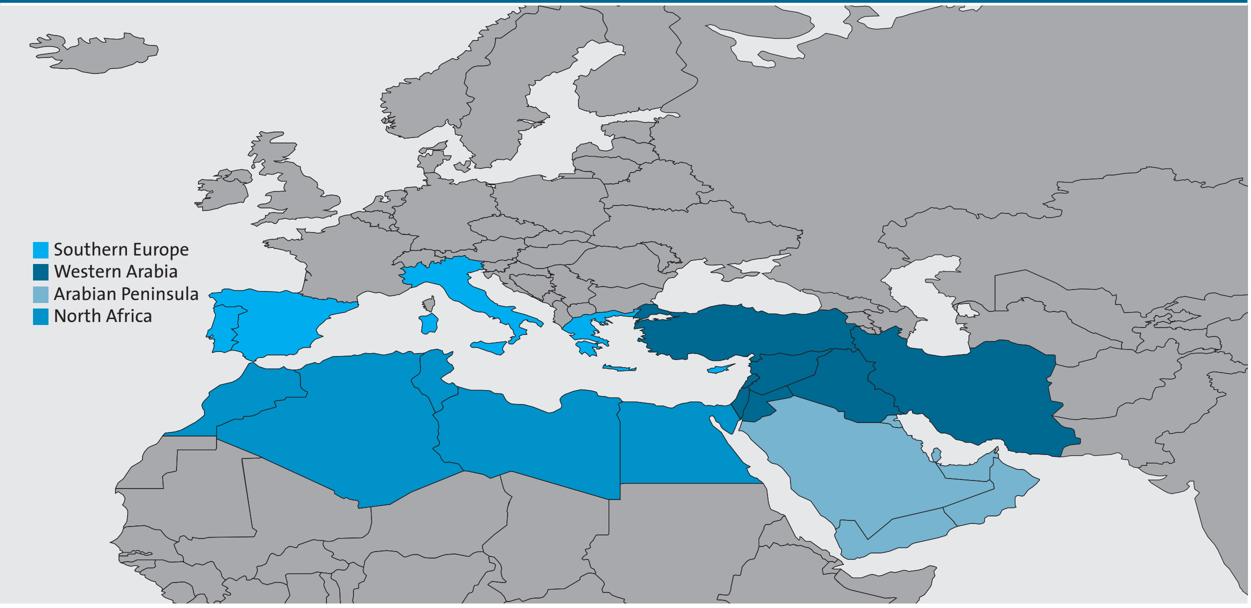


Figure 5.2: Annual direct solar irradiance in the southern EU-MENA region. The primary energy received by each square metre of land equals 1-2 barrels of oil per year

- *Renewable energy resources are plentiful and can cope with the growing demand of the EU-MENA region. The available resources are so vast that an additional supply of renewable energy to Central and Northern Europe is feasible.*
- *Renewable energies are the least-cost option for energy and water security in EU-MENA.*
- *Renewable energies are key for socio-economic development and for sustainable wealth in MENA, as they address both environmental and economical needs in a compatible way.*
- *Renewable energies and energy efficiency are the main pillars of environmental compatibility. They need initial public start-up investments but no long-term subsidies like fossil or nuclear energies.*
- *An adequate set of policy instruments must be established immediately to accelerate renewable energy deployment in the EU and MENA.*

Within the MED-CSP study, solar thermal power plants play the mayor role in the long-term energy supply, because with their capability of thermal energy storage and of solar/fossil hybrid operation they can provide reliable capacity and thus are a key element for grid stabilisation and power security in such a well-balanced electricity mix.

SOLAR ENERGY IN THE MEDITERRANEAN – AN INFINITE ENERGY RESOURCE

By far the biggest energy resource in countries in the Near and Middle East and North Africa is solar irradiance, with a potential that is by several orders of magnitude larger than the total world electricity demand. This resource can be used both in distributed photovoltaic systems and in large central solar thermal power stations. Thus, both distributed rural and centralised urban demand can be covered by renewable energy technologies.

Figure 5.3: Annual electricity demand and generation within the countries in the MED-CSP scenario

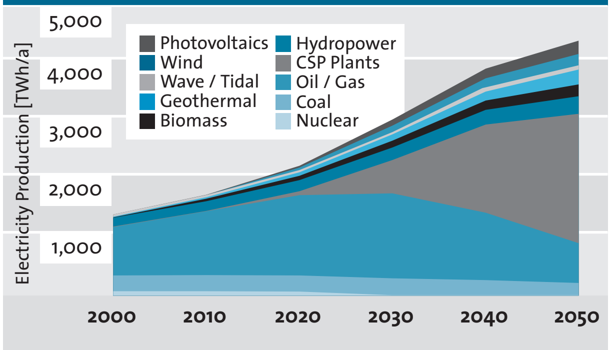
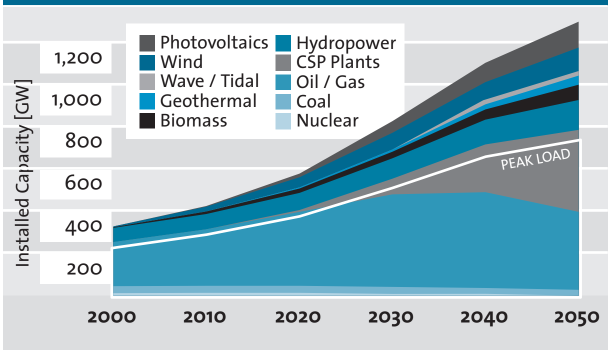


Figure 5.4: Installed power capacity and peak load within the analysed countries in the CG/HE scenario



The growth of population and economy will lead to a considerable growth of energy demand in the MENA countries. By 2050, these countries could achieve an electricity demand in the same order of magnitude as Europe (3,500 TWh/y). Although the Med-CSP scenario considers efficiency gains and moderate population growth, and sometimes even regressive population figures in some of the analysed countries, electricity demand could rise significantly.

To meet this demand, each country will have a different balanced mix of renewables in the future as the result of its own specific natural sources of energy. The MED-CSP scenario shows a way to match resources and demand in the frame of the technical, economic, ecologic and social constraints of each country in a sustainable way. Only a switch to renewable energies can lead to an affordable and secure energy supply. This will not require long-term subsidies, as in the case of fossil or nuclear power, but simply an initial investment in the frame of a concerted action by all EU-MENA countries to put the new renewable energy technologies in place.

By far the largest energy resource in MENA is solar power from concentrating solar thermal power plants, which will provide the core of electricity in most countries. This is due to the fact that they will be able to provide not only the required large amounts of electricity, but also reliable power capacity on demand. In addition, wind energy is a major resource in Morocco, Egypt and Oman, while geothermal power is available in Turkey, Iran, Saudi Arabia and Yemen. Major hydro-power and biomass resources are limited to Egypt, Iran, Iraq and Turkey. Initially, photovoltaic electricity will be mainly used in decentralised, remote applications in the first phase. Further cost reductions will lead to increasing shares of PV in the electricity grid. At a later stage, very large PV systems in desert regions will also become feasible. However, their contribution to reliable capacity is very limited, while concentrating solar power plants can deliver such capacity on demand.

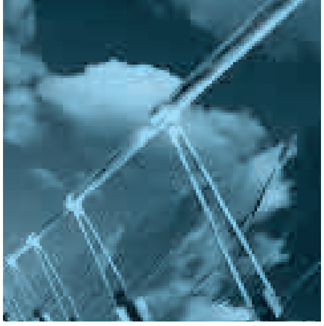
By 2050, the installed capacity of concentrating solar power will be as large as that of wind, PV, biomass and geothermal plants together but, because of their built-in solar thermal storage capability, CSP plants deliver twice as much electricity per year as those other resources.

Therefore, a wise and responsible energy policy in the European Union must support renewable energies on all levels and by all means. This includes CSP as the major future source of electricity supply in the southern EU Member States and southern Mediterranean neighbours.

It is the responsibility of national governments and international policy to organise a fair financing scheme for renewable energies in the EU-MENA region in order to avoid the obvious risks of present energy policies, and to change to a sustainable path for wealth, development, and energy and water security.

Technical and economical potential of solar thermal power plants in the Mediterranean

	Economic Potential	Used until 2050	Direct Normal Irradiance*
	TWh/y	TWh/y	kWh/m²/y
Bahrain	33	4	2050
Cyprus	20	1	2200
Iran	20000	349	2200
Iraq	28647	190	2000
Israel	318	29	2400
Jordan	6429	40	2700
Kuwait	1525	13	2100
Lebanon	14	12	2000
Oman	19404	22	2200
Qatar	792	3	2000
Saudi Arabia	124560	135	2500
Syria	10210	117	2200
UAE	1988	10	2200
Yemen	5100	142	2200
Algeria	168972	165	2700
Egypt	73656	395	2800
Libya	139477	22	2700
Morocco	20146	150	2600
Tunisia	9244	43	2400
Greece	4	4	2000
Italy	7	5	2000
Malta	2	0	2000
Portugal	142	6	2200
Spain	1278	25	2250
Turkey	131	125	2000
Total	**632099**	**2005**	**2000 – 2800**



PART SIX

POLICY RECOMMENDATIONS

PART SIX: POLICY RECOMMENDATIONS

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 – initially, at least – 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 undergoing 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 avoids 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, the 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, not widely known as an energy technology up to now, 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 development bank KfW, 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 on 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.

This is a very rational and impelling energy policy concept considering the rocketing crude oil spot market prices which have surpassed the US$ 50/barrel barrier since the beginning of 2005. Although some of these escalations are due to increased speculation on the world crude oil spot markets, there is a very robust world economy trend which suggests that oil prices will never fall again as low as they were in the mid 1990s. The dynamic economies of China, India and South-East Asia are increasingly important customers for crude oil and gas, and that will remain unchanged. Therefore, strategic back-stop technologies are needed, as in the 1970s when the oil crises turned the world economy downwards for almost a decade.

SUCCESSFUL MARKET-CREATION POLICY MEASURES

A clear, visible market for solar thermal power must be defined 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 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, one 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 54,000 jobs by 2025. In order to attract solar thermal power plant suppliers into establishing 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 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 at present these are not 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.

In the USA, 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 fail 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, is 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. California decided recently to actually exceed these initial targets, raising them to 20% in 2015 and, potentially, 30% in 2020.

Setting mandatory renewable energy targets globally
Setting mandatory national targets for 2010 and beyond, would be appropriate and lead to more efforts globally. New ambitious, legally-binding, national targets for 2020 would demonstrate the long-term commitment to renewable energy and would significantly enhance investor confidence. Greenpeace suggests to establish those global targets at the up coming "Beijing International Renewable Energy Conference 2005" during November 7 – 8, 2005 which will be hosted by the Government of China. The subject of the conference:

1. *Analyze and assess the renewable energy development status and the problems it is facing;*
2. *Explore the policy mechanisms for encouraging enterprises and financial sectors to become involved in renewable energy development;*
3. *Explore the prospects and trends for the technological development of renewable energy, and support its development through technology transfer;*
4. *Strengthen South-South cooperation, and promote the utilization of renewable energy in developing countries.*

How to set the "right" targets: Binding targets for 2010, 2015 and 2020
The development of short-, mid-, and long-term objectives is necessary in order to be able to assess and measure progress made towards fulft. Greenpeace suggests five-year intervals starting from 2010.

Country-specific targets related to previous energy supply
Objectives for individual countries must be defined according to the status quo in energy supply. The starting point for calculating targets must be a combination of both the state of primary energy supply (for heating, industrial heat processes, refrigeration and transport) and of the electricity generation structure. In order for the proportion of renewable energy to increase significantly, targets must be set in accordance with the local potential of each technology (wind, solar, available biomass, etc) and also according to local infrastructure, both existing and still to be built (ease of connection to networks, production and installation capacity, etc).

The market for renewable energy sources needs to grow by at least 30% annually.
The example set in recent years by the wind power and photovoltaic industry shows that manufacturers of alternative energy technologies are able to maintain a long-term growth rate of 30 to 35%. Research, development and a high standard of quality guarantees in planning, finance and installation are essential for long-term success. The basis for setting targets must be higher than the current 30% annual market growth rate.

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 in Europe until Spain published its first Real Decreto on solar power in September 2002 and, in a much enhanced version with even better compensations for CSP and PV, again in March 2004.

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 development bank KfW, 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 (GMI) FOR CONCENTRATING SOLAR POWER (CSP)

Introduction

Solar energy is the largest and most widely distributed renewable energy resource on our planet. Among the solar electric technologies, **concentrating solar power (CSP) is the cheapest and the largest bulk producer of solar electricity in the world.** CSP plants (also referred to as solar thermal power) are capable of meeting a significant percentage of future global electricity demand without technical, economic or resource limitations, specifically in sun-belt regions such as the USA's South-west, southern Europe and broad regions of the developing world. This capability and the ability of solar thermal power plants to dispatch power as needed during peak demand periods are key characteristics that have motivated development banks, such as the World Bank, the European Investment Bank and the German KfW Group, as well as other organisations, such as the United Nations Environment Programme, as an implementing agency of the Global Environment Facility (GEF), the European Union and the US Department of Energy, to support the large-scale implementation of this technology.

CSP systems have been used since the early 1980s to generate electricity and to provide heat. The investment of US$ 1.2 billion between 1984 and 1991 in nine commercial parabolic trough solar power plants in the California Mojave desert, totalling 354 MWe, (known as the SEGS plants) and their successful continued operation and performance, demonstrate the readiness of CSP. Today, these California plants are still operating reliably and have produced more than 50% of all solar electricity in the world. The CSP industry anticipates that solar electricity generation costs will be fully competitive with fossil-based, grid-connected power generation costs once an initial 5,000 MWe of new CSP solar capacity is installed globally.

Two international executive conferences have been held to address the barriers to current and future CSP project opportunities and to expand the global market for CSP. The First International Executive Conference on Concentrating Solar Power, held in June 2002 in Berlin, Germany, was sponsored by the United Nations Environment Programme, the GEF, the German Federal Ministry for the Environment (BMU), the KfW Group, the European Solar Thermal Power Industry Association (ESTIA) and the American Solar Energy Industries Association (SEIA). The conference participants discussed a Global Market Initiative for CSP and defined strategies for facilitating the rapid, large-scale market introduction of this technology. This strategy, published as the Declaration of Berlin, was registered in Johannesburg as a UNEP Market Facilitation WSSD Type-II Partnership for Concentrating Solar Power Technologies.

The Second International Executive Conference on Expanding the Market for Concentrating Solar Power was held in October 2003 in Palm Springs. At this event, the IEA SolarPACES Implementing Agreement joined the sponsors of the Berlin conference to finalise and launch the

CSP Global Market Initiative (GMI).

The objective of the GMI is to facilitate and expedite the building of 5,000 MWe of CSP worldwide over the next ten years. This initiative represents the world's largest, coordinated action in history for the deployment of solar electricity.

Participation is open to all governments in countries or states with adequate solar thermal resources, to countries that have an industrial capability in CSP technologies but lack the appropriate solar resources, and to others which contribute to establishing the framework proposed below. If the benefits of CSP are to be spread globally, it is essential that participating industrial countries outside the sun belt either support investments in sun belt countries and/or allow imports of solar power at cost-covering rates, thereby stimulating investment in CSP plants.

Required elements of the CSP GMI

A visible, reliable and growing market for solar thermal power with normal risk levels must be established in order for project developers and CSP equipment suppliers to make the necessary long-term investments to achieve acceptable investment costs, and hence competitive rates. The following policy areas will have the greatest impact on the use of concentrating solar power.

Each country or state participating in the CSP GMI will contribute to the following policy measures:

1. Targets

As the overall goal of the CSP GMI is 5,000 MWe to reach cost competitiveness by 2015, national and/or regional **targets will be set for CSP capacity.** These targets may be a specific number of MW over a certain period of time, or may be a percentage of CSP within the new capacity to be built over a certain period of time, as in Renewable Portfolio Standards.

2. Tariffs

The level of revenue for CSP projects needs to be adequate to encourage private-sector investment and provide a stable investment climate. This can be achieved by feed-in tariffs, production tax credits, or public benefit charges specific to CSP. These supports will be designed to reduce over time as the CSP technology becomes competitive in the power market, once 5,000 MWe of CSP has been built by 2015. Coordination with participating neighbouring countries, states or regions with preferential tariff schemes will allow CSP-based electricity imports from high solar radiation areas (and therefore lower electricity costs). The use of long-term power purchase agreements or similar long-term contracts with credit-worthy off-takers, or equity ownership by public organisations, will build confidence among investors and financial institutions.

3. Financing

Co-operating bilateral and/or **multilateral financial institutions will ensure that project-related flexible Kyoto instruments, such as Clean Development Mechanisms** and Joint Implementation Actions **become applicable to CSP and ensure that the mechanisms are bankable.** The establishment of national or regional loan guarantee programmes via existing windows at multilateral banks, national lending programmes and global environmental programmes, such as GEF, UNEP, and UNDP, will further reduce the inherent risk of introducing new technology for private-sector banking institutions.

Investment tax credits, which stimulated the first 354 MW of CSP plants in the USA, should be maintained, and **production tax credits** similar to those that have stimulated the growth of wind power in the USA **should be made available** to CSP plants. Cost shared development of transmission lines between regions with excellent solar resources and urban load centres, even across borders of participating countries and regions, will optimise the development and exploitation of all regional resources.

4. Regulation

Limitations on CSP plant capacity or operating strategies that make the technology introduction more costly must be avoided.

Different strategies for different regions

To account for the differences between countries in the development of CSP-related policy instruments and in the amount of their solar resource, the CSP GMI participants have defined three regions with a different strategy for each:

- ***Region I includes those countries and states that have already partially implemented the policy measures recommended by the CSP GMI or that will implement such measures in the near future.*** *Countries in Region I include those in southern Europe, South-west United States and Israel. In these countries, existing CSP-specific targets or portfolio standards will create a market based demand and a feed-in law or public benefit charge. Both rely on the ratepayers, and can be used to cover the price gap between the competitive price and CSP electricity costs.*
  In Region I, ***additional political support is needed*** *to make targets, policies and tariffs stable and predictable so that commercial financing can be secured.*
- ***Region II includes those countries that are or will soon be connected to Region I countries for transnational power exchange.*** *Countries in Region II include Algeria, Morocco and Mexico. Solar power generated from CSP plants in these countries could be exported to Region I countries at a much more attractive price than generating it from the inferior solar resource in Region I. As a result of their excellent solar radiation resources and good grid connections, South-west USA and northern Mexico, as well as southern Europe and North Africa, offer such cross-border possibilities.*
  The Region II participants will take the ***political initiative*** *to formulate a fair scheme that accounts for improved tariffs for clean energy generated in the Region II countries and to enable benefits from enhanced feed-in tariffs for energy that is imported into Region I.*
- ***Region III includes developing countries not interconnected to the Region I countries' grid.*** *Countries in Region III currently include Brazil, Egypt, India, Iran, Jordan and South Africa.* ***Preferential financing in the form of subsidies*** *(which could be grants, soft loans, carbon credits, CDM or green premiums) provided by Region I sources will be required to support the Region III countries' desire for the development of clean CSP power plants.*
- *One example of such sources is the commitment of € 0.5 billion for renewable energy over a five-year period within the scope of the German Economic Co-operation with developing countries that was announced by German Chancellor Gerhard Schroeder in his UN Environmental Summit speech in Johannesburg in September 2002.*

The collaborative effort of the three Regions will ensure that the market introduction cost of CSP will be reduced by aggregating the CSP market and making best use of existing clean power instruments. All participating countries will be helped to reach their Kyoto goals.

Next steps and organisation

An Interim Management Team was established in October 2003 in Palm Springs.

The objective was to receive a mandate at the Renewables 2004 Conference in Bonn for the implementation of the CSP GMI. This mandate should include a strong commitment by the governments of the interested CSP countries to adapt or implement their energy policies in a way able to accommodate the main elements of the GMI.

In order to represent the participating countries, states, multi and bilateral financial institutions and the CSP industry, an Executive Committee will be formed reflecting the interests of the stakeholders and the participating countries and states. This Committee will supervise a GMI Management Team, approve a budget for its operation and help secure that budget. Financing for the GMI Management Team should be provided by participating countries and the CSP industry, augmented by multi- and bilateral financial commitments.

The near-term target to receive a solid mandate for implementing the CSP GMI at the Renewables 2004 Conference in Bonn has been successfully reached:

June 2004: Ministers responsible for energy (specifically including renewable electricity) from Algeria, Egypt, Germany, Jordan, Morocco and Israel, plus Deputy Ministers from Italy and Spain, signed the GMI endorsement bilaterally.

August 2004: CSP GMI was included in the official publication of the Concrete Action Plan of the Bonn Renewables Conference 2004. A GMI Management Team was established.

April 2005: Energy Minister from Yemen signed GMI endorsement and joined the initiative.

Credits

Authors *Rainer Aringhoff, Georg Brakmann (ESTIA)*
Dr. Michael Geyer (IEA SolarPACES)
Sven Teske (Greenpeace)
Project Manager & Author *Sven Teske, Greenpeace International*
Editor *Cecilia Baker*
Design *Bitter Grafik & Illustration, Hamburg*
Picture credits *p. 1, 7, 26, 29, 30, 31, 32, 33, 35, 39, 43*
© www.photon-pictures.com

Printed on recycled paper

Greenpeace International
Ottho Heldringstraat 5
1066 AZ Amsterdam
The Netherlands
T: +31 20 514 81 50
F: +31 20 514 81 51
Email: sven.teske@int.greenpeace.org
www.greenpeace.org

ESTIA
Avenue de la Fauconnerie 73
1170 Brussels
Belgium
T: +32 2 672 43 67
F: +32 672 70 16
Contact: Rainer Aringhoff
Email: aringhoff@solarmillennium.de
www.solarmillennium.de

IEA SolarPACES Implementing Agreement
Avenida de la Paz 51
04720 Aguadulce (Almeria)
Spain
T: +34 950550725
F: +34 950343112
Email: exsec@solarpaces.org
www.solarpaces.org
Dr. Michael Geyer, Executive Secretary