Arizona's Solar Energy Future

Fact Sheet 2 in a series

Solar Energy for Arizona

A Look at Available Technologies

DEMAND FOR CLEAN POWER

"Solar energy" means different things to different people. Some envision solar panels covering residential and commercial rooftops for local use. Others see huge fields of mirrors delivering utility-scale power to the electrical grid. Both are legitimate visions for "solar," but it's important to recognize the differences between these technologies and use them where each works best.

Arizona's solar resources are among the best in the world, and the geographic proximity of large and rapidly growing cities in both Arizona and southern California create an ideal situation for marketing this resource. In addition, Arizona, like many states, mandates that a certain percentage of its electricity in the future must be produced by renewable sources. This policy, known as the Renewable Energy Standard (RES), requires that 15 percent of Arizona's retail electricity sales from regulated utilities be produced by renewable sources by 2025.[1] Capitalizing on the state's solar energy resources could enable Arizona to meet this standard, displace many millions of tons of fossil-fuel plants' carbon dioxide production per year, and enable a robust local economy and high living standard for residents of the region while causing minimal damage to the environment.

But what is the most effective way to realize this solar potential? The solar energy technologies commercially available and viable today fall into two categories: photovoltaic (PV) and concentrated solar thermal (CST). The two systems are largely identical in their need for plentiful sunlight, access to transmission, and a relatively flat grade to build upon. Beyond that, there are several major distinctions that are important to consider so that the technologies—and our energy dollars—can be used to best advantage.

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A Comparison of Solar Energy Systems

Photovoltaics (PV)
PV is the solar energy system most familiar to people. PV panels contain semiconductor materials that generate electricity by absorbing sunlight and releasing electrons. The panels are able to collect both sunlight coming directly from the sun and the diffuse light scattered in the air by humidity, dust, and pollution. PV systems are modular and highly "scalable," meaning they offer great flexibility in terms of system size. Depending on the number of panels used, systems can range from a few hundred watts to hundreds of megawatts (million watts)—from rooftop systems serving a single home; to "community-scale" systems serving end users located close by; to large, "utility-scale" systems feeding power into the electric transmission grid.

PV Characteristics

- Ability to scale up from small rooftop systems all the way to utility-size systems.
- Require minimal water use: 1 gallon/megawatt hour (MWh) of energy generation, mostly for ongoing maintenance, to wash dust off panels.
- No land required if located on rooftops; at utility scale, requirements average from about 4 acres/MW (for flat plate) to 6-10 acres/MW (for thin film).
- Costs for PV systems are higher than for CST. The levelized cost of energy (LCOE: energy cost when capital and operational expenses are spread out over the lifetime of the plant) is 18-22 cents/KWh. As size increases, economies of scale are very small.
- There is currently no cost-effective way to store large amounts of electricity. Therefore, electricity from PV systems must be used when it is generated, regardless of the needs of consumers or the power grid.
- PV's inability to store power also means that PV plants are subject to intermittent outages from passing clouds.
- Wide implementation of rooftop systems requires many individual transactions with homeowners and business owners.

Concentrated Solar Thermal (CST)
CST uses large mirrors to focus sunlight on a relatively small receiver surface, concentrating the sunlight's heat to create high temperatures used to produce steam that drives an engine to generate electricity, much like a conventional power plant. This technology only collects light that comes directly from the sun itself, which works well in the American Southwest with its very clear and dry skies. CST systems are typically utility-scale, ranging from 50 MW up to greater than 500 MW, and need large tracts of land.

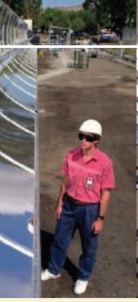
The two CST technologies that are commercially proven at a utility scale today are "trough" and "tower" systems.

Trough
Rows of curved mirrors track the movement of the sun, focusing solar energy on a pipe carrying a fluid that absorbs concentrated energy. The fluid carries the energy to a central plant, where it is used to create the steam to drive the turbine.

Tower
Fields of rotating mirrors surrounding a tower with a heat collector mounted on top track the sun and focus its rays onto the heat collector. Heat is absorbed by fluid in the collector and is used to produce the steam.

CST Characteristics
A significant advantage is CST's ability to store the thermal energy it generates for later use in meeting customers' "peak demand" for electricity, usually late afternoon and early evening (see sidebar). This feature also allows the plant to operate steadily through intermittent clouds.

- Costs are lower than PV: LCOE is 12-16 cents/KWh, decreasing as the system size increases, up to approximately 125 MW.
- Commercially available and technologically proven at utility scale.
- Requires large amounts of water for traditional evaporative ("wet") cooling:[2] 800-1,000 gallons/MWh for trough; 600 gallons/MWh for tower. Alternative technologies can



dramatically reduce this water use. Dry cooling systems essentially eliminate water requirements for cooling, while hybrid wet/dry cooling systems can reduce the water evaporated to as little as 20-30 percent of that used in a wet-cooling system.[3] These alternative cooling technologies increase the cost and reduce the performance of the plant somewhat, increasing the cost of electricity slightly.[4]

- Requires on average from 5-6 acres/MW, though acreage can increase for large-size tower plants (because the mirrors are farther apart when further from the tower).

WHY IS CST'S ABILITY TO STORE POWER IMPORTANT?

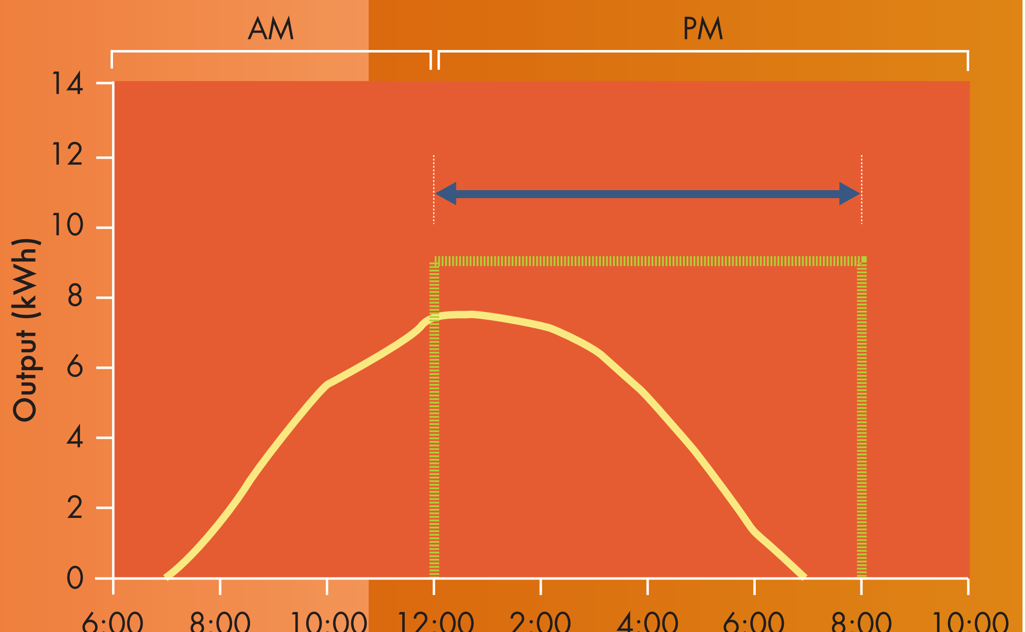
Two key attributes of a power generator is that it reliably produces power and that it can be called upon (or "dispatched") to provide power when customers need it. CST's ability to store thermal power to produce electricity when it is needed satisfies both these requirements. Utilities must always have enough power available to immediately meet the highest point of customer demand for electricity ("peak demand"), so a power plant's ability to be dispatched at any moment to provide the needed power is critical. For this reason, when contracting with a power plant to purchase its power, a utility will pay a higher price for electricity from a plant that can be dispatched. "Dispatchability," then, means a significant economic advantage for CST plants.

CST's storage ability also allows it to run continuously through the passage of clouds, while PV systems will shut down. This sudden loss of power from a utility-scale PV plant, or from many smaller PV systems at the same time, could be tremendously disruptive to the electric power grid.

Solar Power During Peak Times

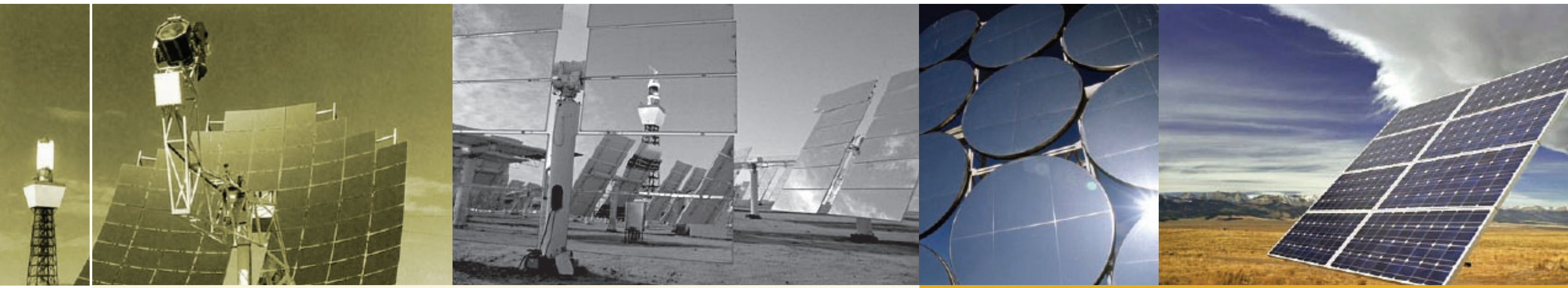
As shown at right, PV power output begins to fall behind customer demand in the late afternoon, as sunlight diminishes. CST plants, on the other hand, are able to use stored thermal energy to produce enough electricity to match customer demand into the evening hours.

Representative Solar Output Profiles



Utility Peak Period
PV Output
CST Output

Source: The Sonoran Institute.



A Place for Each

A further requirement of the Arizona's Renewable Energy Standard is that 30 percent of the power in the state's renewable energy mix comes from distributed—residential and non-utility—sources. Due to this requirement as well as their relative merits, both CST and PV solar technologies will likely have significant roles to play in Arizona's energy future.

PV technology is extremely flexible in terms of sizing, scalable—with the simple addition of more panels—from an individual home, all the way up to a utility-size system. All PV systems need very little water, and rooftop systems require no additional land. A major disadvantage is their inability to cost-effectively store power, and therefore to be dispatched in order to meet peak demand. In addition to lowering the value of these plants to utilities, this drawback also renders PV plants (and the transmission grid, if enough PV power is involved) vulnerable to abrupt changes in generation due to passing clouds. CST is commercially proven at a utility scale, and its ability to store power to meet peak demand and maintain grid stability is its key advantage over similarly sized PV plants. Where water is of paramount concern, dry or hybrid CST cooling technologies can reduce water consumption dramatically.

Each technology has its place. It is our job to understand—and use—them where each makes sense.

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

Footnotes

1 Includes retail sales of electricity from Arizona's regulated utilities. The Salt River Project is not a regulated utility and is not required to comply with the RES.

2 This is the same type of cooling system used on most conventional steam power plants (e.g., coal or nuclear), and the CST systems use roughly the same amount of water per MWh generated.

3 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 run models).

4 IBID.

5 NREL is soon (Fall 2009) to begin a more detailed study of the costs and benefits of advanced cooling systems in CST systems. Chuck Kutscher, NREL, personal communication.

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

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