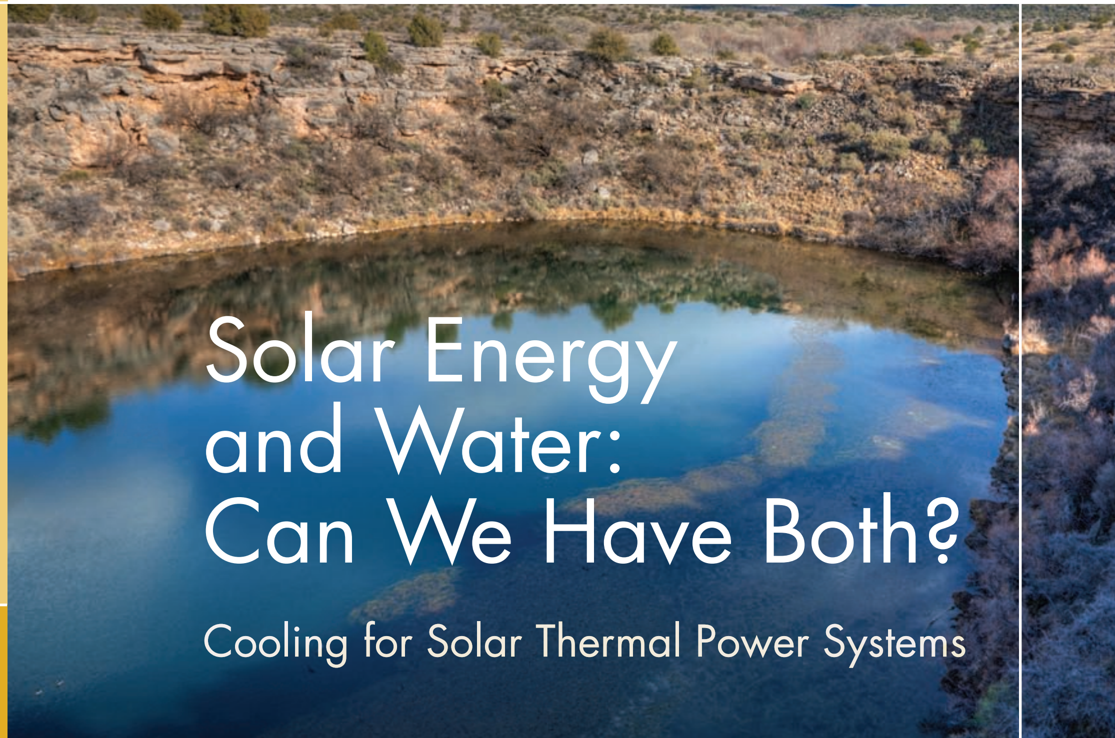
Arizona's Solar Energy Future

Fact Sheet 3 in a series



# Solar Energy and Water: Can We Have Both?

## Cooling for Solar Thermal Power Systems

*Sunlight and water: both are essential for our survival, and both are necessary for the largest solar energy plants to work most efficiently. Unfortunately, in places like Arizona where sunlight is most abundant, water is most scarce. As Arizona considers how to realize its solar power potential, emerging technologies offer viable solutions.*

## THE NEED FOR WATER

The American Southwest has both extraordinary solar energy resources and a rapidly growing population with a demand for electricity. Capitalizing on this solar resource with modern utility-scale concentrating solar thermal (CST) technology can go a long way toward meeting these new power needs without contributing additional carbon dioxide ($CO_2$) emissions to the atmosphere.

One 150-megawatt (MW) CST plant could eliminate almost 400,000 metric tons of $CO_2$ per year produced by a coal power plant. A series of large CST facilities built across the desert Southwest could displace many millions of tons of $CO_2$ per year. A major advantage of this technology over similarly sized systems using the other major solar energy technology—photovoltaic—is that CST is able to store thermal energy to generate electricity when it is needed later in the day, when utilities need it to help meet high customer electricity demands. This ability to be turned on or off, or "dispatched," by utilities as needed increases the value of the power plant's electricity to utilities and customers. CST's storage ability also allows it to operate continuously when passing clouds obscure the sunlight, another critical advantage.

But there's a catch: CST power plants require cooling to operate, and the most common cooling systems—for both solar and for conventional power plants—use significant amounts of water. Water is a scarce resource in the areas best positioned for solar energy production, and water supplies must be carefully managed as the population in the Southwest grows. Fortunately, technologies exist that can help resolve this dilemma, albeit at some cost both in terms of expense and performance.

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**1) Trough:** This technology uses long, parabolic-shaped mirrors to focus the sun's energy onto a central heat-collection pipe. Oil or other fluids running through this pipe is warmed by the sunlight, and is used to generate steam that powers a steam turbine, similar to the ones used by coal, natural gas, or nuclear power plants.

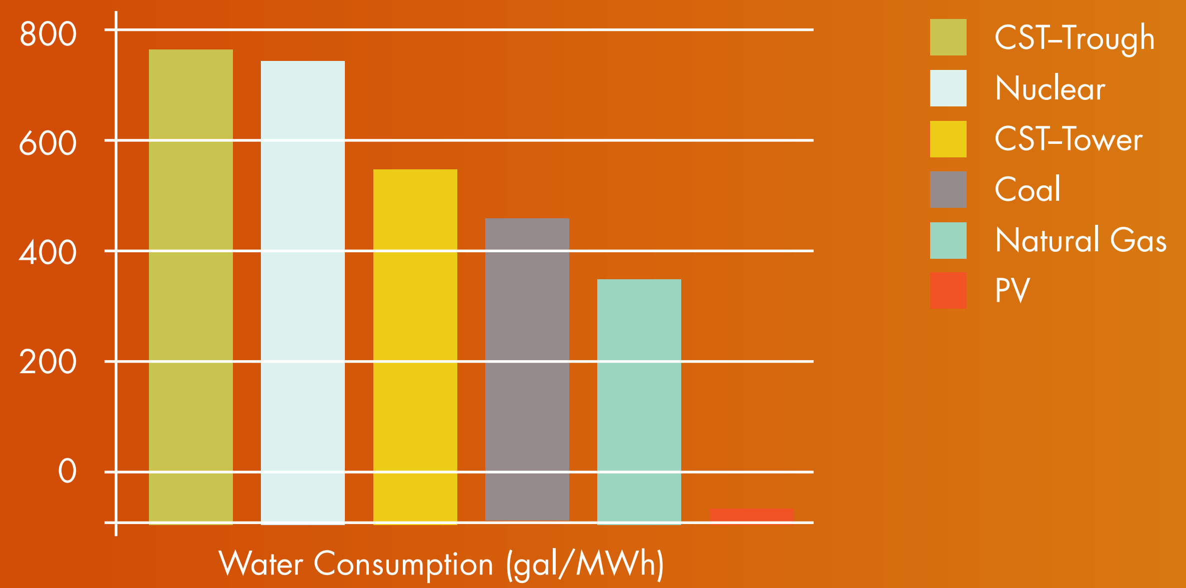
**2) Tower:** With this technology, a series of rotating mirrors surround a tower. The mirrors track the sun and focus the energy onto a heat collector at the top of the tower.

# Concentrating Solar Thermal Technologies

There are two commercially available CST technologies that require cooling: trough systems and tower systems, as described above.

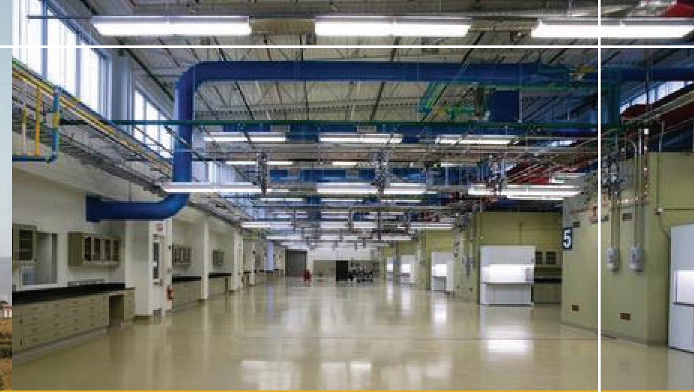
Both trough and tower plants use the high temperatures generated by the sun to create steam that turns a turbine and generates electricity. Once the steam has passed through the turbine, it must be condensed by a cooling system. The efficiency of steam cycles improves dramatically as the difference between the high temperature and the condensing temperature increases. In solar energy systems, the high temperature is limited by technical features, and cannot be raised. To maximize the efficiency of the steam cycle, therefore, the condensing temperature must be kept as low as possible. Water is a key element in keeping this condensing temperature low and minimizing the cost of solar power.

## Water Needed to Generate Electricity, by Source




Source: The Sonoran Institute.





**3) Dry cooling systems:** Dry cooling systems eliminate almost all of the water consumption but are much larger, cost more and reduce the plant's efficiency.

**4) Wet cooling systems:** Wet cooling systems evaporate much of the water they consume, but provide better efficiency.

**Water Consumption in Cooling Systems**

Cooling accounts for nearly 90 percent of the water used in wet-cooled plants. The most common type of wet cooling is called recirculating/evaporative or "closed loop." As anyone who has been swimming on a hot day knows, evaporating water can cool a surface well below the ambient temperature. Power plants with recirculating/evaporative cooling systems evaporate some of the water to cool the remainder, which is then recirculated to cool the plant.

The water that is consumed through evaporation cannot be returned to the water source. Fresh water must be added to make up for both the water that is evaporated and to keep the dissolved salts in the water from building up over time.

In general, tower systems require about 600 gallons of water per megawatt-hour (MWh) generated, while trough systems use 800-1,000 gallons per MWh.

To mitigate the water demands of the wet-cooled systems, two alternative cooling options have been developed: dry cooling and hybrid wet/dry cooling technologies.

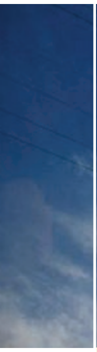
**Alternative Cooling Approaches**

Dry cooling uses rows of large fan-coils (like the radiator on a car) that draw air over finned tubes to cool the water inside the tubes without any evaporation. Dry cooling essentially eliminates water requirements for cooling.

Hybrid wet/dry cooling systems come in various forms, but all typically use a dry cooling system for the majority of the time, and then engage a smaller evaporative cooling unit as a "booster" to keep cooling temperatures low and boost plant performance on hot days with high electricity demand. Depending on the ambient conditions and the particular design, this type of system can reduce the water evaporated by as much as 70-80 percent compared to a full wet-cooling system.[1]

While the water-saving benefits of these technologies are obvious, both dry and hybrid technologies currently present some challenges:

- They can increase the capital cost of a plant because the dry cooling systems are larger and more complex than wet cooling systems.
- They typically decrease system efficiency in hot weather because the condensing temperature rises.
- They increase the cost of producing energy because of the increased capital cost and the decreased system efficiency.





**Why Costs Increase**

Because air temperatures in the desert Southwest are high, dry cooling cannot achieve the low temperatures of the wet-cooling systems. Higher condensing temperatures can result in as much as a 10-20 percent instantaneous decrease in power, and perhaps a 3-5 percent drop in annual power production.[2] Unfortunately, desert temperatures tend to be highest at exactly the time power is needed most and has the highest value to customers and utilities.

Higher capital costs combined with reduced power output can result in a 7-9 percent increase in electricity costs from a dry-cooled trough plant.[3] The numbers are better for tower plants, which operate at higher temperatures, but even here there is potential for a 5 percent increase in the cost of electricity.[4]

A number of dry- and hybrid-cooled power plants have been built both in the U.S. and around the world since the 1960s. However, because of these performance and cost penalties, dry-cooling has typically been restricted to locations that have moderate temperatures and a severe lack of water.

# Conclusion

Concentrating solar technology offers dramatic potential to become a major power source to supply the growing population in the southwestern United States. As noted, however, CST plants' need for water is a challenge that will have to be worked out as the technology develops and matures. A variety of studies are underway currently to assess the optimal way to manage the cooling loads from these plants. These studies have the potential to reduce the performance and cost penalties listed here substantially, and make concentrated solar power systems even more competitive.

*The Sonoran Institute inspires and enables community decisions and public policies that respect the land and people of Western North America.*

# Footnotes

1 Bruce Kelly, "Nextant Parabolic Trough Solar Power Plant Systems Analysis; Task 2: Comparison of Wet and Dry Rankine Cycle Heat Rejection," Final Report, July 2006, National Renewable Energy Laboratories, NREL / SR-550-40163 (average of seven model runs).

2 "Concentrating Solar Power Commercial Application Study: Reducing Water Consumption of Concentrating Solar Power Electricity Generation: Report to Congress" U.S. Department of Energy.

3 IBID.

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*Select photos courtesy of National Renewable Energy Laboratory (NREL).*

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