



## Arizona's Solar Energy Future

Fact Sheet 5 in a series

Thin-Film PV Array  
Courtesy of DOE/NREL  
Credit: Beck Energy

# Emerging Solar Technologies

## Searching for Solar Power's Holy Grail

*Technologies to harness the power of the sun are evolving rapidly as demand for clean energy grows. Here we explore some of these “emerging” technologies: ideas that are beyond the laboratory but are not yet commercially developed. What are the advantages and disadvantages of each, and what barriers do they face before large-scale commercial development can occur?*



Shaping the Future of the West

A RAPIDLY EVOLVING MARKET

Solar energy's promise is enormous, but its technologies are still young. The two most proven, photovoltaic (PV) and Concentrated Solar Thermal (CST), both have strengths and shortcomings. PV uses semiconductor material to convert sunlight directly into energy. It can be scaled up to any size system needed and requires very little maintenance or water. However, semiconductor material is expensive; PV efficiency is relatively low, as measured by the amount of sunlight hitting a panel that is converted into electricity; and PV can only produce power when the sun is shining.

CST systems capture thermal energy from the sun by concentrating the sunlight onto a relatively small receiver. The absorbed heat is used to drive an engine that generates electricity. Thermal energy is attractive because it can be stored, allowing CST systems to be “dispatched,” (i.e., the stored energy can be converted to electricity when needed). Unfortunately, the high temperatures used in CST systems require expensive equipment as well as large amounts of water for traditional evaporative (“wet”) cooling, a major drawback in dry areas like Arizona.

So challenges remain, but in such a rapidly evolving market, today's limitations may not be those of tomorrow. As technologies mature, it is reasonable to believe that efficiencies will increase and production costs will decrease, making solar power even more competitive and attractive.

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**Concentrating Photovoltaic**  
Courtesy of DOE/NREL  
Credit: SAIC



**Concentrating Photovoltaic**  
Courtesy of DOE/NREL  
Credit: SAIC



**Amorphous silicon thin-film modules**  
Courtesy of DOE/NREL  
Credit: Warren Gretz—NREL Staff Photographer

## Emerging PV Technologies

**Roll PV, flexible solar laminate**  
Credit: United Solar Ovonic

**Goal:** *To increase efficiency, or to reduce costs by minimizing semiconductor materials.*

### Concentrating Photovoltaic

In this system, lenses (e.g., Fresnel lenses) or mirrors are used to focus sunlight onto a much smaller photovoltaic panel. Systems typically use a tracking device to follow the sun as it moves across the sky.

#### Advantages

- The system's ability to concentrate sunlight dramatically decreases the size of the receiver, allowing more effective use of a smaller amount of semiconductor material.
- Because of the smaller receiver size, this system is a good candidate for more expensive, higher efficiency receiver materials, including stacks with multiple layers of semiconductors that can absorb much more of the solar spectrum.

#### Disadvantages

- Advanced (e.g., multi-layer) PV materials are more expensive than those used in conventional PV systems.
- Because the sunlight is concentrated on a small area, it will tend to heat the receiver. Since PV cell efficiency decreases at higher temperatures, these systems require cooling, either actively or passively.
- The equipment needed to concentrate and track the sun must be particularly accurate and stable, and is therefore expensive.

To overcome the cost barrier, concentrating systems will need to develop light-weight, low-cost reflector surfaces, inexpensive and strong but accurate tracking mechanisms, and a cost-effective technique for cooling the PV panels.

### Thin-Film PV

Thin-film PV systems use advanced manufacturing techniques to apply very thin layers of semi-conductor materials, substantially reducing the amount of semiconductor material required.

#### Advantages

- The system uses less semiconductor material and employs high-speed, mass-manufacturing techniques that can dramatically lower costs.
- The mechanical flexibility of most thin-film materials allows them to be molded to a variety of surfaces, creating the potential to embed PV power in a wide variety of devices and appliances.

#### Disadvantages

- Thin-film materials typically are less efficient than conventional PV systems, offsetting the technology's manufacturing cost savings and making its cost per kWh roughly equivalent to conventional systems.
- Lower efficiency means that, for a given energy output, a larger system will be needed.
- Efficiency of thin-film systems tends to decrease much more rapidly over time than conventional PV materials.

Before seeing widespread adoption, thin-film systems will need to increase their initial efficiency and improve their lifetimes. These improvements, combined with the progress under way in reducing manufacturing costs, will make them cost effective.







**Solar Dish Installation**  
Courtesy of DOE/NREL  
Credit: Robert McConnell



**Solar Dish/Stirling**



**Linear Fresnel**

## Concentrating Solar Thermal (CST)

**Goal:** *Increase efficiency and reduce the need for water.*

### Dish/Stirling or Dish/Brayton

A parabolic dish is used to concentrate sunlight onto a receiver that converts sunlight into high-temperature energy that is used to drive an engine mounted at the focal point of the dish. “Stirling” and “Brayton” refer to the scientists who invented the two most commonly used heat-engines.

#### Advantages

- High solar concentration combined with high-efficiency, high-temperature engines currently offers the most efficient (although not the lowest cost) form of solar conversion to electricity.
- Dish engines usually do not need any water for cooling.
- These systems typically require less land than other CST systems and are less sensitive to land slope.

#### Disadvantages

- Energy storage is difficult because very hot fluids must be transported from the receiver—which moves as the dish tracks the sun—to a stationary storage facility located on the ground.
- Engines and receivers for these high temperatures are more expensive and have not demonstrated the durability needed for commercial use.
- Stirling engines, which have the best efficiencies, have not yet been mass-produced and widely distributed.

To become competitive, dish systems will need to bring down overall system costs and resolve durability issues. In addition, without storage or hybridization (using fossil fuels to drive the engine), the dish systems can only provide electricity when the

sun is shining and cannot compete with other solar thermal systems that can generate electricity when it is needed most.

### Linear Fresnel

Linear Fresnel technology uses a set of long narrow mirrors, or occasionally lenses, to concentrate sunlight onto a receiver tube. Similar to a parabolic trough system (see solar fact sheet 2), this technology uses long rows of collector/receivers with extensive piping to transport the heated fluid to and from the engines.

#### Advantages

- Placed closer to the ground than troughs, Fresnel systems produce less shading, can be spaced closer together, and are less likely to be disrupted or damaged by winds.
- A stationary receiver tube eliminates issues with rotating joints or flexible tubing typically associated with troughs. This may allow easier adoption of higher temperature fluids which could increase overall efficiency.
- Thermal storage allows dispatchability, maximizing the value of this system’s energy.

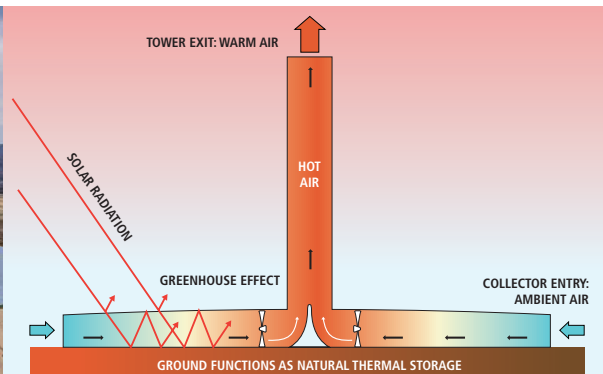
#### Disadvantages

- With a still relatively unproven design, there are a variety of technical issues that developers must resolve before broad commercialization is possible.
- As with trough systems, long piping runs reduce system efficiency and increase cooling water demand.

Although this type of system is quite promising, commercial-scale testing has been limited. Predictions of output and costs will need to be verified through operation of full-scale plants.



**Solar Updraft Tower**  
Artist's rendering



**Diagram of Solar Updraft Tower**  
Credit: based on diagram by Schlaich Bergermann und Partner



## Other Technology

**Goal:** *Something completely different.*

### **Solar Updraft Tower**

This system consists of a very tall, hollow cylinder that is surrounded by a large collector field—usually a clear polymer film 8 to 12 feet above the ground. Air under the collector is warmed by the sunlight, creating a temperature difference between the base of the tower and the top. This temperature difference (around 20–30°C) causes the warmer air at the bottom to rise up through the central tower, and produces an upward draft similar to the action in a chimney. This upward airflow powers large turbines at the base of the tower to generate electricity.

#### **Advantages**

- It may be possible that this type of system can be built relatively inexpensively because most designs can be constructed from common, inexpensive materials, and it will not require the high temperatures—or the costly equipment—needed for concentrating systems.
- This type of system will not need water for cooling.
- Because the ground under the collector field becomes warm during the day, the tower may continue to run at reduced capacity for some time into the early evening, when demand for power is still high.

#### **Disadvantages**

- Because they are less efficient, these systems are quite large for the amount of power they generate. The 200 MW plants proposed for Arizona would have towers 2,000–3,000 feet tall (about ½ mile, nearly as tall as the world's tallest building) and collector fields just over 3 miles in diameter (about 5,000 acres). A tower this size would be visible for quite some distance.

This system has never been tested at commercial scale. The largest existing plant is a small 50 kW pilot located in Europe, which means that the current commercial proposal for a 200 MW plant in Arizona would be 4,000 times larger. This huge jump in scale is much larger than usual in engineering developments, and it creates some concern about the accuracy of the engineering projections for cost and performance.

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## Where do we go from here?

Today's solar technologies are steadily finding new ways to improve efficiencies and lower costs. The marketplace will eventually determine which technologies prevail. In the meantime, a sound public policy approach would be to continue to foster innovation and support experimentation with promising new ideas like the ones described here.

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