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A Review On Power Generation Methods Using Concentrating Solar Power.

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Abstarct: *Concentrating solar power (CSP) is a renewable generation technology that uses mirrors or lenses to concentrate the sun's rays to heat a fluid, e.g., water, which produces steam to drive turbines. CSP differs from solar photovoltaic (PV) technology, which directly converts the sun's ultraviolet radiation to electricity using semiconductors. The CSP technologies discussed here are utility scale.*
Because no input fuel is required, CSP plants release little or no carbon dioxide equivalent (CO2e) emissions. CSP is a proven technology with more than 350 megawatts (MW) of installed capacity operating commercially in the Mojave desert since the 1980s and several smaller new plants brought on line since 2006. The current worldwide installed capacity is more than 500 MW, relying mostly on the established line-focusing parabolic trough technology that provides peak demand generation.
In the world where fuel prices are increasing day by day and impacts of the power generation by using fossil fuels is adversely affecting the climate its time we look out for the renewable sources. CSP which uses the ultimate source of energy-'Sun' can really strengthen our goal of 'Sustainable Development'.
Keywords: *Concentrating solar power, renewable, power.*

I. Introduction

With the advancement of science and the usage of many electronic gadgets, life becomes very difficult without electricity. Hence, ample supply of electricity that can match the power requirements of industry is the key for national progress and prosperity.

Fossil fuels are non-renewable resources because they take millions of years to form, and reserves are being depleted much faster than new ones are being formed. The production and use of fossil fuels also raise environmental concerns. Therefore, a global movement toward the generation of renewable energy is under way to help meet increased energy needs.

Energy is considered a prime agent in the generation of wealth and a significant factor in economic development. The importance of energy in economic development is recognized universally and historical data verify that there is a strong relationship between the availability of energy and economic activity.

The growing evidence of environmental problems is due to a combination of several factors since the environmental impact of human activities has grown dramatically. This is due to the increase of the world population, energy consumption and industrial activities. Achieving solutions to environmental problems that humanity faces today requires long-term potential actions for sustainable development. In this respect, renewable energy resources appear to be one of the most efficient and effective solutions.

II. What Is Csp?

2.1 Introduction

Solar power is the generation of electricity from sunlight. This can be direct as with photo-voltaic (PV), or indirect as with concentrating solar power (CSP), where the sun's energy is focused to boil water which is then used to provide power. The power gained from sun can be used to eliminate or at least cut down the need for purchased electricity (usually electricity gained from burning fossil fuels) or, if the energy harnessed from sun exceeds a home's requirements, the extra electricity can be sold back to the home's supplier of energy, typically for credit.

The advantages of solar energy are as follows

- Solar power is pollution-free during use. Production end-wastes and emissions are manageable using existing pollution controls.
- Solar electric generation is economically superior where grid connection or fuel transport is difficult, costly or impossible.

Solar power is a predictably intermittent energy source, meaning that whilst solar power is not available at all times, we can predict with a very good degree of accuracy when it will and will not be available.

Concentrating solar power (CSP) is a renewable generation technology that uses mirrors or lenses to concentrate the sun's rays to heat a fluid, e.g., water, which produces steam to drive turbines. CSP differs from solar photovoltaic (PV) technology, which directly converts the sun's ultraviolet radiation to electricity using semiconductors. The CSP technologies discussed here are utility scale.
Because no input fuel is required, CSP plants release little or no carbon dioxide equivalent (CO2e) emissions. CSP is a proven technology with more than 350 megawatts (MW) of installed capacity operating commercially in the Mojave desert since the 1980s and several smaller new plants brought on line since 2006. The current worldwide installed capacity is more than 500 MW, relying mostly on the established line-focusing parabolic trough technology that provides peak demand generation.

2.2 Concentrated Solar Power

Concentrating solar power (CSP) is a renewable generation technology that uses mirrors or lenses to concentrate the sun's rays to heat a fluid, e.g., water, which produces steam to drive turbines. CSP differs from solar photovoltaic (PV) technology, which directly converts the sun's ultraviolet radiation to electricity using semiconductors.

CSP uses renewable solar resource to generate electricity while producing very low levels of greenhouse-gas emissions. Thus, it has strong potential to be a key technology for mitigating climate change. In addition, the flexibility of CSP plants enhances energy security. Unlike solar photovoltaic (PV) technologies, CSP has an inherent capacity to store heat energy for short periods of time for later conversion to electricity. When combined with thermal storage capacity, CSP plants can continue to produce electricity even when clouds block the sun or after sundown.

While the bulk of CSP electricity will come from large, on-grid power plants, these technologies also show significant potential for supplying specialized demands such as process heat for industry, co-generation of heating, cooling and power, and water desalination. CSP also holds potential for applications such as household cooking and small-scale manufacturing that are important for the developing world.

In a nutshell, CSP power plants produce electricity by converting concentrated direct solar irradiation into energy. Table 2.1 gives an overview of some of the technical parameters of the different concentrating solar power concepts.

The process of energy conversion consists of two parts:

- □ The concentration of solar energy and converting it into usable thermal energy
- The conversion of heat into electricity

The conversion of heat into electricity is generally realized by a conventional steam turbine (Rankine cycle). Concentrating solar collectors are usually subdivided into two types, with respect to the concentration principle:

1. Line-focusing system: such as the parabolic trough collector (PTC) and linear Fresnel collector. These systems track the sun position in one dimension (one-axis-tracking),
2. Point-focusing systems: such as solar towers or solar dishes. These systems realize higher concentration ratios than line-focusing systems. Their mirrors track the sun position in two dimensions (two axis-tracking).

Table 2.1 Technical Parameters of Different CSP concepts

	Capacity unit MW	Concen-tration	Peak solar efficiency	Annual solar efficiency	Thermal cycle efficiency	Capacity factor (solar)	Land use $m^2\ MWh^{-1}\ y^{-1}$
Trough	10–200	70–80	21% (d)	10–15% (d) 17–18% (p)	30–40% ST	24% (d) 25–70% (p)	6–8
Frensel	10–200	25–100	20% (p)	9–11% (d)	30–40% ST	25–70% (p)	4–6
Power tower	10–150	300–1000	20% (d) 35% (p)	8–10% (d) 15–25% (p)	30–40% ST 45–55% CC	25–70% (p)	8–12
Dish-Stirling	0.01–0.4	1000–3000	29% (d)	16–18% (d) 18–23% (p)	30–40% Stirl. 20–30% GT	25% (p)	8–12

(d) = demonstrated; (p) = projected; ST steam turbine; GT gas turbine; CC combined cycle.

$$\text{Solar efficiency} = \frac{\text{net power generation}}{\text{incident beam radiation}} \qquad \text{Capacity factor} = \frac{\text{solar operating hours per year}}{\text{8760 hours per year}}$$

2.3 Technical Principles

2.3.1 Line Focusing Systems

Line focusing systems use a trough-like mirror and a specially coated steel absorber tube to convert sunlight into useful heat. The troughs are usually designed to track the Sun along one axis, predominantly north–south.

2.3.1.1 Parabolic Trough Collectors

Parabolic trough systems consist of parallel rows of mirrors (reflectors) curved in one dimension to focus the sun’s rays. The mirror arrays can be more than 100 m long with the curved surface 5 m to 6 m across. Stainless steel pipes (absorber tubes) with a selective coating serve as the heat collectors. The coating is designed to allow pipes to absorb high levels of solar radiation while emitting very little infra-red radiation. The pipes are insulated in an evacuated glass envelope. The reflectors and the absorber tubes move in tandem with the sun as it crosses the sky.

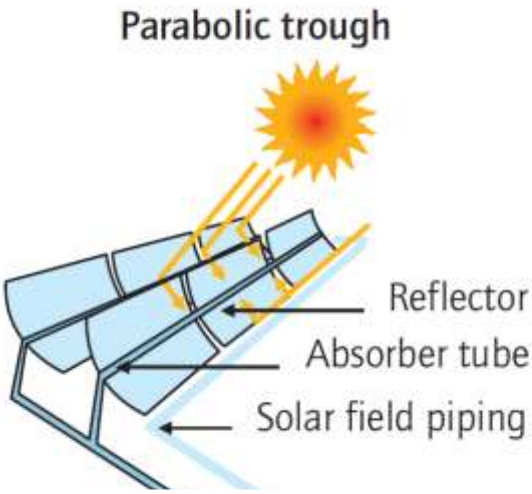

Figure 2.1 Schematic of Parabolic trough collector

All parabolic trough plants currently in commercial operation rely on synthetic oil as the fluid that transfers heat (the heat transfer fluid) from collector pipes to heat exchangers, where water is preheated, evaporated and then superheated. The superheated steam runs a turbine, which drives a generator to produce electricity. After being cooled and condensed, the water returns to the heat exchangers.

Parabolic troughs are the most mature of the CSP technologies and form the bulk of current commercial plants. Most existing plants, however, have little or no thermal storage and rely on combustible fuel as a backup to firm capacity. For example, all CSP plants in Spain derive 12% to 15% of their annual electricity generation from burning natural gas. Some newer plants have significant thermal storage capacities.

Bent mirrors and fixed receivers requires lower investment costs and facilitates direct steam generation (DSG), thereby eliminating the need for – and cost of – heat transfer fluids and heat exchangers. LFR plants are, however, less efficient than troughs in converting solar energy to electricity and it is more difficult to incorporate storage capacity into their design.

2.3.2 Point Focusing System

Point focusing system focuses the suns energy on a single point. As a result the temperature generated is more than that generated by the line focusing system.

2.3.2.1 Heliostat Field Collector

Solar towers, also known as central receiver systems (CRS), use hundreds or thousands of small reflectors (called heliostats) to concentrate the sun’s rays on a central receiver placed atop a fixed tower. Some commercial tower plants now in operation use DSG in the receiver; others use molten salts as both the heat transfer fluid and storage medium.

The concentrating power of the tower concept achieves very high temperatures, thereby increasing the efficiency at which heat is converted into electricity and reducing the cost of thermal storage. In addition, the concept is highly flexible; designers can choose from a wide variety of heliostats, receivers, transfer fluids and power blocks. Some plants have several towers that feed one power block.

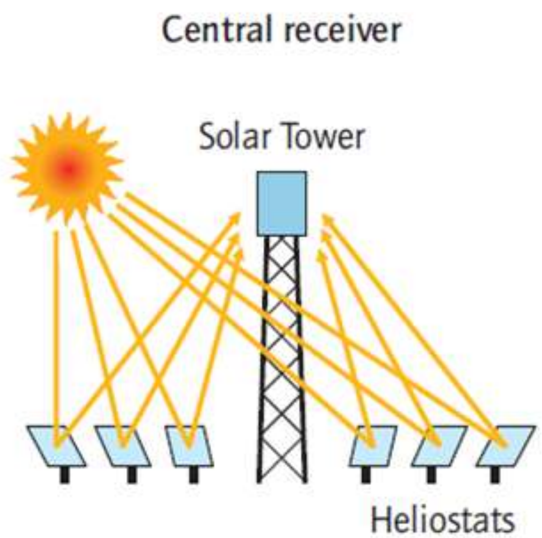

Figure 2.2 Schematic of Heliostat field collectors

III. Power Generation Methods

3.1 Power Generation Methods Using Parabolic Troughs

3.1.1 SEGS with HTF:

A solar electric generating system (SEGS), shown in Figure 3.1, refers to a class of solar energy systems that use parabolic troughs in order to produce electricity from sunlight. The parabolic troughs are long parallel rows of curved glass mirrors focusing the sun's energy on an absorber pipe located along its focal line. These collectors track the sun by rotating around a north–south axis. The heat transfer fluid (HTF), oil, is circulated through the pipes. Under normal operation the heated HTF leaves the collectors with a specified collector outlet temperature and is pumped to a central power plant area. There, the HTF is passed through several heat exchangers where its energy is transferred to the power plant's

3.1.2 SEGS with DSG:

This is the same as before except that there is not HTF and the water is heated to steam directly in the collectors. working fluid, which is water or steam. The heated steam is used in turn to drive a turbine generator to produce electricity.

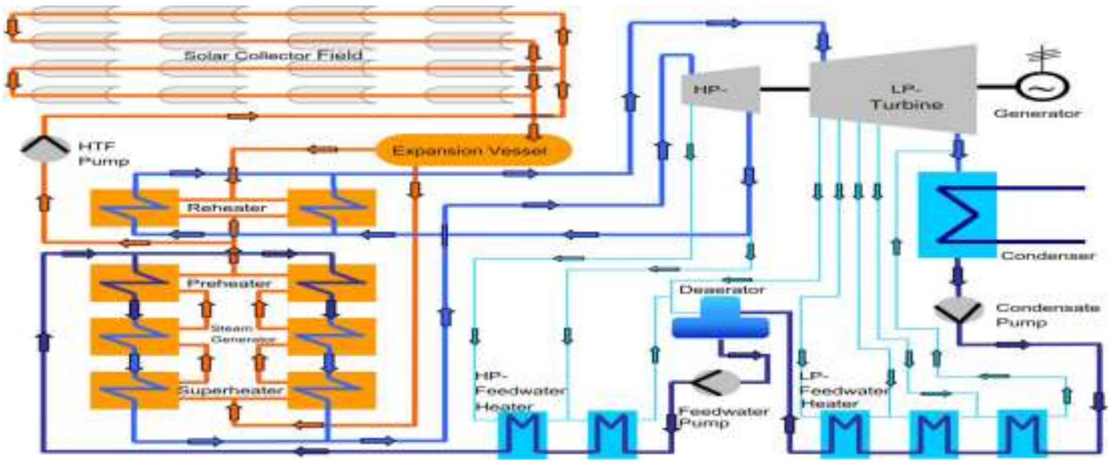

Figure 3.1 A Schematic model of SEGS using HTF

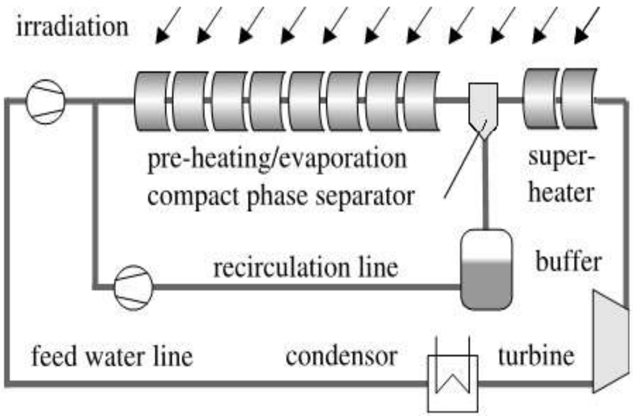

Figure 3.2 DSG operation in Recirculation mode

3.1.3 Combined Power Cycle:

As seen from the above diagram the combined cycle heats the water partly by solar energy and partly by fossil fuel. In this way the plant can run even on night or cloudy forecast when there is no sun and on normal days the running cost of the fuel will be reduced due to lesser fuel input.

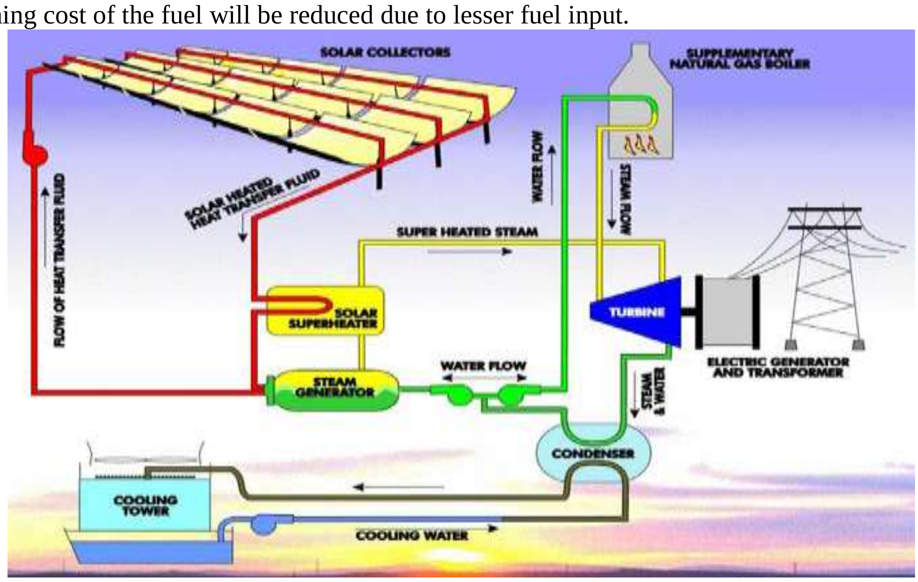

Figure 3.3 A schematic model of Combined Power Cycle

3.2 Power Generation Methods Using Solar Power Tower

3.2.1 Molten salt Power Tower

In a molten-salt solar power tower, liquid salt at 290ºC (554ºF) is pumped from a ‘cold’ storage tank through the receiver where it is heated to 565ºC (1,049ºF) and then on to a ‘hot’ tank for storage. When power is needed from the plant, hot salt is pumped to a steam generating system that produces superheated steam for a conventional Rankine cycle turbine/generator system. From the steam generator, the salt is returned to the cold tank where it is stored and eventually reheated in the receiver. Figure 3.4 is a schematic diagram of the primary flow paths in a molten-salt solar power plant. Determining the optimum storage size to meet power-dispatch requirements is an important part of the system design process. Storage tanks can be designed with sufficient capacity to power a turbine at full output for up to 13 hours.

The heliostat field that surrounds the tower is laid out to optimize the annual performance of the plant. The field and the receiver are also sized depending on the needs of the utility. In a typical installation, solar energy collection occurs at a rate that exceeds the maximum required to provide steam to the turbine. Consequently, the thermal storage system can be charged at the same time that the plant is producing power at full capacity. The ratio of the thermal power provided by the collector system (the heliostat field and receiver) to the peak thermal power required by the turbine generator is called the solar multiple. With a solar multiple of approximately 2.7, a molten-salt power tower located in the California Mojave desert can be designed for an annual capacity factor of about 65%. (Based on simulations at Sandia National Laboratories with the SOLERGY computer code.) Consequently, a power tower could potentially operate for 65% of the year without the need for a back-up fuel source. Without energy storage, solar technologies are limited to annual capacity factors near 25%.

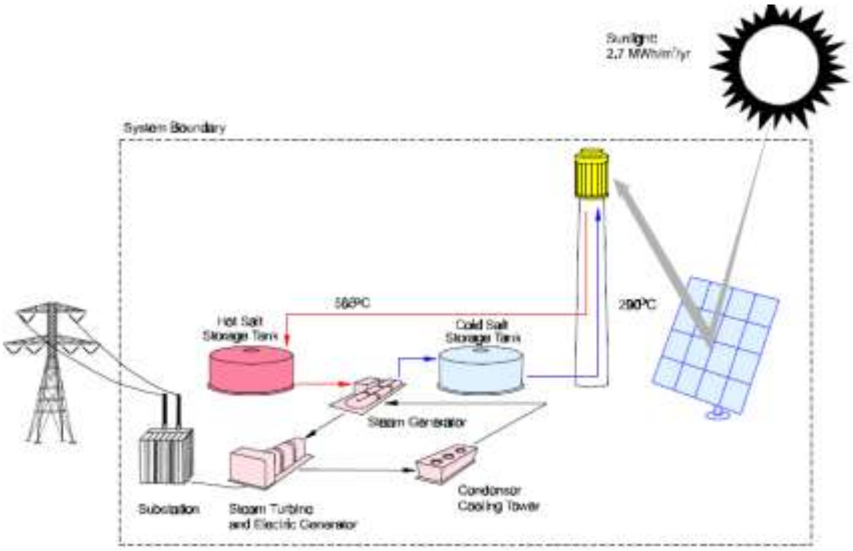

Figure 3.4 Molten-salt power tower system schematic

3.2.2 Hybrid plants

To reduce the financial risk associated with the deployment of a new power plant technology and to lower the cost of delivering solar power, initial commercial-scale (>30 MW) power towers will likely be hybridized with conventional e fossil-fired plants. Many hybridization options are possible with natural gas combined-cycle and coal-fired or oil-fired Rankine plants. One opportunity for hybrid integration with a combined cycle is depicted in Figure 3.5.

In a hybrid plant, the solar energy can be used to reduce fossil fuel usage and/or boost the power output to the steam turbine. Typical daily power output from the hypothetical "power boost" hybrid power plant is depicted in Figure 3.6. From the figure it can be seen that in a power boost hybrid plant we have, in effect,

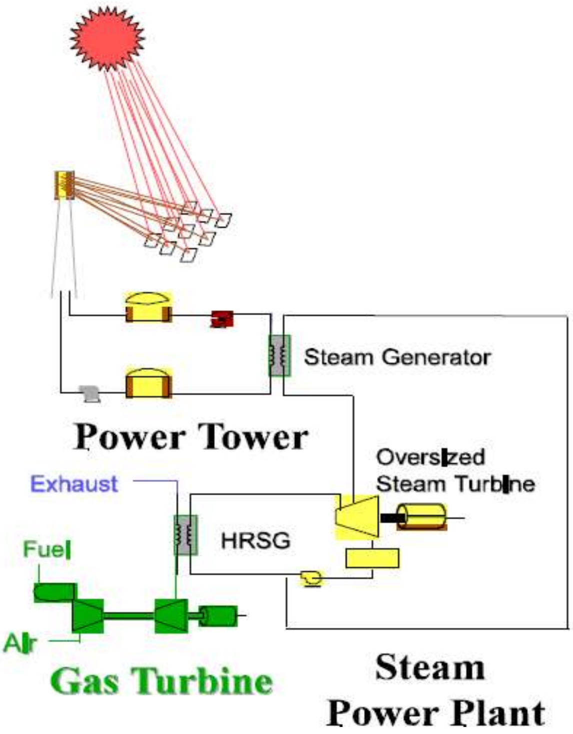

Figure 3.5 A schematic of Hybrid Plant

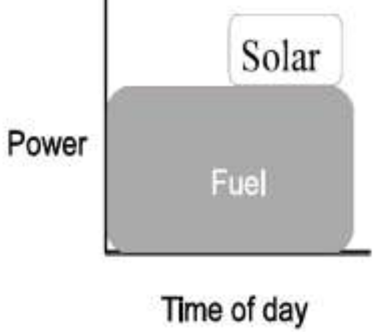

Figure 3.6 Power boost in Hybrid

"piggybacked" a solar-only plant on top of a base-loaded fossil-fueled plant.
In the power boost hybrid plant, additional electricity is produced by over sizing the steam turbine, contained within a coal-fired Rankine plant or the bottoming portion of a combined-cycle plant (Figure 3.5), so that it can operate on both full fossil and solar energy when solar is available. Studies of this concept have typically oversized the steam turbine from 25% to 50% beyond what the turbine can produce in the fossil-only mode. Over sizing beyond this range is not recommended because the thermal-to-electric conversion efficiency will degrade at the part loads associated with operating in the fuel-only mode

IV. Present Status

4.1 Csp Market

CSP market is on the point of taking off. The market is now evolving more dynamically. However, so far it is still a tiny market as there was only about 0.5 GW capacity installed globally by end-2008 (see figure 4.1) compared to most successful low-and medium- temperature solar water heating that has already reached a capacity of 145 GW thermal.

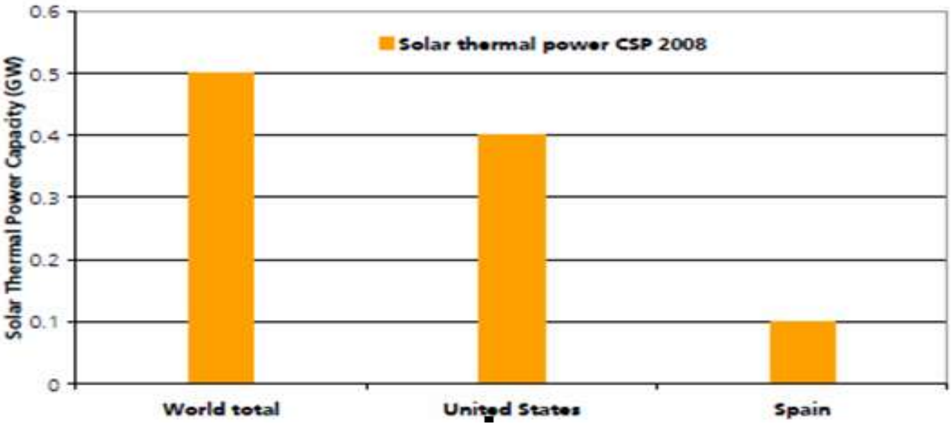

Figure 4.1 CSP capacities in 2008

Utilities are increasingly entering the project-driven market as CSP is a good way to produce large-scale electricity at peak demands times based on a renewable source. The project pipeline has increased accordingly and projects under construction will add at least 1 GW by 2011. Growth rates of around 35% p.a. for the next years could result in an installed global capacity of 20 GW by 2020 as depicted in figure 4.2.

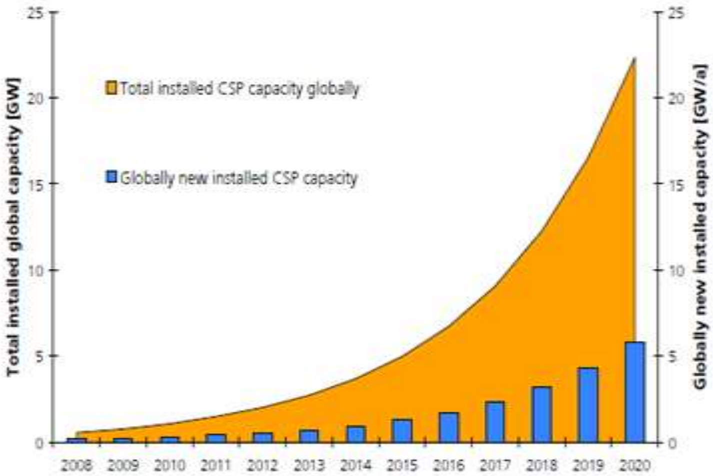

Figure 4.2 CSP growth Expectations

The CSP market is led by Spain and the US. Positive drivers for market growth are declining production costs and the more favourable political environment. In the past, the Spanish market could profit from feed in tariffs for CSP plants creating a strong growth in local installation. It is likely that in autumn 2009 the feed in tariffs for CSP will be lowered. The US is likely to be the upcoming key market given its large project pipeline, which is based on a favourable regulatory framework that includes tax incentives and the Renewable Portfolio Standard (RPS). In addition, the US profits from the existing of an abundance of favourable sites (e.g. California, Nevada, Arizona, Texas etc.).

4.2 Costs

Roughly 80% of costs stem from construction and only 20% from operations, which is not surprising as the fuel to power the plant is provided by the sun for free. CSP electricity production costs per KWh are lower than PV but belong to highest among the renewable. Thanks to technological progress, mass production of components, the scaling-up of plant size and growing market competition, we expect rapid costs reductions (See table). Minimal costs for the large-scale projects on optimal sites are at around USD 0.15/KWh. Similar costs, as for conventional power generation below USD 0.1/KWh, should be achieved in the medium term.

Table 4.1 Electricity production costs

US Cents/kWh	2009	2020-30
CSP	15-40	4-10
Wind	4-15	3-8
PV	25-80	6-25
Coal (with CCS*)	3.5-6.0	4-5.5 (6.0-8.5)
Gas (with CCS*)	4-7	5-8 (7-10)

V. Application

5.1 Introduction

A number of demonstration projects were launched under the Framework Programmes For Research, Technological Development and Demonstration of the European Union. Some of the major projects undertaken are:

- PS10: An11 MW Solar Thermal Power Plant in southern Spain.
- ANDASOL: 50 MW parabolic trough plant with thermal storage.

Both these projects aim to validate the full-scale application of different technological approaches and their viability under market conditions.

5.2 Ps10: An 11 Mw Solar Thermal Power Plant

The PS10 solar thermal power plant is located at Sanlúcar la Mayor, southern Spain. The plant – construction of which started in June 2004 –concentrates the sun’s rays onto the top of a tower 115 m high using mobile mirrors that are faced towards the sun by a control system. The solar receiver on top of the tower produces saturated steam and circulates it to a conventional steam turbine that generates the electricity. The plant should generate some 23 GWh of electricity every year. The project is worth some € 16.7 million, with an EU contribution of € 5 million.

5.2.1How it works

The PS10 features a large solar field of 624 heliostats. Each heliostat is a mobile 120 m^2 curved reflective surface mirror. The receiver on the tower – based on a cavity concept to reduce radiation and convection losses – is designed to produce saturated steam at 40 bar-250ºC from thermal energy supplied by concentrated solar radiation flux. Steam is sent to the turbine where it expands to produce mechanical work and electricity.

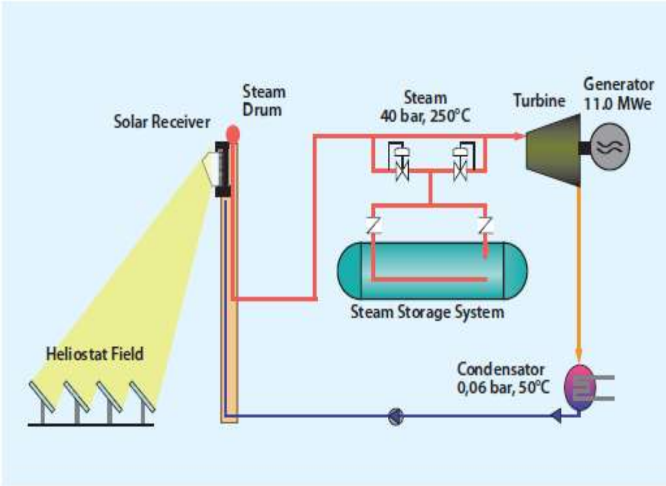

Figure 5.1 Plant Description

The receiver is basically a forced circulation radiant boiler with low ratio of steam at the panels output, in order to ensure wet inner walls in the tubes. Special steel alloys have been used for its construction so that it can operate under significant heat fluxes and possible high temperatures.

It is formed by four vertical panels of 5.40 m wide by 12 m high, each one making up an overall heat exchange surface of about 260 m2. These panels are arranged into a semi-cylinder of 7 m radius.

During operation at full load, the receiver will receive a thermal power of about 55 MW of concentrated solar radiation with peaks of 650 kW/m^2. Flux measurements are performed by a 2D array of calorimeters. Temperature is measured by a thermocouples matrix.

For cloudy periods, the plant has a saturated water thermal storage system with a thermal capacity of 20 MWh (50 at 50% load). The system is composed of four tanks that are sequentially operated in relation to their charge status. During full load operation of the plant, part of the steam produced by the receiver is used to load the thermal storage system. When energy is needed to cover a transient period, energy from saturated water is recovered at 20 bar to run the turbine at 50% partial load.

5.3 Andasol: 50 Mw Parabolic Trough Plant

The "AndaSol" solar power plant is located in the Marquesado del Zenete – a wide valley in Andalusia, Spain – converting solar energy into electricity using a parabolic trough collector and a molten-salt thermal storage system. Due to its altitude of 900-1,100 m, the AndaSol project has one of the best direct solar radiation resources in Spain.

Due to its thermal storage system, the AndaSol project will be able to meet demand for electricity after sunset. Without thermal storage, the solar resources in the Marquesado del Zenete would only allow about 2,000 annual equivalent full-load hours. The thermal storage system increases the annual equivalent full-load hours to 3,589. This is the key to reducing production costs, as it enables better performance of the power block and higher productivity of the operation and maintenance staff. The AndaSol project is worth a total € 14.3 million, with EU backing of € 5 million.

5.3.1 How it works

The fundamental principle of the AndaSol project is to convert primary solar energy into electricity using a 510,120 m^2 SKAL-ET parabolic trough solar field, a 7.5-hour reserve molten-salt thermal storage system and a 49.9 MW-capacity steam cycle. Thanks to the storage system, the AndaSol project can ensure plant capacity and dispatch power day and night.

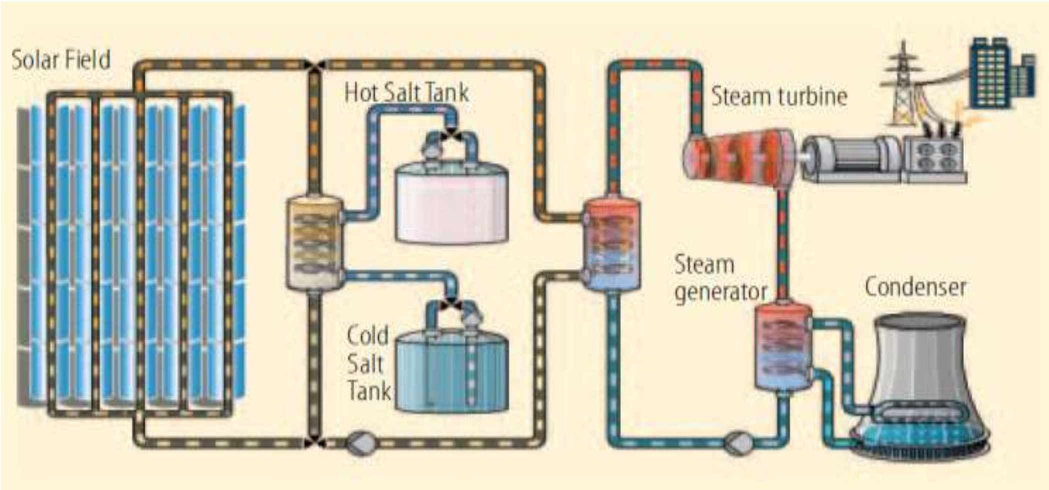

Figure 5.2 Simplified Andasol flow diagram

In the AndaSol plant, the parabolic trough collectors track the sun from east to west using a high-precision optical sensor, thus collecting the maximum solar radiation. A heat transfer fluid (HTF) flows through absorber tubes. This HTF is synthetic oil, similar to the synthetic oil used in automobile motors. Power production in the AndaSol plant varies during the day and different times of year depending on the available radiation.

During the hours of sunlight, the parabolic trough collectors in the solar field concentrate the radiation on the absorber tubes, heating the HTF. The energy contained in this HTF can be pumped directly to the steam generator or it can be pumped to a thermal storage system where it is stored for later use. At midday when the sun is high in the sky, electricity can be generated and the storage system charged at the same time: for this the heat from the HTF is transferred to the thermal storage medium, a molten-salt fluid, which collects the heat while the salt goes from a cold tank to a hot tank, where it accumulates until it is completely full.

In other words, to charge storage, the salt is heated. On discharging, it is cooled down again. During this process, the salt is liquid. The cold and hot salts are kept in separate tanks, so it is called a two-tank system. With this storage, the AndaSol plant can produce solar electricity even when there is no sunshine, to dispatch the power demand at any time and ensure the rated power capacity.

As the day advances and the intensity of the solar radiation drops in the afternoon, heat is no longer sent to the storage system but employed entirely to produce electricity. After the sun sets, the solar field stops working and the storage system begins to discharge. The heat is recovered from the hot salt tank through the thermal oil to keep up electricity production during the night.

To avoid deviation from scheduled production during cloudy periods, and to avoid solidification of the HTF and storage salt when electricity generation is interrupted, the plant has auxiliary gas heaters for hybridization. The AndaSol projects occupy a total area of around 200 hectares.

VI. Future Scope

6.1 Introduction

Technology advances are under development that will enable CSP to boost electricity production and reduce costs, notably through higher temperatures that bring greater efficiency. Other technologies now under development will enable the production of liquid or gaseous fuels by concentrating solar energy. With concerted effort, these milestones can be achieved in the next two to five years. Table 3 summarises the main features of different CSP technologies and their outlook for improvements.

Table6.1 Milestone for technological development

1.	Demonstrate direct steam generation (DSG) in parabolic trough plants	2015 - 2020
2.	Large-scale solar tower with molten salts as heat transfer fluids and storage	2010 - 2015
3.	Mass-produced parabolic dishes with Stirling engines	2010 - 2015
4.	Demonstrate three-step thermal storage for DSG solar plants	2015 - 2020
5.	Demonstrate solar tower with supercritical steam cycle	2020 - 2030
6.	Demonstrate solar tower with air receiver and gas turbine	2020 - 2030

VII. Conclusions

Solar technology has made huge technological and cost improvements, but more research and development remains to be done to make it cost-competitive with fossil fuels. Costs can be reduced by increasing demand for this technology worldwide, as well as through improved component design and advanced systems. Concentrating solar power technologies currently offer the lowest-cost solar electricity for large-scale power generation (10 MW-electric and above). New innovative hybrid systems that combine large concentrating solar power plants with conventional natural gas combined cycle or coal plants can further reduce costs.

Advancements in the technology and the use of low-cost thermal storage will allow future concentrating solar power plants to operate for more hours during the day and shift solar power generation to evening hoursThe goal is to further develop the technology to increase acceptance of the systems and help the systems penetrate growing domestic and international energy markets.

Developing countries in Asia, Africa, and Latin America—where half the population is currently without electricity and sunlight is usually abundant—represent the biggest and fastest growing market for power producing technologies. One key competitive advantage of concentrating solar energy systems is their close resemblance to most power plants. Concentrating solar power technologies use many of the same technologies and equipment used by conventional power plants; they simply substitute the concentrating power of the sun for the combustion of fossil fuels to provide the energy for conversion into electricity. Use of these technologies in these countries can effectively bring down the CO2 levels world over and also provide these countries good technique of sustainable development.

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