

SOLAR INDUSTRY REPORT 2010



Willow Rivers Wealth

Responsible Investments

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1. DID YOU KNOW

1. The total solar energy striking the earth in just one hour, or the World's deserts in 6 hours, is equivalent to the total global human energy consumption in one year.
2. 0.4% of the solar energy landing on the Sahara Desert would cover Europe's annual electricity demand, whilst 2% would cover the World's annual demand.
3. 40% of Europe's energy is consumed in residential and commercial buildings, the majority in heating and cooling and providing hot water.

2. WHY SOLAR ENERGY

- Solar Energy is free and infinite
- Solar Energy is environmentally friendly with zero emissions
- Solar Energy can be harnessed in remote locations
- Solar Energy is the only absolute long-term solution
- Solar Power creates no noise or emission pollution
- Solar Power requires little maintenance
- Solar Power systems are safe and reliable
- Solar Power is almost at cost parity with other power sources
- Solar Power is cheaper than fossil fuels in the long run



3. A HISTORY OF CLIMATE CHANGE

Following the start of the industrial revolution, in 1824 Jean-Baptiste Fourier discovered a global warming “greenhouse” effect and in 1896 Swedish and American scientists independently concluded that CO₂ was the likely cause of global warming. Nearly 90 years later in 1987 the WMO and UNEP established a scientific advisory body called the Intergovernmental Panel on Climate Change (IPCC) which issued its First Assessment Report in 1990, finding that the planet had warmed by 0.5°C in the past century and would rise further by 0.3°C per decade in the 21st century. In 2007 the IPCC released its Fourth Assessment Report, concluding with 90% confidence that human activity is causing climate change and that “Global GHG emissions due to human activities have grown since pre-industrial times with an increase of 70% between 1970 and 2004.”

In 2008 our planet was estimated to contain 385 ppm (parts per million) of CO₂ in its atmosphere, the highest concentration of CO₂ for more than 630,000 years. This is widely agreed to be due to human industrial advancement, specifically the production and consumption of power from the burning of fossil fuels that are estimated to have caused around 85% of CO₂ emissions. It is known that global temperature increase must be kept within 2°C to prevent an irreversible chain reaction of greenhouse gas release from forests, peat bogs, Siberian permafrost and oceans, which would change the planet’s ecosystems irrevocably. To ensure this temperature rise does not occur the concentration of CO₂ must not pass 450 ppm, which means reducing CO₂ emissions to 60% below 1990 levels before 2030.

Extracts taken from World Economic Forum “Green Investing 2009” and University of Copenhagen’s “Synthesis Report from Climate Change”



4. A BRIEF HISTORY OF SOLAR POWER

Since the 1980s the first solar power plants have been installed in testing facilities in the U.S.A and Spain to provide financial institutions with technical evidence for feasibility and performance.

The first commercial power plants were operational in Spain and the USA using photovoltaic and parabolic trough technology.

In **2008, 4.5 GW of photo voltaic cells were installed in Europe**, accounting for 19% of all new installed power capacity in the EU. Since the end of 2008, the first European parabolic trough plant with storage facilities has been operating successfully in Granada, Spain.

Another solar power technology is known as CSP “power tower” with a central receiver at the top of a tower receiving reflected radiation from a surrounding mirrored heliostat field. First tested in the early 80’s in several European countries, the first commercial CSP power plant of 10 MW has been operating in Seville, Spain, since mid-2007 with excellent results.



5. SOLAR POWER GENERATION TODAY

Solar energy is now widely accepted to be the only long-term solution to human energy consumption. Fossil fuels will expire and there is simply not enough wind energy or hydroelectric capacity to fulfil our forecast future global energy consumption.

A mere 2% of the total surface of the Sahara desert could supply today's entire World's energy demands.

Despite this, the extremely high upfront cost of solar power has resulted in solar power being deferred for shorter-term interim solutions such as wind power and hydropower. All governments have more recently been putting in place long-term solutions to structure finance for and financial incentives such as outlining tax breaks and feed in tariffs to encourage solar power plant development.

The world's current annual solar power production is around 15GW, and with solar energy now officially the fastest-growing renewable energy sector today it is estimated that the EU alone could achieve 30GW by 2020 according to EstelaSolar.

According to the World Economic Forum, the solar energy sector attracted US\$ 17.7bn in project financing in 2007 and investment volume grew to US\$ 50bn in 2008.



6. FORECAST SOLAR INDUSTRY GROWTH

Solar energy is now officially the fastest growing renewable energy sector in the world. Altogether the EU's solar power grid grew by 60% to 3.3 GW of new capacity in 2008 and the potential for European Mediterranean countries alone is estimated at 30 GW by the year 2020 according to Estela Report 09.

With advanced industry development and higher levels of efficiency it is believed that CSP could potentially deliver up to 7% of the World's power requirements by 2030, and **up to 830 GW - 25% of the World's power requirements - by 2050.**

The Mediterranean Solar Plan of 13 July 2008 announced an objective of 20GW of renewable energy capacity within Europe by 2020, roughly forecast to be delivered as 10-12 GW from concentrated solar power (CSP), 3-4 GW from photovoltaic technology, and 5-6 GW from wind power, according to Estela Report 09.

The Trans Mediterranean Renewable Energy Cooperation (TREC) aims to boost the generation of electricity and desalination of water by using solar thermal plants in North Africa, Europe and Middle East and transmit the power generated via HVDV transmission lines. www.desertec.com



7. PHOTOVOLTAIC MARKET GROWTH

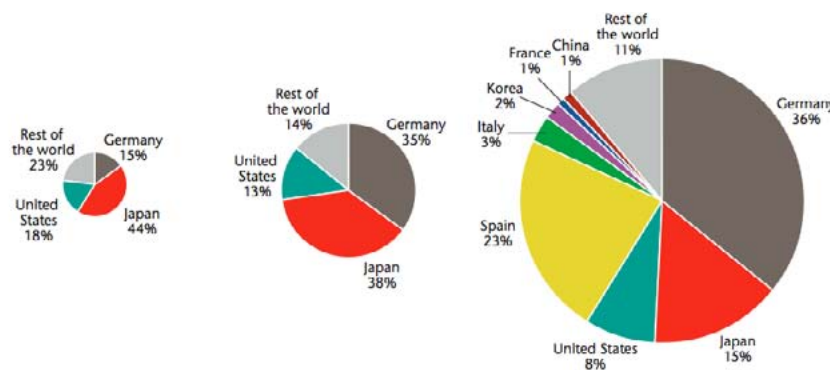
According to the EPIA 2020 Report, photovoltaic (PV) solar power accounted for about 19% of all new installed power capacity in the EU in 2008 and around 4.5GW of PV had been installed in Europe. According to the same EPIA 2020 Report, PV electricity could provide up to 12% of the EU electricity demand (1244 Twh) by 2020, which **would remove as much as 196 million tons of CO2 emissions each year.**

There are no known technological or physical limitations to PV market growth; the semi conducting material used in PV cells is silicon, the second most abundant material in the World, found in sand. Global PV market growth rate is restricted only by the cost of the poly-silicon manufacture and supply chain.

First Solar, one of the World's largest solar module manufacturers and experts in producing thin-film solar modules, has managed to drop manufacturing costs from \$1.40/watt in 2006 down to \$0.93/watt in Q1 2009. The PV industry is committed to reaching a target cost of below €10ct / kWh for industrial grid-linked systems and below €15ct / kWh for residential systems.

The World Economic Forum forecast the cost of manufactured PV cells to plummet from US\$ 4/W to US\$ 2.60/W by 2010. Following large-scale Chinese, Japanese, German and Korean investment since 2005 the number of poly-silicon producers has doubled, production has risen 500% whilst costs have fallen 70% in just the last two years.

The **historic supply-demand in-balance is now expected to end in 2010** and according to Pike Research PV cost-parity should be reached as soon as 2013 rendering PV as cost-effective as any other power source.

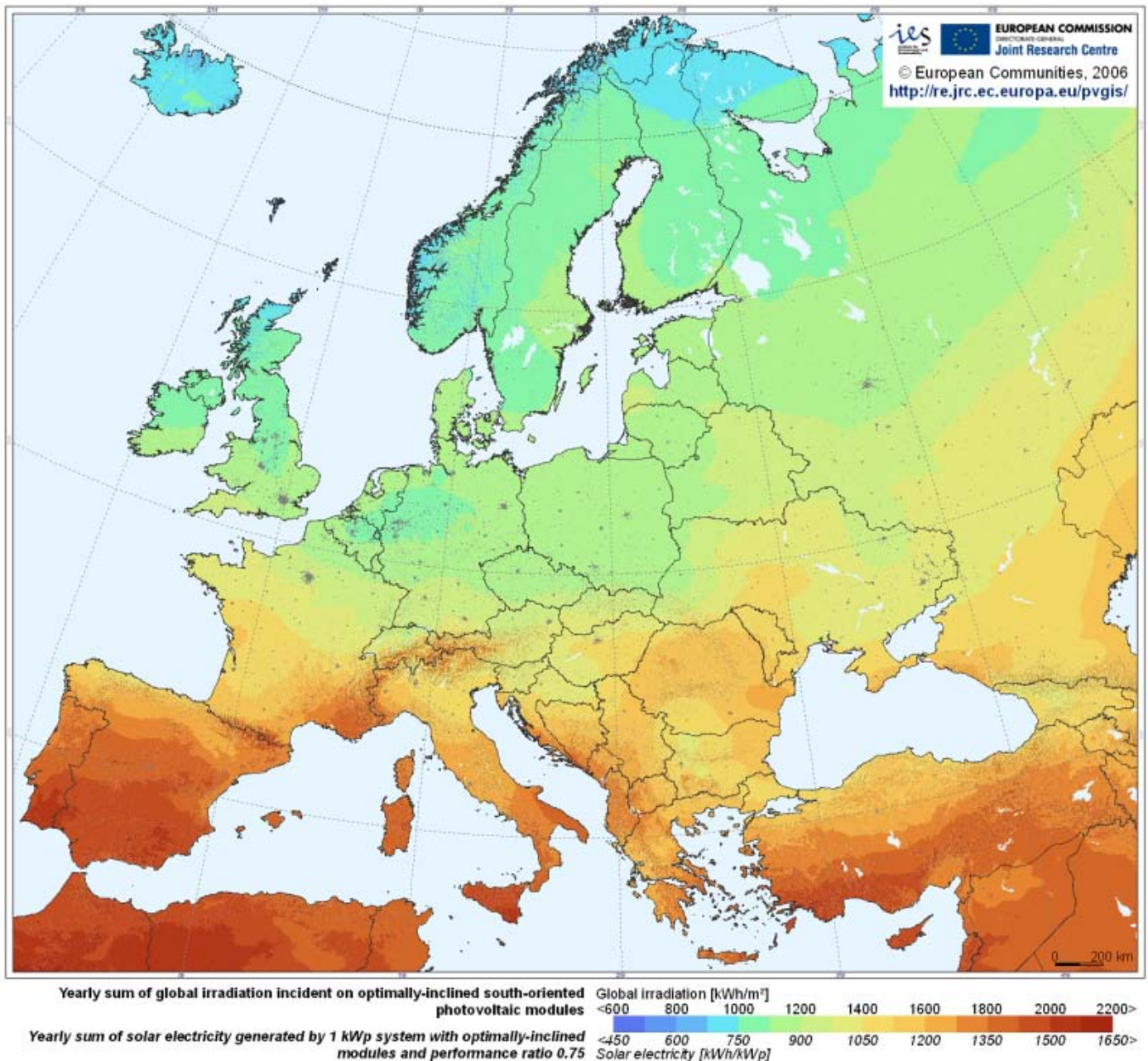


KEY POINT: A handful of countries with strong policy regimes account for 80% of global installed PV capacity; new countries have emerged as important players in the last few years.

8. EUROPE'S LEADERS

Current solar power and technology markets are led by the US, Germany and Spain. Many countries are chasing behind however these are the 3 that lead the development and the actual implementation of real systems in today's World.

Germany has Europe's biggest solar thermal market, which grew to 1.5 GW in 2008, an increase of 120% from 2007. Spain recently became the second largest European solar thermal market with growth of 58% in 2008. Over 300 MW were newly installed last year bringing the Spanish total sector capacity to 988 MW, around 30% of all Europe's solar power according to ESTIF.



9. SOLAR POWER TECHNOLOGY

Solar power is created using solar energy and with two main technological principles; “photo voltaic” (PV) and concentrated solar power” (CSP)

The main advantages of PV over CSP are smaller upfront costs, modular development and cost management control and flexible location application.

9.1. PHOTO-VOLTAIC

9.1.1. PV GENERAL

‘Photovoltaic’ is the marriage of two words, ‘photo’ from Greek roots meaning light, and ‘voltaic’ from ‘volt’ which is the unit used to measure electric potential at a given point. Photovoltaic systems use cells consisting of one or two layers of a semi-conducting material. When light shines upon the cells an electric field is created across the layers causing electricity to flow.

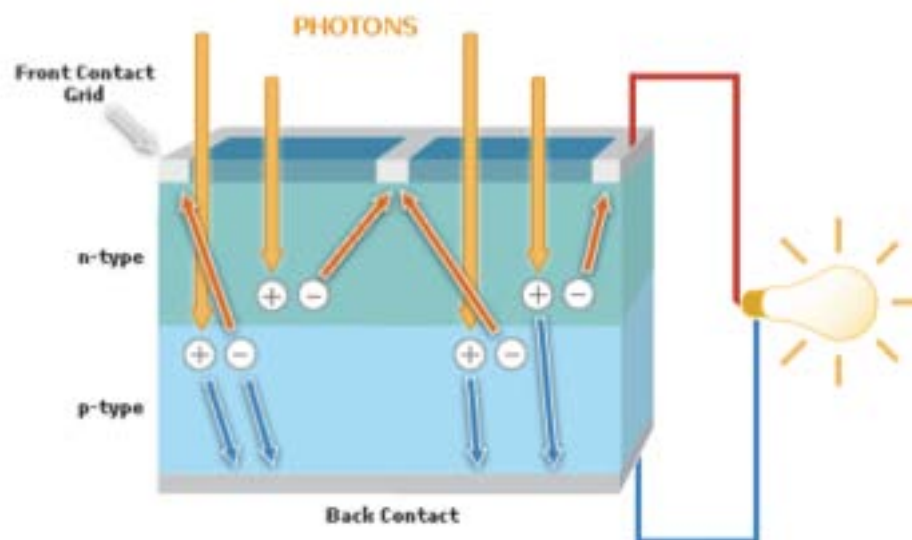


Figure 11 Photovoltaic Operating Principle

Whilst a photovoltaic system does not need bright sunlight to operate, indeed they work well on cloudy days, the greater the intensity of the light the greater the flow of electricity.

The most important parts of a PV system are the cells, the modules that bring together large numbers of cells into a single unit and the inverters used to convert the electricity generated into a suitable form for everyday use.

9.1.2. PV CELL & MODULE TECHNOLOGY

PV solar technology has been used commercially for over 30 years and in comparison with other forms of electricity production, PV solar power stations are relatively uncomplicated using simple and durable components.

PV cells typically have a life period of < 25 years and the performance of a PV cell is measured in terms of its efficiency at turning sunlight into electricity, the highest grade commercial solar cell has an efficiency of 15% (about one-sixth of the sunlight striking the cell generates electricity).

PV Cells are generally made either from crystalline silicon, sliced from ingots or castings, from grown ribbons or thin film deposited in thin layers on a low-cost backing. Photons in sunlight hit the solar panel and are absorbed by semi-conducting materials, such as silicon. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity.

PV Cells are usually connected in series in modules, creating an additive voltage, whilst connecting cells in parallel will yield a higher current. These PV Modules are then interconnected, in series or parallel, to create an array with the desired peak DC voltage and current. PV modules often have a sheet of glass on the front (sun up) side, allowing light to pass while protecting the semiconductor wafers from the elements (rain, hail, etc.).



A) CRYSTALLINE SILICON TECHNOLOGY:

Crystalline silicon cells are made from thin slices cut from a single crystal of silicon (monocrystalline) or from a block of silicon crystals (polycrystalline). Their efficiency ranges between 12% and 17%. This is the most common technology representing about 90% of the market today, with three main types of crystalline cells:

- Monocrystalline (Mono c-Si)
- Polycrystalline (or Multicrystalline) (multi c-Si)
- Ribbon sheets (ribbon-sheet c-Si)

B) THIN FILM TECHNOLOGY:

Thin film modules are constructed by depositing extremely thin layers of photosensitive materials onto a low-cost backing such as glass, stainless steel or plastic. Thin film manufacturing processes result in substantially lower efficiency rates (from 5% to 13%), however have the significant advantage of lower production costs. Four types of thin film modules (depending on the active material used) are commercially available at the moment:

- Amorphous silicon (a-Si)
- Cadmium telluride (CdTe)
- Copper Indium/gallium Diselenide/disulphide (CIS, CIGS)
- Multi junction cells (a-Si/m-Si)

C) CONCENTRATED PHOTOVOLTAIC:

Some solar cells are designed to operate with concentrated sunlight. These cells are built into concentrating collectors that use a lens to focus the sunlight onto the cells. The main idea is to use very little of the expensive semi-conducting PV material while collecting as much sunlight as possible. Better known methods include the "Fresnel Lens" and "Low Concentration" technology which uses mirrors instead of lenses. Efficiencies range from 20 to 30%.

D) FLEXIBLE CELLS:

Based on a similar production process to thin film cells, when the active material is deposited in a thin plastic, the cell can be flexible. This opens the range of applications, especially for building integration and end-consumer applications.

8.1.3 PV COSTS

Global PV market growth is restricted primarily due to PV cost that is directly related to the polysilicon supply chain. Since 2005 the number of polysilicon producers have doubled and so the shortage is expected to end in 2010. As this occurs module prices will fall, and according to the EPIA, with current technological advancements and volume installations, an 8% price decrease year-on-year can now be expected.

First Solar, one of the World's largest solar module manufacturers and experts in producing thin-film solar modules, has managed to drop manufacturing costs from \$1.40/watt in 2006 down to \$0.93/watt in Q1 2009.

The PV industry is committed to reaching a target cost of below €10ct / kWh for industrial grid-linked systems and below €15ct / kWh for residential systems. This generation cost will compete with conventional grid retail electricity prices very soon, around 2010 in southern EU states, at which point the global PV market will thrive considering its policy-backed industry.

8.1.4 PV PLANT LOCATIONS

PV plants make financial sense in locations where the country's FIT is high enough and where radiation levels are high enough (typically 1400 < 1700 kWh/m²/yr).

For precise location the ambient temperature must be carefully considered, because under high radiation and temperatures and low wind speed PV heliostats suffer functionality problems.

A location must be reasonably flat to accommodate the solar field without prohibitive expensive earth works and be close to the grid and a substation to avoid the need to build expensive electricity lines for evacuating the power.

The NELLIS solar power plant in Nevada has some 70,000 PV panels generating 14MW and the SERPA solar power plant in Portugal has 52,000 PV panels generating 11MW.

El Espartal in La Rioja by Sunstroom has been successfully connected and operative since Aug 08 and consists of 12 installations of PV technology of 100kW (total 1.2MW) each producing approx 210,000 kW per year.

Brandis in Germany, by First Solar & Juwi Holding AG, a 40MW PV plant was commissions from 2007 < 2009

Sevilla PV by Abengoa, 1.2MW, the largest single PV plant in the world produced 2.1GWh annually, enough to supply 650 houses and avoid 1800 tonnes CO₂ emissions. Running since May 2006 the operation has performed better than ever expected, using low concentration technology on 154 PV units, the plant covers 30 acres with a PV surface of 6000sqm.

8.2 CONCENTRATED SOLAR POWER (CSP)

8.2.1 CSP GENERAL

CSP systems produce heat or electricity using mirrors which track the sun (“heliostats”), reflecting and concentrating the suns radiation to a communal region where the temperatures can reach between 400 and 1000 deg C. Heat is converted immediately to electricity or alternatively stored in various medium to be released at night or on overcast days.

Linear systems such as parabolic troughs or linear fresnel systems concentrate heat locally to a linear receiver at a factor of around 100, achieving up to 550 deg C. Central receiver systems such as solar power towers or parabolic dishes use arrays of mirrors reflecting radiation to a single point, thereby achieving working temperatures towards 1000 deg C.

Due to various physical constraints, individual CSP plants are typically between 50MW and 200MW in size however larger projects up to 400MW are under planning. A suitable site for a CSP plant should receive at least 2000 kWh/sqm of direct sunlight each year, whilst the best solar resource in the World is the deserts of South Africa and Chile where sunlight provides almost 3000 kWh/sqm/yr. In these regions, 1 sq km of land could generate up to 130 GWh of solar electricity each year.

Historically one of the main issues with CSP was the need to combine it with fossil-fuel back-up, however heat storage technology is improving. Heat energy is now transferred to high-energy density substances such as molten salts, ceramics, concrete or phase-changing salt mixtures for night-time release, giving CSP full electricity grid capability.



8.2.2 CSP TYPES

A) PARABOLIC TROUGH

Parabolic trough power plants use curved troughs that reflect direct solar radiation onto a linear receiver running along the trough. As the sun moves, the troughs track the sun along one axis, typically north to south. A thermal fluid such as synthetic thermal oil is circulated within the linear receivers and is heated to approximately 400 deg C by the reflected radiation. Once heated the fluid is then pumped through a series of heat exchangers to produce superheated steam, then converted in to electrical energy in a conventional steam turbine generator.

Due to their physical size and design, troughs are modular enabling sites to be expanded as necessary. Parabolic troughs also have a very good land-use factor, a low material demand and good storage capability.



B) CENTRAL RECEIVER “POWER TOWER”

Central receiver systems use fields of mirror arrays called “heliostats” that track the sun and focus light to the top of a tower, concentrating sunlight to achieve temperatures up to 1000 deg C. A 100MW solar thermal plant utilizes approximately 50,000 heliostats. Several different heat transfer media from steam to air or molten salts have all been proven, with various efficiencies and storage capacities.

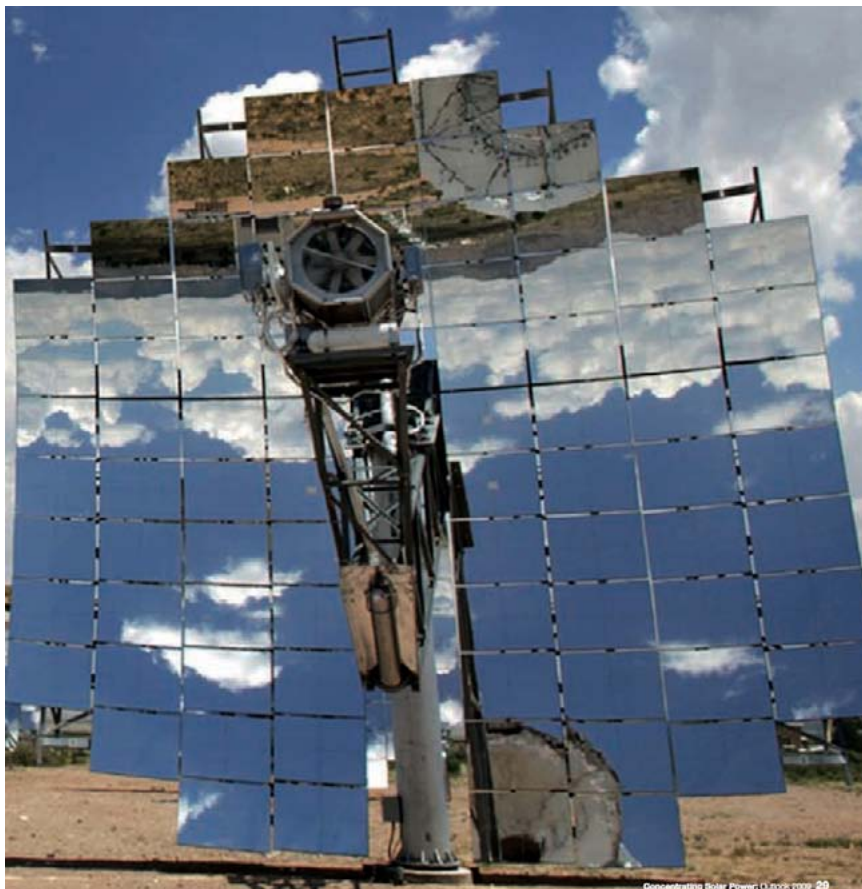


C) PARABOLIC DISH

Parabolic dish concentrators are individual motor-generator units that due to their singularity are ideal for de-centralised power supply and remote, stand-alone power systems. The leading producer of these dishes is Stirling Energy, whose SunCatcher Power Systems are 25 kW comprising of a 38ft diameter dish structure supporting 82 curved glass mirror facets, each 3 ft * 4 ft. These are the only CSP technology to use an engine rather than a steam turbine to convert heat to electricity - the power conversion unit heats tubes containing hydrogen gas and no water is used in the process. These are the most efficient heat-to-electricity conversion systems in the World at 31.25% sun-to-grid.

Parabolic dishes offer these advantages over other CSP systems;

- low unit cost and modularity reduces up front costs
- modular units enable specific plant size selection and scale-ability
- highly focussed mirrors on close object ensure much higher temperatures reached than parabolic troughs
- low water use, 100 times less than water-cooled parabolic troughs
- proven to deliver the Worlds highest solar-to-electricity conversion efficiency out of any of the solar technologies, at 31.25% sun-to-grid conversion
- small, portable, and base design enables location up to a 5 degree bank
- pollution free and no hazardous waste



8.2.3 CSP COSTS

Whilst recognised as one of the ultimate long-term solutions to the global energy and climate situation, the upfront costs involved with concentrated solar power production is the single issue preventing immediate and rapid industry growth.

High initial investment is required for new solar plants with around 80% of the overall cost being upfront construction and associated debt, with only 20% of costs from ongoing operation.

From a climate perspective, it takes only around 5 months on average to payback the energy used in manufacturing and installing a CSP power plant, and considering most solar plants last for 40 years this is a good ratio. However from an investment perspective the payback period for CSP plants can reach over 10 years depending on the technology selected. After payback of course the fuel is free and operating costs are as little as 0.03¢/kWh so profit is very high!

Over the forecast life of the plant, parabolic trough plants are forecast to be achieving average stabilized energy costs of 12-15¢/kWh in the US and < 0.23 €/kWh in Spain, whilst the potential for cost reduction is expected to lead to costs much lower. It is generally believed that solar towers will eventually produce electricity at a cost lower than that of the parabolic troughs, and that both will compete with traditional fossil fuel electricity production as soon as 2020.

A major cost implication for solar plants is also the thermal energy storage. With technology improving CSP electricity can now be supplied at any time, meaning CSP can provide base-load electricity in appropriate locations, however this is still very expensive at set-up. For indirect storage systems such as Andasol 1 they use cool tanks (290 deg C) and hot tanks (390 deg C) with 29,000 tonnes of molten salt in each tank as the storage medium, whereas in PS10 steam is stored in pressurised vessels and can provide only 30 mins < 1 hr of extra electricity.

8.2.4 CSP PLANT LOCATION

Concentrated solar power systems require a minimal radiation, so appropriate site locations are normally situated in arid to semi-arid regions. More exactly, acceptable production costs of solar electricity typically occur where radiation levels exceed at least 1700 kWh/m²/yr.

Regions such as the southwest United States, northern Mexico and Egypt have much higher radiation from 2600 < 2800 kWh/sqm/yr, whereas the best solar resource in the World is the deserts of South Africa and Chile where direct sunlight provides almost 3000 kWh/sqm/yr.

More promising sites include the north African desert, the Arabian peninsula, major portions of India, central and western Australia, northeastern Brazil, southern Spain and several Mediterranean islands.

A good site has to have a high annual beam insolation to obtain maximum solar electricity output, be reasonably flat to accommodate the solar field without prohibitive expensive earth works and be close to the grid and a substation to avoid the need to build expensive electricity lines for evacuating the power. It also needs sufficient water supply to cover the demand for cooling water of its steam cycle. The one exception to this rule is the Stirling Parabolic Dish that can handle more intrepid landscapes and also uses hydrogen rather than water.

As energy transfer losses are crucial to final power delivery, the development of regions around the Mediterranean in Europe and north Africa are focal areas for solar power developers. With Algiers, Morocco, Spain, Italy, and Turkey all receiving high radiation levels, and enormous solar energy supplies across the Sahara Desert, a network of high-voltage direct current (HVDC) lines is under planning to distribute future electric grids.

PS20 at the Sanlucar Platform in Spain, by Abengoa, is the second solar tower at the Plataforma Solar de Sanlucar la Mayor in Spain (PS10 was the first ever functioning commercial power tower). With output of 20MW, PS20 has 1255 heliostats and a tower of 160m and will provide electricity for 12,000 households.

Invanpah 1 in Nevada, by BrightSource Energy. Under planning and pending approval from California's Energy Commission, this 400 MW plant is to be built in two stages, the first 100 MW will be installed by 2010 and the other 300 MW soon after. This project will power 140,000 households and reduce CO2 emissions by over 500,000 tonnes / yr.

Andasol in Spain, by Solar Millennium, 150 MW (50 MW per plant). 624 Parabolic Trough collectors arranged in 168 parallel loops, started its test run in 2008 and is expected to supply 200,000 households and save 149,000 tonnes CO2e per annum. Andasol 2 and 3 are currently under construction. A total surface area of over 510,000 sqm (70 soccer pitches), the Andasol projects gross electricity output is estimated around 180 GWh per year.

SEGS, Kramer Junction, Mojave Desert, by Luz (Israeli/US corp). This has more than 2m sqm of Parabolic Trough mirrors and the 3 plants produce 800 < 900m kWh of electricity to the Californian grid each year.

Hassi R'mel in Algeria, by Abengoa, under planning, 150 MW ISSC (integrated solar combined cycle system) plant with 25 MWe of solar capacity from parabolic troughs

Calico (Solar 1), Mojave Desert, by Stirling Energy www.stirlingenergy.com will have a total of 34,000 SunCatcher Power Systems delivering 850MW.

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