Concentrating Solar Power
Global Outlook 09

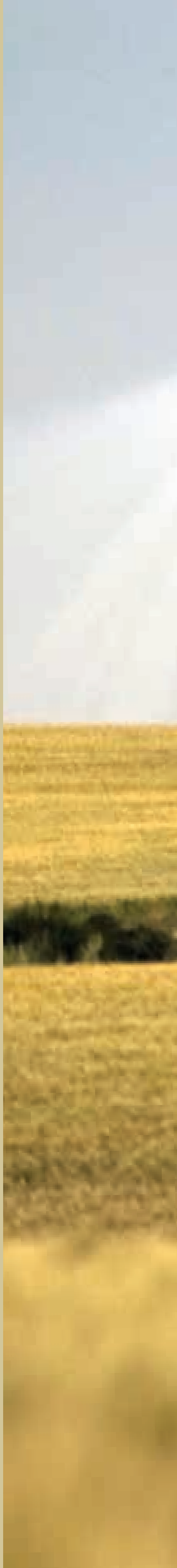
Why Renewable Energy is Hot

SolarPACES

ESTELA

GREENPEACE

image The PS10 Concentrating Solar Tower Plant near Seville, Spain.



Contents

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JN 238

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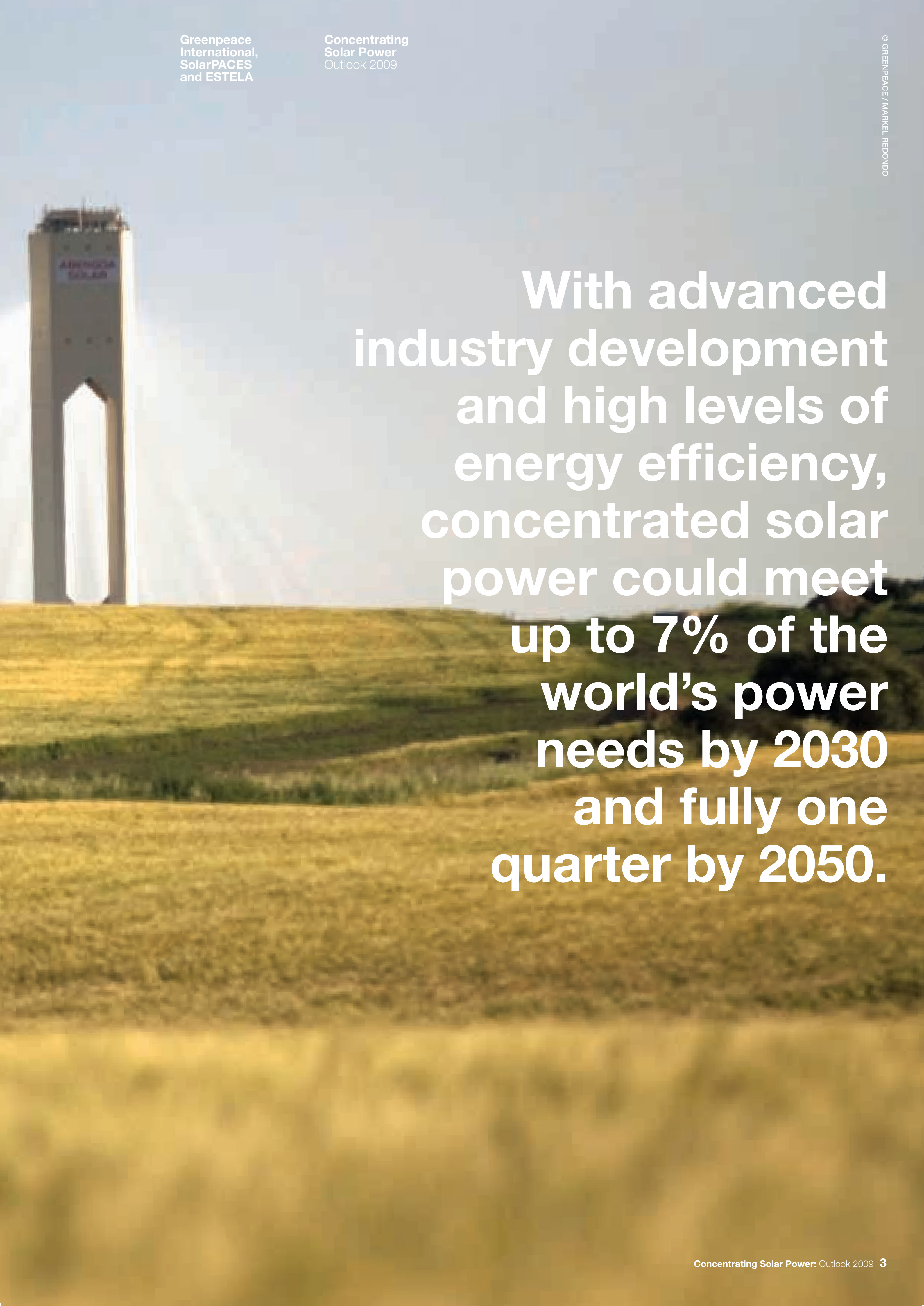
FRONT/BACK COVER PIC

THE PS10 CONCENTRATING SOLAR TOWER PLANT, WHICH CONCENTRATES THE SUN'S RAYS AT THE TOP OF A 115 METRE-HIGH TOWER WHERE A SOLAR RECEIVER AND A STEAM TURBINE ARE LOCATED. THE TURBINE DRIVES A GENERATOR, PRODUCING ELECTRICITY.



With advanced industry development and high levels of energy efficiency, concentrated solar power could meet up to 7% of the world's power needs by 2030 and fully one quarter by 2050.

© GREENPEACE / MARKEL REDONDO

image The PS10 Concentrating Solar Thermal Power Plant near Seville, Spain. This 11 MW solar power tower has 624 heliostats - large mirrors that track the sun.

Foreword

This is the 3rd joint report from Greenpeace International, the European Solar Thermal Electricity Association (ESTELA) and IEA SolarPACES since 2003. With every edition we have increased the projected market volume significantly, and it finally turned over a billion dollars in 2008, this amount could double in 2009. While we highlighted in our first joint report the huge market potential, we were able to move to another message in 2005 when we launched the second report in Egypt: “CSP is ready for take off!”.

We now are delighted to say “CSP has taken off”, is about to step out of the shadow of other renewable technologies and can establish itself as the third biggest player in the sustainable power generation industry. CSP does not compete against other renewable energies; it is an additional one that is now economically viable.

Fighting climate change is paramount as such it is essential that the power generation sector becomes virtually CO_2 free as soon as possible. Greenpeace and the European Renewable Industry Council developed a joint global vision - the Energy [R]evolution scenario – which provides a practical blueprint for rapidly cutting energy-related CO_2 emissions in order to help ensure that greenhouse gas emissions peak and then fall by 2015. This can be achieved while ensuring economies in China, India and other developing nations have access to the energy that they need in order to develop. CSP plays an important role in this concept.

The Global CSP Outlook 2009 goes actually one step further. While the moderate CSP market scenario is in line with the Energy [R]evolution scenario, the advanced scenario shows that this technology has even more to offer. Globally, the CSP industry could employ as many as 2 million people by 2050 who will help save the climate and produce up to one quarter of the world’s electricity. This is a truly inspiring vision. Especially as this technology has developed it’s very own striking beauty – the stunning pictures in this report show that saving the climate look spectacular.

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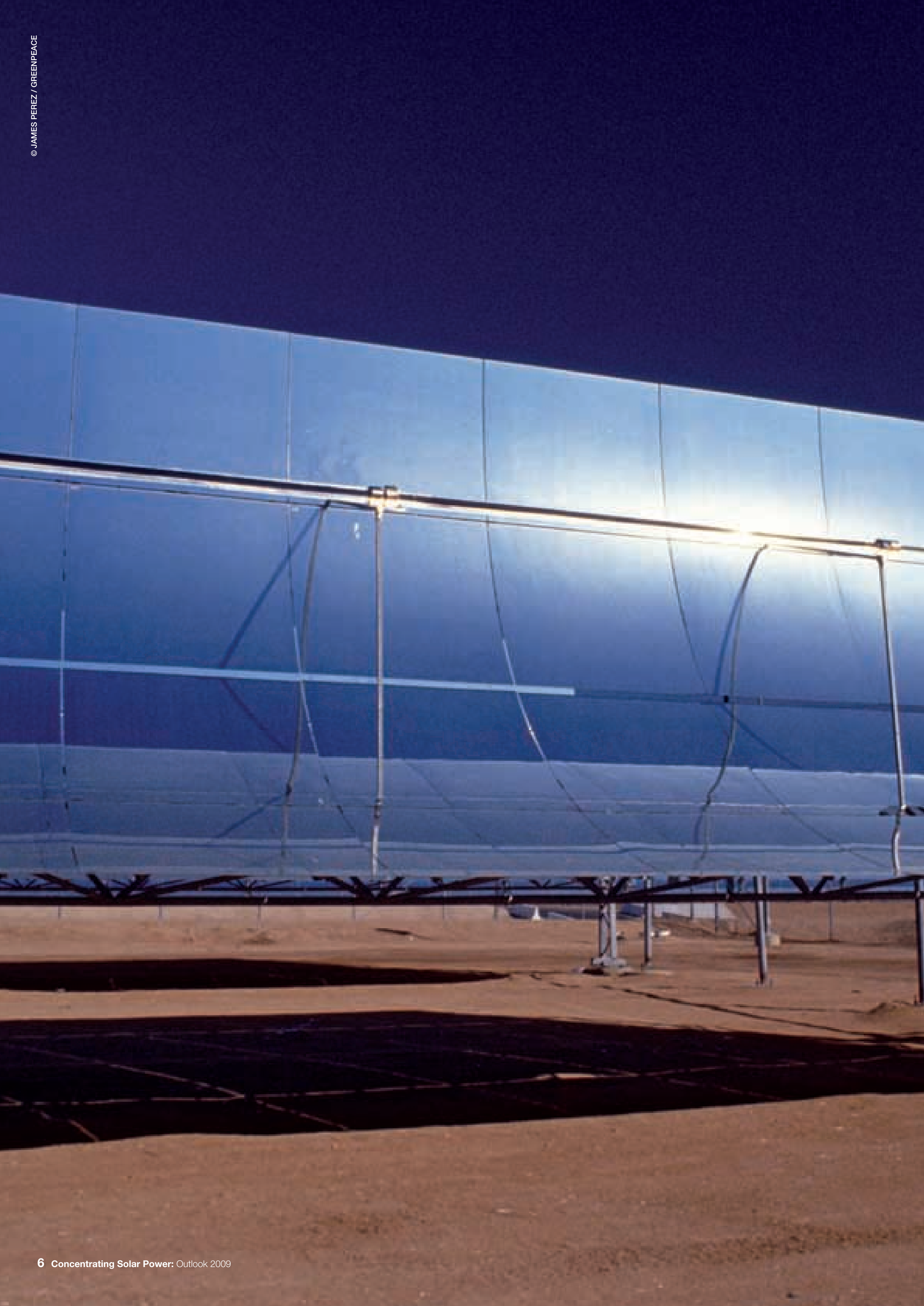


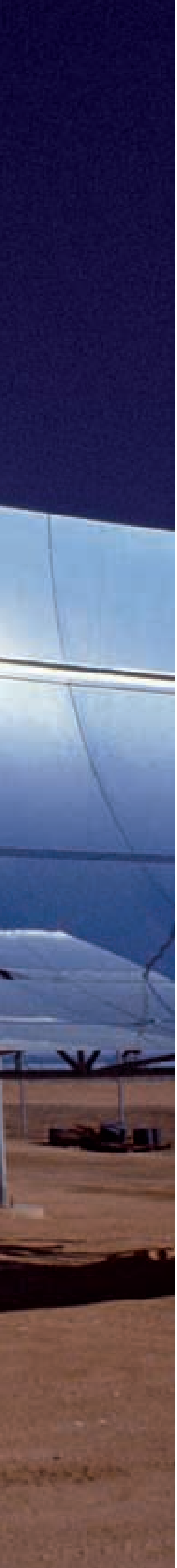


image
Luz International Solar Power plant, California, USA. Part of the SEGS development.

Executive Summary

What is CSP?

CSP (Concentrating Solar Power) systems produce heat or electricity using hundreds of mirrors to concentrate the sun's rays to a temperature typically between 400 and 1000ºC. There are a variety of mirror shapes, sun-tracking methods and ways to provide useful energy, but they all work under the same principle. Individual CSP plants are now typically between 50 and 280MW in size, but could be larger still. CSP systems can be specifically integrated with storage or in hybrid operation with fossil fuels, offering firm capacity and dispatchable power on demand. It is suitable for peak loads and base-loads, and power is typically fed into the electricity grid.

Why use it?

The planet is on the brink of runaway climate change. If annual average temperatures rise by more than 2ºC, the entire world will face more natural disasters, hotter and longer droughts, failure of agricultural areas and massive loss of species. Because climate change is caused by burning fossil fuels, we urgently need an energy revolution, changing the world's energy mix to a majority of non-polluting sources. To avoid dangerous climate change, global emissions must peak in 2015 and start declining thereafter, reaching as close to zero as possible by mid-century.

CSP is a large-scale, commercially viable way to make electricity. It is best suited to those areas of the world with the most sun; Southern Europe, Northern Africa and the Middle East, parts of India, China, Southern USA and Australia, where many are suffering from peak electricity problems, blackouts and rising electricity costs. CSP does not contribute to climate change and the source will never run out. The technology is mature enough to grow exponentially in the world's 'sun-belt'.

What will the size of the market be?

In the last five years, the industry has expanded rapidly from a newly-introduced technology to become a mass-produced and mainstream energy generation solution. CSP installations were providing just 436 MW of the world's electricity generation at the end of 2008. Projects under construction at the time of writing, mostly in Spain, will add at least another 1,000 MW by around 2011. In the USA, projects adding up to further 7,000 MW are under planning and development plus 10,000 GW in Spain, which could all come online by 2017.

According to the Global CSP Outlook 2009, under an advanced industry development scenario, with high levels of energy efficiency, CSP could meet up to 7% of the world's projected power needs in 2030 and a full quarter by 2050.

Even with a set of moderate assumptions for future market development, the world would have a combined solar power capacity of over 830 GW by 2050, with annual deployments of 41 GW. This would represent 3.0 to 3.6% of global demand in 2030 and 8.5 to 11.8% in 2050.

What are the benefits?

For this study, Greenpeace has used a model to generate scenarios based on a reference scenario or 'business-as-usual' for world governments, as well as moderate and advanced scenarios based on realistic policies to support development of this clean, renewable technology. Under just a moderate scenario, the countries with the most sun resources could together:

- create €11.1 billion (USD 14.4)[1] investment in 2010, peaking at €92.5 billion in 2050
- create more than 200,000 jobs by 2020, and about 1.187 million in 2050
- save 148 million tonnes of CO_2 annually in 2020, rising to 2.1 billion tonnes in 2050.

To put these figures into perspective, the CO_2 generated by Australia alone is 394 million tonnes a year; Germany has annual CO_2 emission of 823 million tonnes – equal to the CO_2 emissions of the whole African continent. So, if developed in place of new and decommissioned fossil fuel power plants, CSP technologies could reduce global emissions.

During the 1990s, global investment in energy infrastructure was around €158-186 billion each year; a realistic CSP figure would represent approximately 5% of that total. This is a technology that, along with wind energy, can contribute to a 'New Green Deal' for the economy.

Is the price coming down?

The cost of CSP electricity is coming down and many developers say it will soon be cost-competitive with thermal generation from mid-sized gas plants. The factors affecting the cost of CSP electricity are the solar resource, grid connection and local infrastructure and project development costs. Power costs can be reduced by scaling-up plant size, research and development advances, increased market competition and production volumes for components. Government action can bring costs down further through preferential financing conditions and tax or investment incentives.

What policies and support are needed?

Since 2004, some key national government incentives have boosted CSP technology, creating a massive growth in local installations. In Spain, the premium tariff was raised to a level that made projects bankable and, within two years, over 1,000 MW was under development in that country alone. The measures that countries in the world's 'sun belt' need in order to make CSP work are:

- A guaranteed sale price for electricity. Feed-in tariffs have been successful incentives for development in Spain, with France, Italy and South Africa soon to follow.
- National targets and incentives, such as renewable portfolio standards or preferential loans programmes that apply to solar thermal technologies.
- Schemes placing costs on carbon emissions either through cap-and-trade systems or carbon taxes.
- Installation of new electricity transfer options between nations and continents through the appropriate infrastructure and political and economic arrangements, so that solar energy can be transported to areas of high demand.
- Cooperation between Europe, the Middle East and North Africa for technology and economic development.
- Stable, long term support for research and development to fully exploit the potential for further technology improvements and cost reduction.

With these key policy foundations in place, CSP is set to take its place as an important part of the world's energy mix.

1 Exchange rate: €1 = USD 1.29

Figure 1.0:
Annual CO_2 savings from CSP Scenarios

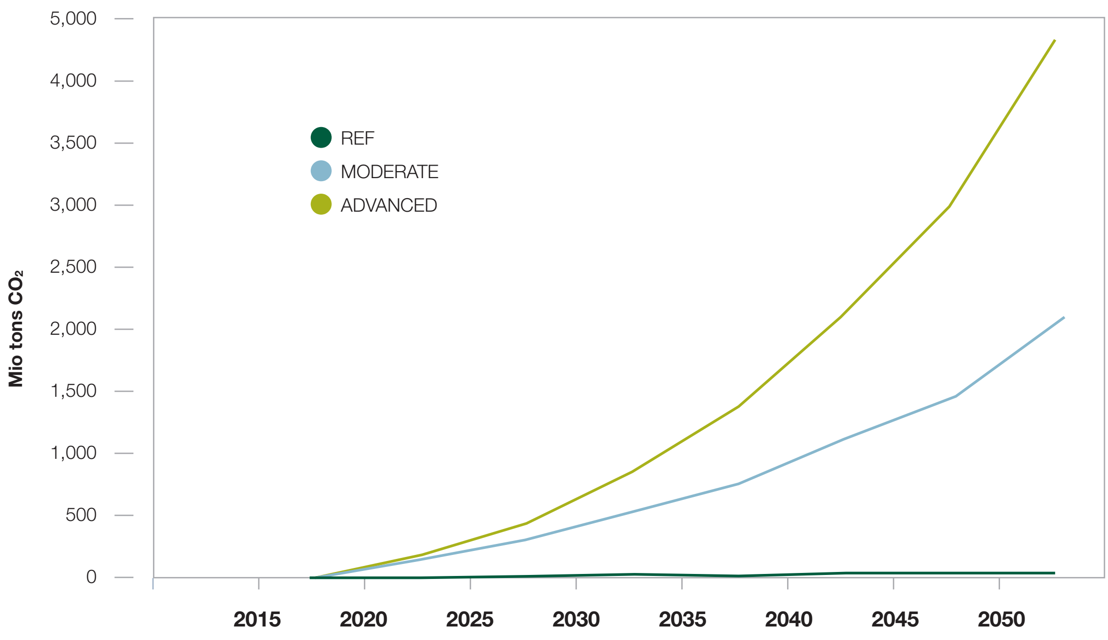
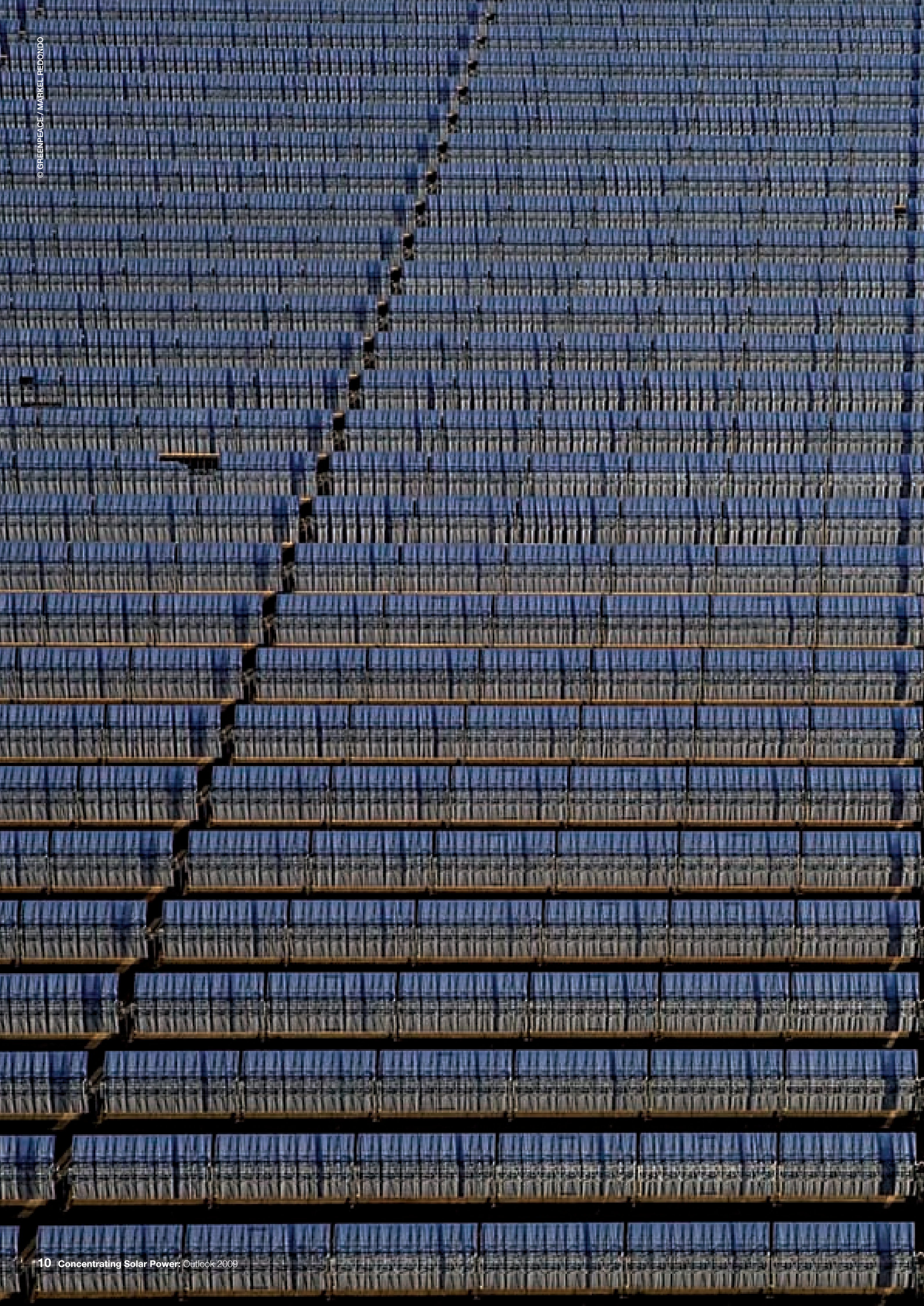


Table 1.0:
Investment and Employment

	2015	2020	2030	2050
Reference				
Annual Installation (MW)	566	681	552	160
Cost € / kW	3,400	3,000	2,800	2,400
Investment billion € / year	1.924	2.043	1.546	0.383
Employment Job-year	9,611	13,739	17,736	19,296
Moderate				
Annual Installation (MW)	5,463	12,602	19,895	40,557
Cost € / kW	3,230	2,850	2,660	2,280
Investment billion € / year	17.545	35.917	52.921	92.470
Employment Job-year	83,358	200,279	428,292	1,187,611
Advanced				
Annual Installation (MW)	6,814	14,697	35,462	80,827
Cost € / kW	3,060	2,700	2,520	2,160
Investment billion € / year	20.852	39.683	89.356	174.585
Employment Job-year	89,523	209,998	629,546	2,106,123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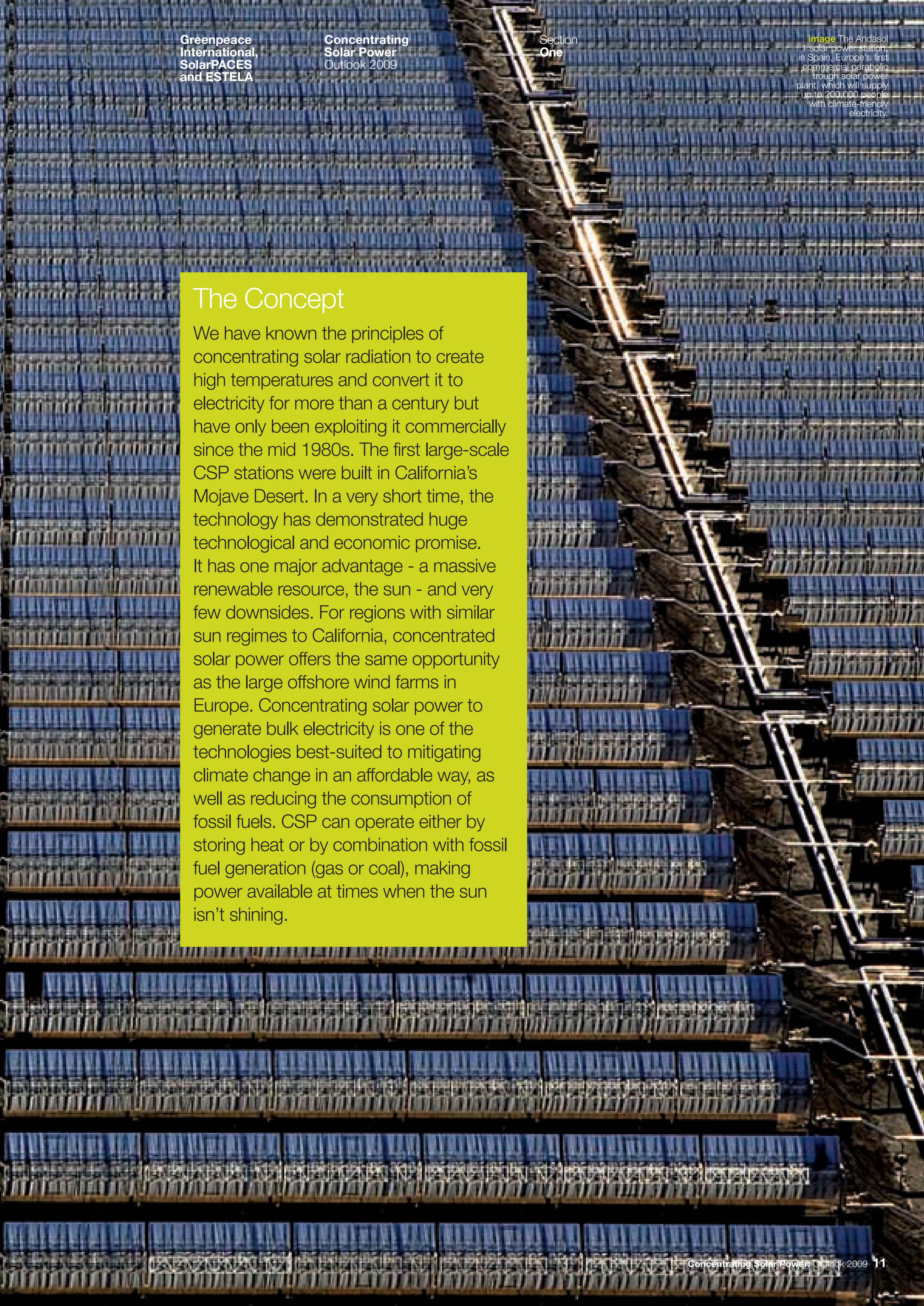


image The Andasol 1 solar power station, in Spain, Europe's first commercial parabolic trough solar power plant, which will supply up to 200,000 people with climate-friendly electricity.

The Concept

We have known the principles of concentrating solar radiation to create high temperatures and convert it to electricity for more than a century but have only been exploiting it commercially since the mid 1980s. The first large-scale CSP stations were built in California's Mojave Desert. In a very short time, the technology has demonstrated huge technological and economic promise. It has one major advantage - a massive renewable resource, the sun - and very few downsides. For regions with similar sun regimes to California, concentrated solar power offers the same opportunity as the large offshore wind farms in Europe. Concentrating solar power to generate bulk electricity is one of the technologies best-suited to mitigating climate change in an affordable way, as well as reducing the consumption of fossil fuels. CSP can operate either by storing heat or by combination with fossil fuel generation (gas or coal), making power available at times when the sun isn't shining.

image The PS10 Concentrating Solar Thermal Power Plant in southern Spain.

1

Concentrating Solar Power: the basics

Environment

The main benefit of CSP systems is in replacing the power generated by fossil fuels, and therefore reducing the greenhouse gas emissions the cause of climate change. Each square metre of concentrator surface, for example, is enough to avoid 200 to 300 kilograms (kg) of CO_2 each year, depending on its configuration. Typical power plants are made up of hundreds of concentrators arranged in arrays. The life-cycle assessment of the components together with the land-surface impacts of CSP systems indicate that it takes around five months to ‘pay back’ the energy used to manufacture and install the equipment. Considering the plants could last 40 years, as demonstrated in the Mojave plants, this is a good ratio. Most of the CSP solar field materials can be recycled and used again for further plants.

Economics

The cost of solar thermal power is dropping. Experience in the US shows that today’s generation costs are about 15 US cents/kWh for solar generated electricity at sites with very good solar radiation, with predicted ongoing costs as low as 8 cents / kWh in some circumstances.[2] The technology development is on a steep learning curve, and the factors that will reduce costs are technology improvements, mass production, economies of scale and improved operation. CSP is becoming competitive with conventional, fossil-fuelled peak and mid-load power stations. Adding more CSP systems to the grid can help keep the costs of electricity stable, and avoid drastic price rises as fuel scarcity and carbon costs take effect.

Hybrid plants can use concentrated solar power and fossil fuels (or biofuels) together. Some, which make use of special finance schemes, can already deliver competitively-priced electricity. For small-scale, off-grid solar power generation, such as on islands or in rural hinterlands of developing countries, the other option is usually diesel engine generators, which are noisy, dirty and expensive to run.

Several factors are increasing the economic viability of CSP projects, including reform of the electricity sector, rising demand for ‘green power’, and the development of global carbon markets for pollution-free power generation. Direct support schemes also provide a strong boost, like feed-in laws or renewable portfolio standards for renewable power in some countries. Last but not least, increasing fossil fuel prices will bring the price of solar in line with the cost of conventional power generation.

Although high initial investment is required for new CSP plants, over their entire lifecycle, 80% of costs are in construction and associated debt, and only 20% from operation. This means that, once the plant has been paid for, over approximately 20 years only the operating costs remain, which are currently about 3 cents/kWh. The electricity generated is cheaper than any competition, and is comparable only to long-written-off hydropower plants.

2 SolarPACES Annual Report 2007

Requirements for CSP

Solar thermal power uses direct sunlight, called 'beam radiation' or Direct Normal Irradiation (DNI). This is the sunlight that is not deviated by clouds, fumes or dust in the atmosphere and which reaches the Earth's surface in parallel beams for concentration. Suitable sites are those that get a lot of this direct sun - at least 2,000 kilowatt hours (kWh) of sunlight radiation per square metre annually. The best sites receive more than 2,800 kWh/m^2 a year.

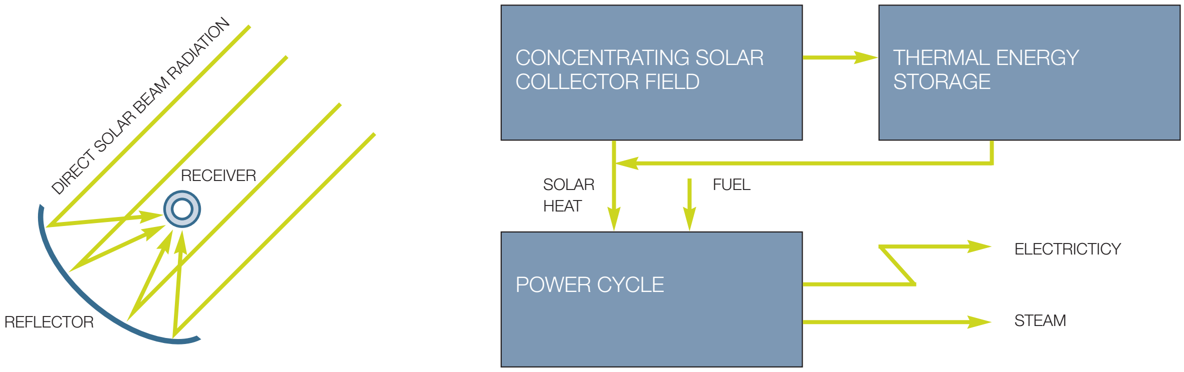
Typical regions for CSP are those without large amounts of atmospheric humidity, dust and fumes. They include steppes, bush, savannas, semi-deserts and true deserts, ideally located within less than 40 degrees of latitude north or south. Therefore, the most promising areas of the world include the south-western 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 these regions, 1 sq km of land is enough to generate as much as 100-130 gigawatt hours (GWh) of solar electricity a year using solar thermal technology. This is the same as the power produced by a 50 MW conventional coal or gas-fired mid-load power plant. 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.

Like conventional power plants, CSP plants need cooling at the so-called "cold" end of the steam turbine cycle. This can be achieved through evaporative (wet) cooling where water is available, or through dry cooling (with air) - both conventional technologies. Dry cooling requires higher investment and eventually leads to 5 – 10% higher cost compared to wet cooling. Hybrid cooling options exist that can optimise performance for site conditions and these are under further development.

However, the huge solar power potential in these areas by far exceeds local demand. So, solar electricity can be exported to regions with a high demand for power but with less solar resource. If the sun-belt countries harvest their natural energy in this way, they would be making a big contribution to protecting the global climate. Countries such as Germany are already seriously considering importing solar electricity from North Africa and Southern Europe as to make their power sector more sustainable. Of course, for any new development, local demand should be met first.

Figure 1.1: Scheme of Concentrating solar collector and concentrating solar thermal power station



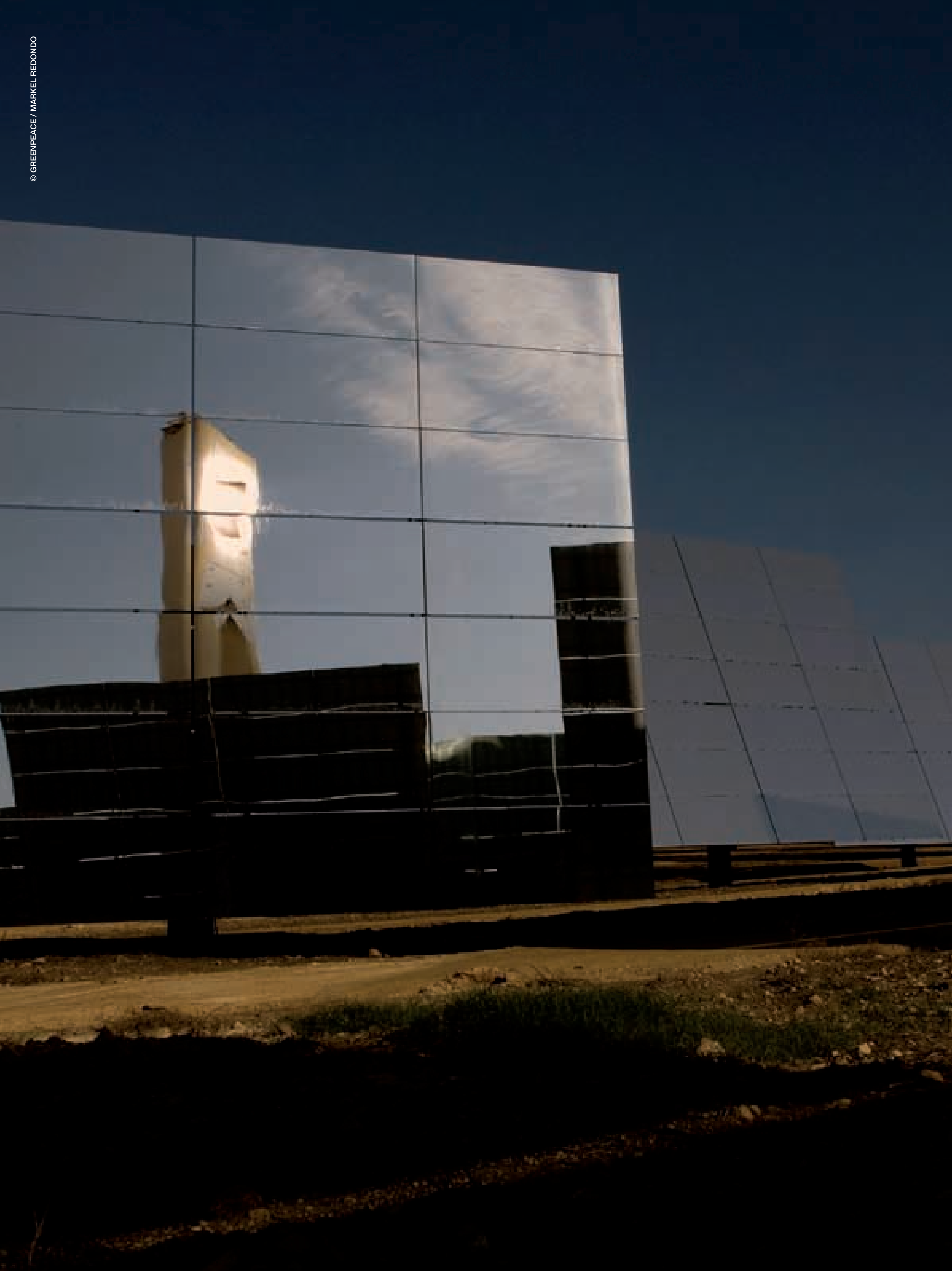
How it works – the technologies

A range of technologies can be used to concentrate and collect sunlight and to turn it into medium to high temperature heat. This heat is then used to create electricity in a conventional way, for example, using a steam or gas 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 phase-changing salt mixtures. At night, it can be extracted from the storage medium to keep the turbine running. Solar thermal power plants with solar-only generation work well to supply the summer noon peak loads in wealthy regions with significant cooling demands, such as Spain and California. With thermal energy storage systems they operate longer and even provide base-load power. For example, in Spain the 50 MWe Andasol plants are designed with about 8 hours thermal storage, increasing annual availability by about 1,000 to 2,500 hours.

The concentrating mirror systems used in CSP plants are either line or point-focussing systems. Line systems concentrate radiation about 100 times, and achieve working temperatures of up to 550°C while point systems can concentrate far more than 1,000 times and achieve working temperatures of more than 1,000°C. There are four main types of commercial CSP technologies: parabolic troughs and linear fresnel systems, which are line-concentrating, and central receivers and parabolic dishes, which are point-concentrating. Central receiver systems are also called solar towers.

Part 2 provides information on the status of each type of technology and the trends in cost. Since the last Greenpeace update on CSP technologies in 2005, there has been substantial progress in three main types of use besides electricity, namely solar gas, process heat and desalination. There have also been advances in storage systems for these technologies. These are discussed further in Part 2.

Part 4 lists the development in the market by region. A full list of the CSP plants operating, in construction and proposed, is provided in Appendix 1.



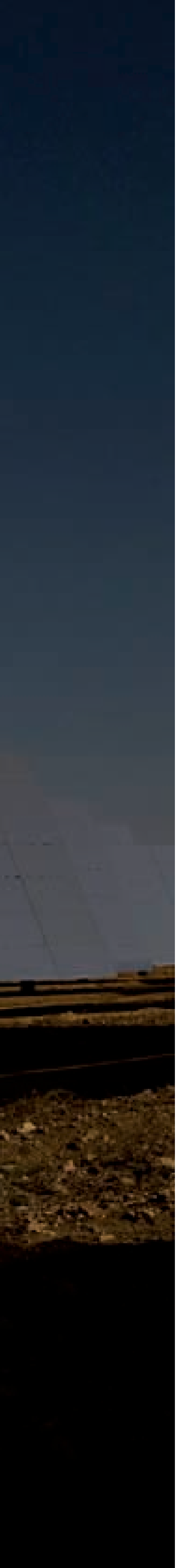


image Close-up of heliostats that collect the sun's energy in the PS10 Concentrating Solar Tower Plant.

2

CSP electricity technologies and costs

Types of generator

CSP plants produce electricity in a similar way to conventional power stations – using steam to drive a turbine. The difference is that their energy comes from solar radiation converted to high-temperature steam or gas. 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. So far, plants with both solar output and some fossil fuel co-firing have been favoured, particularly in landmark developments in the US and North Africa. Hybrid plants help produce a reliable peak-load supply, even on less sunny days. The major advantages and disadvantages of each of the solar generating technologies are given in Table 2.1. Table 2.2 gives an approximate overview of the development stages of the main technologies in terms of installed capacities and produced electricity.

Parabolic trough

(see figure 1 overleaf)

Parabolic trough-shaped mirror reflectors are used to concentrate sunlight on to thermally efficient receiver tubes placed in the trough's focal line. The troughs are usually designed to track the Sun along one axis, predominantly north–south. A thermal transfer fluid, such as synthetic thermal oil, is circulated in these tubes. The fluid is heated to approximately 400°C by the sun's concentrated rays and 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

(see figure 2 overleaf)

A circular array of heliostats (large mirrors with sun-tracking motion) concentrates 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, which is used to generate superheated steam for the turbine. To date, the heat transfer media demonstrated include water/steam, molten salts 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, making use of the excellent cycle (60% and more) of modern gas and steam combined cycles.

Parabolic dish

(see figure 3 overleaf)

A parabolic dish-shaped reflector concentrates sunlight on to a receiver located at the focal point of the dish. The concentrated beam radiation is absorbed into a 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. The troughs are usually designed to track the Sun along one axis, predominantly north–south.

Linear Fresnel Reflector (LFR)

(see figure 4 overleaf)

An array of nearly-flat reflectors concentrates solar radiation onto elevated inverted linear receivers. Water flows through the receivers and is converted into steam. This system is line-concentrating, similar to a parabolic trough, with the advantages of low costs for structural support and reflectors, fixed fluid joints, a receiver separated from the reflector system, and long focal lengths that allow the use of flat mirrors. The technology is seen as a potentially lower-cost alternative to trough technology for the production of solar process heat.

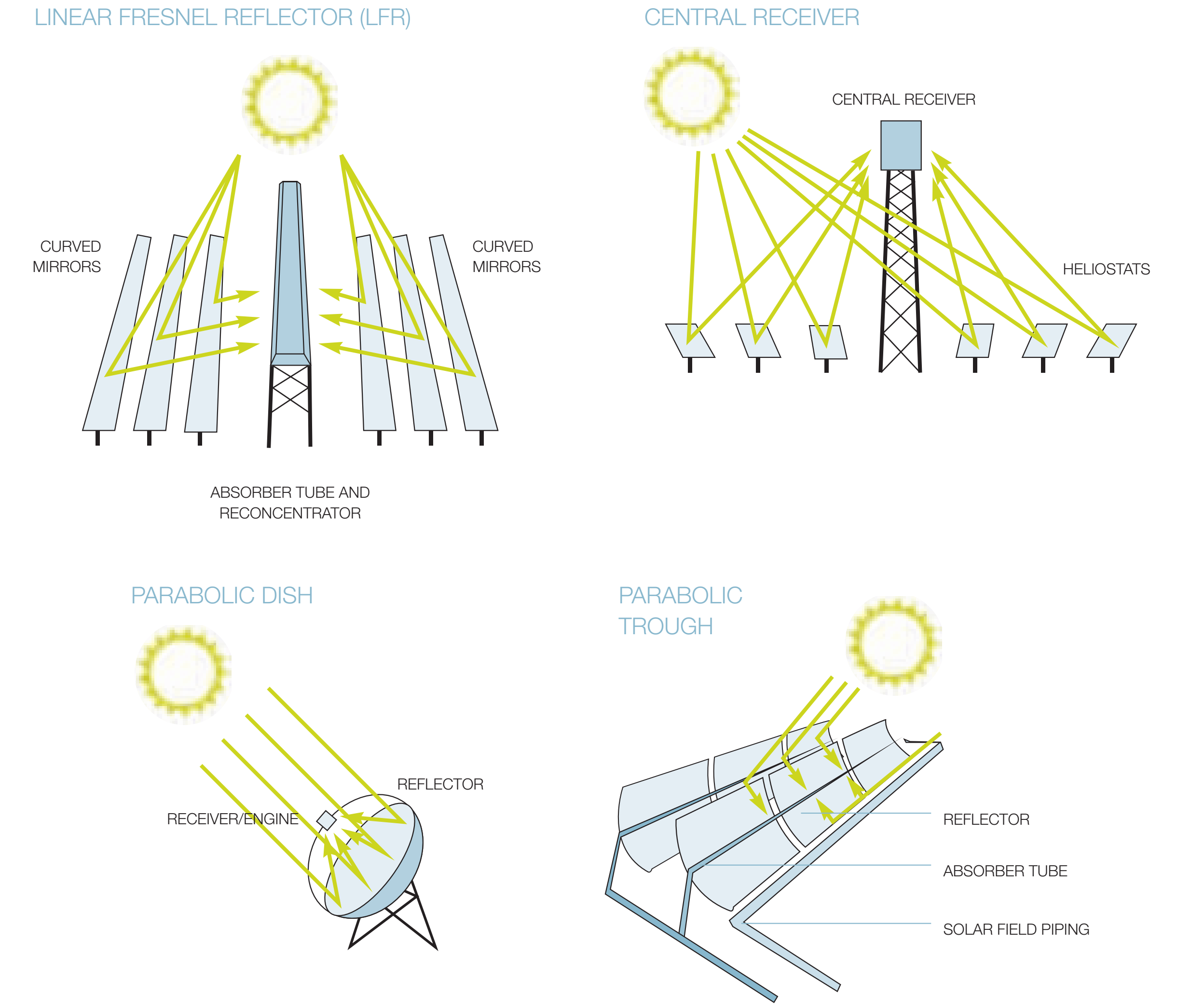


Figure 2.1-2.4: Parabolic trough, Central receiver or solar tower, Parabolic dish, Linear Fresnel Reflector (LFR)

Table 2.2: Operational experience, installed capacity and produced electricity by technology type ***(approximate numbers)***

TECHNOLOGY TYPE	INSTALLED CAPACITY 2009 [MW]	ELECTRICITY PRODUCED UP TO 2009 [GWh]	APPROXIMATE CAPACITY, UNDER CONSTRUCTION AND PROPOSED (MW)
Parabolic trough	500	>16,000	>10,000
Solar tower	40	80	3,000
Fresnel	5	8	500
Dish	0.5	3	1,000

Table 2.1: Comparison of main technology types for CSP

	PARABOLIC TROUGH	CENTRAL RECEIVER	PARABOLIC DISH	FRESNEL LINEAR REFLECTOR
Applications	Grid-connected plants, mid to high-process heat (Highest single unit solar capacity to date: 80 MWe. Total capacity built: over 500 MW and more than 10 GW under construction or proposed)	Grid-connected plants, high temperature process heat (Highest single unit solar capacity to date: 20 MWe under construction, Total capacity ~50MW with at least 100MW under development)	Stand-alone, small off-grid power systems or clustered to larger grid-connected dish parks (Highest single unit solar capacity to date: 100 kWe, Proposals for 100MW and 500 MW in Australia and US)	Grid connected plants, or steam generation to be used in conventional thermal power plants. (Highest single unit solar capacity to date is 5MW in US, with 177 MW installation under development)
Advantages	• Commercially available – over 16 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 • Good land-use factor • 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 • Better suited for dry cooling concepts than troughs and Fresnel • Better options to use non-flat sites	• Very high conversion efficiencies – peak solar to net electric conversion over 30% • Modularity • Most effectively integrate thermal storage a large plant • Operational experience of first demonstration projects • Easily manufactured and mass-produced from available parts • No water requirements for cooling the cycle	• Readily available • Flat mirrors can be purchased and bent on site, lower manufacturing costs • Hybrid operation possible • Very high space-efficiency around solar noon.
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 need wider scale proof in commercial operation	• No large-scale commercial examples • Projected cost goals of mass production still to be proven • Lower dispatchability potential for grid integration • Hybrid receivers still an R&D goal	• Recent market entrant, only small projects operating

image
Andasol 1 solar power station in Southern Spain.

Parabolic trough

Parabolic troughs are the most mature of the CSP technologies and they are commercially proven. The first systems were installed in 1912 near Cairo in Egypt to generate steam for a pump that delivered water for irrigation. At the time, this plant was competitive with coal-fired installations in regions where coal was expensive.

In the trough system, sunlight is concentrated by about 70–100 times on to absorber tubes, achieving operating temperatures of 350 to 550°C. A heat transfer fluid (HTF) pumped through the absorber tube transfers the thermal energy to a conventional steam turbine power cycle. Most plants use synthetic thermal oil for the job of transferring heat. The hot thermal oil is used to produce slightly superheated steam at high pressure that then feeds a steam turbine connected to a generator to produce electricity. The thermal oil has a top temperature of about 400°C, which limits the conversion efficiency of the turbine cycle, so researchers and industry are also developing advanced HTFs. One example is direct generation of steam in the absorber tubes, another using molten salt as the HTF. Prototype plants of both types are currently being built.

Around the world, parabolic trough projects currently in operation are between 14 and 80 MWe in size, and existing plants are producing well over 500 MW of electrical capacity. In southern California, nine plants were developed and grid-connected in the 1980s, forming about 2 million m^2 of mirror area, named solar electricity generating systems (SEGS). After an industry hiatus, commercial construction of parabolic trough plants has resumed with the 64 MW project called Nevada One, owned by Acciona, which will produce 130 GWh of electricity annually. In Spain, the Andasol and Solnova projects in construction will together provide 250 MW of capacity, and more than 14 more projects of their type are proposed since the introduction of a sufficient feed-in tariff. The largest single parabolic trough installation yet proposed is called Solana, and is planned for a site in Nevada.

The Andasol plant developed by Solar Millennium / ACS uses synthetic oil as heat transfer fluid; it is a first-of-its-kind, utility-scale demonstration of the EuroTrough design and thermal storage using molten salt technology. While SEGS and the Solnova projects in Spain also use synthetic oil for heat transfer, other developers are building plants with direct steam generation within the absorber tubes. Using direct steam eliminates the need for a heat transfer medium, and can reduce costs and enhance efficiency by 15–20%.

The SEGS and Solnova plants use a system where the plant can also operate by burning natural gas on days when sunlight is weak. Parabolic trough systems are suited to a hybrid operation called Integrated Solar Combined Cycle (ISCC), where the steam generated by solar is fed into a thermal plant that also uses fossil-fuel generated steam, generally from natural gas. Tenders for ISCC plants have been released in Algeria, Egypt and Morocco, forming an interim step towards complete solar generation in the energy mix.

Case Study
Andasol Plants – using thermal storage

The Andasol Plan was built with 624 EuroTrough (Skal-ET) collectors, arranged in 168 parallel loops. The Andasol 1 plant started its test run in autumn 2008 and Andasol 2 and 3 are currently under construction in southern Spain, with gross electricity output of around 180 GWh a year and a collector surface area of over 510,000 square meters - equal to 70 soccer pitches.

Each power plant has an electricity output of 50 megawatts and operates with thermal storage. The plant is designed to optimise heat exchange between the heat transfer fluid circulating in the solar field and the molten salt storage medium and the water/steam cycle. With a full thermal reservoir the turbines can run for about 7.5 hours at full-load, even if it rains or long after the sun has set. The heat reservoirs are two tanks 14 metres in height and 36 metres in diameter, and contain liquid salt. Each provides 28,500 tons of storage medium. Andasol 1 will supply up to 200,000 people with electricity and save about 149,000 tons of CO_2 a year compared with a modern coal-fired power plant.

image Part of SEGS solar plant in California - the first commercial parabolic trough concentrating solar plants in the world.

Case Study
SEGS – pioneering the technology

Nine plants were constructed in the US Mojave desert by Israeli/American company Luz between 1984 and 1991; the first only 14 MWe, and the final two were 80 MWe, known collectively as Solar Energy Generating System (SEGS). They use solar-generated steam and also gas back-up, but the gas component is limited to 25% of the total heat input. They have more than 2 million square metres of parabolic trough mirrors. They were built with USD 1.2 billion, in private risk capital from institutional investors. Earlier, Luz faced difficulties making a profit because of market issues of energy price fluctuations and tax status. However, the technology is proven and shows that CSP plants have a potentially long operating life. Today, just the three plants at Kramer Junction are delivering 800–900 million kWh of electricity to the Californian grid every year, reaching a total accumulated solar electricity production of almost 9 billion kWh, roughly half of the solar electricity generated world-wide to date. Since their construction, the SEGS plants have reduced operation and maintenance costs by at least one third. Trough component manufacturing companies have made significant advances in improving absorber tubes, process know-how and system integration. The annual plant availability constantly exceeds 99% and, anecdotally, the plant performance level has dropped only about 3% in around 20 years of operation.

Source: SolarPACES

image The PS10 Concentrating Solar Tower Plant near Seville, Spain.

Central receiver

Central receiver (or power tower) systems use a field of distributed mirrors – heliostats – that individually track the sun and focus the sunlight on the top of a tower. By concentrating the sunlight 600–1000 times, they achieve temperatures from 800°C to well over 1000°C. The solar energy is absorbed by a working fluid and then used to generate steam to power a conventional turbine. In over 15 years of experiments worldwide, power tower plants have proven to be technically feasible in projects using different heat transfer media (steam, air and molten salts) in the thermal cycle and with different heliostat designs.

The high temperatures available in solar towers can be used not only to drive steam cycles, but also for gas turbines and combined cycle systems. Such systems can achieve up to 35% peak and 25% annual solar electric efficiency when coupled to a combined cycle power plant.

Early test plants were built in the 1980s and 1990s in Europe and the US. These included SOLGATE, which heated pressurised air, Solar II in California, which used molten salt as heat transfer fluid and as the thermal storage medium for night time operation, and the GAST project in Spain, which used metallic and ceramic tube panels. The concept of a volumetric receiver was developed in the 1990s within the PHOEBUS project, using a wire mesh directly exposed to the incident radiation and cooled by air flow. This receiver achieved 800°C and was used to operate a 1 MW steam cycle.

With the technology proven, there are now some landmark operational projects running in Spain, notably the Sanlúcar Solar Park, the PS10 solar tower of 11 MW and the PS20 that has a 20 MW capacity. A US company is developing a high-temperature, high-efficiency decentralised tower technology, and has a power purchase agreement for up to 500 MW of capacity. The first 100 MW is proposed for installation in 2010.

Case Study
PS10 and 20 - the world's first commercial solar towers

The previous Greenpeace CSP report discussed the project PS10, which was an 11 MW solar tower installation with a central receiver. This plant is now in full operation and the developers, Abengoa, have progressed to building PS20, which is twice as big. Both plants have thermal storage that allows full production for 30 minutes even after the sun goes down. Thermal storage in this case is used to boost power production under low radiation conditions. Additionally, the PS10 can use natural gas for 12-15% of its electrical production. The PS10 generates 24.3 GWh a year of clean energy, which is enough to supply 5,500 households. The PS10 solar field is composed of 624 Sanlúcar heliostats; the entire field has an area of 75,000 m_2. Each heliostat tracks the sun on two axes and concentrates the radiation onto a receiver located on tower that is 115 m tall. The receiver converts 92% of received solar energy into steam.

The PS20 is built is the same location, the Plataforma Solar de Sanlúcar la Mayor in southern Spain. Working in the same way, the PS20 will add electricity supply for another 12,000 homes to the operations. The PS20 solar field has 1,255 heliostats and tower of 160 m.

Source: Abengoa Website

image Artist's impression of the Invanpah solar tower project in northern California.


© BRIGHTSOURCE ENERGY

Case Study
Invanpah 1 – the biggest power contract for a solar tower project yet

A bright prospect for tower technology lies with BrightSource Energy, a start-up in Northern California, which is developing a high-temperature, high-efficiency decentralised tower technology. BrightSource Energy has filed for approval to install a total of 400MW of electric generating capacity in Ivanpah, Nevada using its Distributed Power Tower (DPT) technology at a cost of approximately USD 4500/kW. The company has set up Luz II, a wholly-owned subsidiary of BrightSource Energy responsible for the 1980s development of SEGS, for its technology development. Pending approval from California's Energy Commission, the first 100MW will be installed by 2010 with the rest 300MW following soon after.

Source: Brightsource Energy Website

image
Stirling Energy Systems (SES) parabolic dish, in New Mexico, USA.

Parabolic dish

Parabolic dish concentrators are individual units that have a motor-generator mounted at the focal point of the reflector. The motor-generator unit can be based on a Stirling engine or a small gas turbine. Several dish/engine prototypes have successfully operated over the last 10 years, ranging from 10 kW (Schlaich, Bergermann and Partner design), 25 kW (SAIC) to over 100 kW (the 'Big Dish' of the Australian National University). Like all concentrating systems, they can additionally be powered by fossil fuel or biomass, providing firm capacity at any time. Because of their size, they are particularly well-suited for decentralised power supply and remote, stand-alone power systems.

Within the European project EURO-DISH, a cost-effective 10 kW Dish-Stirling engine for decentralised electric power generation has been developed by a European consortium with partners from industry and research. The technology promoted by Stirling Energy Systems (SES), called 'Solarcatcher', is a 25 kW system that consists of a 38 ft. diameter dish structure that supports 82 curved glass mirror facets, each 3 ft. x 4 ft. in area. The generator is a 4-cylinder reciprocating Stirling cycle engine, generating up to 25 kW of electricity per system. In 2008, Stirling Energy Systems claimed a new solar-to-grid system conversion efficiency record by achieving a 31.25% net efficiency rate in New Mexico.[3]

The Australian Big Dish technology is being brought to market by Wizard Power and has a surface area of 500 m^2. The model that is being commercialised uses an ammonia-based solar energy storage system to power a thermo-chemical process that stores concentrated solar energy until it is required to generate electricity. So the power continues to be produced at night, or under poor weather conditions – providing continuous base-load or on-demand peak power.

Parabolic dish systems are modular and in theory can be scaled up to form huge arrays. The SES company has a power purchase agreement in place for a solar dish array in the Mojave Desert of California that would require more than 20,000 units. However, this development has been proposed for some years without construction starting. In Australia, Wizard Technology, which has commercialised the 'Big Dish', is proposing a project near Whyalla, with applications in steel processing, of 100MW in size to be started in 2009.

3 Press release 12 February 2008, Sandia, Stirling Energy Systems set new world record for solar-to-grid conversion efficiency, via company website www.stirlingenergy.com

© RANDY MONTOYA

image
Ausra's Kimberlina Solar Energy Facility in Bakersfield, California.

Fresnel linear reflector

LFR collectors, which have attracted increasing attention, are mainly being developed by the Australian company Ausra (formerly Solar Heat and Power) in the USA. It built a test plant of 1 MW in the east of Australia in 2003, which feeds steam directly into an existing coal-fired power station. That plant is currently being doubled in size and the company has one 5MW plant operating and one 177 MW planned development in the US.

The Fresnel mirrors are mass-produced at a factory in Nevada with an automated welding/ assembly system. The Fresnel design uses less-expensive reflector materials and absorber components. It has lower optical performance and thermal output but this is offset by lower investment and operation and maintenance costs. The Fresnel system also provides a semi-shaded space below, which may be particularly useful in desert climates. Acting like a large, segmented blind, it could shade crops, pasture and water sheds to protect them from excessive evaporation and provide shelter from the cold desert sky at night.

The PE1 Fresnel plant from Novatec with 1,4 MW electric capacity has recently started grid connected operation in Calasparra, Murcia, Spain.

Case Study
Kimberlina – The first commercial Fresnel reflector

Located in Bakersfield, California, Ausra's Kimberlina Solar Thermal Energy Plant is the first of its kind in North America. The Kimberlina plant was also the first solar thermal project to start operation in California in around 15 years. The rows of mirrors at Kimberlina were manufactured at a custom-built solar thermal power factory in Las Vegas, Nevada. The solar thermal collector lines will generate up to 25 MW of thermal energy to drive a steam turbine at the adjacent power plant. According to the company, at full output the Kimberlina facility will produce enough solar steam to generate 5 MW of renewable power, enough for up to 3,500 central Californian households.

It showcases the technology that was trialled and tested as an add-on to a coal-fired power station in the coal-mining region of the Hunter Valley, Australia. The Compact Linear Fresnel Reflector produces direct steam, and can be built and run at a lower cost than some other types of solar thermal generators. Direct steam generation makes integration into existing systems simple, either as retrofits or new designs. The system produces steam and electricity directly at prices that compete with peak natural gas energy resources.

Ausra is now developing a 177 MW solar thermal power plant for Pacific Gas and Electric Company (PG&E) in Carrizo Plains, west of Bakersfield with components supplied by its Nevada facility.

Source: Ausra Website

Cost trends for CSP

Most of the cost information available for CSP is related to the parabolic trough technology, as they make up the majority of plants actually in operation up until now. Estimates say that new parabolic troughs using current technology with proven enhancements can produce electrical power today for about 10 to 12 US cents/kWh in solar-only operation mode under the conditions in south-western USA. In Spain, the levelled cost of electricity is somewhat higher than this for the parabolic trough technology (up to 23 eurocents/ kWh), but overall the price is coming down.

Commercial experience from the nine SEGS plants built in California between 1986 and 1992 and operating continuously ever since, shows that generation costs in 2004 dropped by around two-thirds. The first 14 MWe unit supplied power at 44 cents/kWhe, dropping to just 17 cents /kWhe for the last 80 MWe unit. For reference, the cost of electricity from the first 14 MWe unit was 25 cents/ kWhe at 1985 US dollar rates. With technology improvements, scale-up of individual plant MW capacity, increasing deployment rates, competitive pressures, thermal storage, new heat transfer fluids, and improved operation and maintenance, the future cost of CSP-generated electricity is expected to drop even further.

As with all CSP plants, high initial investment is required for new plants. Over the entire lifecycle of the plant, 80% of the cost is from construction and associated debt, and only 20% is from operation. Therefore financial institution confidence in the new technology is critical. Only when funds are available without high-risk surcharges can solar thermal power plant technology become competitive with medium-load fossil-fuel power plants. Once the plant has been paid for, in 25 or 30 years, only operating costs, which are currently about 3 cents/kWh, remain and the electricity is cheaper than any competition; comparable only to long-written-off hydropower plants.

In California, there was a 15-year break between construction of the last SEGS IX plant in 1992 and the most recent installations; the PS10 and Nevada Solar One grid connection. For this reason, new industry players have had to recalculate costs and risks for CSP plants for today's market. The data indicates that CSP operating costs have now entered a phase of constant optimisation, dropping from 8 cents/kWh to just over 3 cents/kWh.[4] The industry now has access to a new generation of improved-performance parabolic trough components, which will also improve running costs.

Less is known about the real market costs of electricity for the other types of technology because the first examples have only been built in recent years or are still under construction. However, it is generally thought that solar towers will eventually produce electricity at a cost lower than that of the parabolic trough plants.

Heat storage technologies

CSP can become more 'dispatchable' with the addition of heat storage. This means that power can be dispatched from the plant at other times, not only in high sun conditions. Sometimes referred to as Thermal Energy Storage (TES), this technology stores some of the thermal energy collected by the solar field for conversion to electricity later in the day. Storage can adapt the profile of power produced throughout the day to demand and can increase the total power output of a plant with given maximum turbine capacity. This is achieved by storing the excess energy of a larger solar field before it is used in the turbine. Eventually, plants with storage can operate at nearly 100% capacity factor, similar to fossil fuel plants. This also means that concentrating solar power can provide baseload electricity in appropriate locations.

The different configurations of CSP plants require tailored thermal energy storage solutions that match their particular mix of technologies, for example, the primary working fluid, operation temperature and pressure, capacity and power level. Providing efficient and economic TES systems will require a variety of storage technologies, materials and methods to meet all the different plant specifications.

Storage technologies can be either 'direct' or 'indirect'. Indirect means that the storage medium is not heated directly by the concentrators. Indirect systems use a heat transfer fluid instead, typically a synthetic oil, which passes through a heat exchanger with the storage medium to heat it indirectly. Typically the transfer fluid is synthetic oil and the storage medium is molten salts.

4 SolarPACES Annual Report, 2007

Indirect storage using molten salts

An operating example of this type of technology is Andasol 1 in southern Spain. The plants here use cool tanks (about 290°C) and hot tanks (about 390°C) of molten salts, with about 29,000 tonnes in each tank. The cool salts are passed through a heat exchanger with the oil that is heated by the concentrator, and then stored in the hot tank for later use. To extract the heat, the process is reversed through the exchanger, to transfer heat back into the oil. It can then make steam for the generator. An advantage of this process is that the oils for heat transfer are a tried and tested technology. The downside is that the heat exchangers are expensive and add investment costs to the development.

Direct storage of steam

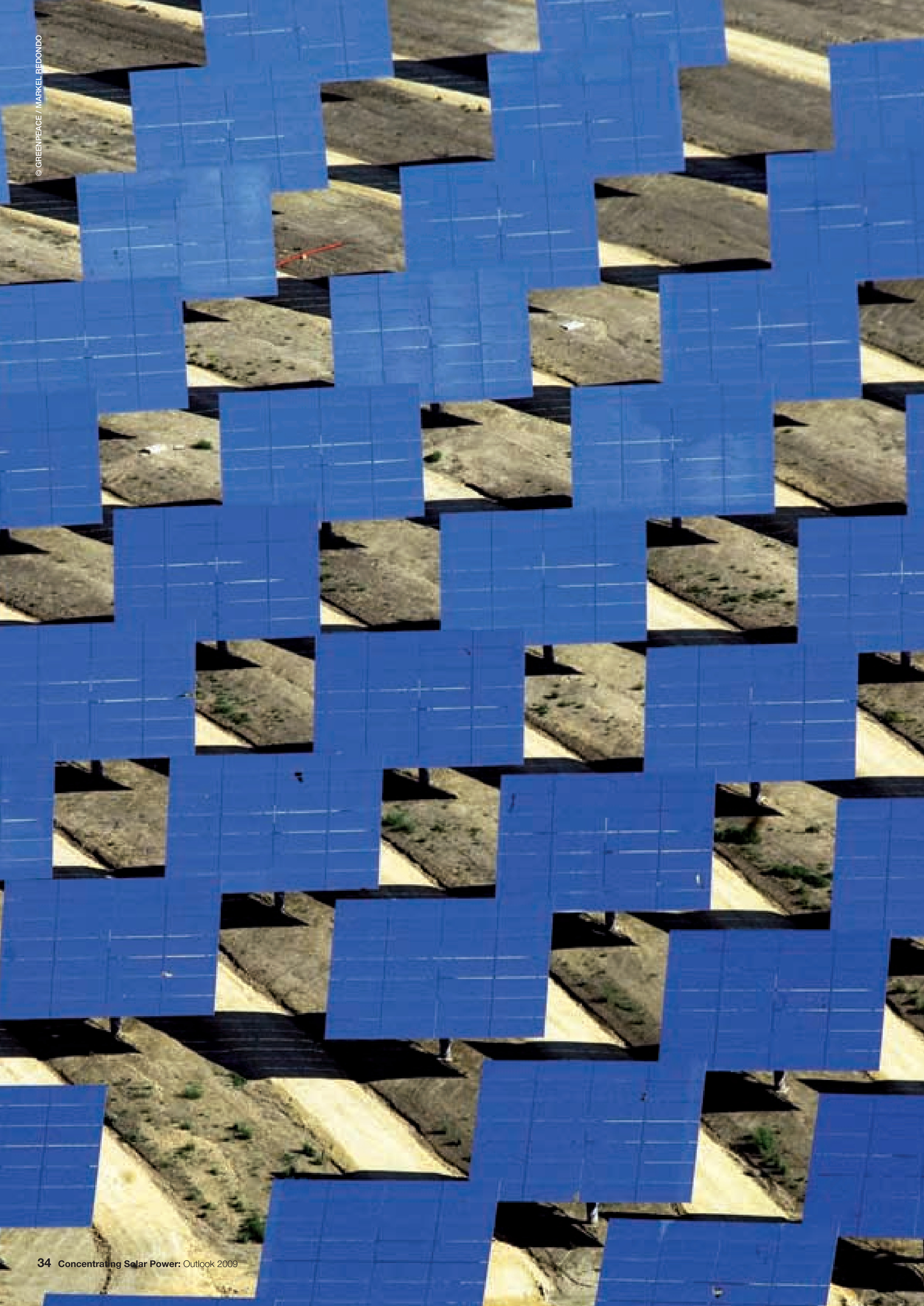
This technique is used commercially in the PS10 plant and provides about 30 minutes to an hour of extra operation. Its capacity for storage is limited because of the high cost of pressurised vessels for large steam volumes and storage capacities. This is, in principle, a conventional technology, also known as Ruth's storage. The best use of this technology is as buffer storage for peak power.

Indirect storage using concrete

Using concrete to store heat is at different stages in prototype installations with a good record so far. The concrete 'store' operates at temperatures of 400 – 500ºC, and is a modular and scalable design having between 500kWh to 1000 MWh capacity. Currently, the investment cost is about € 30 per kWh, but the target is for less than € 20 per kWh. The first generation storage modules, with a 300 kWh capacity, have been operating for two years. Second generation modules have a 400 kWh capacity and are now ready for a demonstration application.

Indirect storage in a phase-changing medium

This technology is under development, and uses the melting/freezing points of salts such as sodium or potassium nitrates to store and deliver heat for condensation and evaporation of steam in direct steam plants. It has only been tested in various prototypes, but there are no commercial applications. In this system, hot heat transfer fluid flows through a manifold embedded in the phase-changing materials, transferring its heat to the storage material. The main advantage of this technology is its volumetric density and the low cost of the storage materials. There are some developmental challenges of this method that need to be overcome before it becomes a commercially-viable solution.



© GREENPEACE / MARKEL REDONDO

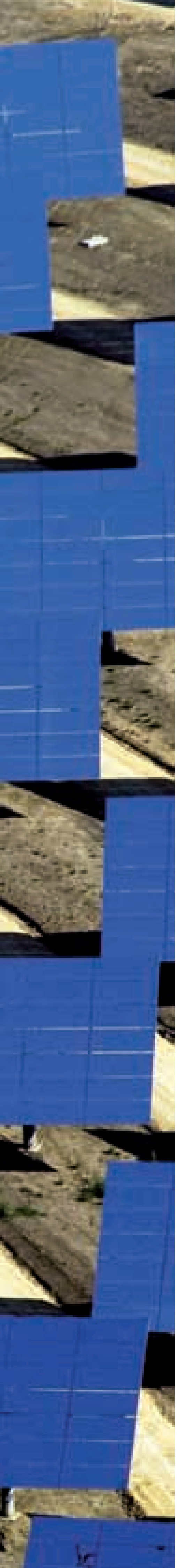


image Tracking mirrors called heliostats, part of the PS10 Concentrating Solar Tower plant in southern Spain.

3

Other applications of CSP technologies

Process Heat

Since the 2005 Greenpeace report, solar thermal power has taken off in countries where the political and financial support is available. Now that it is maturing we can look beyond traditional residential electricity applications towards more innovative applications. Among these solar process heat stands out as a smart and productive way to get the most out of these technologies.

Many industries need high heat processes, for example in sterilisation, boilers, heating and for absorption chilling. A 2008 study commissioned by the International Energy Agency[5] determined that in several industrial sectors, such as food, wine and beverage, transport equipment, machinery, textile, pulp and paper, about 27% of heat is required at medium temperature (100 - 400°C) and 43% at above 400ºC.

Parabolic troughs and Linear Fresnel Systems are most suitable for the capture of heat for industrial processes. They could be considered as an economic option to install on-site for a whole range of industry types requiring medium to high heat. The IEA study recommended that the sectors most compatible with process heat from solar concentrating technology are food (including wine and beverage), textile, transport equipment, metal and plastic treatment, and chemical. The most suitable applications and processes include cleaning, drying, evaporation and distillation, blanching, pasteurisation, sterilisation, cooking, melting, painting, and surface treatment. Solar thermal or CSP should also be considered for space heating and cooling of factory buildings. The use of towers or dishes for high temperature heat processes like that required in ceramics is also under research.

Desalination

Desalination is the process of turning sea water into water for drinking or irrigation for populations in arid areas. There are major desalination plants operating today all over the world, mostly using reverse osmosis and some using thermal distillation. However, large-scale desalination has been controversial, primarily for the large amount of energy it takes and also for the potential harm to marine life from the intakes and discharge of super-concentrated seawater. From a sustainability perspective, large-scale desalination is seen almost as a 'last-resort' in responding to our drying climate – the preference is for more efficient use of water, better accountability, re-use of waste water, enhanced distribution and advanced irrigation systems. Most plants are running either on grid electricity or directly powered by oil and gas. From a climate perspective, building power-hungry desalinations plants simply adds to the problem, rather than addressing it.

However, with the growth and increasing affordability of concentrating solar power, some researchers are looking into how desalination could address water scarcity. Of course, places with large amounts of solar radiation are often also places with water supply problems. A 2007 study by the German Aerospace Centre (DLR)[6] into concentrating solar power for desalination of sea water looked at the potential of this technology for providing water to the large urban centres in the Middle East and North Africa (MENA). The study found that the solar resource in the region is more than enough to provide energy for desalination to meet the growing 'water deficit' of these areas. The report demonstrates that only four of the 19 countries in the region have renewable freshwater that exceeds 1000 cubic metres a person a year, which is considered the water poverty line.[7]

5 Vannoni, Battisti and Drigo (2008) Department of Mechanics and Aeronautics - University of Rome "La Sapienza". Potential for Solar Heat in Industrial Processes, Commissioned by Solar Heating and Cooling Executive Committee of the International Energy Agency (IEA)

6 German Aerospace Centre (DLR), 2007, "Aqua-CSP:Concentrating Solar Power for Seawater Desalination" Full report can be found online at http://www.dlr.de/tt/aqua-csp

7 Ibid.

The study indicates that the potential water deficit in the region is 50 billion cubic metres a year and will grow to about 150 billion cubic metres a year by 2050. It predicts that energy from solar thermal power plants will become the cheapest option for electricity at below 4 cents per kWh and desalinated water at below 40 eurocents per cubic metre in the next two decades. A key finding is that management and efficient use of water, enhanced distribution and irrigation systems, re-use of wastewater and better accountability can avoid about 50% of the long-term water deficit of the MENA region. So solar desalination could have a role to play to provide the other half, using "horizontal drain seabed-intake" and advanced nanotechnology for membranes that minimise environmental impact of high salt load into living systems.

DLR suggests that the most appropriate technology mix would be either concentrating solar power providing the electricity into a reverse osmosis process membrane desalination (RO), or concentrating solar power providing both electricity and heat into a thermal 'multi effect' desalination system (MED). Currently, most of the desalted water in the MENA region is provided by a process called Multi-Stage Flash (MSF) desalination. This is not considered a viable future option for solar powered desalination, because the energy consumption is too high.

The conclusion is that advanced CSP systems have the potential to operate cleaner desalination plants with extremely low environmental impacts compared to today's conventional desalination systems at about 20% higher investment cost, but using a fuel that will be considerably less expensive than today's fossil fuel sources.

Individual plant locations would need to be chosen carefully to allow rapid discharge and dilution of brine, and subject to a thorough environmental analysis to avoid impacts to important marine life. A drying climate is one effect of global warming caused by fossil fuels. Because concentrating solar power is already compatible with hot, dry areas, it could have a role to play in powering future desalination to support populations.

Solar Fuels

To meet the challenges of producing large quantities of cost-effective fuel directly from sunlight, there is now rapid development in solar fuels. Some are a mix of fossil-fuels with solar input, which cut a proportion of greenhouse gases. The ultimate goal is for solar fuel technologies based on processes that are completely independent of any fossil fuel resources.

Much attention is focussed on hydrogen (H_2), a potentially clean alternative to fossil fuels, especially for transport uses. At the moment more than 90% of hydrogen is produced using heat from fossil-fuels, mainly natural gas. If hydrogen is generated from solar energy, it is a completely clean technology with no hazardous wastes or climate-changing by-products. This is the vision outlined in the European Commission's 'European hydrogen and fuel cell roadmap', which runs up to 2050.

Solar fuels such as hydrogen can be used in several ways; 'upgrading' fossil fuels burned to generate heat, fed into turbines or engines to produce electricity or motion, or used to generate electricity in fuel cells and batteries. By storing energy in a fuel like hydrogen, it can be retrieved when needed, and is available even when the sun isn't shining. Clean hydrogen production would be based on water (H_2O) and energy from renewable sources.

There are basically three routes for producing storable and transportable fuels from solar energy:

- ***Electrochemical:*** solar electricity made from photovoltaic or concentrating solar thermal systems followed by an electrolytic process
- ***Photochemical/Photobiological:*** direct use of solar photon energy for photochemical and photobiological processes
- ***Thermochemical:*** solar heat at high temperatures followed by an endothermic thermochemical process.

8 Meier, A, Sattler, C, (2008) Solar Fuels from Concentrated Sunlight, Published by SolarPACES, www.solarpaces.org

Solar towers are most appropriate for future large-scale production of solar fuels, because they can achieve the necessary high temperatures (> 1000 ° C) due to their high concentration ratio.

Achieving the energy revolution that we need will require a complete overhaul of current systems of production and distribution of fuels and electricity. A massive production of solar hydrogen will be required to store energy produced from renewable sources. Secondly, many say our transport and mobility will probably be based on sustainable fuels rather than electricity.

The European Union's World Energy Technology Outlook scenario predicts a hydrogen demand equivalent to about 1 billion tons of oil in 2050. A viable route to this production is using solar electricity generated by CSP technology, and followed by electrolysis of water. It can be considered as a benchmark for other routes that offer the potential of energy efficient large scale production of hydrogen.

Cost considerations

The projected costs of hydrogen produced by CSP and electrolysis range from 15 to 20 US cents per kWh, or USD 5.90 to 7.90 per kg H_2 (assuming solar thermal electricity costs of 8 US cents per kWhe).

The economical competitiveness of solar fuel production is determined by the cost of fossil fuels and the actions we must take to protect the world's climate by drastically reducing CO_2 emissions. Both the US Department of Energy and the European Commission have a clear vision of the future hydrogen economy, with firm targets for hydrogen production costs. The US target for 2017 is USD 3 /gge (gasoline gallon equivalent; 1 gge is about 1 kg H_2), and the EU target for 2020 is €3.50 /kg.[8]

The economics of large scale solar hydrogen production has been assessed in several studies which indicate that solar thermochemical production of H_2 can eventually be competitive with electrolysis of water using solar-generated electricity. As indicated above, it can even become competitive with conventional fossil-fuel-based processes at current fuel prices, especially with credits for CO_2 mitigation and pollution avoidance.

For this, we need further R&D and large-scale demonstrations of solar fuels. This would increase achievable efficiencies and reduce investment costs for materials and components. As more commercial solar thermal power plants come on line, in particular power towers, the price of solar-thermal H_2 production will drop, since heliostats are one of the most expensive components of a production plant.

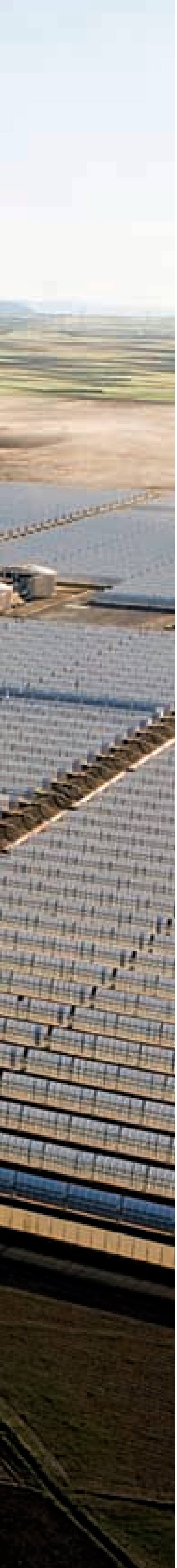


image Aerial photo of the Andasol 1 solar power station in Spain, a development taking advantage of Spain's solar feed-in tariff.

4

Market Situation by Region

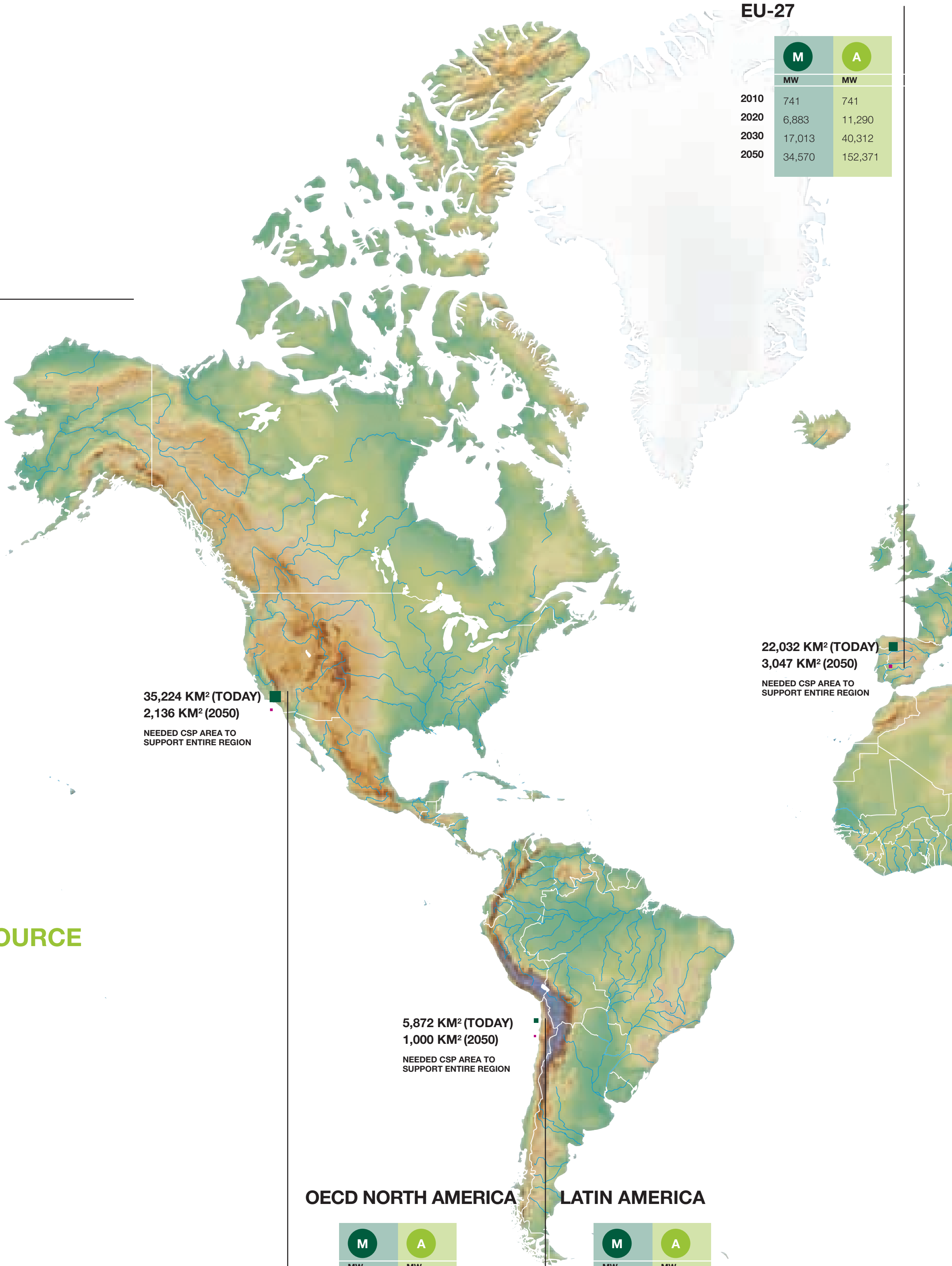
World Overview

The levelised electricity cost of concentrating solar power plants depends on both the available solar resource and development costs of investment, financing and operation. Plants under the same price and financing conditions, in the South western United States or Upper Egypt will have levelised electricity cost 20-30% lower than in Southern Spain or the North African coast. This is because the amount of energy from direct sunlight is up to 30% higher (2,600-2,800 compared to 2,000- 2,100 kWh/m² a year). The solar resource is even lower in France, Italy and Portugal. The best solar resource in the world is in the deserts of South Africa and Chile, where direct sunlight provides almost 3,000 kWh/m² a year. The economic feasibility of a project is determined by both the available solar resource at the site and then by power sale conditions.

If the local power purchase price does not cover the production cost, then incentives or soft loans can cover the cost gap between the power cost and the available tariff. Environmental market mechanisms like renewable energy certificates could be an additional source of income, in particular in developing countries. All the CSP plants in the United States were pre-financed by developers and/or suppliers/ builders and received non-recourse project financing only after successful start-up. In contrast, all CSP projects in Spain received non-recourse project financing for construction. Extensive due diligence preceded financial closure and only prime EPC contractors were acceptable to the banks, which required long-term performance guarantees accompanied by high failure penalties.

'Bankability' of the plant revenue stream has been the key to project finance in Algeria, Spain and the US. Different approaches have been long-term power purchase agreements and feed-in tariffs, but it has taken considerable effort during years of project development to remove the barriers and obstacles to bankability. In Spain, one major barrier for industry development was the right of the government to change tariffs every year, which gave no long-term business plan income security. This barrier was removed by a new version of the feed-in law which now grants the solar power tariffs for 25 years. One important hurdle in the US was the short time frame of the investment tax credits, which has recently been extended.

Map 1 CSP



EU-27

	M MW	A MW
2010	741	741
2020	6,883	11,290
2030	17,013	40,312
2050	34,570	152,371

OECD NORTH AMERICA

	M MW	A MW
2010	1,995	1,995
2020	29,598	25,530
2030	70,940	106,806
2050	162,883	494,189

LATIN AMERICA

	M MW	A MW
2010	0	100
2020	2,198	2,298
2030	8,034	12,452
2050	33,864	50,006

RENEWABLE RESOURCE

CSP

LEGEND

M MODERATE

A ADVANCED

0 1,500 KM

Table 4.1: Specification of world regions (IEA 2007c)

OECD EUROPE	OECD NORTH AMERICA	OECD PACIFIC	TRANSITION ECONOMIES	CHINA	REST OF DEVELOPING ASIA
Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom	Canada, Mexico, United States of America	Australia, Japan, Korea (South), New Zealand	Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Serbia and Montenegro, the former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Lativa, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus[1], Malta[1]	People's Republic of China including Hongkong	Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Chinese Taipei, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Vietnam, Vanuatu

1) Allocation of Cyprus and Malta to Transition Economies because of statistical reasons

MIDDLE EAST

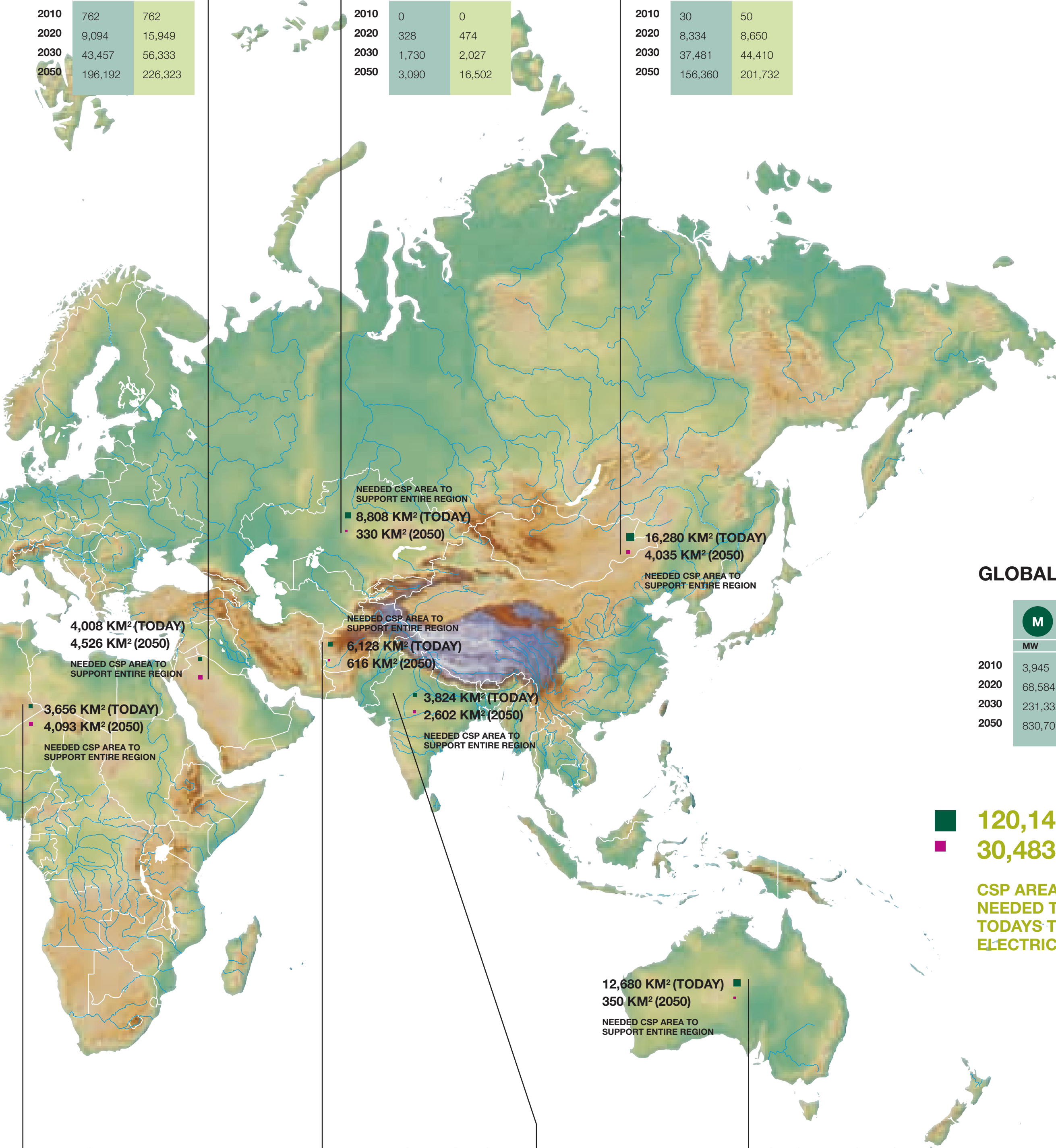
	M MW	A MW
2010	762	762
2020	9,094	15,949
2030	43,457	56,333
2050	196,192	226,323

TRANSITION ECONOMIES

	M MW	A MW
2010	0	0
2020	328	474
2030	1,730	2,027
2050	3,090	16,502

CHINA

	M MW	A MW
2010	30	50
2020	8,334	8,650
2030	37,481	44,410
2050	156,360	201,732



GLOBAL

	M MW	A MW
2010	3,945	4,085
2020	68,584	84,336
2030	231,332	342,301
2050	830,707	1,524,172

120,144 KM² (TODAY)
30,483 KM² (2050)

CSP AREA NEEDED TO SUPPORT TODAYS TOTAL GLOBAL ELECTRICITY DEMAND

AFRICA

	M MW	A MW
2010	150	150
2020	3,968	4,764
2030	22,735	31,238
2050	110,732	204,646

DEVELOPING ASIA

	M MW	A MW
2010	0	0
2020	2,441	2,575
2030	8,386	9,655
2050	23,669	30,818

INDIA

	M MW	A MW
2010	30	50
2020	2,760	3,179
2030	15,815	21,491
2050	97,765	130,083

OECD PACIFIC

	M MW	A MW
2010	0	238
2020	2,848	9,000
2030	8,034	17,500
2050	17,501	33,864

INDIA	LATIN AMERICA	AFRICA	MIDDLE EAST
India	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela	Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Marocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe	Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen

Middle East and India

Israel

In 2002, the Israeli Ministry of National Infrastructures, which is responsible for the energy sector, made concentrated solar power a strategic component of the electricity market. Israel introduced feed-in incentives for solar IPPs from September 2006, effective for 20 years. This was following a feasibility study on CSP incentive done in 2003 and evaluated by the Israeli Public Utilities Authority (PUA). Following this, Greenpeace published a cost-benefit analysis for solar energy in Israel, indicating that the state could use up to 2,000 MW of solar power by 2025.

Israel now has a feed-in tariff incentive solar electricity of approximately 16.3 US cents/kWh (November, 2006) for over 20 MW installed capacity and a maximum fossil back-up of 30% of the energy produced. The tariff for smaller plants of 100 kW to 20 MW range is about 20.4 US cents/ kWh for the first 20 years (November 2006).

In February 2007, the Israeli Ministry ordered a CSP plant to be built at a site already approved in Ashalim, in the south of Israel. The project is comprised of two solar thermal power plants, each with an approximate installed capacity of between 80MW to 125MW and in the aggregate up to 220MW installed capacity plus one photovoltaic power plant with an approximate installed capacity of 15MW with option to increase by an additional 15MW. The Ministry's pre-qualification process in 2008 received seven proposals for the solar thermal power plants and 10 proposals for the photovoltaic power plant. At the time of writing, the government had requested full tenders and a bid winner is expected to be announced towards the end of 2009. Construction is expected to occur between 2010 and 2012.

Turkey

Turkey possesses a substantial potential in Hydro, Wind, Solar, Geothermal and bio-combustible energy resources compared to the European average. Turkey's total solar energy potential is 131 TWh a year and solar energy production is aimed to reach 2.2 TWh in 2010 and 4.2 TWh in 2020.[9] Turkey enacted its first specific Renewable Energy Law in May 2005 (the 'Law on Utilisation of Renewable Energy Sources for the Purpose of Generating Electrical Energy'). The Renewable Energy Law works in line with 'Renewable Energy Source Certificates' (RES Certificate).

The law introduced fixed tariffs for electricity generated out of renewable energy sources and, a purchase obligation for the distribution companies holding retail licenses from the certified renewable energy producers. The price of electrical energy bought in accordance with this provision is determined by EMRA. The initial amount was 9.13 YKr per kWh in 2007, (approximately 5.2 Eurocents per kWh) for the first 10 years of operation for a respective renewable energy generation facility.

Currently there are amendments being made to the RES law. The Draft Law for RES includes a feed-in tariff for CSP of 24 eurocents per kWh for 20 years for the first 10 years, dropping to 20 eurocents per kWh for the second 10 years. Legislations are also discussing an additional tariff for the first five years if at least 40% of the equipment is manufactured in Turkey. There may be further changes to the draft law and the final outcome in Turkey, by the time this report is printed.

9 From update provided to DLR/ SolarPACES. – Reference details required.

10 DLR Website (Institut fur Technische Thermodynamik) http://www.dlr.de/tt/desktop default.aspx/tabid-2885/4422_read-10370/

11 Prime Minister's Council on Climate Change, Government of India (2008) National Action Plan on Climate Change.

12 Ministry of New and Renewable Energy (2008) Guidelines for Generation-Based Incentive – Grid Interactive Solar Thermal Power Generation http://www.mnre.gov.in/pdf/guidelines_stpg.pdf, accessed on 27/4/09

Jordan

Jordan has a long-standing interest in large-scale solar thermal power generation. Over the last 10 years there have been several proposals and analyses of solar thermal potential in Jordan, although progress has been difficult due to the Gulf War.

In 2002, the government published an industry update that stated that the first 100-150 MW solar-hybrid plant should be up and running in Quwairah by 2005. The contract was awarded to Solar Millennium but it appears to have stalled as no further information is available on its status.

A consortium of research institutions started a study in 2007 on the use of solar energy in large scale solar desalination applications, as a step towards the construction of a pilot solar desalination plant for communities in Israel and Jordan.[10]

United Arab Emirates

The UAE, especially Abu Dhabi, have started an important initiative to use renewable energy for an entire city that is currently under development, to build capacity in this key future field of the world economy. The development of this is pursued mainly by the company MASDAR (Arabic for Source), which has launched several renewable energy projects, among them one 100 MW CSP solar-only plant which should go into construction during 2009.

India

In India, there is a very promising solar resource, with annual global radiation of between 1600 and 2200 kWh/m^2, which is typical of tropical and sub-tropical regions. The Indian government's estimate is that just 1% of India's landmass could meet its energy requirements until 2030.[11] The National Action Plan on Climate Change puts forward some specific policy measures, including research and development to lower the cost of production and maintenance, establishing a solar energy research centre, and a target to establish at least 1000MW of concentrating solar power in India by 2017. The stated ultimate aim of the Solar Mission is to develop base-load prices and dispatchable concentrated solar power that is cost-competitive power to fossil fuels within 20 to 25 years. The Indian government is currently trialling a feed-in tariff for solar power, of up to 10 rupees per kWh (19 US cents), for 10 years of operations, with a limit of 10 MW for each state.[12] There appears to be renewed international interest in India. In March, Californian start-up eSolar announced a licence deal for its solar power technology for the construction of up to 1 gigawatt of solar farms in India over the next decade.

Iran

The Islamic Republic of Iran has shown an interest in renewable energy technology, including solar power, and is keen to exploit its abundant solar resource 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 undertook a comprehensive feasibility study on an Integrated Solar Combined Cycle with trough technology from the Electric Power Research Centre (now the NIROO Research Institute) and Fichtner (now Fichtner Solar). Esfahan, Fars, Kerman and Yazd are all excellent regions for installing solar thermal power plants in Iran, but Yazd, where the entire high plateau is characterised by an annual direct normal irradiation of over 2,500 kWh/m^2 a year was finally selected as the site for the first plant. No new developments in the market have been announced since then.

Africa

Algeria

Algeria has excellent solar resources of over 2,000 kWh/m^2/year direct sunlight. Nationally, there is a goal to provide 10% of energy from renewable energy by 2025. Algeria has a domestic commitment to increase the solar percentage in its energy mix to 5% by 2015 but beyond this, they are considering a partnership with the European partners in which power plants in Algeria deliver green energy needed for Europe to meet its targets. A new company called New Energy Algeria (NEAL) was created to enhance participation of the local and international private sectors.

In 2004, the Algerian Government published the first feed-in law of any OECD country with elevated tariffs for renewable power production, called "Decret Executif 04-92" in the Official Journal of Algeria No. 19 to promote the generation of solar electricity in integrated solar combined cycles. This decree sets premium prices for electricity production from ISCCS, depending on the solar share, a 5-10% solar share can earn a 100% tariff, while a solar share over 20% can gain up to 200% of the regular tariff.

In 2005, NEAL launched a request for proposals for their 150 MW ISSC plant with 25 MWe of solar capacity from parabolic troughs. The project called for a tariff under 6 cents/kWh, with a solar share of over 5% and an internal rate of return in the range of 10 to 16%. The Abengoa group won the tender and their solar thermal plant is now under construction at Hassi R´mel. Two more projects are planned; two 400 MW ISCC plants with 70 MW of CSP each, to be developed between 2010 and 2015. The feasibility study of the next project will be conducted in 2009.

Morocco

Morocco undertook an investigation into solar thermal power in 1992 with EU-funding for a pre-feasibility study. In 1999, the Global Environmental Facility (GEF) awarded the national electric utility, ONE, a USD 700,000 grant to prepare the technical specifications, bid documents and evaluation of offers for a 228 MWe Integrated Solar Combined Cycle System with a 30 MWe solar field of about 200,000 m^2. A GEF grant of USD 50 million will cover the incremental cost of the solar component. Based on low interest, the project was changed to a turn-key power plant construction and five year operation and maintenance contract. In 2004, a General Procurement Notice was published and industry response was higher, with four international consortia making pre-qualification. The bid documents were submitted to the World Bank for 'Non-Objection' in 2005. Financing will be by the African Development Bank. The contract went to Abengoa subsidiary Abener, giving the Spanish company the go ahead to build the 470 MW station at Beni Mathar in the northeast. The station is to begin operation in 2009.

image Construction of a Concentrating Solar Power project in Kuraymat, Egypt, part of an integrated combined cycle plant with 20MW solar capacity.

13 South African Department of Minerals and Energy Website, http://www.dme.gov.za/energy/renewable.stm

14 Update on South Africa CSP activities provided by Eskom to SolarPACES

Egypt

Two pre-feasibility studies on parabolic-trough and central tower technologies were done in 1995 followed by a SolarPACES START mission in 1996, and Eygpt decided to a first 140 MW Integrated Solar Combined Cycle system with a 20 MW parabolic trough solar field. The GEF provided consultancy services and offered to cover the incremental cost. The first phase detailed feasibility report was completed in 2000, followed by a short list of qualified and interested developers in 2001. The project stalled due to the unexpectedly high exchange rate of US Dollar-to Egyptian Pound. In mid- 2003, The World Bank decided to change its approach, to creating a government project, allowing private sector participation in a 5 year ownership and maintenance contract. In February 2004, 35 firms expressed their interest to a general procurement notice. In 2007 contracts were awarded to Iberdrola and Mitsui for the Combined Cycle Power Island and a consortium of Orascum and Flagsol to build the solar field. The plant is now under construction and expected to start operation in year 2010.

South Africa

The South African government has set a target of 10,000GWh of energy to be produced from renewable energy sources (mainly from biomass, wind, solar and small-scale hydro) by 2013. This would be equivalent to electrifying approximately 2 million households having an annual electricity consumption of 5 000 kWh. That is about 5% of the present electricity generation in South Africa, or replacing two 660MW units of Eskom's combined coal-fired power stations.

In March 2009, National Energy Regulator of South Africa (NERSA) approved feed-in tariffs for renewable energies, called REFIT. The feed-in tariffs, based on the levelised cost of electricity, are 2.10 R/kWh for concentrated solar, 1.25R/kWh for wind, 0.94R/kWh for small hydro, and 0.90 R/kWh for landfill gas. The term of the power purchase agreement will be 20 years. The REFIT will be reviewed every year for the first 5-year period of implementation and every three years thereafter and the resulting tariffs will apply only to new projects.

By 2010, the South African power utility, Eskom, could be operating the world's largest central receiver CSP plant. Eskom undertook a feasibility study for a 100 MW pilot project molten salt central receiver plant that was updated in mid-2008. Eskom previously studied both parabolic-trough and central receiver technologies to determine which is the cheaper of the two. It will employ local manufacturers of key components and is asking for estimates from local glass and steel manufacturers. Ultimately, a decision will be based on a variety of factors, including cost, and which plant can be constructed with the most local content. A request for tenders should be released in the first half of 2009. Selected project will receive a premium tariff to ensure bankability. At the same time, feed-in tariffs are being investigated by the national regulator.

To further develop CSP, the government is supporting research through the Department of Science and Technology, providing funding to universities for this area. There is a National Solar and CSP research programme and the possibility that South Africa will establish a national solar/CSP centre in the future.[14]

Europe

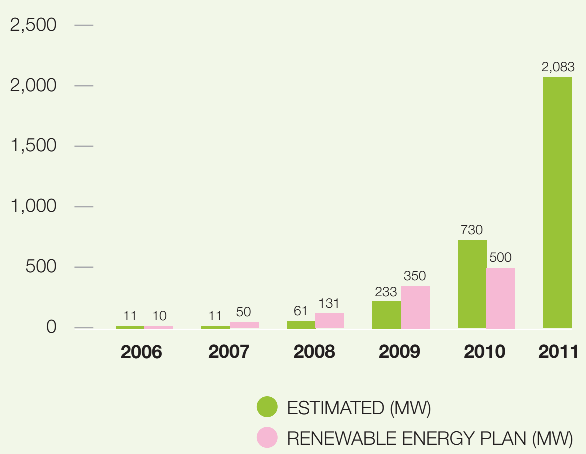
Spain

Spain is leading the world in the development of CSP. Firstly, it has a 2010 CSP target of 500 MW installed capacity. Secondly, it was the first southern European country to introduce a 'feed-in tariff' funding system. CSP plants up to 50 MW now have a fixed tariff of 26.9 eurocents/kWh for 25 years, increasing annually with inflation minus one percentage point. After 25 years the tariff drops to 21.5 eurocents/kWh. This tariff was fixed by Royal Decree 661 of 2007. It separated the tariff from the market reference price, which goes up with oil prices, automatically increasing renewable tariffs.

Spain has progressively increased the tariff, from 12 eurocents per kWh in 2002, to 27 eurocents per kWh from 2004. The 2004 decision triggered a lot of development proposals, but it was only with the increase to current levels that a large number of projects became bankable. The current decree of 2007 keeps some key elements of the former decree of 2004 (RD 436); in particular it makes projects bankable with a 25-year guarantee and it allows 12-15% natural gas backup to allow for optimised plant operation. At present, the target is exceeded by the number of planned installations. See box for more on the situation in Spain.

The best proof of the success of the Spanish support system for CSP is the current state of development of projects in the country. At the time of writing this report, there are six power plants in operation, totalling 81 MW, plus another 12 plants under construction, adding a further 839 MW. More projects have been announced for several thousand megawatts. (See table 4.1)
The figures and graph supplied by Protermosolar and IDAE show how development is outstripping targets and how much potential Spain has to introduce concentrating solar power into energy supplies.

In operation:	81 MW
In construction:	839 MW
In development (close to construction starting)	2, 083 MW
Proposed (in early permitting stage)	7, 830 MW
Total under development	10,813 MW
Additional (Have paid the grid connection fee)	3,418 MW
Total all potential projects in Spain (April 2009)	14,231MW

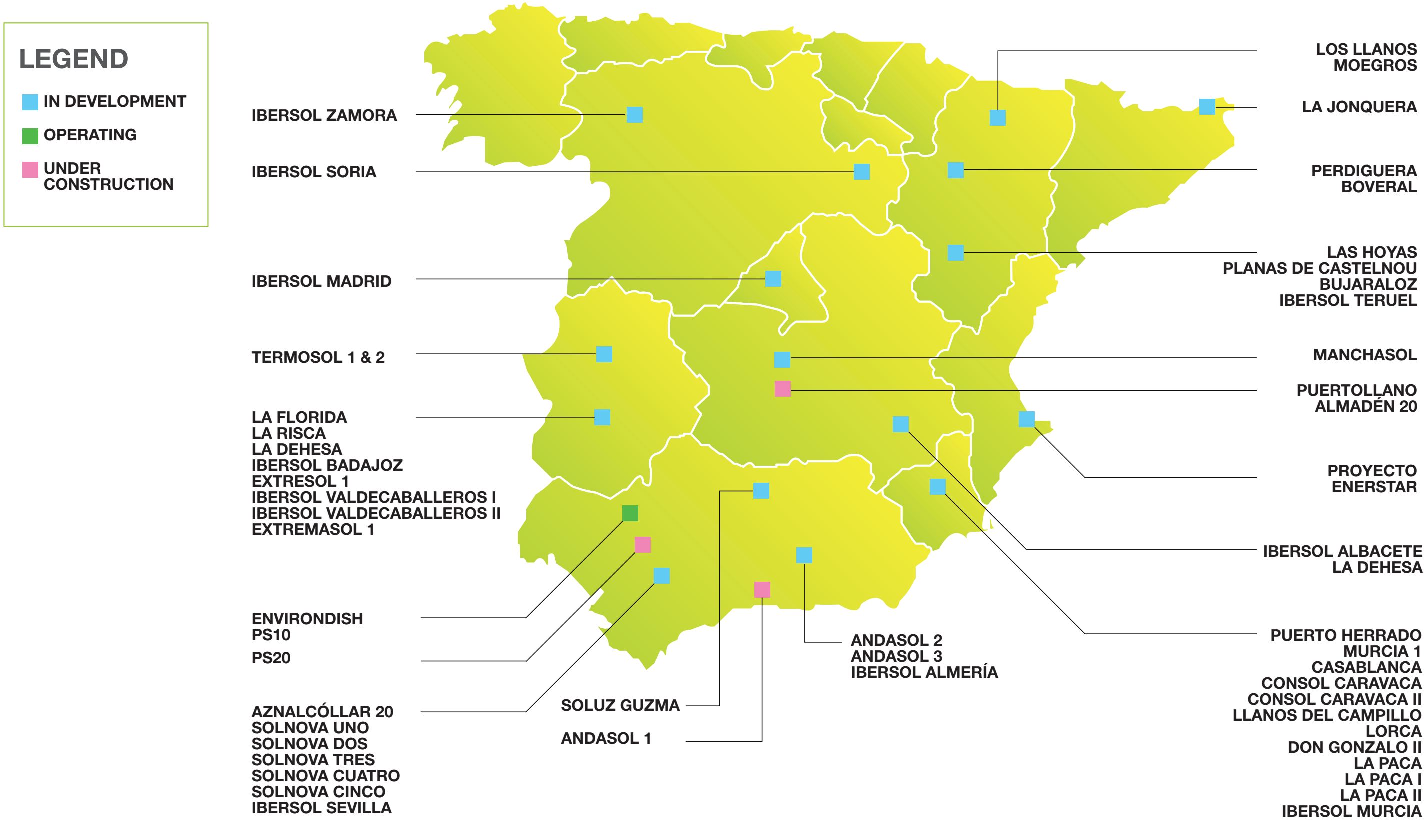


The National Commissions of Energy is responsible for monitoring the register of installations. It has established a website that will show the progress to the national target by plants that have met all the requirements for construction. When 85% of the target is reached, the authority will determine how much longer newly-registered projects can claim the premium fixed tariff. This approach is creating a race by developers to register their projects before the 85% is reached. The industry now requires more certainty about the target and tariff level so that investments in future projects can also be guaranteed. Industry participants have proposed a target of 1,000 MW a year. Industry advocates Protermosolar say that a tariff should be no lower than 24 or 25 eurocents per kWh; any less than this would put a halt to market development, and not meet the costs of producing electricity under current market conditions.

The revised law should also remove the current limit of 50 MW per power plant to be eligible for the feed-in tariff, because this is now lower than the economic-technical optimum.

Figure 4.1
At the time of writing this report therer are six power plants in operation, totalling 81MW, plus another 12 plants under construction, adding a further 839MW.

Figure 4.2


LEGEND
IN DEVELOPMENT
OPERATING
UNDER CONSTRUCTION
IBERSOL ZAMORA
IBERSOL SORIA
IBERSOL MADRID
TERMOSOL 1 & 2
LA FLORIDA
LA RISCA
LA DEHESA
IBERSOL BADAJOZ
EXTRESOL 1
IBERSOL VALDECABALLEROS I
IBERSOL VALDECABALLEROS II
EXTREMASOL 1
ENVIRONDISH
PS10
PS20
AZNALCÓLLAR 20
SOLNOVA UNO
SOLNOVA DOS
SOLNOVA TRES
SOLNOVA CUATRO
SOLNOVA CINCO
IBERSOL SEVILLA
SOLUZ GUZMA
ANDASOL 1
ANDASOL 2
ANDASOL 3
IBERSOL ALMERÍA
LOS LLANOS
MOEGROS
LA JONQUERA
PERDIGUERA
BOVERAL
LAS HOYAS
PLANAS DE CASTELNOU
BUJARALOZ
IBERSOL TERUEL
MANCHASOL
PUERTOLLANO
ALMADÉN 20
PROYECTO
ENERSTAR
IBERSOL ALBACETE
LA DEHESA
PUERTO HERRADO
MURCIA 1
CASABLANCA
CONSOL CARAVACA
CONSOL CARAVACA II
LLANOS DEL CAMPILLO
LORCA
DON GONZALO II
LA PACA
LA PACA I
LA PACA II
IBERSOL MURCIA

Europe

Italy

In 2001, the Italian parliament allocated € 100 million to ENEA (National Agency for New Technologies, Energy and the Environment) for a CSP development and demonstration programme. These funds have been subsequently reduced to € 50 million, due to budget restrictions, and to date, only a limited part has been spent. With the available funding ENEA undertook an ambitious research programme, firstly to develop and industrialise a new high-performance parabolic trough system using molten salts as heat transfer fluid and secondly to develop hydrogen production by solar-driven thermochemical water splitting. In early 2004, ENEA and ENEL signed a cooperation agreement to develop the Archimede Project in Sicily, the first Italian CSP plant; a project with a 5 MW solar field coupled to an existing gas-fired power station. The solar field uses parabolic troughs and molten salts as heat transfer fluid and storage medium, and is due to be completed in 2010. In 2008, Italy published a feed-in tariff scheme for CSP plants, providing between 22 and 28 eurocents per kWh for the solar proportion of a plant's output, depending on the percentage solar operation of the plant (the highest tariff is for over 85% solar operation). The tariff applies to plants whose operation will start between the date of the new law and 31 December 2012, and is fixed for 25 years. The incentive scheme is limited to a cumulative amount of plants totalling 1.5 million of m^2 of aperture area (plus a 0.5 million reserve for public entities). Other conditions include mandatory thermal storage - use of synthetic oil is admitted only in 'industrial' applications.

France

A new feed-in tariff for solar electricity was published on July 26, 2006, granting 30 eurocents per kWh (40 eurocents per kWh overseas) plus an extra 25 eurocents /kWh if integrated in buildings (plus 15 eurocents per kWh overseas). This tariff is limited to solar-only installations with less than 12 MW capacity and less than 1,500 hours a year operation. For production over this limit the tariff is 5 eurocents /kWh. A revised feed-in tariff is expected in 2009. The government is promoting the development of 'one solar plant per region', through its Agreement on Environment, 2007. A call for projects is expected in 2009.

Current projects under development include a 2MW hybrid gas turbine with 50% solar capacity, using new and refurbished heliostats and a mini -PAGASE receiver and a 12 MW CSP project by the 'Solar Euromed SAS' Company which uses parabolic trough and oil, plus 'solar salt' storage.

Other European Countries

More European countries, especially in the south, are preparing the ground for CPS deployment, mostly through feed-in laws already in place or under preparation. Examples of this are Portugal and Greece. Germany has a feed-in law that would also allow for CSP, but does not have solar resources to match. However, following long-term research and industry activity in this field, a 1.5 MW Solar Tower in Jülich began operation at the end of 2008. It will serve as a showcase for volumetric air receiver technology and also as a test facility.

Americas

USA

Several more paths towards CSP market development have recently gained momentum, focused on projects in the southwest US, where there is an excellent direct-beam solar resource and demand for power from a growing population.

- State of California's Renewable Energy Portfolio Standard (RPS) now requires investor-owned utilities to produce 20% of their retail electricity sales from renewables by 2017. Out-of-state generators are subject if they deliver electricity directly into California.
- In 2003, Nevada passed a Renewable Energy Portfolio Standard, which requires the State's two investor-owned utilities (Nevada Power, Sierra Pacific Power) to generate at least 15% of their retail electricity sales from renewable energy by 2013.
- In 2002, the US Congress asked the Department of Energy (DOE) to develop and scope a policy initiative for reaching the goal of 1,000 MW of new parabolic-trough, power-tower and dish/engine solar capacity to supply the southwestern United States by 2006. Since late 2006, electric utility companies in the southwest have launched several thousand MWs of renewable request for proposals (RFPs), including CSP.
- The Western Governors' Association (WGA) Clean and Diversified Energy Advisory Committee's Task Forces on Advanced Coal, Biomass, Energy Efficiency, Geothermal, Solar, Transmission and Wind have identified the necessary changes in state and federal policy to achieve 30,000 MW of new clean, diversified energy generation by 2015, a 20% increase in energy efficiency by 2020 and adequate transmission capacity for the region over the next 25 years. In the 2006 WGA Report, the Solar Task Force identifies 4000 MW of high-quality CSP sites in the American Southwest and recommends a process for developing state policies and deployment incentives.
- The State of New Mexico has had a Renewable Portfolio Standard in place since July 2003, which already required investor-owned utilities to generate at least 5% of their retail power sales from renewables for New Mexico customers by 2006, and at least 10% by 2011.
- The Arizona Environmental Portfolio Standard will increase to 1.1% in 2007 (60% from solar sources); these requirements may be met with out-of-state solar energy if it is proven that it reaches customers in Arizona. The State also has renewable energy credit multipliers, which provide additional incentives for in-state solar power generation.
- Recently the 30% Investment Tax Credit, an important funding tool, was extended through to 2017. It is unknown how this will operate since the 2008 financial crisis, but for a 2-year period it will provide a direct 30% payment back to the project upon commissioning.

image A welder works on the 'Big Dish' solar technology developed at the Australian National University. The prototype has been generating reliable power since 1994.

Asia - Pacific

China

To promote the development of CSP in China, the China Renewable Energy Scale-up Programme (CRESP) recently released a report on solar power generation economic incentive policies. The report suggested measures including taxation and financial preference, discounted loans and direct financial subsides, and included information on preferential price policies and management, increasing technical research and development investment, and strengthening R&D capacity, establishing technical standards, management regulations and an authentication system.

NDRC has also undertaken research on feed-in-tariff of solar thermal power plant to calculate the price of electricity generated from solar thermal power plant with different capacities. It's expected that 4 Yuan/kWh premium will be applied to some demonstration desert solar power plants soon.

The Chinese National Development and Reform Commission's 11th 5-year plan 2006-2010 includes 200 MW of commercial CSP plants in the states of Inner Mongolia, Xin Jiang and Tibet, for which a 25-year power purchase agreement will be offered. A solar thermal power technology and system demonstration project is listed as Key Project 863 of this plan for National Hi-Tech R&D, administered and executed by the Institute of Electrical Engineering of the Chinese Academy of Sciences. This project focuses on solar tower technology development and demonstration as a shorter route to local supply than parabolic-trough technology.

There are several instances of research and development occurring, including research into 100kW parabolic trough technology research, supported by Nanjing municipal government in 2007 and carried out by Nanjing Zhongcaitiancheng New Energy Company. CAMDA New Energy is undertaking research on 1MW parabolic trough demo system, which is the key project of Guangdong Province in its Energy Saving and Emission Reduction & Renewable Energy plan of 2008. Solar Millennium AG, together with Inner Mongolia Ruyi Industry Co., Ltd is implementing a feasibility study of 50 MW parabolic trough system in Ordos of Inner Mongolia.

Australia

The government of Australia had announced a 20% renewable energy target by 2020, but at the time of writing this had not been enacted into law. Also under discussion is an overall national target for emissions reductions and a 'cap and trade' carbon trading scheme which should provide additional income for solar thermal plants, although the scheme's operation was not yet finalised.

A new fund of AUD 50 million is now available for the Australian Solar Institute to expand Australia's solar thermal research capacity and to build on the existing CSIRO centre over four years. Its aims are to build CSP research and development capability, establish facilities, develop international collaboration and build a larger PhD programme.

Technically, there are three main areas of solar thermal electricity generation in Australia. The most commercially advanced of these is the Concentrating Linear Fresnel Reflector (CLFR) system, which now incorporated into an existing coal-fired power station, producing steam to feed into the main thermal generator. A first 1MWe plant was constructed in 2003, which is now being expanded to double the size. The company Ausra has now developed a stand-alone design with its own turbine, with one 5MWe installation in California and another 177 MWe plant soon to follow. The parabolic mirror 'big dish' technology has a surface area of 500m^2 for each unit, three or four times larger than other examples of this technology. It was developed by the Australian National University and is now being commercialised. A test field for a solar tower producing 'solar gas' has been built by the Commonwealth Science and Industry Research Organisation (CSIRO), and is currently being tested for electricity generation.

© GREENPEACE / MARKEL REDONDO

image Andasol 1 solar power station, Europe's first commercial parabolic trough solar power plant. It will supply up to 200,000 people with climate-friendly electricity.

5

Global CSP Outlook Scenarios

In this section we examine the future potential of solar power up to the year 2020, and then looking out towards 2050, as a model for what is possible both technically and economically. The outlook is based on some assumptions to model how the industry will progress under different types of market conditions which will influence the concentrated solar power industry's development. This exercise is a collaboration between the European Solar Thermal Electricity Association (ESTELA), SolarPaces and Greenpeace International.

The Scenarios

Three different scenarios are outlined for the future growth of concentrated solar power around the world.

Reference scenario

This is the most conservative scenario based on the projections in the 2007 World Energy Outlook report from the International Energy Agency (IEA). It only takes into account existing policies and measures, but includes assumptions such as continuing electricity and gas market reform, the liberalisation of cross-border energy trade and recent policies aimed at combating pollution.

Moderate scenario

This scenario takes into account all policy measures to support renewable energy either under way or planned around the world. It also assumes that the targets set by many countries for either renewables or concentrated solar power are successfully implemented. Moreover, it assumes increased investor confidence in the sector established by a successful outcome from the current round of climate change negotiations, which are set to culminate at UNFCCC COP-15 in Copenhagen, Denmark, in December 2009. Up to 2012 the figures for installed capacity are closer to forecasts than scenarios because the expected growth of worldwide markets over the next five years is based on orders for solar power plants that have already been made. After 2012 the pattern of development is more difficult to anticipate.

Advanced scenario

This is the most ambitious scenario. It examines how much this industry could grow in a best case 'concentrated solar power vision'. The assumption here is that all policy options in favour of renewable energy, along the lines of the industry's recommendations, have been selected, along with the political will to carry them out. It assumes also a rapid and coordinated increase of new grid capacity (especially HVDC) to harvest solar energy through CSP plants at the optimal sites and make it available and export it to industrial countries and emerging economies with high and growing electricity demand. While again, the development after 2012 is more difficult to predict, this scenario is designed to show what the concentrated solar power sector could achieve if it is given adequate political commitment and encouragement.

Energy efficiency projections

In the modelling, these three scenarios for CSP worldwide are set against two projections for the future growth of electricity demand. Importantly, these projections do not just assume that growing energy demand by consumers must be matched purely by increasing supply. Instead, they assume greater emphasis on policies and measures to use energy more efficiently. This approach gives energy security and combats climate change, but it also makes economic and environmental sense.

Reference Energy Efficiency Projection: This is the more conservative of the two global electricity demand projections; again based on data from the IEA's 2007 World Energy Outlook, extrapolated forwards to 2050. It does not take into account any possible or likely future policy initiatives, and assumes, for instance, that there will be no change in national policies on nuclear power. The IEA's assumption is that in the absence of new government policies, the world's energy needs will raise inexorably. Under the reference efficiency scenario global demand would almost double from the baseline 18,197 TWh in 2005 to reach 35,384 TWh by 2030.

High Energy Efficiency Projection: This sets IEA's expectations on rising energy demand against the results of a study on potential energy efficiency savings developed by DLR and the Ecofys consultancy. It describes ambitious exploitation of energy efficiency measures, focusing on current best practice and available technologies, and assuming that continuous innovation takes place. In this projection the biggest energy savings are in efficient passenger and freight transport and in better insulated and designed buildings which together account for 46% of worldwide energy savings. Under this projection, input from the DLR/Ecofys models show how energy efficiency savings change the global electricity demand profile. Although it assumes that a wide range of technologies and initiatives have been introduced, their extent is limited by the barriers of cost and other likely roadblocks. Even with realistic limits, this projection still shows global demand increasing by much less than under the reference projection. With 'high energy-efficiency', global demand in 2030 would be 23,131 TWh and by 2050 demand will be 35% lower than under the Reference scenario.

Core Results

The Global Concentrated Solar Power Outlook scenarios show the range of outcomes possible depending on the choices we make now for managing demand and encouraging growth of the CSP market. Even in the next five years (2015) we could see as little concentrating solar power as 566 MW installed each year under a conservative model, to as much as 6,814 MW (6.8 GW) annually under an advanced scenario.

Even under the moderate scenario of fully achievable measures the world would have a combined solar power capacity of over 68 GW by 2020 and 830 GW by 2050, with the annual deployment running close to 41 GW. This would represent 1 - 1.2% of global demand in 2020 but jump to 8.5 - 11.8% in 2050. In the moderate scenario, economic outcomes would be over € 92 billion in investment and over a million jobs a year.

The carbon dioxide savings would be 148 million tonnes of CO_2 annually in 2020; rising to 2.1 billion tonnes in 2050. To put this in context, the projected installed capacity in 2050 is about equal to the generation capacity of the USA today - or almost equal to all coal power plants in operation in 2005. The CO_2 savings under the moderate scenario would be comparable to 8% of today's global CO_2 emissions.

Under an advanced industry development scenario, with high levels of energy efficiency, concentrating solar power could meet up to 7% of the world's power needs in 2030 and a full quarter by 2050.

Table 5.2
Scenarios for Concentrating Solar Power Development Between 2015 and 2050 under conservative, moderate and aggressive development scenarios

Full Results

Annual and cumulative capacity

	2015	2020	2030	2050
Reference				
Annual Installation (MW)	566	681	552	160
Cost € / kW	3,400	3,000	2,800	2,400
Investment billion € / year	1.924	2.043	1.546	0.383
Employment Job-year	9,611	13,739	17,736	19,296
Moderate				
Annual Installation (MW)	5,463	12,602	19,895	40,557
Cost € / kW	3,230	2,850	2,660	2,280
Investment billion € / year	17.545	35.917	52.921	92.470
Employment Job-year	83,358	200,279	428,292	1,187,611
Advanced				
Annual Installation (MW)	6,814	14,697	35,462	80,827
Cost € / kW	3,060	2,700	2,520	2,160
Investment billion € / year	20.852	39.683	89.356	174.585
Employment Job-year	89,523	209,998	629,546	2,106,123

The cumulative totals of installed MW are shown in figure 5.1

Reference scenario

The reference ('business-as-usual') scenario is derived from the IEA's World Energy Outlook 2007. It starts off with an assumed growth rate of 7% for 2011, decreases to only 1% by 2015, and then remains at this level until 2040. After 2040 the scenario assumes no significant further growth of CSP. As a result, the scenario foresees the following.

- By the end of this decade, cumulative global capacity would have reached 1.6 Gigawatts (GW), producing 5 TWh a year, and covering 0.03% of the world's electricity demand.
- By 2020, global capacity would be 7.3 GW, growing to only 18 GW of concentrated capacity by 2050.
- Around 22 TWh would be produced in 2020, accounting for 0.12-0.14% of the world's electricity production, depending on whether low or high levels of energy efficiency measures are introduced.
- By 2050, the penetration of solar power would be no higher than 0.2% globally.

Moderate scenario

Under the moderate concentrated solar power scenario growth rates are expected to be substantially higher than under the reference version. The assumed cumulative annual growth rate starts at 17% for 2011, and increases to 27% by 2015. The growth rate stays at 27% per year until 2020 then falls gradually to 7% by 2030, 2% in 2040 and 1% after 2050. As a result, the scenario foresees the following.

- By the end of this decade, global solar power capacity is expected to have reached 4 GW, with annual additions of 2.9 GW.
- By 2020, global solar power capacity would be 68.6 GW with annual additions of 12.6 GW. By 2050, the world would have a combined solar power capacity of over 830 GW, with the annual market running close to 41 GW.
- In terms of generated electricity, the moderate scenario would mean over 246 TWh produced by concentrated solar power in 2020. Depending on demand side development, this will account for 1.1-1.2% of global demand in 2020 and 8.5 – 11.8% in 2050.

Advanced scenario

Under the advanced concentrated solar power scenario the assumed growth rate starts at 24% in 2010, falls to 19% by 2015, then to 7% by 2030 and 5% by 2040. Thereafter, the growth rate will level out at around a 3% annual increase. As a result, the scenario foresees the following.

- By 2015 global capacity would have reached 29 GW, with annual additions of around 6.8 GW.
- By 2020, global capacity would be over 84 GW, with annual additions of around 14.7 GW. By 2030, the total solar generation capacity would reach almost 342 GW. The annual market would by then stabilise in the range of 70 to 80 GW.
- By 2050, the word's total fleet of solar power plants would have a capacity of 1,500 GW.
- In terms of generated electricity, the advanced scenario would mean 355 TWh produced by concentrated solar power in 2020, and over 7,800 TWh by 2050. Depending how much demand has been curbed by energy efficiency, solar power would cover 1.5 – 1.7% of global electricity demand in 2020 and as much as 18.3 – 25.69% by 2050

Under an advanced industry development scenario, with high levels of energy-efficiency, CSP could meeting up to a quarter of the world's power needs in less than 50 years.

Figure 5.1
Cumulative CSP Capacity

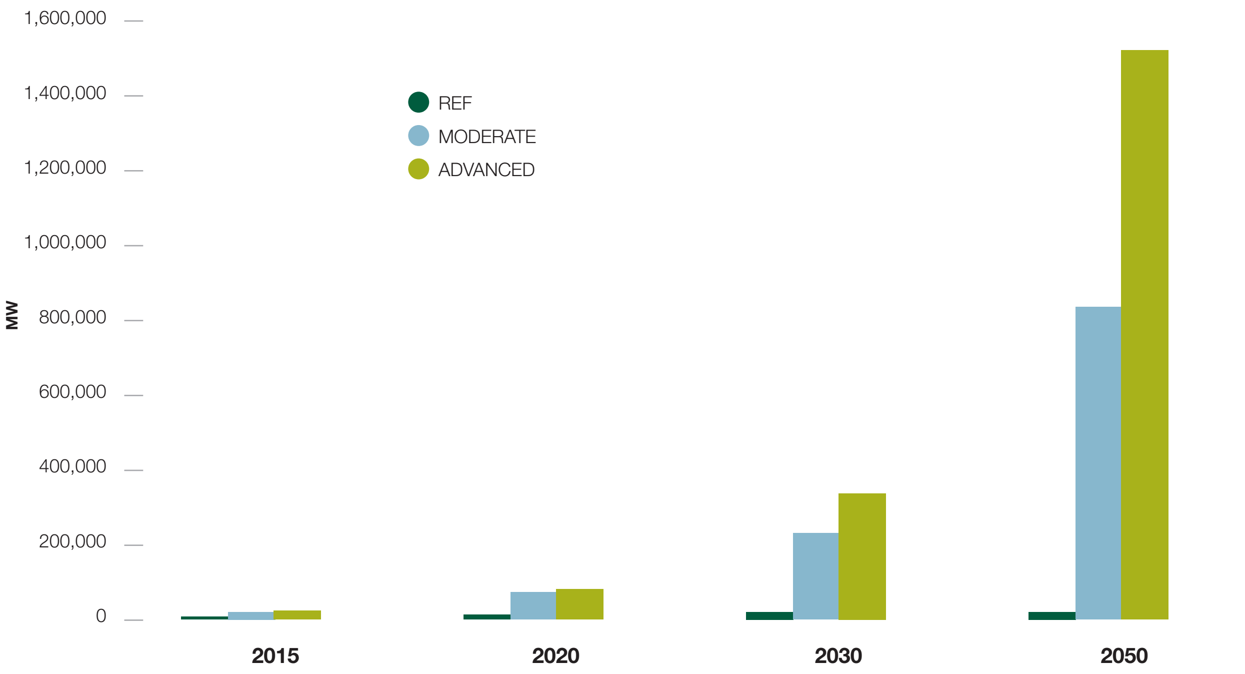


Table 5.1
Cumulative CSP Capacity

	2015	2020	2030	2050
Reference				
MW	4,065	7,271	12,765	18,018
TWh	11	22	40	66
Moderate				
MW	24,468	68,584	231,332	830,707
TWh	81	246	871	3,638
Advanced				
MW	29,419	84,336	342,301	1,524,172
TWh	116	355	1,499	7,878

Regional breakdown

All three scenarios for solar power are broken down by region of the world as used by the IEA, with a further differentiation in Europe. For this analysis, the regions are defined as Europe (EU-27 and the rest of Europe), the Transition Economies (former Soviet Union states, except those now part of the EU), North America, Latin America, China, India, the Pacific (including Australia, South Korea and Japan), Developing Asia (the rest of Asia), the Middle East and Africa. This breakdown of world regions is used by the IEA in the ongoing series of World Energy Outlook publications. It is used here to help compare Greenpeace and IEA projections and because the IEA provides the most comprehensive global energy statistics. A list of countries covered by each of the regions is shown in Appendix 4.

The level of solar power capacity expected to be installed in each region of the world by 2020 and 2030 is shown in figures 5.2, 5.3 and 5.4.

- ***Reference Scenario:*** Europe would continue to dominate the world market. By 2030 Europe would still host 49% of global solar power capacity, followed by North America with 24%. The next largest region would be Africa with 9%.
- ***Moderate scenario:*** Europe's share is much smaller – only 7% by 2030, with North America contributing a dominant 31% and major installations in Middle East (19%), China (16%), India (7%) and OECD Pacific (2%), mainly in Australia.
- ***Advanced scenario:*** Even stronger growth for North America, its share of the world market would increase to 31% by 2030. The North American market would by then account for almost one third of global solar power capacity, whilst Europe's share becomes 12%, behind Middle East (16%) and China (13%), but ahead of Africa (9%), India (6%) and 5% OECD Pacific (mainly Australia). In moderate and advanced scenarios, developing Asia and the Transition Economies would play only a minor role in the timeframe discussed.

Table 5.2
Outlook for cumulative installed capacity of CSP per region in 2020

	EUROPE (EU 27)	TRANSITION ECONOMIES	NORTH AMERICA	LATIN AMERICA	DEVEL ASIA	INDIA	CHINA	MIDDLE EAST	AFRICA	OECD PACIFIC
Advanced										
2020 (MW)	11,290	474	29,598	2,298	2,441	3,179	8,650	15,949	4,764	9,000
Moderate										
2020 (MW)	6,883	328	25,530	2,198	2,575	2,760	8,334	9,094	3,968	2,848
Reference										
2020 (MW)	3,065	100	1,724	121	0	30	30	612	1,113	475

Table 5.3
Outlook for cumulative installed capacity of CSP per region in 2030

	EUROPE (EU 27)	TRANSITION ECONOMIES	NORTH AMERICA	LATIN AMERICA	DEVEL ASIA	INDIA	CHINA	MIDDLE EAST	AFRICA	OECD PACIFIC
Advanced										
2030 (MW)	40,312	2,027	106,806	12,452	9,655	21,491	44,410	56,333	31,238	17,500
Moderate										
2030 (MW)	17,013	1,730	70,940	8,034	8,386	15,815	37,461	43,457	22,735	8,034
Reference										
2030 (MW)	6,243	201	2,724	339	0	30	30	1,050	1,113	1,025

Figure 5.2
Regional installation of CSP under the reference or 'business-as-usual' scenario

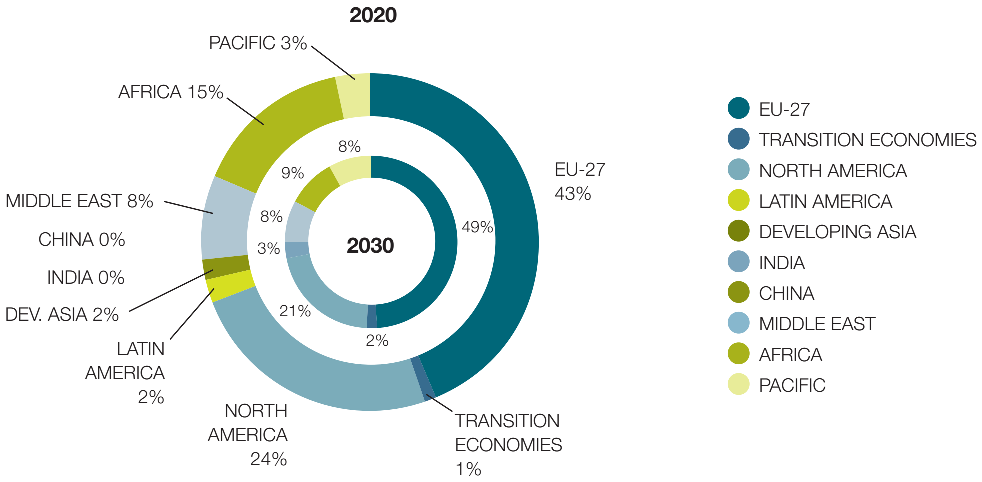


Figure 5.3
Potential regional installation of CSP under the moderate development scenario

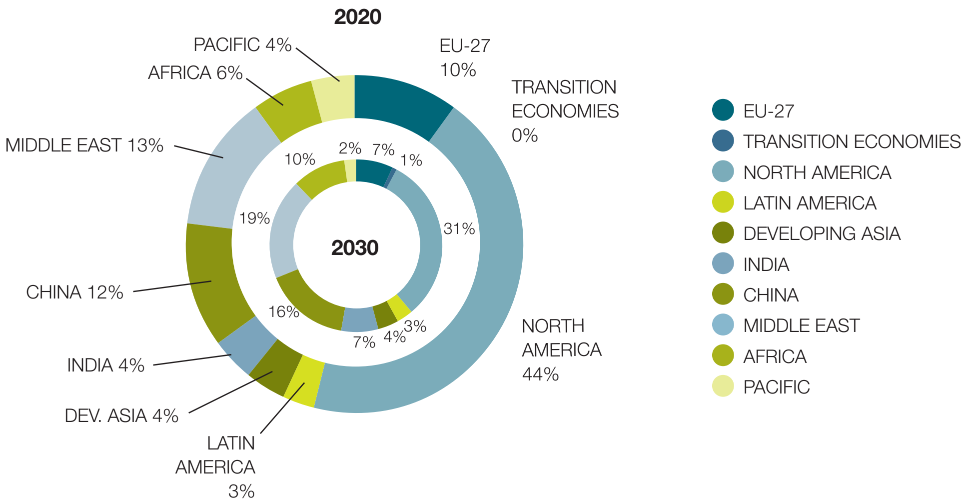
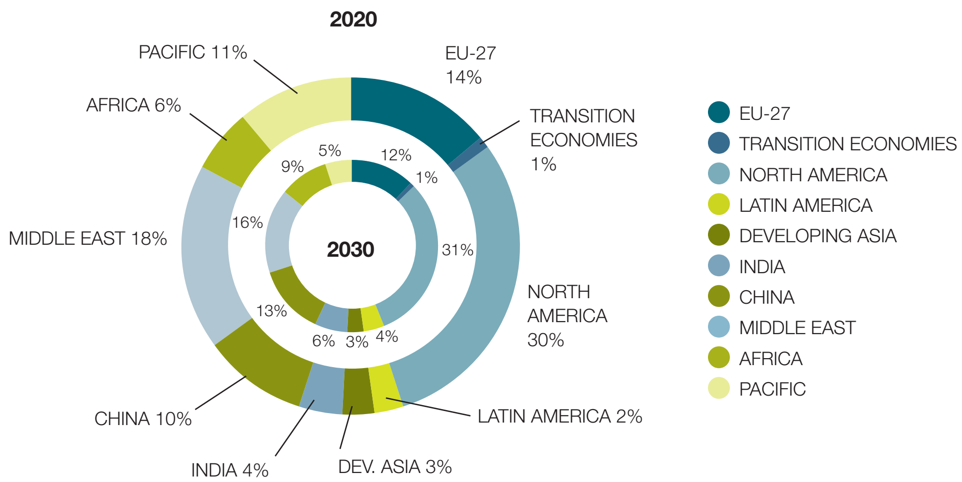


Figure 5.4
Potential regional installation of CSP under the advanced development scenario



Investment

Generating increased volumes of solar powered electricity will require a high investment over the next 40 years. At the same time, the contribution from the solar electricity will have massive economic benefits from protecting the global climate and increased job creation.

For investors to be attracted to the concentrated solar power market depends on the capital cost of installation, the availability of finance, the pricing regime for the power output generated and the expected rate of return. In these outlook scenarios the investment value of the future concentrated solar power market has been assessed on an annual basis. This is based on the assumption of a gradually decreasing capital cost per kilowatt of installed capacity as described above.

- In the reference scenario the annual global investment in the solar thermal power industry would be €2.5 (USD 3.2) billion in 2010, falling to €1.5 billion (USD 1.9) by 2030 and finally down to only € 383 million (USD 494) in 2050 [all Euro figures at 2008 values].
- In the moderate scenario the annual value of global investment in the solar power industry would be €11.1 billion (USD 14.3) in 2010, increasing to € 53 billion (USD 68 billion) by 2030 and peaking at € 92.5 billion (USD 119 billion) in 2050.
- In the advanced scenario the annual value of global investment reaches € 15.4 billion (USD 19 billion) in 2010, increasing to €39.7 billion (USD 51 billion) by 2020 and increasing further to € 89 billion (USD 51.4 billion) in 2030 and €174 billion (USD 224 billion) in 2050.

These figures may appear large, but they represent only a portion of the total level of investment in the global power industry. During the 1990s, for example, annual investment in the power sector was running at some €158-186 billion (USD 203 – 240 billion) each year.

Generation costs

Various parameters need to be taken into account when calculating the generation costs of solar power. The most important are the capital cost of solar power plants (see above) and the expected electricity production. The second is highly dependent on the solar conditions at a given site, making selection of a good location essential to achieving economic viability. Other important factors include operation and maintenance (O&M) costs, the lifetime of the turbine and the discount rate (the cost of capital).

The total cost per generated kWh of electricity is traditionally calculated by discounting and levelising investment and O&M costs over the lifetime of a CSP power station, then dividing this by the annual electricity production. The unit cost of generation is thus calculated as an average cost over the lifetime of the power plant, which could be 40 years, according to industry estimation. In reality, however, the actual costs will be lower when a power plant starts operating, due to lower O&M costs and increase over the lifespan of the machine.

Taking into account all these factors, the cost of generating electricity from concentrated solar power currently ranges from approximately 15 eurocents per kWh (USD 0.19) at high solar irradiation (DNI) sites up to approximately 23 eurocents per kWh (USD 0.29) at sites with low average solar resource. With increased plant sizes, better component production capacities and more suppliers and improvements from R&D, costs are expected to fall to between of 10 – 14 eurocents per kWh (USD 0.15-0.20) by 2020. Besides the estimation of further price drops, the gap with generation costs from conventional fuels is expected to decrease rapidly due to increased prices of conventional fuels at world markets. The competitiveness with mid-load, for example gas-fired plants, might be achieved between five to 10 years from now.

Solar concentrating power has a number of other cost advantages compared to fossil fuels, which these calculations do not take into account, including the following.

- ‘External costs’ of electricity production. Renewable energy sources such as solar have environmental and social benefits compared to conventional energy sources such as coal, gas, oil and nuclear. These benefits can be translated into costs for society, which should be reflected in the cost calculations for electricity output. Only then can a fair comparison of different means of power production be established. The ExternE project, funded by the European Commission, has estimated the external cost of gas at around 1.1 - 3.0 eurocents per kWh (US 1.4 – 3.8 cents) and that for coal at as much as 3.5 - 7.7 eurocents per kWh. (US 4.5 – 10 cents)
- The ‘price’ of carbon within the global climate regime and its regional/national incarnations such as the European Emissions Trading Scheme (ETS), which will drive up the prices of fossil fuels and hopefully improve that of renewable technologies.
- The fuel cost risk related to conventional technologies. Since concentrated solar power does not require any fuel, it eliminates the risk of fuel price volatility of other generating technologies such as gas, coal and oil. A generating portfolio containing substantial amounts of concentrated solar power will reduce society’s risks of future higher energy costs by reducing exposure to fossil fuels price fluctuations. In an age of limited fuel resources and high fuel price volatility, the benefits of this are immediately obvious.
- The avoided costs for the installation of a conventional power production plant and avoided fossil fuel costs would further improve the cost analysis for concentrated solar power.

Employment

The employment generated under the scenarios is a crucial factor to weigh alongside their other costs and benefits. High unemployment rates are a drain on the economies of many countries in the world and any technology which demands a substantial level of skilled and unskilled labour is of considerable economic importance. Job creation should feature strongly in political decision-making over different energy options.

A number of assessments of the employment effects of solar power have been carried out in Germany, Spain and the USA. The assumption made in this scenario is that for every megawatt of new capacity, the annual market for concentrated solar power will create 10 jobs through manufacture, component supply, solar farm development, installation and indirect employment. As production processes are optimised, this level will decrease, falling to eight jobs by 2030 under the reference scenario. In addition, employment in regular operations and maintenance work at solar farms will contribute a further one job for every megawatt of cumulative capacity.

Table 5.4
Assumed job numbers created by CSP under reference, moderate and advanced scenarios

	REFERENCE		MODERATE		ADVANCED	
	Jobs Manufactoring & Installation (Job years)	Jobs O&E	Jobs Manufactoring & Installation (Job years)	Jobs O&E	Jobs Manufactoring & Installation (Job years)	Jobs O&E
Year	(Jobs/MW)	(Jobs/MW)	(Jobs/MW)	(Jobs/MW)	(Jobs/MW)	(Jobs/MW)
2005	10	1	10	1	10.00	1.00
2010	10	1	10	1	10.00	1.00
2015	10	1	10	1	8.82	0.86
2020	10	1	10	1	8.55	0.81
2030	9	1	10	1	8.10	0.77
2040	9	1	9	1	7.65	0.72
2050	8	1	9	1	7.20	0.68

- Under the reference scenario this means that more than 13,000 jobs would be created by 2020 and almost 20,000 jobs by 2050.
- In the moderate scenario there could be more than 200,000 jobs by 2020 and about 1.187 million in 2050.
- Under the advanced scenario, the results show up to 210,000 new jobs by 2020 and about 2.1 million by 2050.

Figure 5.5
Outlooks for Employment in CSP

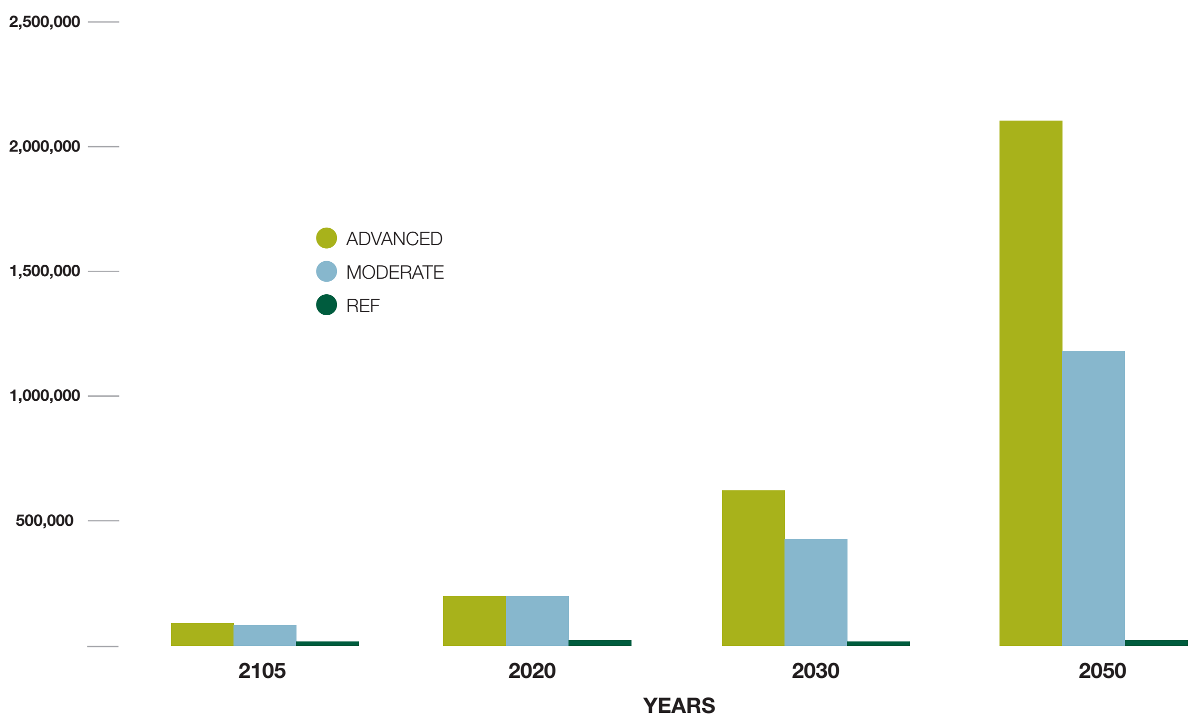


Table 5.5
CO_2 savings by CSP under reference, moderate and advanced scenarios.

	ANNUAL CO_2 REDUCTION (MIO TONS CO_2)	CUMULATIVE CO_2 REDUCTION (MIO TONS CO_2)
Reference		
2010	3	6
2015	7	31
2020	13	82
2025	18	162
2030	24	267
2035	28	400
2040	33	552
2045	34	721
2050	40	901
Moderate		
2010	6	10
2015	49	143
2020	148	630
2025	302	1,814
2030	523	3,920
2035	774	7,270
2040	1,157	12,113
2045	1,549	19,050
2050	2,183	28,318
Advanced		
2010	27	70
2015	70	176
2020	213	887
2025	472	2,672
2030	900	6,189
2035	1,444	12,265
2040	2,279	21,659
2045	3,187	35,724
2050	4,727	55,250

CO_2 savings

A reduction in CO_2 being emitted into the global atmosphere is the most important environmental benefit from solar power generation. CO_2 is the gas largely responsible for exacerbating the greenhouse effect, leading to the disastrous consequences of global climate change.

At the same time, modern solar technology has an extremely good energy balance. The CO_2 emissions related to the manufacture, installation and servicing over the average 20-year lifecycle of a solar power plant are 'paid back' after the first three to six months of operation.

The benefit from CO_2 reductions is dependent on which other fuel, or combination of fuels, any increased generation from solar power would displace. Calculations by the World Energy Council show a range of CO_2 emission levels for different fossil fuels. On the assumption that coal and gas will still account for the majority of electricity generation in 20 years' time – with a continued trend for gas to take over from coal – this analysis uses a figure of 600 tonnes per GWh as the average amount that solar generation can reduce CO_2.

image The PS10 Concentrating Solar Thermal Power Plant with 624 heliostats tracking the sun.

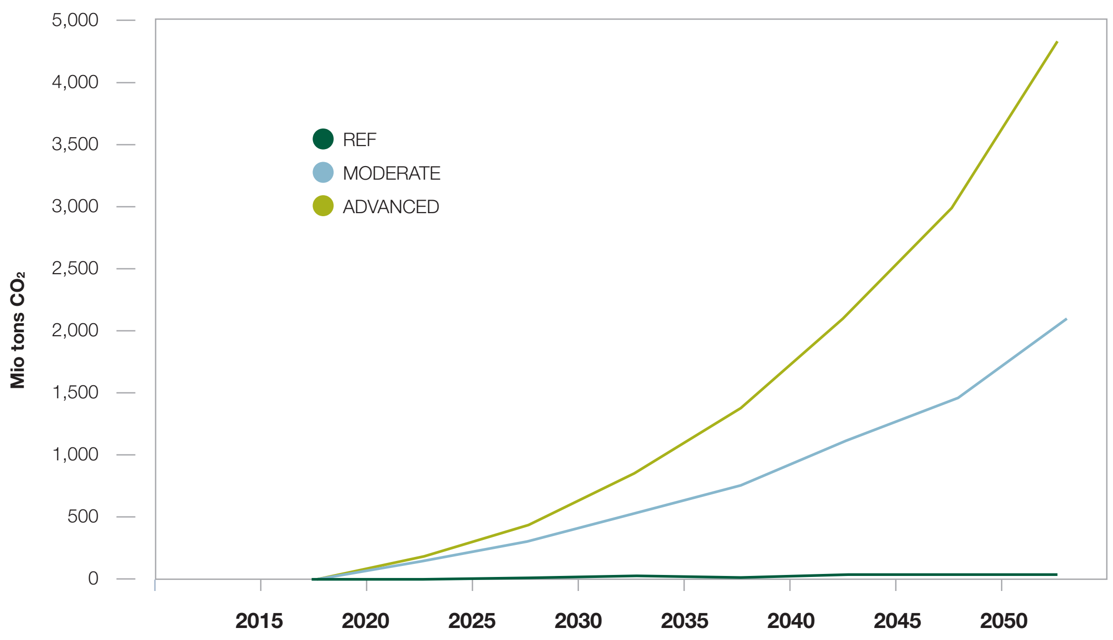
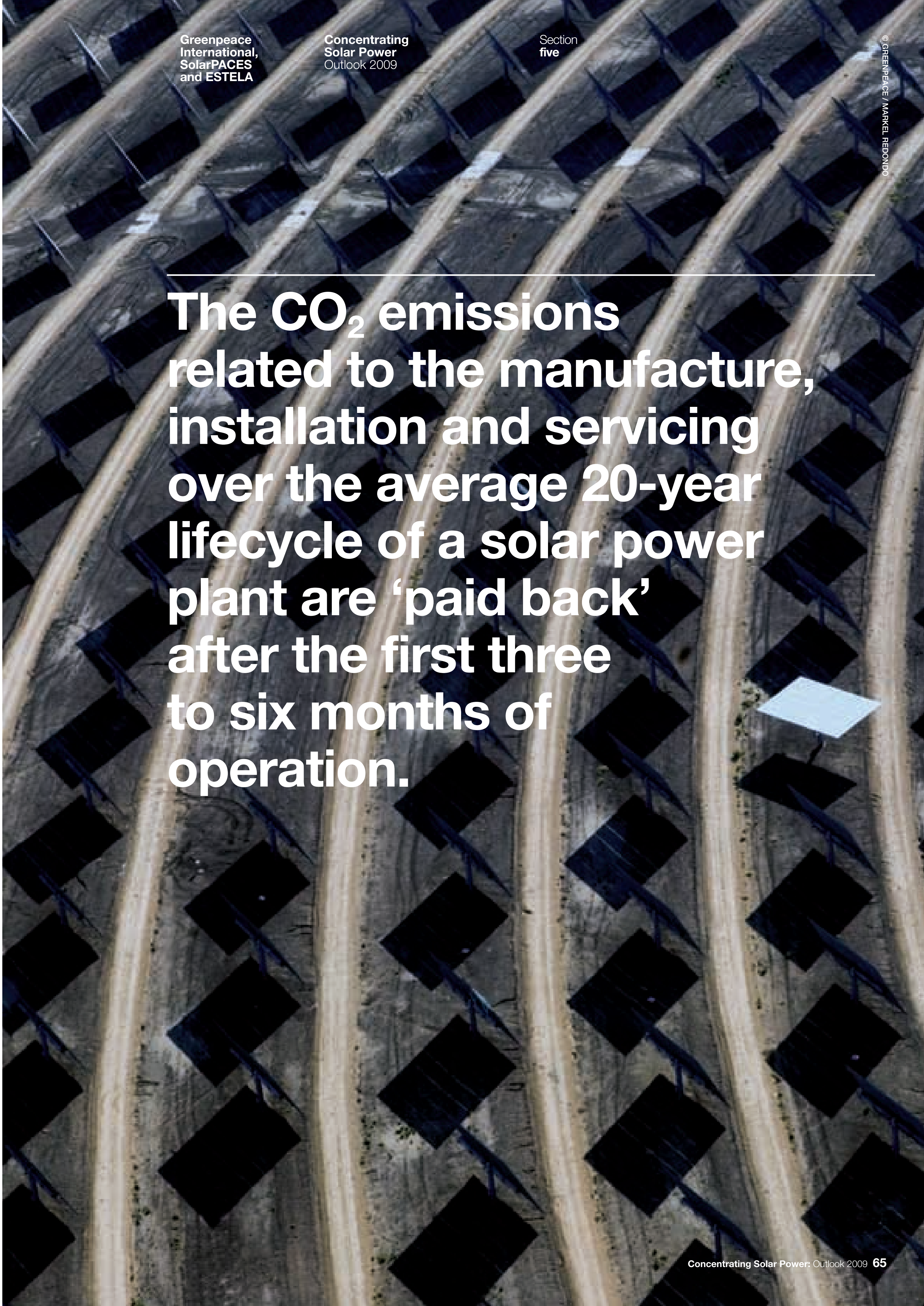


Figure 5.7
Annual CO_2 emission savings (in millions of tonnes)

This assumption is further justified by the fact that around half of the cumulative solar generation capacity expected by 2020 will be installed in OECD regions (North America, Europe and the Pacific). The trend in these countries is for a significant shift from coal to gas. In other regions the CO_2 reduction will be higher due to the widespread use of coal burning power stations. Taking account of these assumptions, the expected annual saving in CO_2 by concentrated solar power would be:

- Moderate scenario: 148 million tonnes of CO_2 annually in 2020, rising to 2.1 billion tonnes in 2050. The cumulative saving until 2020 would account for 630 million tones of CO_2, and over the whole scenario period, this would come to just over 28.3 billion tonnes.
- Advanced scenario: 213 million tonnes in 2020 rising to 4.7 billion tonnes by 2050. Until 2020, a total of 887 million tones of CO_2 would be saved by concentrated solar power alone, and this would increase to 55.2 billion tones over the whole scenario period.



The CO_2 emissions related to the manufacture, installation and servicing over the average 20-year lifecycle of a solar power plant are 'paid back' after the first three to six months of operation.

Main Assumptions and Parameters

Growth rates

The advanced scenario assumes annual growth rates of more than 20% a year, which is high for an industry that manufactures heavy equipment. Market growth rates in this scenario are based on analyses of the current CSP market. However, both the solar photovoltaic and the wind industry have shown much higher growth rates in recent years. For example, global wind power capacity has grown at an average cumulative rate of more than 30%, over the last 10 years - 2008 was a record year with more than 27 GW of new installations, bringing the total up to over 120 GW. Assumed growth rates eventually decline to single figures across all three scenarios, but with the level of solar power capacity possible in 40 years' time; even small percentage growth rates would by then translate into large numbers of megawatts installed each year.

Average power capacity

This scenario makes a conservative assumption that the average size of solar plants will gradually increase to 100 MW in 2020 and then level out. Individual solar power plants can significantly vary in total capacity. While single solar dishes can have a capacity of up to some 25 kilowatts, the size of parabolic trough power stations are already between a few MW to over 250 MW. It is expected that CSP power stations will continue to grow to an average size of 200 – 300 MW per location. However, the figure may be higher in practice, requiring fewer power plants to achieve the same installed capacity. It is also assumed that each CSP power plant operates for 40 years, after which it will need to be replaced. This replacement of older power plants has been taken into account in the scenarios.

Capacity factor

The scenario assumes that the capacity factor of CSP plants will increase steadily from the estimated average capacity factor today of 30%, to 45% in 2020 and 54% by 2030, based on increased integration of thermal storage and optimal siting. The scenario projects that the average global capacity factor will reach 34% by 2015.

'Capacity factor' refers how much of the nameplate capacity that a CSP plant installed in a particular location will deliver over the course of a year. The capacity factor depends on the solar resource at a given site, and with CSP it can be increased by thermal storage. The solar field may be increased over the nominal capacity of the steam turbine at design point (this ratio is referred to as Solar Multiple) and the excess heat stored to run the turbine during more hours after sunset. In principle, near 100% capacity could be built at appropriate sites, making CSP a possible baseload-option in the mid- to long term future. As an example, a 100 MW CSP power plant operating at a 30% capacity factor will deliver 263 GWh of electricity in a year.

Capital costs and progress ratios

The capital cost of producing solar power plants will fall steadily over the coming years as manufacturing techniques improve. Plant design has been largely in parabolic trough technology, but solar towers are starting to have an increased role. Mass production and automation will resulted in economies of scale and lower installation costs over the coming years. The general conclusion from industrial learning curve theory is that costs decrease by some 20% each time the number of units produced doubles. A 20% decline is equivalent to a progress ratio of 0.80. CSP has a unique history; in the 1990s prices dropped by more than half but the industry has since had a 15-year hiatus. It is now experiencing a boom in installations, with further gains of mass-production and economies of scale. The changes in electricity prices for the industry so far in its first development phase is equivalent to a progress ratio of about 0.90.

In the calculation of cost reductions in this report, experience has been related to numbers of units, i.e. power plants and not megawatt capacity. The increase in average unit size is therefore also taken into account. The progress ratio assumed in this study starts at 90% up until 2015, then rises again from 2016 onwards to 94% under the reference scenario and 92% under the moderate scenario by 2020. In the advanced scenario it is assumed that due to the huge market development, the high progress ratio of less than 90% can be maintained until 2030. Beyond 2041, when production processes are assumed to have been optimised and the level of global manufacturing output has reached a peak, it goes down to 0.98. Only the advanced scenario assumes a progress ratio of 93 %.

The reason that this assumption is graduated, particularly in the early years, is because the manufacturing industry has not yet gained the full benefits from series production, especially due to the rapid up-scaling of products. Also, the full potential of future design optimisations has not been utilised. The cost of CSP power plants has fallen significantly overall, but the industry is not yet recognised as having entered the "commercialisation phase", as understood in learning curve theories.

Capital costs per kilowatt of installed capacity are taken as an average of € 4,000 (USD 5,160) in 2008, falling to € 3,800 (USD 4900) in 2010 in all three scenarios. The different rates of price drops across the three scenarios are shown in the table below. All figures are given at 2008 prices.

Table 5.1
Assumed costs per MW for CSP under conservative, moderate and advanced development scenarios

	REFERENCE		MODERATE		ADVANCED	
	Progress ratio	Investment cost	Progress ratio	Investment cost	Progress ratio	Investment cost
Year	(%)	(Euro/kW)	(%)	(Euro/kW)	(%)	(Euro/kW)
2005	0.90	4,000	0.90	4,000	0.90	4,000
2010	0.90	3,800	0.90	3,800	0.90	3,800
2015	0.90	3,400	0.92	3,230	0.86	3,060
2020	0.94	3,000	0.96	2,850	0.89	2,700
2030	0.96	2,800	0.98	2,660	0.91	2,520
2040	0.96	2,600	0.98	2,470	0.91	2,340
2050	0.98	2,400	1.00	2,280	0.93	2,160

Notes on Research

The projections for world electricity demand used in this report were developed for Greenpeace's Energy [R]evolution 2008. For more background on how energy efficiency and other factors are incorporated to the reference scenario, please refer to that document. The Energy [R]evolution can be downloaded from http://www.energyblueprint.info. and www.greenpeace.org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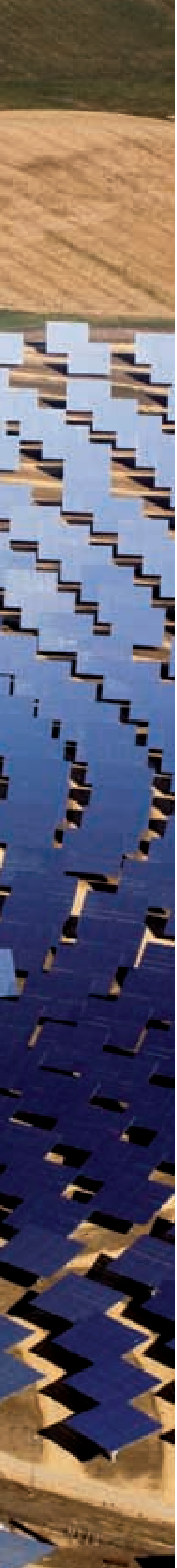

image The receiving tower of the PS10 Concentrating Solar Thermal Power Plant in southern Spain.

6

CSP for Export: The Mediterranean Region

Technically, it would only take 0.04% of the solar energy from the Sahara Desert to cover the electricity demand of Europe (E25). Just 2% of the Sahara's land area could supply the world's electricity needs. This concept is staggering. With the growth of CSP technology into a large-scale application, electricity export from Northern Africa to Western Europe is a viable option. It requires massive investment in large, landmark plants and high voltage transmission lines which dramatically reduce transmission losses.

Areas with high peak electricity demands, like southern Spain, are already having summer blackouts, in particular from use of air-conditioning. In southern Europe, at least, cooperation with neighbouring countries for energy supplies is already a day-by-day practice. There are gas and power interconnections between Italy, Tunisia and Algeria, as well as between Morocco and Spain.

Mediterranean Solar Plan 2008

The Mediterranean Solar Plan was announced on 13 July 2008 at the Paris Summit for the Mediterranean region. The objective is to reach 20 GW of new renewable energy capacity by 2020 in the region. Of this, 3-4 GW would be covered by photovoltaic technology, 5-6 GW by wind and 10-12 GW by concentrating solar power. The physical interconnection of Tunisia-Italy and Turkey-Greece would be a pre-requisite for the implementation of such a plan.

The summit concluded that 'market deployment as well as research and development of all alternative sources of energy are a major priority in efforts towards assuring sustainable development' and that the 'feasibility, development and creation of a Mediterranean Solar Plan' will be examined.

2009 is a crucial year for the world to really curb climate change. Talks in Copenhagen will determine whether the European target recommendation for emissions reductions of 30% by 2020 comes into force.
A strong partnership between the European Union (EU), the Middle East and North Africa (MENA) is a key element to meeting the target of the plan.

The Mediterranean region 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.

Technical potential for CSP in the Mediterranean/ MENA region

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 a year). Even with efficiency gains and a mix of regressive population figures in some countries, electricity demand is still likely to go up significantly.

To meet this demand, each country will need a different balanced mix of renewable energies in the future based on its own specific natural sources of energy.

A 2005 study by the German Aerospace Centre (DLR) called 'Concentrating Solar Power for the Mediterranean Region' showed that solar thermal power plants have huge technical and economical potential and that there is a potentially enormous market in the Mediterranean (MENA), especially for export to Europe. This region is blessed with intense solar radiation although it currently exports mainly fossil fuels, with all their devastating climate impacts and unpredictable price fluctuations. The MED-CSP study focused 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 were:

- 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, making fossil fuels available for longer in a more sustainable way.
- 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 economic needs in a compatible way.
- Renewable energies and efficiency need initial public start-up investments but do not require long-term subsidies like fossil or nuclear energies.

Within this region, solar thermal power plants can provide thermal energy storage and solar/fossil hybrid operation for a reliable, stable supply and power security. The full report is available at: http://www.dlr.de/tt/med-csp. Part 7 of this report, Policy Recommendations, outlines the steps required to accelerate renewable energy deployment in the EU and MENA, and the other Sun Belt regions of the world.

Solar Energy Scenario for Mediterranean

The CSP scenario for the Mediterranean shows a way to match resources and demand in the frame of the technical, economic, ecological and social constraints of each country in a sustainable way. This will not require long-term subsidies, like fossil or nuclear power, but simply an initial investment to put large-scale 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 because they can provide large amounts of electricity and reliable power capacity on demand. Wind energy, hydro-power and biomass resources are available in some countries, and their role in a sustainable energy future is provided in Greenpeace's Energy [R]evolution. In the future, very large photovoltaic systems in desert regions will also become feasible. Concentrating solar power plants can deliver capacity on demand and can be rolled out immediately.

While the EU must support renewable energies on all levels, CSP is likely to become 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 risks of present energy policies, including international conflicts, and to head off massive economic and environmental costs of climate change.

Table 6.1
Installed capacity and produced electricity for CSP under different scenarios

		2015	2020	2030	2050
Reference					
Africa	MW	488	1,113	1,113	1,113
	TWh/a	1	3	4	4
Middle East	MW	393	612	1,060	1,955
	TWh/a	1	2	3	7
Europe	MW	1,741	3,065	6,243	8,071
	TWh/a	5	9	20	30
Total Region	MW	2,622	4,790	8,470	11,138
	TWh/a	7	14	27	41
Moderate					
Africa	MW	1,043	3,968	22,735	110,732
	TWh/a	3	14	86	485
Middle East	MW	4,171	9,094	43,457	196,192
	TWh/a	14	33	164	359
Europe	MW	2,220	6,883	17,013	34,570
	TWh/a	7	25	64	151
Total Region	MW	7,434	19,945	83,205	341,494
	TWh/a	25	72	313	1,496
Advanced					
Africa	MW	1,176	4,764	31,238	204,646
	TWh/a	5	20	137	1,058
Middle East	MW	6,049	15,949	56,333	226,323
	TWh/a	24	67	247	1,170
Europe	MW	4,379	11,290	40,312	152,371
	TWh/a	17	47	177	768
Total Region	MW	11,604	32,003	127,882	583,340
	TWh/a	46	135	560	3,015

image The PS10 Concentrating Solar Tower Plant in southern Spain.

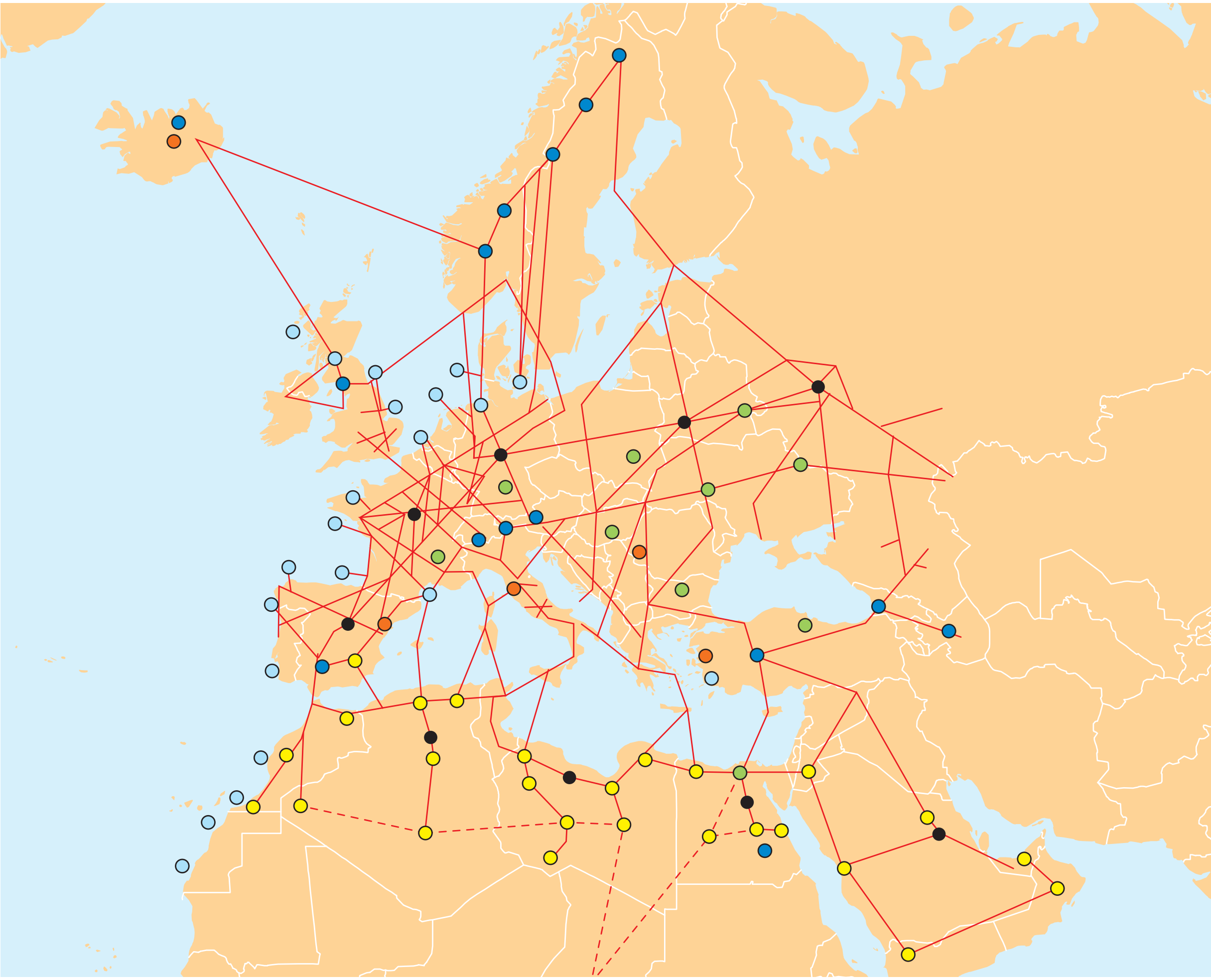

Figure 6.1
Exemplary HVDC interconnection lines for the export of solarelectricity from concentrating solar power plants from North Africa to Europe

LEGEND

- WIND POWER
- BIOMASS
- GEOTHERMAL
- HYDROPOWER
- CONVENTIONAL
- SOLAR POWER

This Graph shows a possible interconnection of the electricity grid of Europe, the Middle East and North Africa (EUMENA) with the purpose of supplying solar electricity to Europe. The conventional electricity grid is not capable of transferring large amounts of electricity over long distances. Therefore, a combination of the conventional alternate current (AC) grid with High Voltage Direct Current (HVDC) transmission technologies must be used in such a Trans-European electricity scheme.

There are several good reasons for such a transmission scheme:

- the huge solar energy potential of MENA can easily produce 560 TWh/y in 2050 for export, reducing significantly the European CO_2-emissions,
- CSP in MENA provide around the clock firm capacity for base load, intermediate load and peak load and can complement the European renewable energy mix to provide secured power supply,
- a well balanced mix of national and imported renewable energy will reduce the dependency on energy imports in Europe and provide a basis for economic development in MENA,
- electricity from CSP will become the least cost option for electricity in MENA, a well balanced mix of renewables is the only guarantor for stable electricity prices.

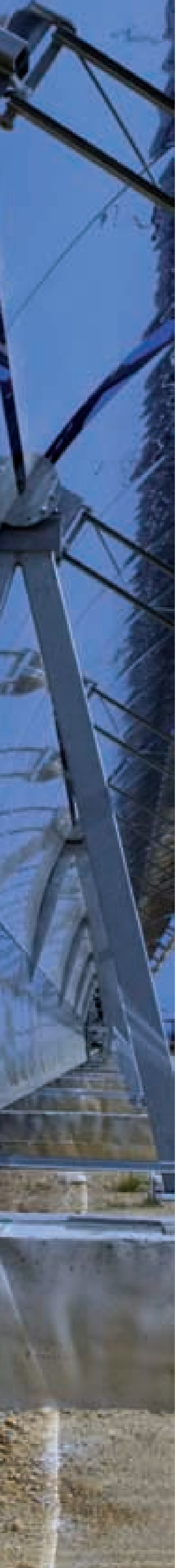

image Workers examine parabolic trough collectors in the PS10 Concentrating Solar Tower Plant. Each parabolic trough is 150 meters long and concentrates solar radiation to a heated fluid, which creates steam for a generator.

7

CSP Policy recommendations

The Concentrating Solar Power Outlook Scenarios show that with advanced industry development and high levels of energy efficiency, CSP could meet up to 7% of the world's power needs by 2030 and fully one quarter by 2050.

Even with a moderate scenario of market development measures, the world would have a combined solar power capacity of over 830 GW by 2050, with the annual market running close to 41 GW. This would represent 3.0 to 3.6% of global demand in 2030 and 8.5 to 11.8% in 2050.

According to the European Industry Association ESTELA strong market growth of CSP will be demonstrated by a number of factors. Technical and economic success of the initial projects is the first step. To make this technology mainstream will require stable green pricing or incentives to bridge the initial gap in levelised electricity costs and cost reduction of the components and power produced. New markets and market opportunities, for example in exporting power from North Africa to Europe, are vital for the long term development of the industry and strong research and development is required to continue technical improvements in power production.

Governments and industry development must now put the measures in place to usher in the maximum amount of concentrating solar power possible. Together with other renewable resources like wind, solar PV, geothermal, wave and sustainable forms of bioenergy, this technology has a major role to play in averting catastrophic climate change.

A directive of the European Parliament was passed on 23 April 2009 on the promotion of renewable energy sources which set a solid 20% target for power sourced from renewable energy by 2020. (Directive 2009/28/CE).This, in addition to the extend the greenhouse emission trading scheme provide a well-defined legislative framework for concentrating solar power. Dramatic expansion of the market can now occur, if the directives are now properly implemented by the EU and nation states.

What policies are working to boost CSP?

Long-term and stable feed-in-tariffs have proven as the most efficient instrument for sustainable renewable market penetration. The experience of Spain demonstrates how the right level of tariff can increase the market for this technology exponentially. Legislated feed-in tariffs are already in place in Spain, Greece, Italy, France, Algeria, South Africa, France and Israel and under discussion in Turkey, the amounts are shown in table 7.1

Legislated renewable energy sales targets aimed at the electricity retail sector are another effective way to boost installation of CSP. The experience of southwestern states in the US, especially California, is evidence of these policies in action. Another final measure working to support the industry is grants, as in the case of Morocco and Egypt.

Table 7.1
Overview on feed-in tariffs in various countries, in place or under preparation

COUNTRY	TARIFF	STATUS
Algeria	Up to 200% of regular tariff for ISCC plants with >20% solar generation.	Since March 2004
France	30 eurocents per kWh	Since 2006
South Africa	2.10 R / kWh (17 eurocents per kWh)	Announced March 2006
Israel	16.3 US cents/kWh (12.6 eurocents per kWh)	Since November, 2006
Spain	27 eurocents per kWh for 25 years	Since 2007
Italy	22 – 28 eurocents per kWh	Since 2008
India	Up to 10 rupees per kWh (19 US cents per kWh)	2008 announcement (under trial)
Turkey	24 eurocents per kWh for first 10 years, then 20 eurocents per kWh thereafter	Draft proposal, not final

International Policy Frameworks

There are two major international policy instruments relevant to CSP at the moment - The Global Market Initiative and the Mediterranean Solar Plan.

The Global Market Initiative was signed by a number of countries agreeing to put in place targets, fixed tariffs, financing and regulation. For those that undertook the measures, the CSP markets are taking off, most notably in Spain and hopefully soon in South Africa, Israel and other nations. However, this initiative does not stand alone as an answer. As an agreement it has no legally binding power, and only effects the solar markets in countries with the political will to put words into action. While the policy initiatives in the GMI are still relevant to boost the market, the overall target of 5,000 MW is likely to be exceeded in Spain alone by current projects under construction and development.

The Mediterranean Solar Plan was announced in mid-2008 and it seeks a total of 10 to 12 gigawatts of concentrating solar power by 2020. This better reflects the potential in the region for the technology to provide both local and export power. Under the moderate scenario in this report Africa, Europe and the Middle East combined would host nearly 17 gigawatts of CSP in 2020 and 241 gigawatts by 2050. However, the plan's success would depend on high-voltage connections between Tunisia and Italy and Turkey and Greece. The political instability in the region is a major barrier to the implementation of the plan, but an initial statement by the Mediterranean Heads of State is a positive sign of market development.

Recommendations

Mandatory, binding renewable energy targets

To keep the world within a safe level of climate change, CO_2 emissions must peak by 2015 and be phased out as soon as possible after 2050. The Greenpeace Energy [R]evolution sets out a blue print for how that can happen, with no new coal or nuclear power.

The major policy approaches required to make the energy revolution a reality are to:

- Phase out all subsidies for fossil fuels and nuclear energy as well as subsidies that encourage the use of these fuels
- Internalise the external (social and environmental) costs of energy production through ‘cap and trade’ emissions trading
- Mandate strict efficiency standards for all energy-consuming appliances, buildings and vehicles
- Establish legally binding targets for renewable energy and combined heat and power generation
- Reform the electricity markets by guaranteeing priority access to the grid for renewable power generators
- Provide defined and stable returns for investors, for example by feed-in tariff programmes
- Increase research and development budgets for renewable energy and energy efficiency

In addition to these global approaches, we put forward a set of concrete measures to boost concentrating solar power, to the level where it can account for between 8% and 25% of the world’s energy demand in 2050

Market creation measures

Spain and USA show how big potential markets can be for concentrating solar power, with the right market mechanisms in place. To open up massive potential of other regions requires:

- That the Kyoto instruments such as Cleaner Development Mechanism (CDM) and Joint Implementation (JI) are applicable to CSP and mechanisms are bankable and sufficient
- That governments install demand instruments and promote feed-in-laws as the most powerful instrument to push generation
- To fully implement the Mediterranean Solar Plan
- To open the European transmission grid for solar power from North Africa and secure this power import by implementing demand ‘pull’ instruments
- Open the renewable energy market to operate inside and outside the European Union, effectively letting renewable electricity cross intra-European borders. Such an interchange would require bankable transnational renewable transfer tariffs
- For European organisations to engage and partner with Northern Africa. Africa has an unlimited solar resource, which can be accessed by sharing technology, know-how and employment. This would build up an industrial and human resource base for the implementation of CSP in those countries, develop economic relationships and create an investment framework by supporting electricity market liberalisation in North Africa

Specific policy measures

Feed-in tariffs

The general consensus among industry players is that a legislated tariff of between 24 and 27 eurocents per kWh with a guarantee of 20 to 25 years is required in Southern Europe to make projects bankable. Feed-in tariffs also need to:

- Provide investor confidence that the premiums will not change, so that project returns on investment can be met
- Have clear and published time-scales for project eligibility
- Consider a period after which the tariff is lowered, after projects are paid-off, so as not to have an unnecessary effect on the consumer price for electricity

Loan Guarantees

To provide greater access to investment funds requires new loan guarantee programmes via existing windows at multilateral banks, existing national lending programmes and global environmental programmes such as GEF, UNEP, and UNDP for CSP for North Africa's developing economies.

Supporting new technology development

As with any developing industry, the next generation technologies will significantly drive down costs. To allow for this to keep driving cost reductions requires:

- Funding for pre-commercial demonstration plants so next generation technologies to enter the market
- Demonstration plants need loan guarantees from the EU to cover the technology innovation risk
- Research and development funding for material, component and system development (e.g. coatings, storage, direct steam/molten salt systems, adapted steam generators, beam down)

Specific Technology Measures

Solar Fuels

For solar fuels, the ultimate goal is developing technically and economically viable technologies for solar thermochemical processes that can produce solar fuels, particularly H_2. Policy measures recommended by the industry association SolarPACES and supported by Greenpeace are:

- Immediate and accelerated implementation of research and development transition from today's fossil fuel-based economy to tomorrow's solar driven hydrogen economy. The EU-FP6 project INNOHYP-CA (2004-2006) has developed a roadmap which shows the pathway to implementing thermochemical processes for massive H_2 production
- Development and demonstrations of solar chemical production technologies to prove technical and economic feasibility
- A worldwide consensus on the most promising future energy carriers – both renewable electricity and hydrogen
- A clear decision to start the transition from fossil to renewable energies and from petrol to H_2
- Concrete steps from governments, regulators, utility companies, development banks and private investors to develop infrastructure and create new markets

Process Heat

Calls for future development of process heat by the International Energy Agency (IEA) and supported by Greenpeace are:

- Economic incentives available for industries willing to invest in solar thermal aimed at reducing payback periods; for example, low interest rate loans, tax reduction, direct financial support, third party financing. To date, only local examples of these support schemes have been applied
- Carry out demonstration and pilot solar thermal plants in industries, including advanced and innovative solutions, like small concentrating collectors
- Providing information to the industrial sectors involved to make them more aware of issues around process heat, namely:
  - the real cost of heat production and use of conventional energy sources and their relevance in the total industry management cost; and
  - the benefits of using appropriate solar thermal technology
- Support further research and innovation to improve technical maturity and reduce costs, especially for applications at higher temperatures

About the authors

ESTELA

ESTELA is a European Industry Association created to support the emerging European solar thermal electricity industry for the generation of green power in Europe and abroad, mainly in the Mediterranean region. ESTELA involves and is open to all main actors in Europe : promoters, developers, manufacturers, utilities, engineering companies, research institutions.

- To promote high and mid temperature solar technologies for the production of thermal electricity to move towards sustainable energy systems
- To support research and innovation, including vocational training, and favouring equal opportunities
- To promote excellence in the planning, design, construction and operating of thermal electricity plants
- To promote thermal electricity at international level, mainly in the Mediterranean area and developing countries
- To co-operate at international level to contribute to combat climate change
- To represent the solar thermal electricity sector at European and world level

SolarPACES

SolarPACES is an international cooperative organisation bringing together teams of national experts from around the world to focus on the development and marketing of concentrating solar power systems (also known as solar thermal power systems). It is one of a number of collaborative programmes managed under the umbrella of the International Energy Agency to help find solutions to worldwide energy problem. The organisation focuses on technology development and member countries work together on activities aimed at solving the wide range of technical problems associated with commercialisation of concentrating solar technology. In addition to technology development, market development and building of awareness of the potential of concentrating solar technologies are key elements of the SolarPACES programme.

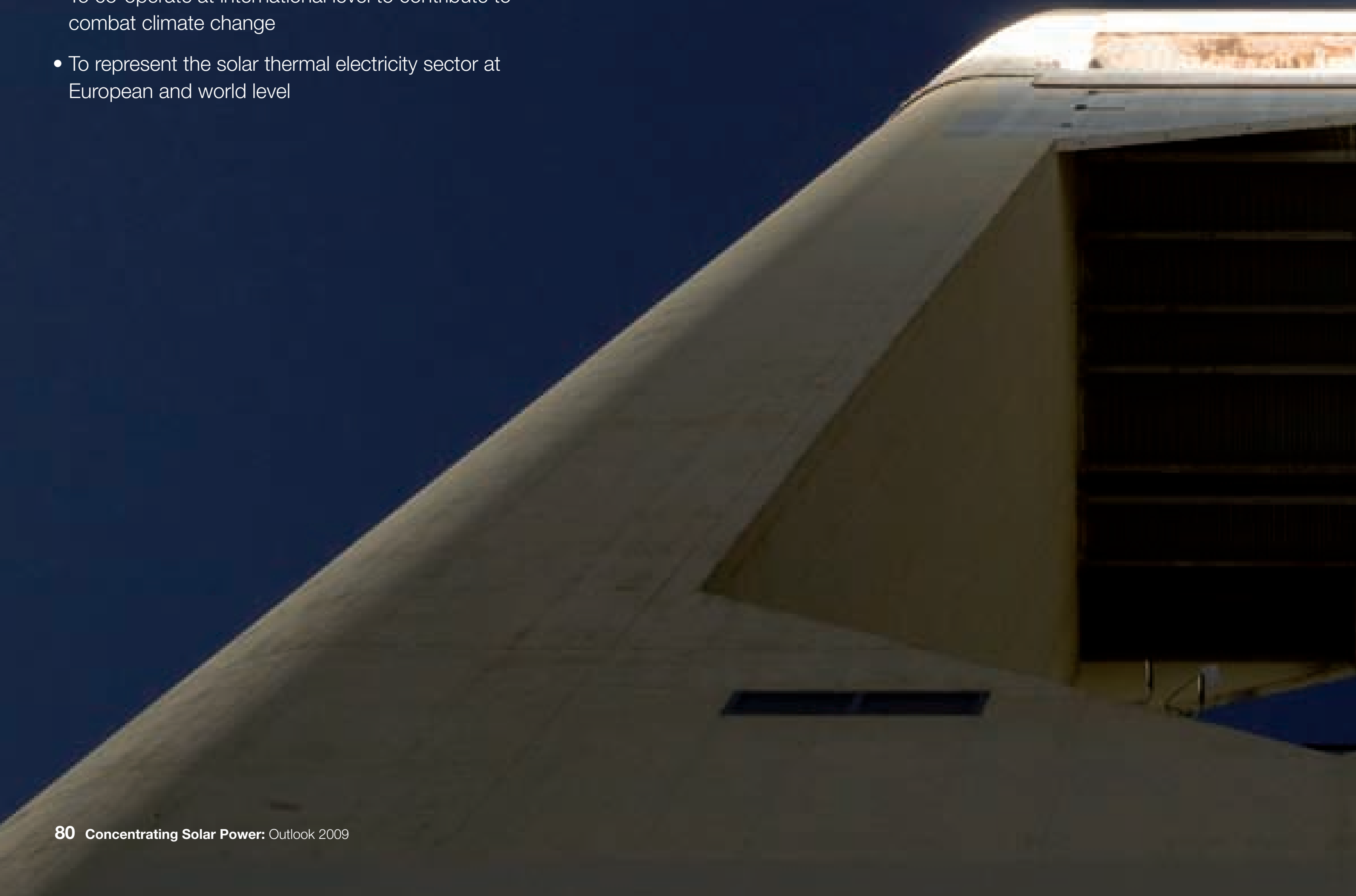

image The 115 metre-high tower at the PS10 Concentrating Solar Tower Plant.

Abbreviations

Greenpeace International

Greenpeace is a global organisation that uses non-violent direct action to tackle the most crucial threats to our planet's biodiversity and environment. Greenpeace is a non-profit organisation, present in 40 countries across Europe, the Americas, Asia and the Pacific. It speaks for 2.8 million supporters worldwide, and inspires many millions more to take action every day. To maintain its independence, Greenpeace does not accept donations from governments or corporations but relies on contributions from individual supporters and foundation grants.

Greenpeace has been campaigning against environmental degradation since 1971 when a small boat of volunteers and journalists sailed into Amchitka, an area west of Alaska, where the US Government was conducting underground nuclear tests. This tradition of 'bearing witness' in a non-violent manner continues today, and ships are an important part of all its campaign work.

EPC Engineering, Procurement, Construction – a type of contract for 'turnkey' solutions

GEF Global Environmental Facility

DISS Direct Solar Steam

ISCC Integrated Solar Combined Cycle

LFR Lineal Fresnel Reflector

NEAL New Energy Algeria

NREA New and Renewable Energy Authority

ONE Office National D'electricite (Electricity company of Morocco)

SEGS Solar Energy Generating System

Major solar thermal and CSP plants operating and under construction in mid-2009

Status indicates O = operating, C = under construction/commissioning, P = proposed

Information taken from many sources, including SolarPACES and Protermosolar (http://www.protermosolar.com/), and company press releases.

Appendix 1

Major solar thermal and CSP plants operating and under construction in mid-2009*

(Status indicates O = operating, C = under construction/commissioning, P = proposed)

LOCATION	INSTALLATION NAME: DEVELOPER	STATUS	TYPE	SIZE (MW)	SOLAR OUTPUT (MWE)	INSTALL DATE
Israel	Ashalim: Request for Tender Two solar thermal power plants, each with an installed capacity of between 80MW to 125MW and in the aggregate up to 220MW installed capacity.	P	Trough	220	220	2012
Morocco	Morocco ISCC Plant 2	O	Trough		6	TBD
Morocco	Abi Ben Mathar: ONE / Abengoa	C	ISCC/Trough	470	20i	TBD
Algeria	Hassi R'mel: Abengoa (GEF Funding) NEAL issued a request for build-own-transfer bids to national and international investors for this 150-MW hybrid solar/gas power plant	C	ISCC/Trough	150	25ii	2010
Egypt	Kuramayat: Iberdola/Flagsol/OCI The thermal plant will be co-financed by a JBIC soft loan for US$97 million. The project will be owned by NREA which will cover the local currency required for the project. (GEF Funding)	C	ISCC/Trough	150	25	2010i
Algeria	2 x ISCC plants: NEAL Two plants of 400MW each, with 70 MW each of solar energy	P	ISCC/ Trough	800	140	2015
South Africa	Northern Cape Province: Eskomi	P	Tower	100	100	TBC
Spain	Solucar PS – 10: Abendgoa Located near Seville, the first Spanish CSP project to connect to the grid. The PS-10 project received €5 million from the European Union 5th Framework programme. It will generate 24 GWh of solar electricity annually.	O	Tower	11	11	2006
Spain	Anzalcollar TH: Abengoa	O	Dish Stirling	8 x 0.01	0.08	TBD
Spain	Andasol 1 & 2: Solar Millennium/ ACS Cobra Two plants of 50 MW each	O	Trough	100	100	2008/09ii
Spain	Andasol 3: Solar Millennium 50 MW, 7.5 h storage	C	Trough	50	50	2011
Spain	Ibersol: Solar Millennium 50 MW, 7.5 h storage	C	Trough	50	500	2011
Spain	PS-20: Abengoa Construction has already started and will be connected in 2008 at the same site as the PS-1, producing 4.8 GWh / annum.	C	Tower	20	20	2009
Spain	Solnova Electricidad 1, 3 and 4: Abengoa Three 50 MW plants in construction with another two proposed. Together, Solnova 1, 2, 3, 4 and 5 will produce 114.6 GWh / annum.	C	Trough	150	150	2009-10iii
Spain	Lebrija: Sacyr, Solel (Valoriza)	C	Trough	50	50	2010iv
Spain	Ibersol Ciudad Real: Ibrerdrola Will produce 114 GWh per/ annum, over 25 years.	C	Trough	40	40iii	2009
Spain	Alvarado 1: Acciona	C	Trough	50	50	2009
Spain	Palma de Rio 1 & 2: Acciona Two plants of 50 MW each, the second starts construction June 2009.	C	Trough	100	100	2010
Spain	Puertollano : Iberdrola	C	Trough	50	50	TBC
Spain	Manchasol 1: ACS Cobra Two plants of 50 MW each	C	Trough	100	100	2010/11
Spain	Extresol 1 & 2: ACS Cobra Two plants of 50 MW each	C	Trough	100	100	2009/10v
Spain	Gemasolar (Solar Tres): Sener, Masdar The first utility grade solar power plant with central tower and salt receiver technology. It will produce about 100 GWh/ yr.	C	Tower	50	17	2008
Spain	PE1: Novatec/Prointec	O	LFR	1.4	1.4	2009
Spain	Badajoz: La Dehesa: SAMCA	C	Trough	50	50	2009
Spain	Badajoz: La Florida: SAMCA	C	Trough	50	50	2010
Spain	Majadas 2: Acciona	C	Trough	50	50	2009
Italy	Solar capacity integrated into existing combined cycle plant	C	Trough	760	5	2010
Spain	Andasol 3: Solar Millennium	P	Trough	50	50	2011
Greece	Solar capacity using steam cycle	P	Trough	50	50	TBD
Germany	Solar Tower Jülich	O	Tower	1.5	1.5	2008

LOCATION	INSTALLATION NAME: DEVELOPER	STATUS	TYPE	SIZE (MW)	SOLAR OUTPUT (MWE)	INSTALL DATE
USA	SEGS VIII and IX: Luz / Solel Two plants of 80 MW each	O	Trough	160	160	1989/90i
USA	SEGS I1- VII: Luz / Solel Six plants of 30 MW each	O	Trough	180	180	1984-89
USA	SEGS I: Luz / Solel	O	Trough	13.8	13.8	1984
USA	Saguaro APS Plant: Solargenix	O	Trough	1	1	2006
USA	Nevada Solar One: Acciona Construction started in 2006. Commercial operation will produce more than 130 GWh annually.	O	Trough	64	64	2007
USA	Kimberlina: Ausra	O	LFR	5	5i	2008
USA	Idaho Demonstration plant: Sopogy	C	Micro CSP		0.05	
USA	Mojave: Solel This plant would power 400, 000 homes. A power purchase agreement was made in 2007.	P	Trough	553	553ii	2011
USA	Solar One, Phase 1: Stirling Energy Systems (SES)	P	Dish-Engine	300	300	2009-2012
USA	Solar Two, Phase 1: SES Stirling Energy Systems (SES) have secured a power purchase agreement with Southern California Edison Company for 500MW of power from their Stirling Engines, with expansion option to 850MW.	P	Dish- Engine	500	500	2009-2010
USA	Solana: Abengoa Located in Arizona, the developer has signed a contract with Arizona Public Service to build and operate.i	P	Trough	280	280	2012
USA	Carrizo (California): Ausra The components of this installation are being manufactured at a purpose-built facility in the United States.	P	LFR	177	177	2010ii
USA	Harper Lake (California): NextEra	P	Trough	250	250	2011
USA	Beacon (California): NextEra	P	Trough	250	250	2011
USA	Ivanpah 1: Brightsource Energy	P	Tower	100	100	2010
USA	Invanpah 2 : Brightsourece Energy	P	Tower	300	300	2012-2013
USA	California: BrightSource Power purchase agreement with PG&E	P	Tower	900	900	TBD
USA	California: Brightsource Power purchase Agreement with Southern California Energy	P	Tower	1300	1300	TBD
USA	Florida: Florida Power And Light, Ausraii	P	LFR	300	300	No data
USA	New Mexico: eSolar	P	Tower	105	105	2011
USA	Southern California: eSolar Power purchase agreement with SCEiii	P	Tower	140	140	2011
USA	Coalinga: Martifer Renewables	P	Trough	107	107	2011
USA	Next Generation Solar Centre: NextEra	P	Trough add-on to ISCC	75	75	2011
USA	Solar Two, Phase 2: SES	P	Dish/ Engine	600	600	2011
USA	Solar One, Phase 2: SES	P	Dish/Engine	300	300	2013-2014
USA	Nevada: Solar Millenuem	P	Trough	250	250	2013*2014
Mexico	Hybrid Solar Thermal Plant: GEF funding, contract not awardediv	P	Trough	480	31	TBD
USA	California: Bethel Energy	P	Parabolic trough	100	100	TBD
USA	Palmdale Hybrid: Inland Energy	P	Trough add-on to IGCC	50	50	TBD
USA	Victorville Hybrid: Inland Energy	P	Trough add-on to IGCC	50	50	TBD
China	China Plant Expansion: Solar Millennium	C	Trough		50	TBD
Australia	Liddel Power Station: Ausra/ Macquarie Generation	C	LFR	2000	2	2009
	Total Operating (MW)			560 MW		
	Total In Construction (MW)			984 MW		
	Total Announced in Development (MW)			7,463 MW		

Notes for Table

i Abengoa Solar Project Information Page
http://www.abengoasolar.com/sites/solar/en/our_projects/international/morocco/index.html. Accessed on 9/4/09.

ii Abengoa Solar Project Information Page
http://www.abengoasolar.com/sites/solar/en/our_projects/international/algeria/index.html. Accessed on 9/4/09.

iii Flagsol Project Information Page:
http://www.flagsol.com/gef_projects.htm. Accessed on 9/4/09.

iv Eskom Fact Sheet (2007)
http://www.eskom.co.za/live/content.php?Item_ID=28&Revision=en/113 Accessed on 27/04/09

v Project Information Page Flagsol,
http://www.flagsol.com/andasol_projects.htm Accessed on 20/04/09

vi Project Information page, Abengoa Solar
http://www.abengoasolar.es/sites/solar/en/our_projects/solucar/index.html Accessed on 20/04/09

vii Solel Press Release, February 19 2009: Solel Begins Construction on New 50 MW Solar Field in Spain Using Advanced SunField LP Technology http://www.solel.com/files/press-pr/lebrija-release-english-final2.pdf. Accessed on 20/04/09

viii Renewable Energy Word, April 9, 2007,
http://www.renewableenergyworld.com/rea/news/article/2007/10/iberdrola-ingenieria-to-build-isccs-150-mw-solar-thermal-plant-in-egypt-50195. Accessed on 20/04/09

ix ACS Press Release Cobra begins construction on Extresol-1 in Torre de Miguel (Bajaoz), July 2007,
http://www.grupoacs.com/adjuntos/2173_nota_de_prensa_extresoleng_.pdf. Accessed on 20/04/09

x Presentation By SolarGenix Energy to IEEE, 2006
http://ewh.ieee.org/r6/las_vegas/IEEELASVEGASMAY2006.pdf. Accessed on 20/04/09.

xi Ausra Fact Sheet, The Kimberlina Solar Thermal Energy Plant.
http://www.ausra.com/pdfs/KimberlinaOverview-101108.pdf. Accessed on 20/04/09.

xii PG&E Press Release, June 2007 PG&E Signs Contract with Solel for 553 MW http://www.solel.com/files/press-pr/pge_solel.pdf. Accessed on 20/04/09.

xiii Abengoa Project Update,
http://www.abengoasolar.com/sites/solar/en/our_projects/solana/index.html accessed on 9/4/09.

xiv Ausra Press Release, Nov 2007. PG&E and Ausra announce 177 MW Solar Thermal Agreement
http://www.ausra.com/news/releases/071105.html. accessed on 9/4/09.

xv FPL Press Release Sept 2007 FPL Plans to boost US Solar Energy Production http://www.fplgroup.com/news/contents/2007/092607.shtml. accessed on 9/4/09.

xvi CNET news, June 3 2008, eSolar lands solar power plan deal
http://news.cnet.com/8301-11128_3-9959107-54.html. accessed on 9/4/09.

xvii World Bank Project database: Project ID: P066426
http://web.worldbank.org/. Accessed on 9/4/09.

Appendix 2

Some of the Companies active in CSP

Trough Systems
- Acciona
- ACS
- Abengoa
- Sener
- Solar Millennium
- SkyFuel
- Solel
- Solare XXI

Linear Fresnel Reflectors
- Ausra
- MAN/ SPC
- Novatec/ Biosol
- SkyFuel

Power Towers
- Abengoa
- Brightsource Energy
- SolarReserve
- eSolar

Dish Engine Systems
- Stirling Energy Systems
- Schlaich Bergermann und P.
- Infinia Corporation
- Brayton Energy

Stirling Engines
- Kockums
- Cleanenergy
- Stirling Energy Systems
- Infinia Corporation
- Sunpower

Molten Salt Components
- Friatec-Rheinhuete
- SQM

Appendix 3

Early solar power plants

REFERENCE	LOCATION	SIZE (MWE)	TYPE, HEAT TRANSFER FLUID & STORAGE MEDIUM	START–UP DATE	FUNDING
Eurelios	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

Appendix 4: List of countries in IEA Regions

oecd north america
Canada, Mexico, United States

latin america
Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela

oecd pacific
Australia, Japan, Korea (South), New Zealand

oecd europe
Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom

transition economies
Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Serbia and Montenegro, the former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus* , Malta*

india
India

china
People's Republic of China including Hong Kong

developing asia
Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Chinese Taipei, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Vietnam, Vanuatu

middle east
Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen

africa
Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe

Appendix 5

Summary Scenario Key parameter

REFERENCE Year	CUMULATIVE [GW]	ANNUAL GLOBAL MARKET VOLUME [MW]	CAPACITY FACTOR	PRODUCTION (TWh)	CO_2 REDUCTION (WITH 600GCO2/kWh) (ANNUAL MIOTCO2)	AVOID CO_2 REDUCTION SINCE 2007 (CUMULATIVE MIO TCO2)	PROGRESS RATIO
2007	0.41	0	30%	1	1		90%
2008	0.48	0	30%	1	1	1	90%
2009	1.0	529	30%	3	2	2	90%
2010	1.6	663	31%	5	3	3	90%
2015	4.1	566	32%	11	7	6	90%
2020	7.3	681	34%	22	13	31	94%
2025	10.0	550	34%	30	18	82	94%
2030	12.8	552	36%	40	24	162	96%
2035	14.9	371	36%	47	28	267	96%
2040	16.4	273	38%	55	33	400	96%
2045	17.2	160	38%	57	34	552	96%
2050	18.0	160	42%	66	40	721	98%
						901	

MODERATE Year	CUMULATIVE [GW]	ANNUAL GLOBAL MARKET VOLUME [MW]	CAPACITY FACTOR	PRODUCTION (TWh)	CO_2 REDUCTION (WITH 600GCO2/kWh) (ANNUAL MIOTCO2)	AVOID CO_2 REDUCTION SINCE 2007 (CUMULATIVE MIO TCO2)	PROGRESS RATIO
2007	0.41	0	30%	1	1	1	90%
2008	0.48	0	30%	1	1	2	90%
2009	1.0	529	30%	3	2	4	90%
2010	3.9	2,936	31%	11	6	10	90%
2015	24.5	5,463	38%	81	49	143	92%
2020	68.6	12,602	41%	246	148	630	96%
2025	140.1	16,082	41%	503	302	1,814	96%
2030	231.3	19,895	43%	871	523	3,920	98%
2035	334.6	24,008	43%	1,291	774	7,270	98%
2040	478.6	29,541	46%	1,929	1,157	12,113	98%
2045	640.7	34,456	46%	2,582	1,549	19,050	98%
2050	830.7	40,557	50%	3,638	2,183	28,318	100%

ADVANCED Year	CUMULATIVE [GW]	ANNUAL GLOBAL MARKET VOLUME [MW]	CAPACITY FACTOR	PRODUCTION (TWh)	CO_2 REDUCTION (WITH 600GCO2/kWh) (ANNUAL MIOTCO2)	AVOID CO_2 REDUCTION SINCE 2007 (CUMULATIVE MIO TCO2)	PROGRESS RATIO
2007	0.41	0	30%	1	1		90%
2008	0.48	0	30%	1	1	1	90%
2009	1.4	3,500	31%	32	19	2	90%
2010	4.1	4,208	31%	46	27	42	90%
2015	29.4	6,814	45%	116	70	70	86%
2020	84.3	14,697	48%	355	213	176	89%
2025	186.9	25,202	48%	786	472	887	89%
2030	342.3	35,462	50%	1,499	900	2,672	91%
2035	549.6	45,829	50%	2,407	1,444	6,189	91%
2040	818.2	59,486	53%	3,799	2,279	12,265	91%
2045	1,144	69,211	53%	5,312	3,187	21,659	91%
2050	1,524	80,827	59%	7,878	4,727	35,724	93%
						55,250	

INVESTMENT COST (EURO KW)	ANNUAL INVESTMENT €BILLION	JOBS MANUFACTURING & INSTALLATION	JOBS O&E (JOBS/MW)	JOBS TOTAL (JOBS/MW)	CSP POWER PENETRATION OF WORLDS ELECTRICITY IN % - REFERENCE	CSP POWER PENETRATION OF WORLD'S ELECTRICITY IN % - CONSTRAINT
4,000	not available	not available	418	418	0.0	0.0
4,000	1.000	not available	481	481	0.0	0.0
4,000	2.116	5,290	1,010	6,300	0.0	0.0
3,800	2.519	6,631	1,673	8,304	0.0	0.0
3,400	1.923	5,546	4,065	9,611	0.1	0.1
3,000	2.042	6,469	7,271	13,739	0.1	0.1
2,941	1.616	5,221	10,009	15,230	0.1	0.1
2,800	1.546	4,971	12,765	17,736	0.1	0.2
2,783	1.033	3,343	14,856	18,199	0.1	0.2
2,600	0.709	2,318	16,420	18,738	0.2	0.2
2,595	0.414	1,358	17,219	18,577	0.1	0.2
2,400	0.383	1,278	18,018	19,296	0.2	0.2

INVESTMENT COST (EURO KW)	ANNUAL INVESTMENT €BILLION	JOBS MANUFACTURING & INSTALLATION	JOBS O&E (JOBS/MW)	JOBS TOTAL (JOBS/MW)	CSP POWER PENETRATION OF WORLDS ELECTRICITY IN % - REFERENCE	CSP POWER PENETRATION OF WORLD'S ELECTRICITY IN % - CONSTRAINT
4,000	not available	not available	418	418	0.0	0.0
4,000	1.000	not available	481	481	0.0	0.0
4,000	2.116	5,290	1,010	6,300	0.0	0.0
3,800	11.156	29,358	3,945	33,304	0.1	0.1
3,230	17.645	58,890	24,468	83,358	0.4	0.4
2,850	35.916	131,694	68,584	200,279	1.0	1.2
2,761	44.399	168,053	140,053	308,106	1.9	2.2
2,660	52.920	196,960	231,332	428,292	3.0	3.6
2,637	63.319	237,674	342,607	580,281	4.0	5.1
2,470	72.967	276,211	478,632	754,843	5.4	7.1
2,455	84.574	322,159	640,668	962,827	6.6	8.9
2,280	92.470	356,903	830,707	1,187,611	8.5	11.8

INVESTMENT COST (EURO KW)	ANNUAL INVESTMENT €BILLION	JOBS MANUFACTURING & INSTALLATION	JOBS O&E (JOBS/MW)	JOBS TOTAL (JOBS/MW)	CSP POWER PENETRATION OF WORLDS ELECTRICITY IN % - REFERENCE	CSP POWER PENETRATION OF WORLD'S ELECTRICITY IN % - CONSTRAINT
4,000	not available	not available	418	418	0.0	0.0
4,000	1.000	not available	481	481	0.0	0.0
3,273	13.773	42,082	11,932	54,014	0.0	0.0
3,139	15.361	48,941	16,826	65,767	0.0	0.0
3,060	20.852	60,103	29,419	89,523	0.6	0.6
2,700	39.682	125,662	84,336	209,998	1.5	1.7
2,460	61.986	215,476	186,978	402,454	3.0	3.5
2,520	89.365	287,245	342,301	629,546	5.1	6.7
2,412	110.529	371,217	549,582	920,798	7.4	9.4
2,340	139.196	455,066	818,182	1,273,248	10.6	14.0
2,269	157.071	529,466	1,144,109	1,673,575	13.5	18.3
2,160	174.585	581,951	1,524,172	2,106,123	18.3	25.6

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Greenpeace is an independent global campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment and to promote peace.

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