

# SAINTS

 *Open Courseware System*

 *enabled*

## Concentrated Solar Power (CSP)

### What you need to know

Written by: Kerry Thoubboron

[EnergySage, Updated Dec 6, 2023](#)

Many people are familiar with solar photovoltaic (PV) or solar hot water systems. But in sunny spaces across the world, another lesser-known technology exists as a different way to take advantage of the sun's energy: concentrated solar power (CSP). In this article, we'll describe how concentrated solar power technology works, the types of concentrated solar systems, and how the technology compares to the solar photovoltaic panels you might install on your property.

### What is concentrated solar power?

Have you ever tried using a mirror or magnifying glass to fry an egg on the pavement during a hot, sunny day? Concentrated solar power (also known as concentrating solar power or concentrating solar-thermal power) works in a similar way conceptually. **CSP technology produces electricity by concentrating and harnessing solar thermal energy using mirrors.** At a CSP installation, mirrors reflect the sun to a receiver that collects and stores the heat energy. That heat is used to power an engine or turbine that is connected to an electricity generator.

CSP is used in utility-scale applications to help provide power to an electricity grid. They can be paired with energy storage technologies to store thermal energy to use when solar irradiance is low, like during the night or on a cloudy day. Today, roughly 1,815 megawatts (MW) of CSP plants operate in the United States.

Generally, concentrated solar power is not installed at a residential scale and instead will almost always be installed over a large area as a utility-scale generating facility.

# SAINTS

 *Open Courseware System*

flexbook<sup>®</sup>

enabled



For residential and commercial property owners, solar photovoltaic panels are the best way to harness the sun's energy for use.

## **Concentrated solar power system types**

CSP systems come in all shapes and sizes, but most installations fall into one of four major categories:

- 1) Parabolic dishes
- 2) Solar power towers
- 3) Parabolic troughs
- 4) Linear Fresnel systems

These types of CSP installations all have different advantages and disadvantages to their use. Below, we'll dive into some of the details:

# SAINTS

## Open Courseware System

flexbook<sup>®</sup>

enabled

### Parabolic Dishes

With parabolic dish concentrated solar power systems, mirrors are set up in a satellite-dish shape with a receiver mounted in the middle, away from the mirrors. Sunlight reflects off the mirrors and hits the receiver focal point, which typically has a heat engine mounted directly on it.



# SAINTS

## Open Courseware System



enabled

Two of the biggest advantages of parabolic dishes over other types of CSP systems are that they require very little land space and don't need to be installed on a flat surface.

### Solar Power Towers

Solar power towers have a host of mirror reflectors at the ground level, also known as heliostats. These heliostats run on a tracker system and concentrate sunlight throughout the day, reflecting it to a single point at the top of a tower that hosts the receiver.



Within the receiver is a heat transfer fluid that will warm up, generate steam, and then power a turbine in the generator, creating electricity. Oftentimes this heat transfer fluid is a **molten salt**, which can retain heat more effectively than many other fluids, given its high heating capacity.

# SAINTS

## Open Courseware System

flexbook<sup>®</sup> enabled

### Parabolic Troughs

Parabolic troughs are the most common type of CSP system used throughout the world. Long, u-shaped mirrors reflect sunlight towards a tube that runs along their center, parallel to the mirrors. Inside the tube is a heat transfer fluid that gets heated as sunlight is reflected toward the tube. Once hot, this liquid runs to a central power generator that will use the heat to produce electricity.



### Linear Fresnel Systems

Similar to parabolic troughs, linear Fresnel systems use rows of mirrors with a parallel absorber that carries a heat transfer fluid. The biggest distinguishing factor between these two technologies is that parabolic troughs remain

# SAINTS

 *Open Courseware System*

flexbook<sup>®</sup>

enabled

stationary, while linear Fresnel systems use trackers systems on the mirrors to maximize the amount of thermal energy concentrated and reflected towards the absorber.



## Concentrated Solar Power Efficiency

The solar-to-electricity efficiency of a CSP system depends on many factors, including the type of CSP system, the receiver, and the engine. Most concentrated solar power technologies will have an efficiency somewhere between **7% and 25%**.

# SAINTS

 *Open Courseware System*

 *enabled*

To compare this to the electricity conversion efficiencies of other renewable energy technologies, wind turbines can achieve up to 59% efficiency, and hydropower systems can have efficiencies of up to 90%. When it comes to solar photovoltaics, the conversion efficiencies of solar cells are in a similar range as CSP; most solar panels available on the market today have efficiencies between 14% and 23%.

## **Concentrated Solar Power Plants around the world**

Concentrated solar power has gained a lot of traction worldwide for utility-scale solar projects. CSP plants need to be placed in areas with high irradiance because the mirrors need to reflect as much concentrated light as possible. Another important note about **CSP plants is that they need 5 to 10 acres of land per MW of capacity, and since CSP plants are most cost-effective and efficient when built in sizes of 100 MW or higher, a huge amount of land (most times in a desert)** is needed for these types of projects.

### **Ivanpah Solar Electric Generating System**

The Ivanpah power tower CSP plant produces 392 Megawatts of electricity annually with the help of 173,500 heliostats and three 450-foot power towers spread out over 3,500 acres in the Mojave desert. When the installation commenced in 2011, it created 1,000 jobs and now powers over 100,000 homes in the United States. Along with a steep economic impact, Ivanpah cuts out 500,000 metric tons of CO<sub>2</sub> from our environment as well.

### **Mojave Solar One**

Mojave Solar One was developed by Abengoa Solar in 2011 with a \$1.2 billion dollar loan. Unlike Ivanpah, Mojave One is a parabolic trough plant, which means it uses carefully placed mirrors to heat water in a large tube to power a generator that creates electricity. The Mojave Solar One CSP plant produces enough electricity to power over 90,000 homes.

# SAINTS

 *Open Courseware System*

 *enabled*

## **Genesis Solar**

Located in Blythe, California, the Genesis Solar Energy Project is a 250 MW concentrated solar power installation. This particular solar project uses heated synthetic oil to propel a steam turbine, and its 600,000 parabolic mirrors span over 1,800 acres.

## **Ouarzazate Solar Power Station**

Also known as the Noor Power Station, the Ouarzazate Solar Power Station is the biggest operating solar power plant in the world, with an installed capacity of 510 megawatts. Spanning across the equivalent of 3,500 soccer fields, this power tower CSP solar plant The Moroccan Agency for Solar Energy has even installed PV solar panels to ramp up production by 72 more megawatts.

## **Concentrated Solar Power vs. Photovoltaic Solar**

Though CSP and PV have similar efficiencies, there are a few notable differences between them when it comes to applications, costs, and storage capacity. The main difference between CSP and photovoltaics is that CSP uses the sun's heat energy indirectly to create electricity, and PV solar panels use the sun's light energy, which is converted to electricity via the photovoltaic effect.

### **Application**

Concentrated solar power systems require a significant amount of land with direct sunlight or irradiance. Because of this, there are limited places to build these types of systems. CSP systems tend to be large, utility-scale projects capable of providing a lot of electricity as a power source to the grid. They're not used in residential applications, unlike solar PV.

PV is a lot more common because solar panels can be installed just about anywhere that the sun is shining. While utility-scale solar installations will require similar amounts of space that a CSP plant would, you can also install



# SAINTS

 *Open Courseware System*

flexbook<sup>®</sup> enabled

solar panels for your own personal use on your home in business without developing new, unused sunny land.

PV systems are also capable of generating electricity in more weather conditions than CSP. CSP technology requires direct solar radiation to operate. Because of this, the performance of a CSP system is more sensitive to cloudy weather, while PV systems will still generate electricity on cloudy days.

## **Cost**

**Solar PV is the least expensive technology**, both in terms of installation costs and leveled cost of energy (LCOE). This is due to a number of factors, including ease of installation and hardware requirements. Concentrated solar power is a newer technology that requires more specialized technology and installation practices, driving up the costs of these projects.

According to IRENA, CSP deployment by the end of 2016 was at 5 GW. For comparison, solar PV deployment by that time had reached 291 GW of installed capacity. Just as the price of PV has dropped as installations become more widespread, CSP costs are also expected to decrease in the future as technology advances.

## **Storage**

One major advantage that concentrated solar power has over PV is its storage capabilities. With CSP, the heat transfer fluid used to move the heat from the absorbers to the engine has high heating capacities, allowing this fluid to retain heat for a long period of time. Storing thermal energy with the use of thermal energy storage tanks is much easier than storing electricity. As a result, concentrated solar power is often dispatchable even when the sun isn't shining.

Solar PV has a disadvantage when it comes to storage - while you can store solar electricity using solar battery technologies, it's more difficult and

# SAINTS

 *Open Courseware System*

flexbook<sup>®</sup>

enabled

expensive to do so at large power levels. This makes it a less feasible source of electricity to the grid come nighttime.

## **Concentrated Solar Power vs Natural Gas**

CSP and photovoltaics are both solar technologies, but in some ways, it's not truly fair to compare them against one another. Although you can compare the cost, efficiency, applications, and storage options of these two renewable energy resources, concentrated solar power is more readily comparable to natural gas because it creates thermal energy. Natural gas is also CSP's true competitor because they are both dispatchable, unlike photovoltaics. This means that they can be turned on and off relatively easily, which is a desirable trait for any power plant providing electricity to the grid. What sets these two apart is price: natural gas is currently the cheaper option of the two.

## **Frequently asked questions about CSP**

### **Is concentrated solar power better than photovoltaics?**

CSP can deliver better grid stability than photovoltaics because of its dispatchable nature, but producing electricity with PV panels is currently far cheaper and more accessible, especially for small-scale residential solar installations. In order to build an effective CSP plant, you need to choose an area with particularly high irradiance, like in the American Southwest. PV technology lends itself to individual use because it can produce electricity in any place the sun is shining.

### **How is concentrated solar power used?**

Concentrated solar power uses software-powered mirrors to concentrate the sun's thermal energy and direct it towards receivers which heat up and power steam turbines or engines that produce electricity. Some CSP plants can take that energy and store it for when irradiance levels are low. This is why concentrated solar power is a viable utility-scale electricity generating option.

# SAINTS

 *Open Courseware System*

flexbook<sup>®</sup> enabled

There are four different types of plants used around the world to create electricity- parabolic dishes, solar power towers, parabolic troughs, and linear fresnel systems. All of these types of plants have nuanced differences, for example, in the type of receiver or heating fluid it employs, but all concentrated solar power plants use mirrors to concentrate the sun's thermal energy to a receiver.

## **What are CSP's limitations?**

Concentrated solar power is a great renewable energy option, but as with anything, there are pros and cons. Perhaps the biggest downfall of concentrated solar power energy is its high installation and construction costs. This limitation goes hand in hand with CSP's inability to translate to rooftop or commercial projects: given the current technology, it is just too expensive to do. This is one of the reasons that traditional PV solar panels have gained so much traction in recent years: they go right on your roof.

Since concentrated solar power plants take up a lot of space and have a relatively low-efficiency rate, the amount of energy they produce per unit of land they take up is also low. Additionally, concentrated solar power has some performance limitations. If CSP technology isn't paired with an energy storage solution (like batteries for PV solar panels), then their energy production will be intermittent and, therefore, not the most reliable option. ■

## **Related Articles:**

**The Future of Solar Energy | MIT Energy Initiative**

<https://energy.mit.edu/research/future-solar-energy/>