STUDY ON CSP AND IT'S POSSIBILITY IN BANGLADESH

A Thesis submitted in partial fulfillment of the requirements for the

award of Degree of

Bachelor of Science in Electrical and Electronic Engineering

by

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DECEMBER 2019

Certification

This is to certify that this thesis entitled "**STUDY ON CSP AND IT'S POSSIBILITY IN BANGLADESH**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on
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List of Abbreviations

CSP	Concentrating Solar Power
PV	Photovoltaic
PTSC	Parabolic Through Solar Collector
PTC	Parabolic Trough Collector
CSTES	Concentrating Solar Thermal Electric System
PSTG	Parabolic Solar Thermal Generation
HTF	Heat Transfer Fluid
DNI	Direct Normal Irradiance
SCA	Solar Collector Assembly
SCF	Sola Collector Field
ISCCS	Integrated Solar Combined Cycle System
PDR	Parabolic Dish Reflector
PDS	Parabolic Dish System
GW	Giga Watt
CPV	Concentrator Photovoltaics
TES	Thermal Energy Storage
FIT	Feed-In-Tariffs
SHS	Solar Home System

ACKNOWLEDGEMENT

First of all, we give thanks to Allah. Then we would like to take this opportunity to express our appreciation and gratitude to our project and thesis to **Dr. Md. Shahid Ullah, Professor and Head** of the **Department of EEE** for being dedicated to supporting, motivating and guiding us through this project. This project can't be done without his useful advice and helps. Also thank you very much for giving us the opportunity to choose this project.

We also want to convey thankfulness to our Co-Supervisor **Md. Mahabub-Ud-Jaman, Lecturer** the **Department of EEE** for his help, support and constant encouragement.

Apart from that, we would like to thank our entire friends for sharing knowledge; information and helping us in making this project a success. Also thanks for lending us some tools and equipment.

To our beloved family, we want to give them our deepest love and gratitude for being very supportive and also for their inspiration and encouragement during our studies at this University.

ABSTRACT

Solar power (CSP) is an exciting energy generation technology that concentrates solar radiation to produce high temperatures in a solar power plant to generate steam. In this process, no fossil fuel is used; therefore, no greenhouse gas is released. This study explores Bangladesh's average yearly sunlight period and was compared to other developing countries, such as Germany and Spain, prominent for their growth in the field of renewable energy. Suitable locations are recommended for solar plants based on optimum efficiency variables such as sunlight hours, obtained sunshine radiation, form of plane etc. Possible solar technologies such as solar concentration (CSP) have been mentioned with their optimal power, performance, storage installation and unit cost. The analysis is based on the annual direct normal irradiation (DNI) results. Suitable locations are recommended for solar plants based on optimum efficiency variables such as sunlight hours, obtained sunshine radiation, form of the plane etc. Possible solar technologies such as solar concentration (CSP) have been mentioned with their optimal power, performance, storage installation and unit cost. The analysis is based on the annual direct normal irradiation (DNI) results. The area needed for the generation of 100MWe of electricity with an average annual DNI of 2,000kWh/m^2 is about 2km^2. The average annual DNI in Bangladesh is almost 1900 kWh/m^2 that are enough to run the CSP plant. As fuel costs are absent in CSP, the energy crisis in Bangladesh may be an attractive choice. This paper focuses on the possibility of CSP use in Bangladesh. The area needed for the generation of a 100MWe of electricity with an average annual DNI of 2,000kWh/m^2 is about 2km^2. The average annual DNI in Bangladesh is almost 1900 kWh/m^2 that are enough to run the CSP plant. As fuel costs are absent in CSP, the energy crisis in Bangladesh may be an attractive choice. This paper focuses on the possibility of CSP use in Bangladesh. [1] [2]

Key words: Solar Energy, Concentrating Solar Power (CSP), Solar radiation, Direct Normal Irradiance (DNI), Solar radiation atlas, Solar Power Tower, Parabolic Trough.

CHAPTER 1

1.1. Introduction

We get a significant amount of energy from the sun. Per day we receive about 1,300 watts of power per hour per meter in the Earth's outer atmosphere. Roughly 30% of this power is reflected back, resulting in a remarkable 4.2 kilowatt-hours of energy per meter per day. It can be further assumed with accuracy for each square meter absorbs the estimated energy equivalent of approximately a barrel of oil annually. The amount of solar energy reaching the planet's ground is so significant that it will be about twice as much in a year as all the Earth's non-renewable coal, oil, natural gas, and uranium reserves. Combined deserts with lower cloud cover get approximately 50% more energy per square meter and higher sunshine hours do have equatorial regions. As a result, solar power can also be harnessed at different levels based on the geographic location of the regions. The squandering use of fossil fuel has caused massive climate change through the greenhouse effect and caused large-scale ozone contamination. The shortage of non-renewable energy resources and the need to minimize several of the CO_2 emissions have forced the world to move towards the production of electricity by green energy. Green energy refers to environmentally sustainable and un-polluting sources of hydro, wind, geothermal and solar energy. The most profuse and easy sources of renewable energy are photovoltaic (PV) and Concentrating Solar Power (CSP) technology. CSP has now become popular in recent years following a stagnation period of 15 years until the 1990s. California will generate 20% of its total energy in 2010 using green solar technology and 33% in 2020. [3] Renewable energy currently produces a total of 559.80MW of electricity, of which the government of Bangladesh has already included CSP in the 2009 Renewable Energy Strategy with a whopping 325.82MW or 52.8% [4]. Since CSP would soon become less costly than PV factor 3, installing large-scale CSP plants would be easier to harness solar energy to ease Bangladesh's current and future power crisis.

1.2. Objectives

i) To study the CSP technology

ii) To observe the condition of CSP plants all over the world

iii) To know the possibility of implementation of CSP plant in Bangladesh

1.3. Methodology

Through this technology firstly the water is heated from the solar power and then the hot water is go through the molten salt tank to heat store then the cold water is go through the solar super heater, later the water is turn into steam through solar preheater and steam generator. And then the steam go through the turbine and run the turbine with the pressure of steam after that the turbine also run the generator and lastly the electricity is generated by the generator.

We can learn the whole mechanism through this diagram-

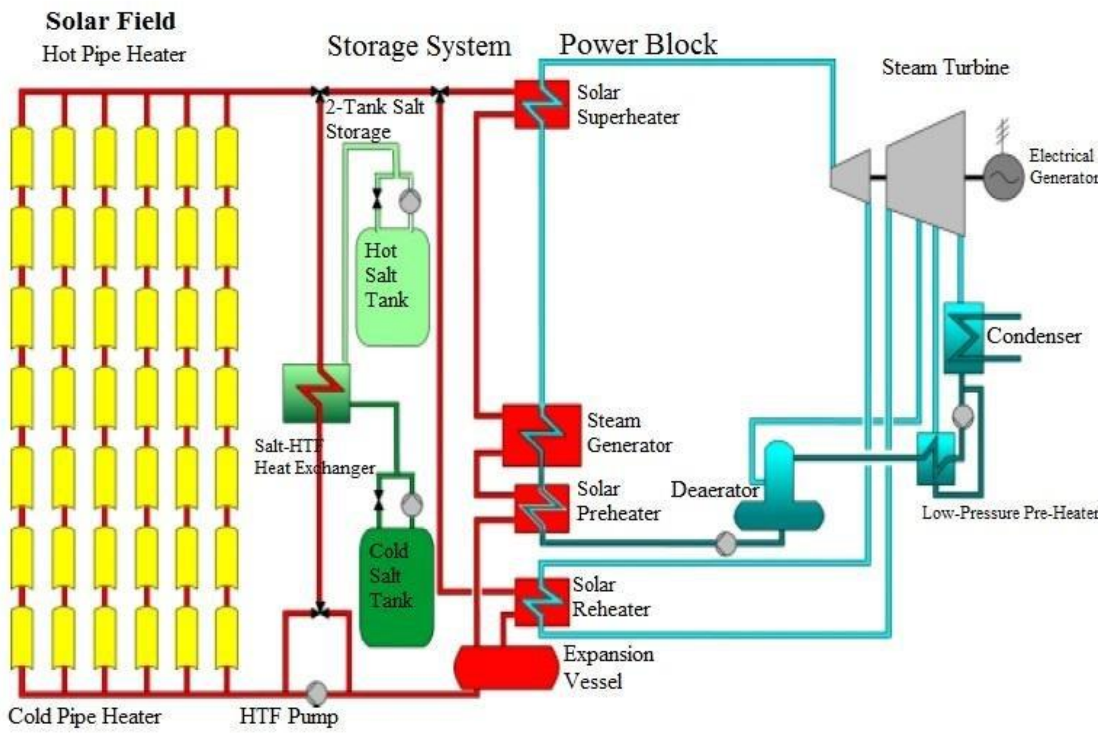


Fig. 1.1. The methodology of CSP plant to generate electricity.

1.4. Literature Review

Over the past 19 years, the study has centered on Middle East countries to integrate and work on the concentration of solar collector systems for various applications [5].

Analyzed the Parabolic Trough Solar Collector's (PTSC) efficiency, this collector's results were fair as it is the first attempt to create these collected and analyzed locally in the Iraq region. The theoretical viability of using PTSC contributes to solar irradiance of about 400-500 W/m^2 of thermal energy at concentrations up to 150^0C.A. Soteris Kalogirou 2004. [6].

An overview of the different models of solar thermal collectors covering flat-plate, parabolic compound, evacuated tube, parabolic trough, Fresnel lens, collectors and applications of the parabolic dish and heliostat sector.

Depending on the similarities of each type with either the different types of heating and cooling space, industrial heating, ventilation, steam generation and desalination of water. The study found that solar power can cover a range of implementations for energy generation and can cover the diverse horizon of future global energy generation. [7].

In 2007, Dr. Franz Trieb addressed the use of Concentrating Solar Thermal Power (CSP) plants for electrical or hybrid seawater desalination. The project's goal of solving the Middle East water shortage issue is a rather easy approach; the result encourages the prospect by using alternative energy is available. A. Mokhtari etal.

Investigation of the 250 KW solar power plants in Shiraz, 2007[8]. The power plant consisting of the oil and vapor cycle process. The oil cycle requires 48 parabolic trough reservoirs, and through the collector parabolic trough method, the article focuses on the efficiency of hot oil production. Through researching optical failures and optical consistency of parabolic trough collectors (PTC), the results will be achieved in enhancing optical performance and ensuring the required quality in solar power plantsMohammed S. Al-Soud, Eyad S. Hrayshat, proposed a prototype of a 50 MW CSPP for electricity generation in Jordan during 2008. [9]

The positive potential of using the CSPP was found after analyzing the solar irradiation data, particularly in Jordan's southern area such as Quweira. In 2009, Haitham Adas et al conducted research in Israel and Jordan on the price-effective, sustainable and feasible technical solution for the use of medium-sized solar energy in solar desalinization implementations (500 – 50 000 m^3/d). During the study, three suitable locations are selected for the future pilot scheme in Israel and Jordan in view of the temperature, irradiation and water conditions.

Yasemin USTA, 2010, conducted an investigation into the theoretical output of a Concentrating Solar Thermal Electric System (CSTES) using a Parabolic Trough Collector (PTC) sector [10]. The monthly energy output of the California and Antalya network was measured in terms of both monthly performance quality and absolute monthly output.

Antalya's system is found to generate 30% less energy per year than California's system. The ratio of Antalya's minimum (December) to the average (July) monthly resources was (0.04). Over the course of the year, findings showed an increase in thermal storage and gone up and down. The maximum energy stored was obtained in August with an improvement of about 56.1 percent to the standard goal, 58.6% to black painting, 62.23% to reflector alone and 64.69 percent to the black target together with reflector, compared to the energy stored in March. K performed the analyzed tests at the Shiraz pilot solar thermal power station. Azizian, the initial solar power plant in Iran to be built near Shiraz Town in 2011[11]. Three states were tested, painting with a specific black color the central target, fixing a reflector with the arc from behind the target, and using these two modifications together. Fareed, in Iran. M designed and built a 250 kW pilot solar power plant using the Solar Dish Concentration Parabolic Trough Collectors. Stirling motor, galvanized steel metal was used to produce the platter with a diameter (1.6) meters for solar energy application and the inner layer was coated with a reflective coating up to (76 percent) and fitted with a CenterPoint receiver. Temperature and solar power measurements were made.

Temperature calculation Martin Haagen 2012 assessed the capacity for solar heat production in the Middle East and North Africa with linear Fresnel collectors for government and private sectors[12].

The study discussed the parallel position of solar power plants in this area with Iran's various projects. In a Stirling cycle, Mohammad Hossein Ahmadi and Hadi Hosseinzade, 2012, we researched the performance of a solar-powered heat engine running [13]. In addition, the effect of design parameters on the solar receiver's optimum temperature and overall efficiency was considered. The study also showed that the effect of solar collector design parameters such as total heat failure coefficient, concentration ratio, and heat engine parameter on Stirling solar power systems ' overall efficiency. The study also showed that the effect of solar collector design parameters such as total heat loss coefficient, concentrating ratio, and heat engine parameter on Stirling solar energy systems ' overall efficiency. In addition, the concentration rate was lowered by increasing the overall heat loss coefficient slope of the output reduction of the device due to the fact that they didn't consider using the flat surface solar collector. M. Hossein Mehrabanjahromi conducted an investigation in the Linearly polarized Solar Thermal Generation (PSTG) to improve the management techniques of solar thermal generation. Andal 2013 [14].

Following an investigation after PSTG modeling, a hybrid control system was proposed and used with real data in PSTG, and results were collected through this process for different working days[15].

The study found an overall optical performance of 73.5 percent in Dhahran, whereas the minimum optical efficiency was 61 percent. This research also disclosed the approximate cost per unit aperture area of a PTC field is reduced by about 46 percent and 48 percent of 10 hectares, and the specific cost of various mechanical works is about 72 percent and 75 percent of 160 hectares, compared to 2,8 hectares. As the solar field scale rises, the cost ratio of the PTC to the domain of the solar field has been found to decrease significantly. This decrease was very substantial until the scale of the solar field reached 60 hectares and then the slope of the decrease was marginal. Consequently, a solar field size of 60 hectares or more has been proposed.

Baha's T. Chiad etal 2014 [16]. Performed an increase in efficiency conditions of the Concentrating Parabolic Trough Solar Collector (PTSC), experimental experiments were conducted in climatic conditions in Baghdad (33.3N, 44.4E) during different days of the month of October.

PTSC performance was assessed using advanced outdoor processing, including good heat gain, immediate thermal capacity, and storage tank energy retained. Through drawing, the temperature of the storage tank water rose from 9:30 a.m. to 94 a.m. at 13:30 a.m. The experimental test showed that 50 percent of a local PTSC's average thermal efficiency was relatively fair results. Ghanim Kadhim Abdul Sada, Afreen Emad Saad-Alden, 2015, used a concentrated solar dish to investigate a steam generator using solar energy. [17].The results of this experimental action over a short period of time gave a good indication of solar steam output in Iraq.

1.5. Outline of the thesis

This thesis is described as follows

Chapter 2 is basically about the types of solar energy and the all types of technology of the CSP plant.

Chapter 3 is about the global scenario of all over the world, also the condition of CSP power plants.

Chapter 4 is about the possibility of implementation of CSP plant in Bangladesh.

Chapter 5 is the proposal of implementation a CSP plant in Bangladesh.

Chapter 2

2.1. Solar Energy

Solar energy is radiant light and heat from the Sun that is exploited using a variety of ever-evolving technologies such as solar heating, solar cells, solar thermal energy, solar technology, molten salt power plants and artificial photosynthesis.[18] [19]
It is an important source of renewable energy and its technologies are usually characterized as either passive solar or active solar depending on how solar energy is harvested and processed or turned into solar energy
Effective solar methods include the use of photovoltaic devices, concentrated solar energy and solar water heating to use electricity.
Passive solar strategies include the orientation of a building towards the Sun, the selection of materials with desirable thermal mass or light-dispersing properties and the construction of spaces that disperse air naturally.

2.2. Kinds of Solar Energy

There are two kinds of solar energy.

1. Electricity Production (Photovoltaic or PV Technology)
2. Water Heating (Solar Thermal or Flat Plate Technology).

2.2.1. Technology Outline (CSP)

Take the natural heat from the Sun and reflect it against a mirror concentrate all that heat on one place and send it through a power system and have a clean way to generate energy called solar power concentration or CSP. CSP is used for electricity generation (sometimes referred to as solar thermoelectricity produced by steam). Concentrated solar power systems use mirrors or lenses with monitoring systems to focus on a wide area of sunlight onto a small area. The concentrated light is then used in a conventional energy plant (solar thermoelectricity) as heat or as a source of heat.

In CSP technology, suns direct normal irradiation based on HTF, which then flows through heat exchangers to produce superheated steam. In a typical steam turbine, this steam is converted into electrical energy. A portion of heat is also retained in some liquid or solid media such as molten salt, preserve for use at night or during periods when there is no sunlight thus continuing turbine operation. [20]

2.3. Types of solar thermal CSP plant

There are several CSP techniques, but generating is the same as their basic principle. The CSP is split into two schemes-

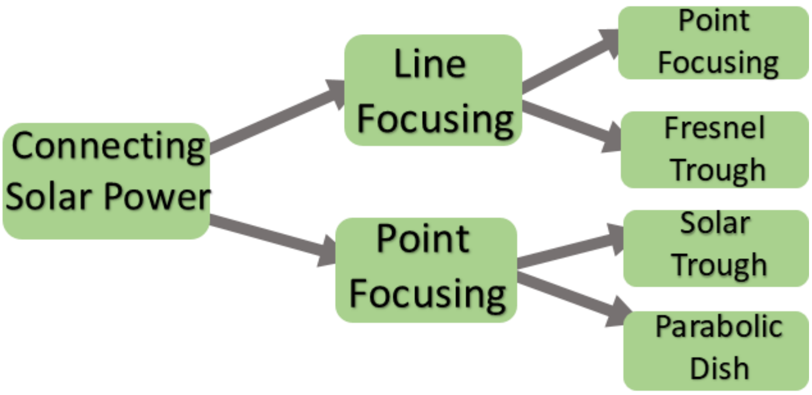


Fig. 2.1 Kinds of the CSP plants

There are four optical types of concentrating technologies, including parabolic troughs, panels, linear Fresnel concentration reflectors, and solar power towers. [21] Using linear focusing system and solar power tower to concentrate linear Fresnel reflector and parabolic trough, and use point focusing system for Dish stirling.

2.4. Description of technology

2.4.1. Line Focusing

Solar dish is a point-focusing device that concentrates direct solar radiation on a receiver using curved sun-tracking mirrors. It is appropriate for stand-alone systems, utility-scale projects, off-grid, and small grids, and in isolated areas and islands can play a major role within the province.

2.4.1.a. Parabolic Trough

This design uses parabolic trough-shaped mirrors to concentrate the DNI incident on a receiver tube mounted at the trough's focal line. Solar collector area, conventional electricity generation unit (steam rankine cycle or combined cycle) and thermal storage (optional) are the basic components of the parabolic trough power plant.

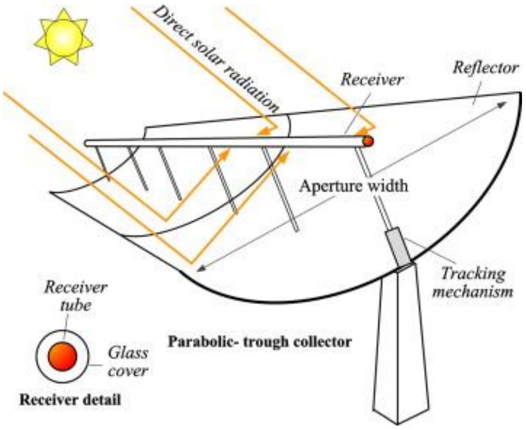


Fig. 2.2 Parabilic Trough

Fig. 2.2 The reflector consists of a 0.85 mm thick silver-coated mirror on the back layer and a 4 mm high transmittance glass on top of it, achieving an overall reflectivity of approximately 93.5% [22]. The receiver tube consists of a 70 mm diameter stainless steel tube with a high heat absorption coating enclosed by a 115 mm diameter vacuum glass tube with an anti-reflective coating[23]. The tube circulates a heat transfer fluid (HTF), such as synthetic thermal oil, which the concentrated solar energy heats up to 400^0 C [24].

The building containing the mirrors and recipients is called the frame of the concentrator. Growing SCA is fitted with a local control system that automatically rotates the concentrator structure using a drive motor to track the sun from dawn to dusk in order to effectively collect the DNI. The solar collector field (SCF) of the parabolic trough power plant is formed by multiple SCAs aligned in parallel rows on north-south axis.

The HTF in the receiver tube heated by the concentrated solar energy is circulated to the steam power plant on sunny days where the HTF preheats the water, produces steam in the steam generator and also overheats the steam. The cooled HTF is circulated back to the SCF after discharging heat in the power plant to be heated again, thus completing the cycle. The machine can be fitted with the optional storage system to continue producing electricity at night or in cloudy days. The most famous' two-tank molten salt storage system' is a hot tank, cold tank and heat exchanger. A part of the heated HTF is moved to the heat exchanger during the day. Cold molten salt pumped from the cold tank is deposited in the hot tank and receives thermal energy from the HTF in the heat exchanger. The above-mentioned storage process is reversed at night or in cloudy days; the hot molten salt returns its thermal energy to the cold HTF that is then used for steam generation. Using the thermal storage system[25], an annual capacity factor of 70% or higher can be obtained. One big advantage of these trough systems is that it is possible to store the heated fluid and use it later to keep making energy when the Sun is not shining sunny skies and hot temperatures that make the Southwest an ideal place for such power plants. Most concentrated solar power plants will produce 250 megawatts or more, which is enough to power about 90,000 households, which is a lot of electricity. The solar thermal power plant can be hybridized with a fossil fuel backup system to supply the peak load in sunny days or to maintain service in cloudy days. Instead of the steam Rankine cycle, the combined cycle can also be used where the gas turbine flue gas preheats or overheats the steam produced by the Rankine bottom cycle. The Integrated Solar Combined Cycle System (ISCCS) is called this thermal-efficient power station. [26].

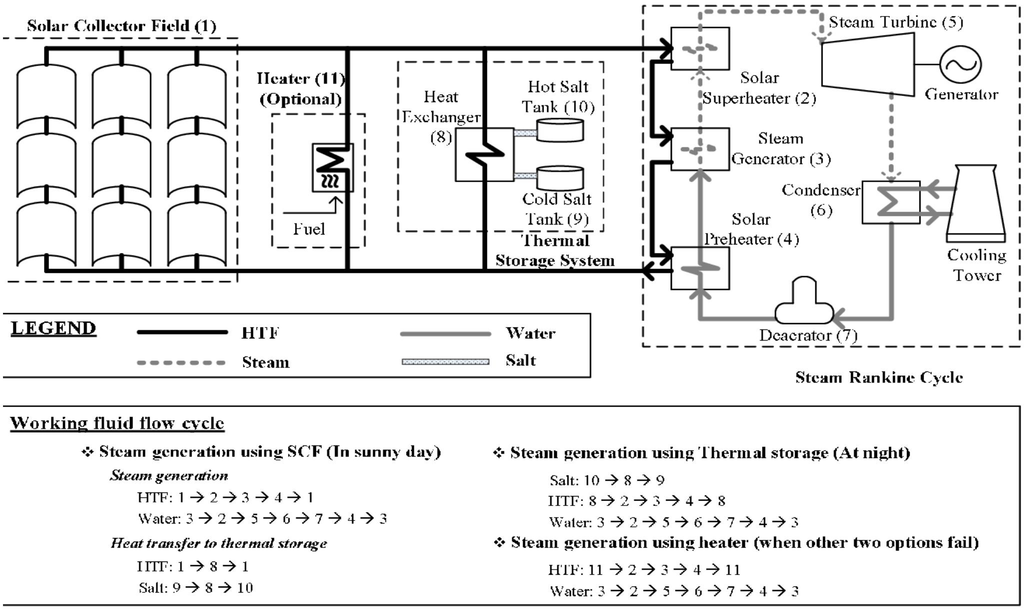


Fig. 2.3 To generate electricity through parabolic trough.

2.4.1.b. Linear Fresnel Reflector

The Fresnel linear reflector technology got its name from the Fresnel lens, which has many refracting planes designed to improve the focus of light from many different angles on a single point or line. This lens was developed in the 18th century by Augustin-Jean Fresnel and allows for a substantial reduction in the lens ' thickness, volume and weight, but also reduces the image quality.

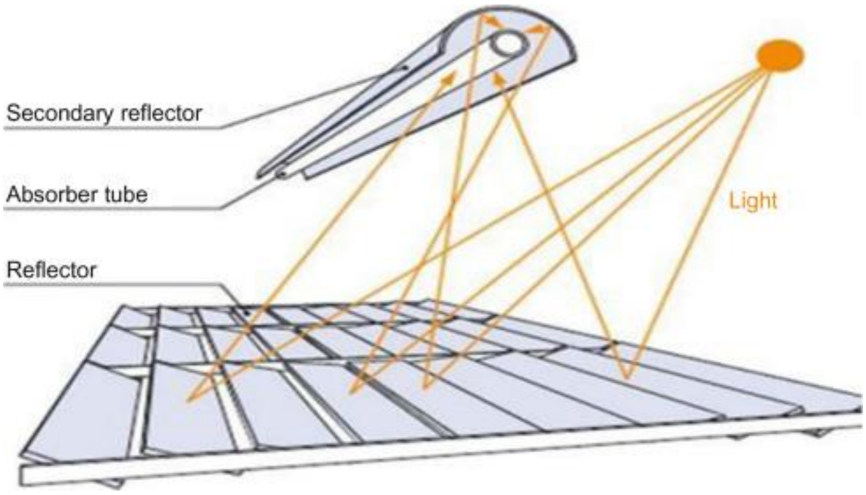


Fig.2.4 Linear Fresnel Reflector System

It was first applied by Giovanni Francia of Italy in 1960 for the development of the Fresnel steam generating system linear and a two-axis tracking system. The design of a linear Fresnel reflector is based on a principle between the power tower and the parabolic trough concentrator system. It is identical to the parabolic trough system which requires a fixed receiver pipe when tracking mirrors. The shape of the trough is divided into many facets of the mirror.

This mirror-based system uses the same idea that a Fresnel lens uses to reflect light on a tube for flat plane mirrors that monitor the sun. In some systems behind the focal plane, an external secondary mirror is used that directs the sunlight into the absorber shaft. The Fresnel linear reflector system shown in Fig2.4 Using long rows of flat or slightly curved mirrors to reflect sunlight on an elevated linear collector with two absorber tubes in stainless steel facing down.

The collector in this system is a fixed absorption tube mounted on the mirror reflector's common focal line fitted with a single or dual axis sensor to maximize the amount of sun energy obtained throughout the day. In the acceptance line, a secondary concentration is used to reflect the rays. The Fresnel reflectors surround a stationary receiver with beam radiation. The receiver consists of two absorber tubes made of stainless steel. Each receiver is fitted with a secondary CPC reflector, which directs beam radiation to the tube. A sealed glazed case encloses the whole optical system. The absorber tube contains heated transfer fluid to produce superheated steam driving a turbine to generate electricity. New systems are designed to heat water in the absorber tubes to produce steam at 285 ° C (545 ° F), which will be used directly to drive a turbine to generate electricity instead of using a heat exchanger to generate steam from other high temperature fluids. In a sealed glazed case, the whole optical device is enclosed.[27]

2.4.2. Point Focusing

The solar dish is a point-focusing device that concentrates direct solar radiation on a receiver by using curved sun-tracking mirrors. Ideal for stand-alone infrastructure, services, off-grid and tiny grids, this technology can play a significant role in isolated areas and islands of the country.

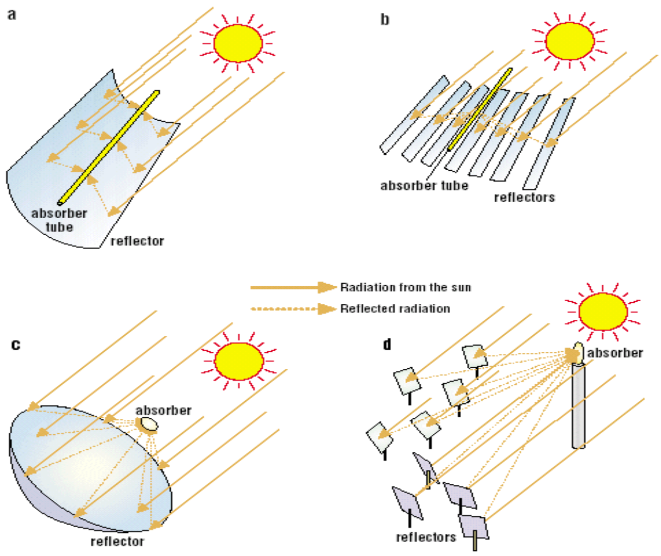


Fig.2.5 Different of point focusing.

2.4.2.a. Solar power tower

Concentrated solar power uses thousands of mirrors to capture and focus sunlight on a central heating stage, which in turn is used for electricity generation. Over ten thousand Heliostats tracking mirrors live in an area of four square miles where they capture and focus sunlight on a large heat exchanger called a receiver. That sits on top of a tower of five hundred and fifty feet. Fluid flows through the piping inside the recipient, creating the external walls. The fluid from the intense sunlight absorbs the heat. The fluid used in this process is molten salt that is heated from 500 to more than 1,000 degrees Fahrenheit. Molten salt is an excellent medium for heat capture as it provides a wider range of liquid operating temperatures. Enabling the system to work at low pressure to capture and store superior and healthy energy. The molten salt flows down the piping inside the tower after passing through the receiver and then into a thermal storage tank where the energy is stored as molten salt at high temperature before electricity is needed. This technology uses liquid molten salt as both the source of energy and the storage mechanism to isolate energy collection from the generation of electricity. What electricity the utility wants day or night. The high temperature molten salt flows into the steam generator as water is piped in to produce the steam from the water storage tank. Once the hot salt is used to create steam, the cold molten salt is then piped back into the cold salt reservoir where it flows back to the receiver to be heated as the process goes on. After the steam is used to drive a steam turbine, it is condensed back into the water and returned to the water holding tank where it flows back into the steam generator if necessary. The effect is a high-quality overheated steam to drive the conventional steam turbine at peak efficiency during peak demand hours to produce stable anti-intermittent electricity. The method of steam generation is similar to the technology used in natural gas, coal or nuclear power plants where as with zero harmful emissions or waste, it is 100 percent renewable. Such plants provide reliable on-demand and energy from the Sun long after you are dark from a renewable source. In 2017, the US National Renewable Energy Laboratory (NREL) calculated that 5.47 cents per kWh of electricity could be generated from power towers by 2020.[28] In 2007, companies such as E Solar (then backed by Google.org) developed cheap, low-maintenance, mass-produced heliostat components that were to reduce costs in the near future[29]. An report in Green Tech Media in October 2017 indicated that Solar should cease business at the end of 2016[30].

Improvements in working liquid systems such as switching from current two (hot / cold) tank designs to single tank thermocline systems with quartzite thermal fillers and oxygen blankets will further improve the efficiency of materials and reduce costs. Noor Complex, situated in the Sahara Desert, is the world's largest concentrated solar power plant (CSP). The plant has a capacity of 580 megawatts and is projected to provide electricity to more than 1 million people by 2020.[43]

Noor 1, the first phase of the three-part project provides 160 MW of the total capacity of 580 MW and since it was turned on in 2016 has already lowered the country's carbon emissions by hundreds of thousands of tons per annum.[44]

2.4.2.b. Parabolic Dish Systems

A Parabolic dish system is made up of a point focuser in the shape of a dish that reflects solar radiation on a receiver placed at the focus point. Such concentrateurs are placed on a frame to monitor the sun with a two-axis tracking system. Usually, the stored heat is used directly by a heat engine installed on the receiver with the arrangement of the pot. Dish can reach extreme temperatures and promises to be used in solar reactors to produce solar fuel that needs very high temperatures. Currently, Stirling and Brayton cycle engines are preferred for power conversion, but dish has rarely been commercially deployed for power generation [31]. Parabolic dishes only use DNI and require a two-axis tracking system to ensure a proper day-round focus. Typical PDR concentration ratios ranges from 500 to 3000, making this technique ideal for high temperature applications (up to 450°C for SORCs), but unlike other types of collectors, PDRs are rarely connected in solar field [32].

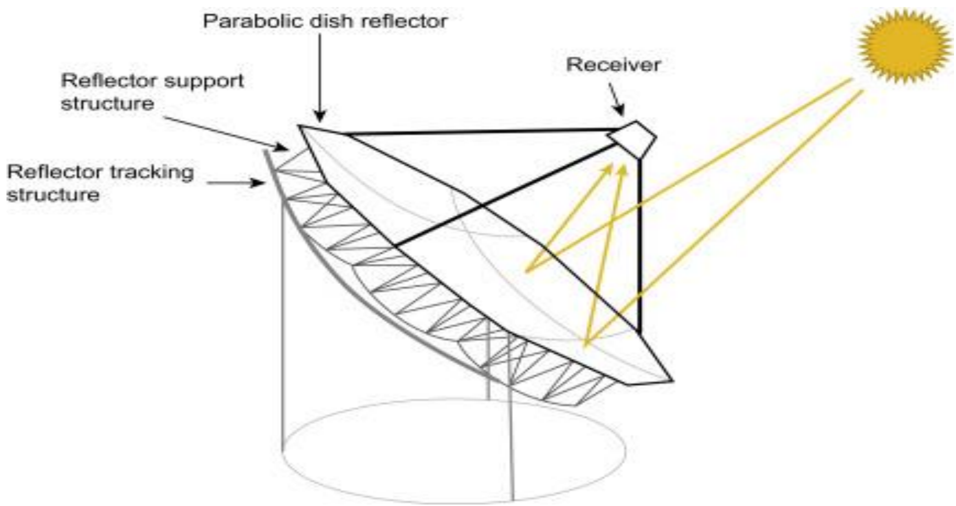


Fig.2.6. Parabolic Dish System.

Table 2-1 The details of each technology with efficiency, storage, temperature and cost.

Technology	Short description	Annual solar to electricity efficiency[a]	Storage	Tempe-rapture (°C)[b]	Cost ($/W)[c]
Parabolic trough	Long, curved mirror Parabolic sheet of reflective material	12-15%	Molten salt	300-550	4.0-2.7
Linear Fresnel	Flat mirror instead of curved mirror in parabolic trough	8-10%	Storage has not been perfected	250-500	2.2
Parabolic dish	Parabolic mirror is used to focus heat directly on a Stirling engine	20-30%	Does not accommodate thermal storage	400-1500	12.6-1.3
Solar tower	It contains large heliostat field with tall tower in its center	20%-30%	Molten salt	300-1000	4.4-2.5

2.4.3. Power Block

The concentration of solar thermal power (CSP) and specifically the parabolic trough is a known large-scale solar power technology. Nonetheless, when subsidized, CSP costs are not yet competitive with conventional alternatives Current CSP plants typically include a condensing steam cycle power block, preferably configured for continuous operation and higher operating conditions, thereby decreasing cost efficiency and device installation.

The disadvantages of this power block are as follows: I no power generation during low insolation periods (i) costly, large condenser (typically water-cooled) due to poor extracted steam properties (high specific volume, sub-atmospheric pressure) and (ii) high installation and operating costs. The power block consists of steam generators, turbines, condensers and other auxiliaries like preheaters, super heaters, heaters and de-aerators.

In steam generators, the HTF heated solar field is used to produce high-pressure superheated steam. The overheated or drained steam is driven into the steam turbine combined with a generator.

The steam works by rotating them through the blades of the turbine. At certain stages of the turbine, steam is bled and heated to improve its strength to prevent condensation in the turbine that could affect the turbine blades. Electricity generated by the generator is either supplied to the grid or used locally.

The turbine exhaust steam is collected in a condenser and returned to the generator of steam. The condenser will either be cooled by water, sea or cooling towers until it returns to the steam generators and the condensate will be heated and compressed. This is done to improve the efficiency of the thermodynamic cycle and to reduce the energy needed to generate steam.

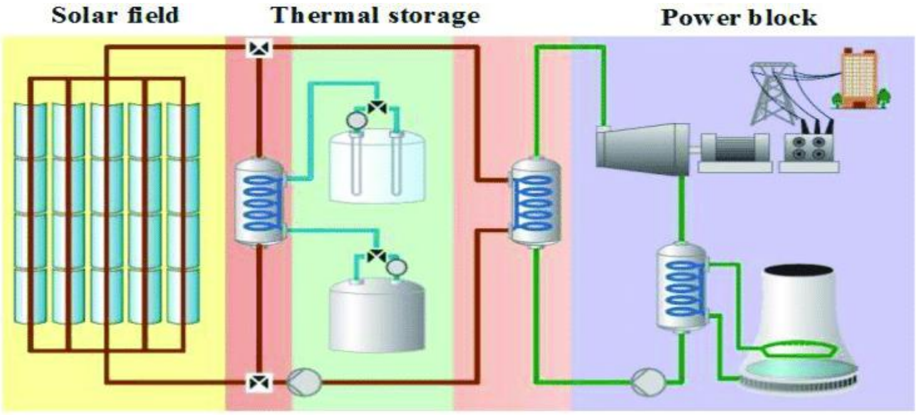


Fig.2.7 The Power block mechanism of CSP plant.

Source-
https://www.researchgate.net/publication/259167422_Evaluation_of_the_Moroccan_Power_Grid_Adequacy_with_Introduction_of_Concentrating_Solar_Power_CSP_Using_Solar_Tower_and_Parabolic_Trough_Mirrors_Technology/figures

2.4.4. Thermal Storage

Thermal energy storage facilities are used in CSP plants to store excess solar energy in isolated storage tanks, retrieved during sunny periods and used during phases of inadequate or no solar energy when required. Various energy storage options are being used to store excess energy. The techniques that are widely used in existing CSP plants are direct steam and molten salt.

Among other things, potential CSP plants can use alternatives for phase transition such as ceramic materials, concrete structures and materials. These still occur however in large-scale implementations of research and development. The coagulated excess heat improves the durability of the turbine and thus increase the plant energy factor, providing improved turbine output. As per the CSP today Organization document, thermal storage permits CSP plants to achieve significantly greater annual capacity factors, which vary from 25 percent to 70 percent or higher without molten salt storage. Improvements to the solar field are required to optimize the thermal energy storage facility in a plant. It increases the productivity of the solar concentrator and overall cost of the plant.

A 7-hour molten salt storage facility for a 50MW parabolic groundwater plant would cost roughly 9 percent of the total capital cost, but will reduce the overall cost of electricity of a 50MW parabolic plant. Thermal storage techniques vary with various CSP configurations. The heat can be stored directly or indirectly with these devices.

Every working liquid is used in the direct thermal storage system both as the heat transfer and the thermal energy storage medium. At operation 11, the PS10 plant in Spain uses steam compression to store heat directly. During low-steam delivery periods this steam is extended and the turbine may be powered for the next 30 minutes. Other plants of analogous heat storage technology are included in SEGS 1 plants. This approach is more costly than the indirect one due to expensive pressure vessels and storage devices for huge volumes of steam (Solar PACES, ESTELA & Green Peace 2009).

The goal is to protect the plant from the sun from a very short periods of inadequate energy. The indirect thermal storage system basically uses two different working fluids for thermal energy storage and heat transfer. During the normal operation of this facility, the hot transfer liquid is used to generate the steam for the turbine generator; at the same time, it is used to heat the thermal energy storage liquid from the cold tank via a heat exchanger system. The thermal power storage liquefaction is used to heat the heat transfer liquid to produce steam for the turbine generator. Some existing plants and plants under development in Spain use thermal storage technologies as a theory of indirect thermal energy storage.

2.4.5. Water cooling options and cost requirements for CSP technologies

Water is used for the washing of glasses, the processing of steam and cooling in a CSP plant. The cost of the energy plant's water consumption depends on its source. As with all steam cycle plants, CSP plants can cool and condense the vapor within the condenser use a steam cycle. Refrigeration may be given by air or water. The smaller Dish engines are almost always air-cooled, and mostly water is used for cleaning mirrors in this situation. Nonetheless, air-cooled plants with steam cycles have a lower output than water-refrigerated plants due to the improved water-to-air cooling properties. The refrigeration of these thermal processes of CSP plants can be accomplished with different methods such as wet cooling, dry cooling and water / air hybrid cooling (evaporative water or one-time coolings).

Although dry cooling can be achieved with or without condensers, water cooling and refrigeration towers are used in wet cooling and wet / dry combination. Cooling approaches that use least water are often preferable for CSP plants, because most plants are located in remote and warm areas with good energy from the solar sector, but not enough water reserves. The one-by-one cooling process extracts water from a cold source and returns it at a high temperature to its source. This technique calls for seasonal river flows, large dams, water reservoirs or seas. Because many CSP plants are in warm, remote locations without large water sources, this cooling system is usually confined to traditional coal and nuclear power stations. The power station of Eskom Köberg uses a unique refresher method by pumping water from the sea and returning it.

2.4.5.a. Wet Cooling

Refrigerating water passes through the condenser funnel through wet evaporation devices, which refill and condense the working steam outside the pipes. The cooling water flows through the condenser tube into evaporatory water cooling systems.

The cold water is then poured down. In many Eskom coal-fired power stations and in the existing parabolic trough plants, this is the most common cooling method because of its most efficient and least expensive cooling technology (SEIA 2010). CSP plants that use this system use about the same quantity of water per kWh of electricity generated as traditional coal and nuclear power.

In conjunction with the single-through technology, this cooling method is the most water severe possible in terms of water volumes and has an increasing water loss in the air.

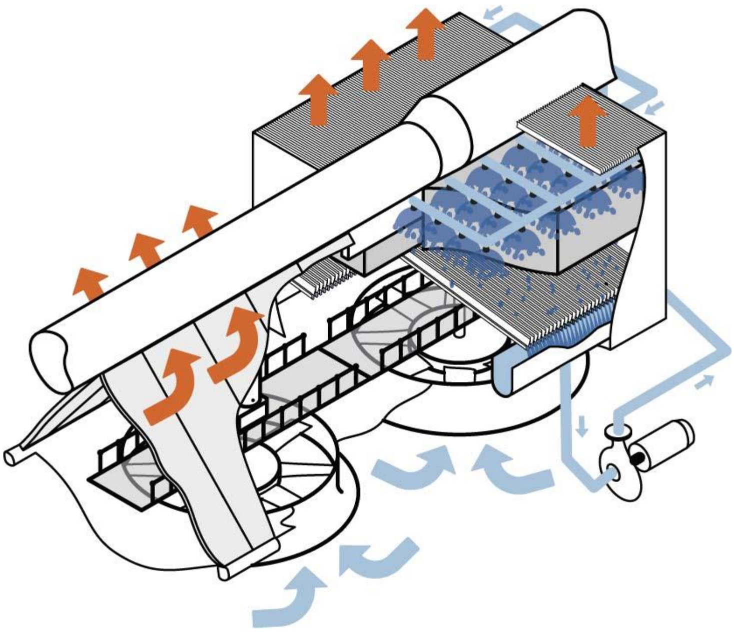


Fig.2.8 Wet cooling system

2.4.5.b. Dry Cooling

The dry cooling method can be done directly as steam is channeled from turbines to heat exchangers cooled by fans. A cooling tower is not used by many. For indirect dry cooling systems, a closed water cooling circuit helps to drain the heat from the condenser and transfer it to the increasing cold air in the cooling towers.

Such dry cooling methods use less water but are more costly to build. The broad cooling ventilators generate plenty of noise, and decreased thermal transmission efficiency in the energy cycle helps to reduce thermodynamic efficiencies by a few percent (see Table 2-2). The main direct and indirect dry-cooled power plant in South Africa are Matimba and Kendal power plants. Compared to the disadvantages of these dry coiling techniques, they may be the most appropriate for CSP plants in areas with very limited water supplies.

2.4.5.c. Hybrid dry/wet cooling

This is a combination of wet and dry cooling methods. Those hybrid models are designed primarily to reduce the feather produced by water cooling towers and/or to reduce water consumption in a thermal power station. Most of the time, the hybrid system could use its dry cooling component to improve the overall thermal cycle efficiency, and the wet cooling portion is used during very hot days. According to Parsons (2008), this cooling strategy is less expensive than conventional dry-cooling methods, but costly than conventional wet-cooling methods.

Table 2-2 Comparison of the consumptive water use of various power plant technologies using various cooling methods

Technology	Cooling Method	Gallons/MWh	Litres/MWh [d]	Performance Penalty[a]
Coal/Nuclear	Once through	$23\,000 - 27000^{b}$	87064-102206	
	Recirculating	400-750	1518-2839	
	Air cooling	50-65	189-246	
Natural gas	Recirculating	200	757	
Power Tower	Recirculating	500-750	1893-2839	
	Hybrid	90-250	340-946	1-3%
	Air cooling	90	340	1.3%
Parabolic Trough	Recirculating	800^{c}	3028	
	Hybrid	100-450	379-1703	1-4%
	Air cooling	78	295	4.5-5%
Dish/engine	Mirror washing	20	75	
Fresnel	Recirculating	1000	3785	

Note:

a-Annual depletion of power output is the most effective technique of cooling.

b- Most of the water is returned at a high temperature to the source. Some are lost by evaporation.

c-The parabolic mirrors converted from Gallons / MWh by the author (rounded off) are used to wash 2 percent of this volume.

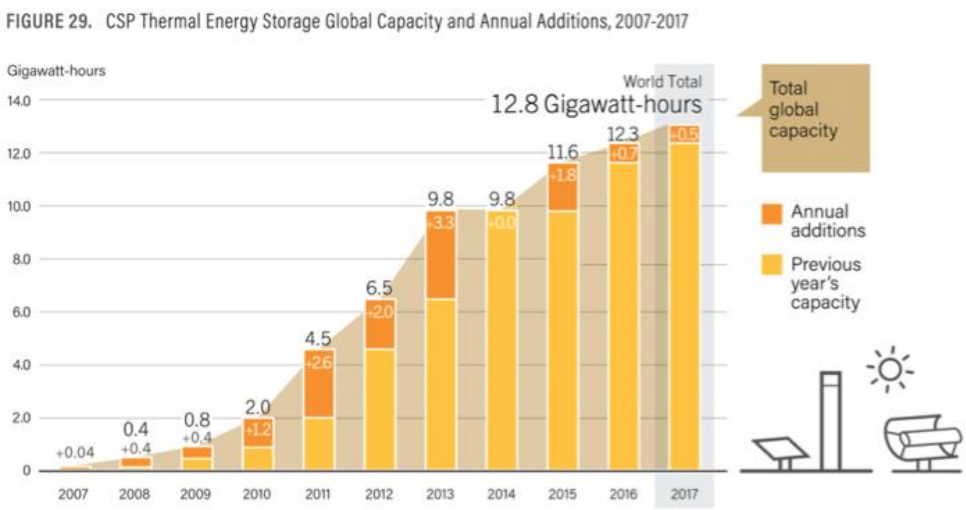
Chapter 3

3.1. Global CSP scenario

In 1984, the commercial introduction of CSP plants started with the U.S. SEGS plants. The last plant of SEGS was completed in 1990. Between 1991 and 2005, no CSP plants were built anywhere in the worldGlobally deployed CSP capability increased nearly tenfold between 2004 and 2013 and rose over the past five years by an average of 50% per annum.[33]

In 2013, installed capacity increased by 36% or approximately 0.9 gigawatt (GW) to more than 3.4 GW. Spain and the USA remained the leaders of the world. While the number of other countries with installed CSP has increased but solar photovoltaic costs have declined rapidly, policy changes and the financial crisis hindered most of these countries ' growth. 2014 was the best year for CSP, but only one large plant completed in the world in 2016 followed a rapid decline. Developing countries and regions with several large plants under construction in 2017 are witnessing a significant trend towards high solar radiation. CSP is also competing increasingly with affordable solar power and photovoltaic concentrator (CPV), a fast-growing technology that is suitable for high-solar regions, including CSP. [34][35]. Recently, however, a new CPV / CSP solar hybrid system was proposed [36]. Of the 17 commercial projects currently under construction worldwide, 15 include TES (Thermal Storage Systems), as per the CSP Today Global Tracker, October 3, 2016.

It is estimated that by the end of 2017, according to the Ren21 Global Status Report 2018, some 13 GWh of thermal energy storage (TES) was functioning in the Concentrating Solar Thermal Power (CSP) segment in relation to the CSP plants in the five regions.



Source-http://helioscsp.com/current-status-of-concentrated-solar-power-csp-globally/

Fig.3.1 CSP thermal energy storage global capacity and annual additions 2007-2017.

3.2. Current Concentrating Solar Power (CSP) projects development.

The following data is available for the period up to November 2019 on the development of commercial CSP plants. This includes data from Spain, the US, Morocco, South Africa and the rest of the world for operating CSP plants who are under construction and production. Using information and tables from Internet sources, the tables below were created. CSP had 5,500 MW of installed gross capacity globally in 2018, up from 354 MW in 2005. Despite the fact that no new capacity has entered Spain since 2013. Spain accounted for nearly half of the world's 2,300 MW capacity, making it the largest's leading country at the end of 2018. Basically the country (23) which are operating CSP projects are-

Table 3-0 The list of country which are operating CSP plants.[37]

Country	Number of Projects
Algeria	1
Australia	6
Canada	1
Chile	5
China	25
Denmark	1
Egypt	1
France	3
Germany	1
Greece	1
India	11
Israel	2
Italy	3
Kuwait	1
Mexico	1
Morocco	7
Saudi Arabia	2
South Africa	7
Spain	53
Thailand	1
Turkey	1
United Arab Emirates	3
United States	52

3.3. Operating CSP Plants

Over the past couple of years, the CSP market has been very competitive. Implementing beneficial CSP strategies and systems such as the Feed-In Tariffs (FIT) by various governments has led to the development of industry in Spain, the United States, Morocco and South Africa in general. [38].

3.3.1. Spain

Spain was among the globe's first huge-scale applications of concentrated solar energy (CSP). In Spain, 170MW of CSP production industry was installed in 2011, 450MW in 2010, 173MW in 2009 and 2,300 MW of total concentrating solar power plants in 2018.

In Spain, 170MW of CSP production was installed in 2011, 450MW in 2010, 173MW in 2009 and 2,300 MW of total concentrating solar power plants in 2018. Since 2013, 50 CSP plants have been in service with a total capacity of 2.3 GW since 2017. Forty-five of these use parabolic trough technology, three; total 50 MW, employ power tower technology and 2 plants, total 31.4 MW, use Fresnel linear technology.[39]

In the below the table is showing the current operating CSP plants in Spain.

Table 3-1 Operating CSP plants in Spain. (March 20, 2017)

Project Name	Technology	Owner(s)%	Turbine capacity(Gross /Net)	Status	Start Year	Gross Annual Solar-to-Electricity Efficiency (Percentage)	Turbine Efficiency
Andasol-1 (AS-1)	Parabolic Trough	ACS/Cobra Group (100%)	50 MW/49.9 MW	Operational	2008	16%	38.10% @ full load (Percentage)
Andasol-2 (AS-2)	Parabolic Trough	ACS/Cobra Group (100%)	50 MW/49.9 MW	Operational	2009	16%	38.10% @ full load (Percentage)
Andasol-3 (AS-3)	Parabolic Trough	Ferrostaal/Solar Millennium/ RWE/Rhein E./SWM (100%)	50 MW/50 MW	Operational	2011	17%	--------------
Arcosol 50 (Valle 1)	Parabolic Trough	Torresol(100%)	49.9 MW/49.9 MW	Operational	2011	16%	38.10% @ full load (Percentage)
Arenales	Parabolic Trough	RREF/OHL (100%)	50 MW/50 MW	Operational	2013	17%	37% @ full load (Percentage)
Aste 1A	Parabolic Trough	Elecnor/Aries/ABM AMRO (100%)	50 MW/50 MW	Operational	201	15%	-------

La Florida	Parabolic Trough	Renovables SAMCA (100%)	50 MW/50 MW	Operational	2010	14%	38.13% @ full load (Percentage)
La Dehesa	Parabolic Trough	Renovables SAMCA (100%)	49.9 MW/49.9 MW	Operational	2011	14%	38.13% @ full load (Percentage)
Manchasol-1 (MS-1)	Parabolic Trough	ACS/Cobra Group (100%)	49.9 MW/49.9 MW	Operational	2011	16%	38.10% @ full load (Percentage)
Puerto Errado 1 Thermosolar Power Plant (PE1)	Linear Fresnel reflector	Novatec Solar España S.L. (100%)	1.4 MW	Operational	2009	-------	---------
Planta Solar 20 (PS20)	Power Tower	Abengoa Solar	20 MW/20 MW	Operational	2009	----------	---------
Solacor 2	Parabolic Trough	Abengoa Solar (74%) JGC (26%)	50 MW/50 MW	Operational	2012	-----------	-------------

3.3.2. Current operating CSP plants in US.

The U.S. remained the second-largest market in terms of total demand, ending the year with 507 MW in operation. As in 2011, there was no generating capacity on site, but by the end of 2012, just over 1,300 MW were under construction, all due to projects beginning in the next two years.

By the end of the year, the Ivanpah facility under construction in Mojave Desert in California was completed 75 percent once operational, this 392 MW power tower plant will be the largest CSP facility in the world and is projected to provide ample energy for 140,000 U.S. homes.

12 At the end of the year, the Solana plant (280 MW) will be the world's largest parabolic trough plant after completion.39]

Table 3-2 Operating CSP plants in Usa. (Status-October 1, 2015)

Project Name	Technology	Owner(s)%	Turbine capacity(Gross/Net)	Status	Start Year
Solana Generating Station (Solana)	Parabolic Trough	Abengoa Solar Liberty Interactive Corporation	280 MW/250 MW	Operational	2013
Genesis Solar Energy Project	Parabolic Trough	Genesis Solar, LLC	250 MW/250 MW	Operational	2014
Ivanpah Solar Electric Generating System (ISEGS)	Power Tower	NRG Energy; BrightSource Energy; Google	392 MW/377 MW	Operational	2014
Solar Electric Generating Station VIII (SEGS VIII)	Parabolic Trough	NextEra (50%)	89 MW/80 MW	Operational	1989
Martin Next Generation Solar Energy Center (MNGSEC)	Parabolic Trough	Florida Power & Light Co. (100%)	75 MW/75 MW	Operational	2010
Crescent Dunes Solar Energy Project (Tonopah)	Power Tower	SolarReserve's Tonopah Solar Energy, LLC (100%)	110 MW/110 MW	Operational	2015
Stillwater GeoSolar Hybrid Plant	Parabolic Trough	Enel Green Power	2 MW/2 MW	Operational	2015
Solar Electric Generating Station IX (SEGS IX)	Parabolic Trough	NextEra (50%)	89 MW/80 MW	Operational	1990

3.3.3. Others Countries

Rest of those country there are several countries which is operating CSP plants.[39]

Table 3-3 Operating CSP plants others countries (Status-October 1, 2015)

Electrical Capacity(MW)	Name	Country	Location	Technology Type	Storage Hours	Ref.
510 [R1-6]	Noor / Ouarzazate Solar Power Station	Morocco	Ghassate (Ouarzazate province)	Parabolic trough and solar power tower (Phase 3)	3 / 7 / 7.5	1.2.4.5.6
125	Dhursar	India	Dhursar, Jaisalmer district	Fresnel reflector	0	7.8.9.10
121	Ashalim Power Station (Negev Energy)	Israel	Ashalim	Parabolic trough	4.5	11
100	Shouhang Dunhuang	China	Dunhuang (Ga Provience)	Solar power tower	7.5	12
100	Kathu Solar Park	South Africa	Northern Cape	Parabolic trough	4.5	13.14 15.16.17
50	Shagaya CSP	Kuwait	Shagaya	Parabolic trough	10	18.19
50	Waad Al Shamal ISCC Plant	Saudi Arabia	Waad Al Shamal	ISCC with parabolic trough	-----	20

3.4. CSP project under construction (Last information 15 Dec 2019)

A total of 3257MW of CSP power projects are under construction, on which 1662MW are under construction in the United States, followed by Spain with a capacity of 1403 MW, as per Table 3-3 below. In other regions of the world, projects under construction are mostly Integrated Solar Combined Cycle System (ISCCS) technology plants (Table 3-4) with a total solar capacity of the only 192MW. Spain is now the global leader in CSP installed capacity and will continue to dominate the global CSP market before other countries like the U.S. and solar resilient Africa begin in the near future to develop CSP plants. CSP ability under construction in the United States accounts for nearly 51% of the total projects under construction globally, closely followed by Spain with a share of roughly 43%. The parabolic trough technology continues to be the system of preference in construction projects with a market share of approximately 64% and the central receiver system is roughly 34%. For the central receiver equipment, this is a major step forward for the 4 percent of the total operating programs. Ninety-nine percent of these centralized receiver infrastructure programs, totaling 1102MW, will be in service in the U.s in 2013 and 2014. These are the Invapah 392MW, the BrightSource 600MW as well as the Crescent Dunes 110MW projects.[39]

Table 3-4 Under construction CSP plants.

Project Name	Technology	Owner(s)%	Turbine capacity(Gross/ Net)	Status	Start Year	Country
Abhijeet Solar Project	Parabolic Trough	Corporate Ispat Alloys Ltd. (100%)	50MW/50MW	Under Construction	2015	India (Rajasthan)
Agua Prieta II	Parabolic Trough	Fed Meral Electricity Commission (100%)	12 MW/14MW	Under Construction	2014	Mexico
KVK Energy Solar Project	Parabolic Trough	KVK Energy Ventures Ltd (100%)	100MW/100M W	Under Construction	2013	India (Rajasthan)
Gujarat Solar One	Parabolic Trough	Cargo Solar Power (100%)	25 MW/28 MW	Under Construction	2014	India (Gujarat)
Hami 50 MW CSP Project	Power Tower	Northwest Electric Power Design Institute	50MW/50MW	Under Construction	2016	China
Waad Al Shamal ISCC Plant	Parabolic Trough		50MW/50MW	Under Construction	2018	Saudi Arabia
Atacama-1	Power Tower	Abengoa Solar (100%)	110 MW/110 MW	Under Construction	2018	Chile
Dadri ISCC Plant	Linear Fresnel reflector	NTCP	14 MW/---	Under Construction	2017	India (Uttar Pradesh)

Dacheng Dunhuang 50MW Molten Salt Fresnel project	Linear Fresnel reflector	Lanzhou Dacheng Technology Co., Ltd	50 MW/50 MW	Under Construction	Dec 11, 2018	China
Diwakar	Parabolic Trough	Lanco Infratech (100%)	100 MW/100 MW	Under Construction	2013	India (Rajasthan)
Yumen 50MW Molten Salt Tower CSP project	Power Tower	Yumen Xinneng Thermal Power Co., Ltd	50 MW/50 MW	Under Construction	2018	China
ISCC Duba 1	Parabolic Trough	Saudi Electricity Co.	43 MW/43 MW	Under Construction	2017	Saudi Arabia
IRESEN 1 MWe CSP-ORC pilot project	Linear Fresnel reflector	IRESEN	1 MW/---	Under Construction	2016	Morocco
Rayspower Yumen 50MW Thermal Oil Trough project	Parabolic Trough	Rayspower Energy Group Co., Ltd.	50MW/50MW	Under Construction	2017	China
Golmud	Power Tower	----	200MW/200MW	Under Construction	2018	China
DEWA CSP Trough Project	Parabolic Trough	Dubai Electricity & Water Authorit	600MW/600MW	Under Construction	2021	United Arab Emirates (Dubai)

3.5. CSP projects under development or announced

CSP projects under construction or planned are hard to study because the data on such projects are incomplete and the available data are continually changing (O'Sullivan, 2009). The following table 3-4 showed the potential by country and technology form of projects being built or revealed.

It is created from the information from the CSP Today Global Farm's location map. Completed or confirmed ventures do not mean they are built and connected to the gridSome may be delayed for a few years, and some will be washed out for different reasons, such as lack of resources, changes in government policies and incentives, and changes in expectations for shareholders.[40]

Table 3-5 Under Development or announced CSP plants.

Project Name	Technology	Electricity Generation	Turbine capacity(Gross/Net)	Status	Start Year	Location
Aurora Solar Energy Project	Power Tower	500,000 MWh/yr (Expected)	135 MW/150MW	Under Development	2020	Australia (SA)
Copiapó	Power Tower	1,800,000 MWh/yr (Expected)	260 MW/260 MW	Under Development	2019	Chile
Likana Solar Energy Project	Power Tower	2,800,000 MWh/yr (Expected)	390.0 MW/390.0 MW	Under Development	2021	Chile (Antofagasta)
Redstone Solar Thermal Power Plant	Power Tower	480,000 MWh/yr	100 MW/100 MW	Under Development	2018	South Africa
Tamarugal Solar Energy Project	Power Tower	2,600,000 MWh/yr (Expected)	450.0 MW/450.0 MW	Under Development	2021	Chile (Tarapacá)

Also remain… Zhangjiakou 50MW CSG Fresnel project,, Yumen 50MW Thermal Oil Trough CSP project,, Shangyi 50MW DSG Tower CSP project,, MINOS,, Golden Tower 100MW Molten Salt project.

3.6. CSP projects currently non-operational

Here it is given the currently non-operational CSP plants all over the world-[41]

Table 3-6 CSP projects currently non-operational.

Project Name	Technology	Electricity Generation	Turbine capacity(Gross/Net)	Status	Start Year	Location
Colorado Integrated Solar Project (Cameo)	Parabolic Trough	----------	2 MW/2 MW	Currently Non-Operational	2010	United States (CO) / Palisade (CO)
Holaniku at Keahole Point	Parabolic Trough	4,030 MWh/yr	2 MW/2 MW	Currently Non-Operational	2009	Keahole Point (HI)/ United States (HI)
Sierra SunTower (Sierra)	Power Tower	-------	5 MW/ 5 MW	Currently Non-Operational	2009	United States (CA)/ Lancaster (CA)
Liddell Power Station	Linear Fresnel reflector	13,550 MWh/yr	3 MW/ 3 MW	Currently Non-Operational	2012	Australia

Other

Yumen 100MW Molten Salt Tower CSP project..

Urat 50MW Fresnel CSP project.

Yumen 100MW Molten Salt Tower.

CSP project Zhangbei 50MW DSG Fresnel CSP project.

Kimberlina Solar Thermal Power Plant (Kimberlina).

3.7. Causes of growth or stagnation of CSP by country

The CSP technology sector is a modern U.S. and Spanish-dominated electricity sector. After the last of the SEGS plants was placed on line in 1991, the CSP technology sector has been inactive until 2007 when the solar plants of Nevada Solar One and PS10 started business operations in the Us and Spanish respectively . It was due to various governments ' favorable solar incentives and initiatives, including feed-in tariffs, power purchase deals, and incentives. In addition to financial and policy benefits, CSP technology's effectiveness is also dependent on the particular location's solar advantage and site latitude. Spain has the least potential for Direct Normal Irradiation (DNI) for the areas shown, whereas South Africa has the highest DNI, as per the solar potential table 3-5 below. South Africa is expected to be the global leader in the development of CSPs and to generate the lowest solar energy based on these DNI concepts alone.

Table 3-7 Solar potential for selected world places.[42]

Location	Site Latitude	Annual DNI (kWh/m2)
South Africa		
Upington, Northern Cape	-28°27'12", 21°14'48"	2935 kWh/m2arrow
United States		
Barstow, California	34°53'45", -117°01'02"	2912 kWh/m2a
Las Vegas, Nevada	36°09'59", -115°08'57"	2725 kWh/m2ar
Albuquerque, New Mexico	35°05'03", -106°39'04"	2697 kWh/m2arr
International		
Northern Mexico	36°00'14", -106°05'02"	2651 kWh/m2
Wadi Rum, Jordan	29°41'57", 35°23'48"	2729 kWh/m2
Al Wahat Al Dakhla	24°08'09", 26°56'48"	2514 kWh/m2
Ouarzazate, Morocco	30°55'00", -06°55'00"	2462 kWh/m2
Crete	35°18'35", 24°53'36"	1854 kWh/m2 per year
Jodhpur, India	26°10'23", 73°15'41"	1837 kWh/m2 per year
Spain	40°00'00", -03°00'00"	2058 kWh/m2 per year

Source: GLOBAL SOLAR ATLAS.[https://globalsolaratlas.info/map?c=23.616129,90.301025,7&s=23.819187,89.630859&m=site]

Chapter 4

4.1. Opportunities In Bangladesh.

For the smooth functioning of the CSP plant, abundance DNI is required. Direct Normal Irradiation (DNI) is characterized as the radiation intensity that originates immediately before scattering through the sun. Bangladesh is ideally located around 20.30 ° -26.38 ° latitude north and 88.04 ° -92.44 ° latitude east. At the location near the equatorial plane, sunlight receives almost perpendicular. Luckily Bangladesh is very close to the near the equator line (23.50 ° North). From the calculation here, we notice that solar radiation varies across the country from 4 to 6.5 KWh/m^2.

For CSP technology there is needed annual average Direct Normal irradiations(DNI) 2000KWh/m^2. In Bangladesh, approximately 1900 KWh/m^2 [16]. Annual solar radiation is sufficient. The average DNI of Bangladesh is shown in Fig. 9. Bangladesh's labor costs are higher than any developed country, so reducing costs by 15 % could be feasible. Most of the raw materials of CSP power stations are sheets of steel and glass. Bangladesh has become ego-sufficient in the manufacture of glass. In several countries, glasses are being shipped [17].

Bangladesh operates more than 400 steel re-rolling business. This will reduce capital costs and create more jobs for the unemployed [18]. Almost all of Bangladesh's energy production comes from coal, diesel and gas-powered power stations. Nevertheless, the inventory of such resources (natural gas) is being depleted at an alarming rate, with estimates indicating that the current rate of consumption will last for many decades or so. This should be of grave concern, as well as the fact that more than 70% of Bangladesh is outside of the national grid. Then again the places inside the grid have an intermittent and often unreliable supply of electricity, in answer to which only 4500~4600 MW can be generated, the country has a total demand of 7000 MW per day, despite having the ability to produce 6700 MW each day.

This is mainly due to the obsolete and stretched-out infrastructure at 81 stations in the countries. Bangladesh is a semi-tropical country that is located in the northeastern part of South Asia. In the dry season in Bangladesh, the average bright sun is about 7.6 hours a day and in the monsoon season it is about 4.7 hours.

The maximum sunshine hours earned are from 2.86 to 9.04 hours in Khulna and from 2.65 to 8.75 hours in Barisal. These are very reliable statistics compared to Spain's 8 daylight hours, which provided 7GW of energy covering 5% of consumer spending by the end of 2018. Furthermore, with only half of the solar radiation received by Bangladesh, Germany produces electricity which is 7% of its national demand.
Thus solar power could be used in Bangladesh in combination with the infrastructure (combined cycle power station) if necessary not as a specific generation scheme.
Optimal locations for a solar power plant should be an arid, flat land with low cloud cover, high availability of solar radiation and high average hours of sunlight throughout the year. In Bangladesh, mainly three different types of ecosystems are found in floodplains, terraces, and hills with its most frequent floodplains (about 80% of the total landscape) [42].

Table 4-1.The following chart of Solar (DNI, GHI)

Region	Direct normal irradiation DNI Per year	Global horizontal irradiation GHI Per year	Diffuse horizontal irradiation DIF	Global tilted irradiation at optimum angle GTI opta	Latitude	Average dni
Chittagong	1297kWh/m2	1774kWh/m2a	879 kWh/m2	1297kWh/m2	22°15'19", 92°00'59"	1307 kWh/m2 per year
Barisal	1086kWh/m2	1698kWh/m2	935kWh/m2	1813kWh/m2	22°44'22", 90°32'46"	1098 kWh/m2 per year
Khulna	1067 kWh/m2	1706 kWh/m2	947kWh/m2	1815 kWh/m2	22°29'55", 89°16'29"	1079 kWh/m2 per year
Pabna	1044kWh/m2	1681kWh/m2	944 kWh/m2	1795 kWh/m2	24°02'51", 89°23'37"	1055 kWh/m2 per year
Naogaon	1053kWh/m2	1673kWh/m2	936 kWh/m2	1794 kWh/m2arr	24°54'11", 88°39'51"	1064 kWh/m2 per year

Sylhet	1157kWh/m2a	1650kWh/m2	869 kWh/m2	1796 kWh/m2	24°51'34", 91°53'51"	1161 kWh/m2 per year
Mymensingh	1039kWh/m2	1624kWh/m2	908kWh/m2	1752kWh/m2	24°53'56", 90°29'58"	1052 kWh/m2 per year
Rangamati Fulgazi Baper Chhara	1320kWh/m2	1773kWh/m2	861 kWh/m2	1919 kWh/m2	22°36'23", 92°16'40"	1330 kWh/m2 per year
Cox's Bazar Naikhongchari	1336 kWh/m2	1779 kWh/m2	864 kWh/m2	1925 kWh/m2	21°25'49", 92°11'01"	1347 kWh/m2 per year
Bandarban Parada	1394 kWh/m2a	1790 kWh/m2	829 35h/m2	1950 kWh/m2	21°50'52", 92°32'27"	1263 kWh/m2 per year
Bhola	1185 kWh/m2	1749 kWh/m2	915 kWh/m2	1869 kWh/m2	21°56'04", 90°38'20"	1197 kWh/m2 per year
Rangpur	1012 kWh/m2arr	1618 kWh/m2	921 kWh/m2	1743 kWh/m2	25°42'15", 89°08'05"	1023 kWh/m2 per year
Rajshahi	1055 kWh/m2arr	1684 kWh/m2a	943 kWh/m2	1802 kWh/m2	24°28'49", 88°36'24"	1065 kWh/m2 per year
Kishoregonj	1096 kWh/m2	1667 kWh/m2	901 kWh/m2	1793 kWh/m2arr	24°23'18", 91°06'50"	1108 kWh/m2 per year
Lakshmipur	1133 kWh/m2	1717 kWh/m2	923 kWh/m2	1836 kWh/m2	22°41'58", 90°57'13"	1144 kWh/m2 per year
Patuakhali	1139 kWh/m2a	1738 kWh/m2	932 kWh/m2arr	1847 kWh/m2	21°53'05", 90°06'51"	1152 kWh/m2 per year
Bandarban	1363 kWh/m2	1776 kWh/m2	840 kWh/m2	1931 kWh/m2	21°44'48", 92°33'13"	1369 kWh/m2 per year

4.2. The solar DNI time per hour also the horizon and sun-path.[42]

1) Bandarban[21°44'48", 92°33'13"]

Horizon and Sun path

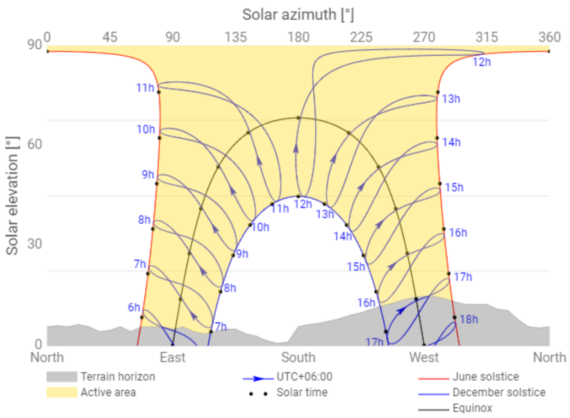


Fig. 4.1a

Average hourly profiles
Direct normal irradiation [Wh/m^2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6					6	8	3					
6 - 7	1	25	36	83	83	60	46	45	66	90	75	17
7 - 8	259	283	247	216	176	108	85	92	156	264	390	298
8 - 9	493	488	390	332	268	168	138	165	261	381	525	491
9 - 10	620	618	500	421	329	224	188	237	348	482	659	627
10 - 11	699	694	581	475	368	273	228	280	380	520	714	707
11 - 12	733	724	604	487	359	275	242	286	375	500	711	725
12 - 13	728	714	593	463	339	252	222	271	356	461	670	691
13 - 14	690	676	553	425	308	218	197	240	322	426	617	638
14 - 15	619	613	498	372	250	161	151	174	254	348	546	564
15 - 16	510	511	401	298	190	113	102	104	144	233	435	456
16 - 17	186	284	268	207	131	64	63	64	66	43		82
17 - 18					22	20	25	10				
18 - 19												
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	5536	5629	4670	3780	2829	1944	1690	1968	2729	3747	5341	5297

Fig. 4.1b

Fig.4.1a the horizon and sun path and 4.1b the average DNI profiles of per hour in Bandarban.

2) Barisal[22°44'22", 90°32'46"]

Horizon and Sun path

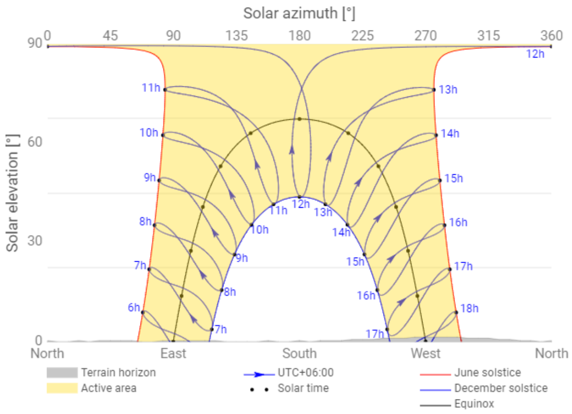


Fig. 4.2a

Average hourly profiles
Direct normal irradiation [Wh/m^2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6					2	5	5					
6 - 7		1	14	45	57	50	44	37	36	39	31	1
7 - 8	74	109	138	158	138	94	83	86	126	211	224	103
8 - 9	204	258	267	254	212	143	133	147	197	317	369	253
9 - 10	306	380	385	349	288	194	191	210	268	398	475	357
10 -	392	471	477	421	347	230	225	255	312	439	537	443
11 -	447	528	527	454	358	244	235	267	324	449	549	484
12 -	463	541	534	446	341	232	226	266	309	438	533	486
13 -	448	512	509	416	307	208	225	255	297	411	495	456
14 -	391	445	453	356	260	181	201	226	260	349	420	385
15 -	292	350	351	275	199	151	174	189	194	247	304	277
16 -	133	204	224	178	132	103	130	138	130	114	89	75
17 -	4	25	47	42	49	48	68	51	22	4		
18 -						1	3					
19 -												
20 -												
21 -												
22 -												
23 -												
Sum	3154	3822	3926	3394	2690	1882	1943	2128	2475	3416	4026	3319

Fig.4.2b

Fig.4.2a the horizon and sun path and 4.2b the average DNI profiles of per hour in Barisal.

3) Chittagong [22°15'19", 92°00'59"]

Horizon and Sunpath

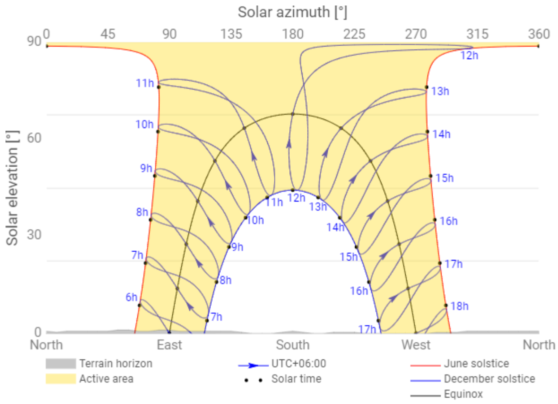


Fig. 4.3a

Average hourly profiles
Direct normal irradiation [Wh/m^2]

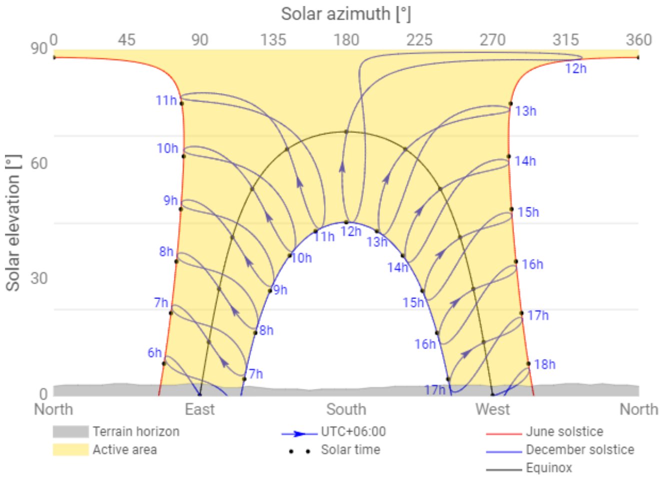
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6				1	6	7	5	2				
6 - 7	2	5	26	69	74	64	56	49	67	73	67	6
7 - 8	159	186	190	188	162	122	118	123	168	243	316	195
8 - 9	337	379	321	292	240	198	187	193	262	355	469	379
9 - 10	460	503	436	373	306	247	244	279	337	443	593	514
10 - 11	554	585	508	431	344	283	276	321	373	490	658	599
11 - 12	605	629	550	463	356	290	290	314	364	490	660	630
12 - 13	614	639	560	468	356	271	257	300	346	483	633	618
13 - 14	583	611	544	458	354	249	230	266	329	457	590	582
14 - 15	514	546	493	401	309	205	195	205	279	394	518	515
15 - 16	409	446	388	315	240	152	131	142	175	282	404	402
16 - 17	200	268	246	205	154	91	87	78	91	123	110	106
17 - 18	3	25	46	37	55	39	45	24	9	2		
18 - 19						1	3					
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	4439	4823	4308	3701	2957	2219	2124	2295	2802	3834	5018	4545

Fig. 4.3b

Fig.4.3a the horizon and sun path and 4.3b the average DNI profiles of per hour in Barisal.

4) Cox's Bazar Naikhongchari [21°25'49", 92°11'01"]

Horizon and Sunpath



Average hourly profiles
Direct normal irradiation [Wh/m^2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6					7	7	2	2				
6 - 7	5	6	30	74	84	62	49	48	68	91	85	26
7 - 8	207	217	215	201	171	112	98	113	170	277	380	267
8 - 9	414	423	346	298	245	172	147	184	265	392	529	456
9 - 10	541	559	461	374	303	220	199	243	331	476	633	574
10 - 11	629	642	549	449	337	253	226	273	351	502	686	640
11 - 12	667	684	592	494	343	251	230	276	341	479	681	657
12 - 13	668	684	594	510	352	237	209	248	326	444	647	633
13 - 14	638	657	570	493	355	220	190	232	306	427	599	586
14 - 15	572	597	516	436	310	184	164	191	253	376	532	519
15 - 16	463	495	415	343	239	145	123	135	161	269	426	419
16 - 17	241	307	273	223	160	88	83	80	90	122	121	117
17 - 18	5	33	55	41	54	39	48	24	10	2		
18 - 19						1	1					
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	5051	5305	4615	3935	2959	1990	1768	2049	2671	3858	5319	4892

Fig.4.4 a

Fig.4.4 b

Fig.4.4a the horizon and sun path and 4.4b the average DNI profiles of per hour in Cox's Bazar Naikhongchari.

5) Khulna [22°29'55", 89°16'29"]

Horizon and Sunpath

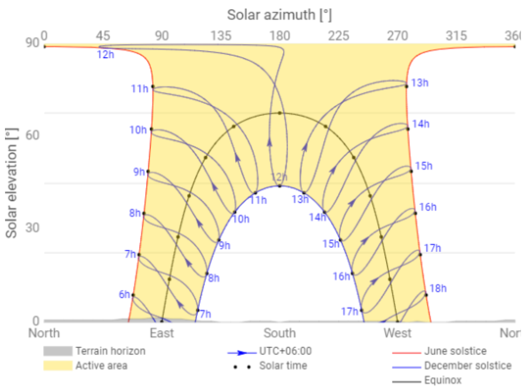


Fig. 4.5 a

Average hourly profiles
Direct normal irradiation [Wh/m²]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6						1	1					
6 - 7		1	8	45	47	41	40	37	30	27	13	
7 - 8	59	95	135	156	131	98	88	95	130	186	165	79
8 - 9	192	246	276	262	214	157	140	156	203	295	316	217
9 - 10	299	377	402	364	307	217	193	220	290	374	423	319
10 - 11	388	472	498	442	380	265	229	267	333	425	486	407
11 - 12	448	527	551	492	401	263	230	271	341	434	510	445
12 - 13	460	546	562	496	394	231	210	241	305	419	499	442
13 - 14	442	519	541	467	359	197	194	199	263	394	456	411
14 - 15	386	457	488	403	302	157	161	160	203	324	383	346
15 - 16	287	361	389	309	230	121	132	128	141	216	273	243
16 - 17	137	226	254	204	146	81	103	94	86	100	99	86
17 - 18	6	42	46	69	53	41	71	55	18	4	1	1
18 - 19						1	7	1				
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	3105	3868	4149	3709	2964	1871	1799	1923	2343	3200	3625	2996

Fig. 4.5 b

Fig.4.5a the horizon and sun path and 4.5b the average DNI profiles of per hour in Khulna.

6) Rangamati Fulgazi Baper Chhara[22°36'23", 92°16'40"]

Horizon and Sunpath

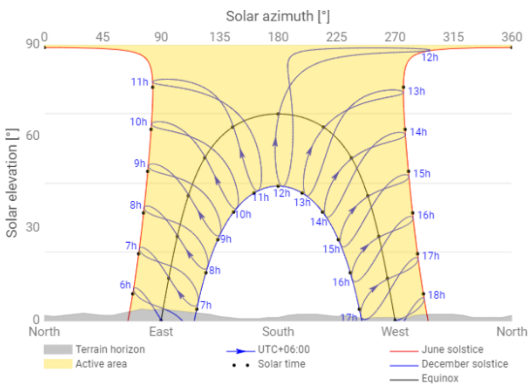


Fig. 4.6 a

Average hourly profiles
Direct normal irradiation [Wh/m²]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6					4	7	4	2				
6 - 7	1	14	27	66	71	64	54	51	64	70	63	16
7 - 8	168	207	194	180	154	121	113	118	157	238	310	203
8 - 9	340	387	325	287	236	187	180	195	254	348	453	352
9 - 10	470	514	439	380	311	254	240	268	341	450	576	493
10 - 11	575	600	519	435	362	297	289	326	388	508	657	623
11 - 12	629	642	558	455	367	306	290	338	415	522	674	670
12 - 13	641	645	557	445	352	281	271	333	409	520	656	667
13 - 14	616	618	537	425	320	256	247	301	377	500	623	629
14 - 15	548	553	477	376	270	199	191	221	311	430	540	553
15 - 16	436	446	377	296	208	142	127	135	202	298	415	425
16 - 17	198	268	233	189	137	82	75	73	105	123	106	109
17 - 18	4	24	43	42	40	33	38	21	10	2		
18 - 19							1					
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	4626	4916	4286	3577	2831	2231	2121	2382	3032	4008	5072	4740

Fig. 4.6 b

Fig.4.6a the horizon and sun path and 4.6b the average DNI profiles of per hour in Rangamati Fulgai Baper Chhara.

4.3. Analyzing the possible area from the data table.

Bangladesh sections like Khulna, Rajshahi, Chittagong, Rangamati, Cox bazar display the propensity to receive higher than the average solar radiation (Table) comparison with the rest of the world. Even though there is a trend in the amount of solar radiation received decreasing during the rainy season, the annual average sunlight hour and solar radiation are adequate for the activity of tiny-scale SHS(Solar Home Systems) in most areas of Bangladesh. The annual production of solar radiation in Bangladesh is currently as high as 1900kwh/m². The mean availability of solar radiation throughout the country is approximately 174.2 cal/cm²/min during the rainy season. Many sections of Barisal and Khulna even have high radiation and sunlight hour estimates for the perfect operation of PV or even CSP (Concentrated Solar Power) linked grid stations. The majority of solar radiation is obtained in Khulna from 180.30 to 318.70cal / cm2/min and in Barisal from 185.5 to 348.9cal/cm²/min. Throughout the year, except during the rainy season, the above mentioned areas often obtain much less cloud coverage. The lowest cloud coverage is in Rajshahi and Khulna, with measurements in Rajshahi ranging from 0.34 to 6.36 okta and in Khulna 0.32 to 6.97 okta. The maximum country-wide cloud coverage during the rainy season is 5.42 okta. Most solar radiation is obtained in Bandarban and its 1394 kWh/m² annually during this winter period. About 1,350 kWh/m² to 1,900 kWh/m² of the highest annual solar radiation in this area. At about 5.5KWH / square meter/day, CSP systems work properly. The cost of electricity generation using CSP technology is presently between 15 and 23 BDT per watt [3]. Concentrating technology exists primarily in four types, each with specific performance levels due to differences in the way sunlight is monitored and concentrated. Some have even provided storage facilities as it is not feasible to operate normally at night. Studies have found that the CSP plant's initial cost will be $3800/kWe by the year 2015. Since no fuel is needed in CSP, it can be an attractive option to mitigate Bangladesh's power crisis.

4.4. Case Study

A plan for a 2MWe pilot CSP project in the Bandarban districtIn this article, the expenditure needed to build a 2MWe parabolic trough power station is estimated. The estimate is based on the Godawari Solar Project in Nokh India, Rajhastan Latitude / LongitudeLocation: 27 ° 36'5.00"North,72 ° 13'26.00"East. The proposed location is Bandarban with 21 ° 44'48, "92 ° 33'13Using Google Earth, the proposed area was selected. This region is chosen since Bangladesh's DNI (Direct Normal Irradiance) map indicates that throughout the year it receives an almost constant DNI shown in the table. The electricity generated from such a plant could be used to electrify some of Bandarban's remote villages, where there is still no electricity. In Table, along with the Godawari Solar Project, the features of the proposed pilot project are shown.

Land calculation For 2 MW power plant.

The solar irradiation can be taken equal to 500W/m2 Assume a thermal effiency of 20% (this varies with the geographical poisition for the incident angle and the operational temeprature).

Equation-

2MW =$2e^6$Watt

Area*500*0.2=$2e^6$

so: Area=20000m^2

As final conclusion,

20000m^2 of land will be the total area for a 2 MW plant.

Table 5-1 A proposal CSP plant in Bangladesh with respect to Godawari Solar.

Criteria	Godawari Solar Project	Proposed project
Annual DNI	1674 kWh/m2 per year	1400 kWh/m2 per year approximately
Land area	1500000 m2	20000 m2
Heat-Transfer Fluid Type	Dowtherm A	Synthetic oil (400ºC)
Thermal storage	Molten salt (60% NaNO3 and 40% KNO)	Molten salt (60% NaNO3 and 40% KNO)
Electricity Output	50 MW	2 MW

The proposed plant's DNI is marginally (16 percent) lower than that of the model plant; thus, with the same ratio, the area needed for the projected plant and the capital cost of the solar field are to be increased. On the other hand, a 15 percent decline in solar field capital costs is anticipated due to the lower labor costs in Bangladesh relative to those in Europe or the Us. These considerations are incorporated in the land area and investment cost calculation.

Chapter 5

5.1. Conclusion

While in just a few decades, as in the mobile communications industry, Bangladesh has achieved state-of-the-art technology, the power sector still stumbles with primitive machinery. It's about time the government of Bangladesh thought about how the country produces electricity. A pilot project should be taken as soon as possible to check the feasibility of the non-polluting and CO2-free CSP system. Use local staff to assemble various components and build the solar power plant would reduce investment costs by 30%. In addition, daily plant operation and maintenance will generate thousands of new permanent jobs that will help to some degree reduce the serious problem of unemployment in the country. Parabolic troughs are ideal for large-scale generation of power in Bangladesh. In view of land use, the solar tower power plant should be a second option. For small-scale power generation systems, on the other hand, parabolic dish is suitable. Therefore, the government of Bangladesh will take the necessary steps to incorporate parabolic trough technology to generate large-scale power and install parabolic plates as separate, small-scale power generation units.

5.2. Future Work

As we have collected the data about CSP plants of all over the world. There are plenty of possibilities and room for future works and improvements. Some of the future works are given below-

i. We can use Integrated Solar Combined Cycle System (ISCCS) for better efficiency.
ii. There are several places around the Bangladesh in which we can implement a CSP plant like our proposal.
iii. If we can, we will make a primary graph on a CSP plant of all over the world.

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