

# Concentrated Solar Power Generation: A Viable Alternative to Conventional Energy Sources In UAE

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**Abstract—** This report focuses on the how Concentrated Solar Power (CSP) generation can be implemented in UAE along with water desalination technique. In UAE, solar energy is the amplest, direct and clean form of renewable energy available [4]. Total solar energy absorbed by the Earth is about 3,850,000 extra joules (EJ) in one year, which is even twice as much as all the non-renewable resources on the earth found and used by the human being, including coal, oil, natural gas, and uranium [1]. There are two major challenges to the energy situation in the UAE. One of the important concerns is the rising demand of power and alarming power bills. The other important concern is the environmental challenges resulting from overreliance on the fossil-fuel-based thermal electrical plants in the country. The climatic condition in the UAE demands heavy energy use to run the air conditioners throughout the day for most part the year. Therefore, it is becoming a compelling need to develop less expensive and sustainable sources of power in the country.

**Index Terms—** CSP, Concentrating Solar Thermal, Desalination, Energy, Environment, Storage

## I. INTRODUCTION

Until now, people around the globe largely depend on fossil fuels for their energy needs. Fossil fuels are limited in amount, expensive and polluting the environment. Therefore, a significant amount of research and developments have been proposed to solve different aspect this serious problems. One of the effective strategies is to utilize the available renewable energy resources. In UAE, solar energy is the amplest, direct and clean form of renewable energy available [4]. Total solar energy absorbed by the Earth is about 3,850,000 extra joules (EJ) in one year, which is even twice as much as all the non-renewable resources on the earth found and used by the human being, including coal, oil, natural gas, and uranium [1]. There are two major challenges to the energy situation in the UAE. One of the important concerns is the rising demand of power and alarming power bills. The other important concern is the environmental challenges resulting from overreliance on the fossil-fuel-based thermal electrical plants in the country. The climatic condition in the UAE demands heavy energy use to run the air conditioners throughout the day for most part the year. Research indicates that power consumption in the UAE extremely high and it is growing at 9 percent annually [13]. The country currently depends on natural-gas-run power plants to produce electricity that poses severe challenge to

the environment. Hence, the country is aiming to diversify the energy mix and seeks to achieve at least 24 % of power production from clean energy sources by 2020 [3]. Therefore, it is becoming a compelling need to develop less expensive and sustainable sources of power in the country. In this context, Concentrated Solar Power (CSP) generation has great relevance in the UAE.

The Concentrated Solar Power (CSP) system is relatively a new technology in which heat from the solar light is focused using mirrors that helps producing huge amount of heat energy which is used to run conventional turbines to generate electricity [4]. Purpose of this research to provide insight on the relevance and applications of the CSP system to the general public and the officials of the Sharjah Municipality. It will help educating people about the benefits of CSP system over the conventional solar power generating systems as well make them realize the cost effectiveness and environmental significance of the CSP system.

## II. THE CSP TECHNOLOGY

The Concentrated Solar Power (CSP) systems capture heat energy from light rays from the sun and transform it effectively to produce electricity.

Technical Features of CSP system

The CSP system make use of sunshine as input to produce energy, therefore, it requires adequate system to convert energy from the solar sources to produce energy.

### CSP Plant Design

In the CSP technology mirrors or lenses are used to concentrate the sun's light rays to produce electricity. The important components of a typical CSP plant includes mirrors or lenses, tracking system, receivers, energy storage system, steam generator and solar super heater, turbine, and condenser. The mirrors or lenses, also known as solar collectors, are used to concentrate the sun's rays. The tracking system is functional to keep the collectors aligned toward the direction of the sun, thereby increasing the solar output. The receivers are used to capture the concentrated solar rays which will be used to heat up the heating fluid. The steam generator and solar super heater are functional to generate superheated steam in the steam generator and solar super heater. The turbine is used transform the heat energy into electricity. Most plants have an energy storage system, in most cases using the molten salts, to store energy which can later be used to generate electricity in the absence of sunlight. The condenser of a CSP plant is used to cool the output steam from the turbine which will be sent again to the steam generator and solar super heater to generate the superheated steam (U.S. Department of Energy, 2006).

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LOCATION OF CSP Plant

The geographical location and weather conditions are important considerations for effectively utilizing the CSP technology for power production. The CSP plants need certain specific locational requirements. Availability of sunshine is one important condition. Since the input for power production in the CSP is the sunlight, the places that offer plentiful sunshine are best suited for establishing the CSP plants. The second important criteria is sufficient flatness of the locality. Open and flat terrain without any obstructions is required to set up the CSP plants. About 1 square kilometer open area is ideally needed for a CSP plant of 50 MW electric capacity.

Besides, low population density is the other suitability factor [2]. The conditions in the UAE are perfectly suitable for the large scale projects to produce energy using the CSP technology. The vast plane desert locality, low population density as well as availability of plentiful sunshine throughout the year offer outstanding background for setting up the CSP plants in the UAE.

GENERATION ENERGY IN CSP

The CSP plants convert the heat energy from the sunshine to produce electricity. Basically, heat energy from the light rays are captured and intensified to produce electricity.

A. CSP Methodology

The devices in the CSP system facilitate collection and concentration of heat energy, and conversion of heat energy into electricity. It converts heat energy from the Sun into electricity without using any photovoltaic panels. The mirrors help centering and amplifying the heat from the Sun onto a container of water and then the steam from this tank will be used to drive the turbine to produce electricity as is done the conventional thermal plants [2]. The arrays of mirrors can be 100 meters (m) long or more, with the curved aperture of 5 m to 6 m. A single-axis tracking mechanism is used to orient both solar collectors and heat receivers toward the sun [7]. In order to maximize the collection of sunlight the receivers are usually aligned North-South and also there is one axis tracking in order to track the Sun as it moves from East to West. The receiver tube is made of metal and is placed inside an evacuated glass envelope because it helps to reduce heat losses [6].

One of the most important components of the CSP is the heat transfer fluid (HTF), which is circulated through the absorber tubes to collect the solar energy. The absorbed solar energy is then transferred to the steam generator or to the heat storage system. Conventional turbine is attached to the thermal generators. Heat from the steam generator will drive the turbines to produce electricity. The thermal storage device attached to the CSP system helps storing the heat energy gathered during the day for producing electricity in the night or non-shiny phase of the day. The CSP system is considered to be the most efficient energy- power plants as they have the highest power conversion (solar heat to electricity) efficiency than any other power plants [14]. Conventionally synthetic oils were used as the heat transfer fluid, which could sustain up to 400°C, however newly used technology uses molten salt at 540°C either for heat transfer and/or as the thermal storage medium [6].

There are three major forms of CSP plants commonly used such as the CSP trough, the CSP tower, and the CSP parabolic

dish [7]. In the parabolic trough based CSP plants, mirrors in the shape of parabola are used to capture and concentrate heat energy that will be used to heat up the transfer fluid which will then be used to drive a conventional turbine to generate electricity (Fig.1).

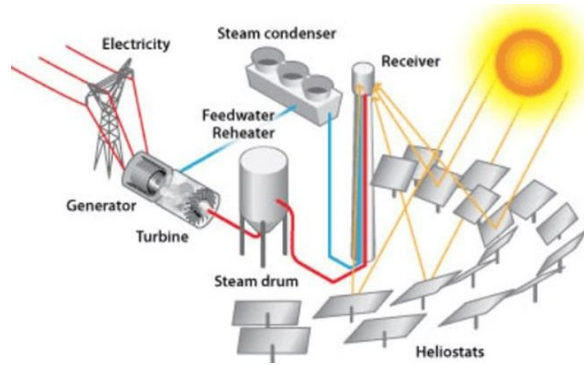


Figure 1: CSP: Linear Parabolic Trough [8]

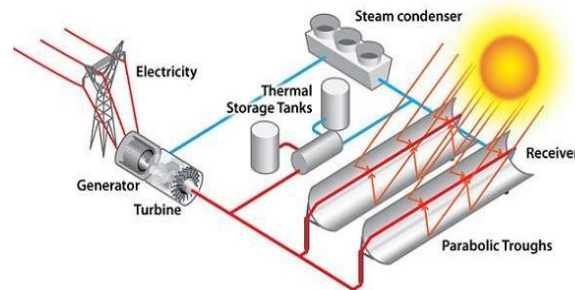


Figure 2: CSP: Parabolic Tower

In the case of the CSP based on parabolic towers several individual mirrors, known as heliostats are utilized to capture and concentrate heat from sunshine onto the receiver attached at the top of the tower system (Figure 2). Several dish shaped mirrors are used to concentrate and convert heat energy in the case of the dish-based CSP systems (Figure 3) [11]

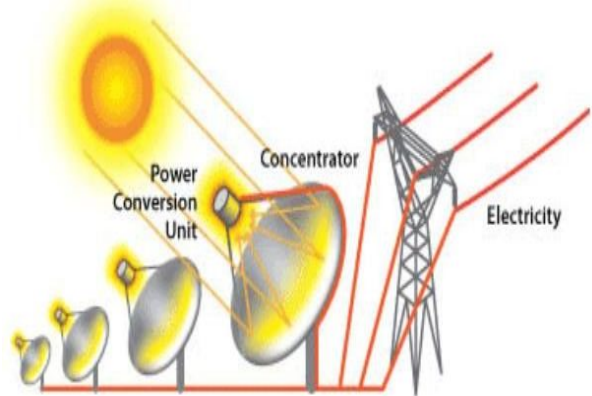


Figure 3: CSP: Parabolic dish[8]

The parabolic trough is considered to be the most commonly used commercial system owing to its cost, ease in installation and effectiveness [11]. The CSP based on parabolic towers are especially useful for large scale operations as this system has greater efficiency to convert heat and enhanced ability to store high density energy [11]. The dish CSP system are especially useful for small scale operations because each individual dish system is capable of generating 10 KW to 25

KW electricity [11]. Perhaps, this utility is highly advantageous for household installation. Therefore, the dish based CSP system could be recommended to for standalone housing units or villas in the UAE. At the same time the trough based CSP system are suitable for buildings that have several apartments. The material cost is low at the time efficiency is quite good. The CSP based on parabolic towers may be useful for commercial applications such as Municipalities and communities that serve for large number of residents or users.

Table 1: Cost of Different CSPs

Types Of CSPs	Parabolic Trough	Thermal Solar Tower	Solar Disk
Max. Temp Output	300 -500 degree Celsius	270 degree Celsius	800 degree Celsius
Life	30-40 Years	30-40 Years	20-30 Years
Storage Capacity	6 hours	6-8 hours	12-15 hours
*Cost in \$ US/ per KWh	6300-8500 (3900-4100)	6300-8300	8100-9000

Sources: Extracted from IEA-ETSAP & IRENA (2013) and IRENA (2012).

\* Size of the plant will determine quantity of electricity generated. The investment cost will be reduced significantly with the increase in plant size (30-50%) and economy of scale (20 % reduction if capacity increased from 50 MWh to 200 MWh).

The table (1) provides information on the cost required to set up the different CPS plants. Although the initial investment appears to be quite high, there is great potential for cost reduction if large scale operations is sought for. Cost stability is a distinct feature of the CSP plants. They can offer stable price for 20-40 years as the life of the plants range between 20 to years. The researchers suggest that parabolic trough are more recommendable owing to its technology maturity, stability and maintenance and cost. Without storage facility it costs as low as 3900 per KWh electricity [4].

#### COST BENEFIT ANALYSIS of CSP

The CSP system are have several advantages. It includes cost advantage as well as environmental stability.

#### Reducing Cost of Energy Using CSP

The CPS systems are less expensive and viable methods to produce electricity compared to other methods of generating electricity excepting those thermal electrical plants that use gas [11]. The CSP technology is proved successful in the U.S since last two decades. The solar energy technology that makes use parabolic troughs is one of the least expensive solar electrical power alternatives today and researchers argue that it has great potential for cost reduction in future [15].

Even though the initial cost of setting up of the CSP plant is high in comparison to the conventional power generation plants, the CSP plants in particular parabolic trough, is a proven and low cost large-scale solar power technology [15]. For instance, in US alone there is 1176 MW units of utility-scale solar power generation and about 43% of this capacity is provided by parabolic based CSP [8] Around the world, the total power produced by CSP has reached 2.5 GW and in the coming years the plants which are currently under construction is expected to generate an additional 2 GW [10].

Another highlight of a CSP plant is that since the heat absorbed is stored the form of molten salts it is possible to can generate electricity even when in times of no sunshine or winter season. Moreover, high temperatures required for certain industrial processes are directly accessible as CSP-Parabolic trough plants can produce up to 150–350 °C (300–660 °F) [5]. Besides, compared to other technologies, the dish based CSP’s solar-to-electric efficiency are the highest, reaching over 30% of peak efficiency [9]. Longer price stability is another important element of cost effeteness of the CSP technology. Once established, they are highly economical compared to other power plants as the maintenance cost is very low. The researchers estimate that the CSP plants in Europe could offer cost stability for period of minimum 40 years of operation [14].

The large scale production of electricity of using the CSP technology in the US costs between \$ 0.08 and 0.10 per KWh (U.S. Department of Energy, 2006), which is equal to UAE Dhs. 0.294- 0.367. At the same time in the actual cost of electricity in the UAE is Dhs 0.318 [1]. This reveals that the unit cost of electricity generated by conventional way and CSP technology is almost similar.

However, there is great potential for cost reduction in the near future if production is carried economy of scale and in the event of development of low cost materials for the CSP systems. The U.S Department of Energy (2006) reveals that since the material used to build the CPS plants include steel, glass and concrete and also rigorous research is being carried out to improve the technology, great cost reduction is very likely. Such potential is not expected in the case of conventional thermal plants. Therefore, the CSP plants could be violable alternative to the currently used thermal power plants that uses gas in the UAE.

#### Environmental Value

The environmental contribution is another significant benefit of power production using the CSP technology. The CSP plants make use of costless but abundantly available renewable source, the sunlight, for power generation instead of using fossil fuels. The thermal electrical plants that use



fossil fuel pose severe challenge to the environmental stability. This concern is quite severe in the UAE. Therefore, the UAE government made a strategic priority to diversify the energy mix and seeks to achieve least 24 % of power production from clean energy sources by 2020 [3]. The CSP plants are important means to achieve this goal to a great extent as they produce significantly low level of greenhouse gases compared to fossil fuel-powered power plants. Researchers have found that if a CSP thermal plant with 1 MWh production capacity is used in place of a conventional thermal plant run by natural gas with the same production capacity, it will be able to cut down about 688 tons of carbon dioxide and if used in place of a conventional coal plant it will be able to reduce to about 1360 tons of carbon dioxide annually ([13]). The environmental researchers consider that the CSP plants are the best available renewable energy options for the Middle East North Africa considering the environmental stability and quality of power they offer [14]. Hence, the CSP system can be considered as a green technology and the most sustainable way to produce power.

### FUTURE OF CSP

The energy demand is growing in the country which will be unstoppable as the climatic conditions in the UAE remain hot and humid most part the year on one hand and the commercial and industrial activities as well as the population size are on the rise in the country on the other hand. The current method of producing power using the fossil-fuel based thermal plants to generate electricity is a matter of severe concern in the UAE. Since it uses non-renewable fossil resources, it is likely to be depleted in the future. Moreover, the environmental concerns that the fossil fuel powered thermal electrical plants are growing.

Besides, people are hard pressed by the rising cost of energy bills. Hence, a less expensive, and environmentally safe method of producing power is a compelling and inevitable requirement in the country.

In the given context, power generation using the CSP technology has huge scope. The climatic and geographic conditions in the country are well suited for establishing both small scale and large scale CSP plants. The vast desert locality as well as availability of plentiful sunshine throughout the year offer outstanding background for commercial utilization of the CSP technology to produce power in the country. If not adopted, this technology to meet the entire energy requirements, it could serve as an important energy mix to meet the growing demands of energy. Adoption of the CSP technology will do much to accomplish the strategic goal of the nation that seeks to diversify the energy mix and achieve least 24 % of power production from clean energy sources by 2020.

### CONCLUSION

The rising energy bills and growing environmental concern make it inevitable for the UAE to seek a cheap and sustainable source of energy. Although the initial investment is higher, the CSP technology will be a viable and promising source of energy in the UAE. It makes use of costless and renewable input, the sunlight that creates negligible environmental concern. The country is perfectly suitable to establish the CSP plants. The CSP system could offer clean, secure, reliable and affordable energy to the UAE. If not sought to meet the energy requirements, the CSP technology

can certainly be an important energy mix to meet the growing demands of energy in the UAE. The CSP power plants will be promising cheap and sustainable source of energy for the UAE.

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