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Are Engines the Future of Solar Power?

Stirling engines might be the best way to harvest the power provided by the sun

By Cynthia Graber

SOLAR ENGINE: Stirling engines will be employed to harvest the sun's heat commercially for the first time early next year in Arizona.
COURTESY OF SES

Nearly 200 years after their invention, and decades after first being proposed as a method of harnessing solar energy, 60 sun-powered Stirling engines are about to begin generating electricity outside Phoenix, Ariz., for the first time. Such engines, which harness heat to expand a gas and drive pistons, are not used widely today other than in pacemakers and long-distance robotic spacecraft.

The 1.5 megawatt (MW) demonstration site, known as Maricopa Solar, is set to begin operations early January 2010, with units provided by the Arizona-based Stirling Energy Systems (SES). While 1.5 MW is only a fraction of the power that may be generated at sites SES has contracted to develop in California and Texas, spokesperson Janette Coates says this is a necessary first step in the technology's commercialization. "It's important for our industry to see—and our partners and investors—that we can take a small-scale plant and get it operational before we break ground on larger ones," she says.

That's because Stirling heat engines have a reputation for being a bit impractical. First invented by Robert Stirling in 1816, the engines use a heat source to warm gas, which expands and is pushed into another chamber. When the gas cools and contracts, it flows back. The expansion and contraction pushes a piston, which in turn produces electricity.

In 1996, SES bought solar Stirling design and engineering patents from companies such as McDonnell-Douglas and Boeing. SES then partnered with Sandia National Laboratories, and over the next decade tweaked and refined the technology. In the SES SunCatcher, a circle of curved mirrors, resembling an upturned satellite dish, tracks the sun on two axes and reflects the sun's heat onto a single focus point, the power conversion unit (PCU). The PCU contains four cylinders, in which hydrogen gas expands and contracts to move pistons.

Stirling engines are significantly more efficient at converting sunlight into energy than most photovoltaic panels or concentrating solar power plants, whether parabolic trough or tower designs. The test units have reached 31 percent efficiency, compared to 16 percent for parabolic troughs and about 14-18 percent for PV panels in use today (though newer designs not yet on the market range from 24 to as high as 41 percent). The high efficiency numbers alone, however, have not made Stirling an easy sell. The systems have been criticized as being too expensive, unreliable and requiring extensive maintenance thanks to many moving parts. Also, ground has not yet been broken on either California site for which SES signed purchase power agreements in 2005, adding to skepticism that these systems will ever become commercially viable.

"At these high temperatures, with this many moving parts, people doubted whether SES could really pull it off," says Reese Tisdale, research director for solar power at Cambridge, Mass.-based Emerging Energy Research. The relatively small Arizona plant is intended to allay those concerns.

Proponents of the technology point to the advantages it has over other forms of solar power, particularly concentrating solar

power (CSP), which also captures the sun's heat. Most CSP systems require significant amounts of water, which has proven to be a challenge in desert regions of the U.S. where solar power is most attractive, while Stirling engines require none other than small amounts for cleaning the mirrors. In addition, if one engine goes down, it has minimal impact on overall production.

SES faced a manufacturing challenge in preparing its SunCatchers for mass production though. "The systems at Sandia were basically hand-built," says Charles Andraka, a Sandia engineer and Stirling expert who worked with SES on the system's design. For the Phoenix site, he notes, Sandia and SES engineers built 60 units in three months. "We have to do that many in a day for the larger plants."

In order to do this, SES turned to the experts in rapid production of engines and related parts: the automotive industry. In partnership with automotive companies such as Tower Automotive and Linamar Corporation, SES managed to reduce the parts in the PCU by 60 percent (to about 650) and slash the weight of the entire system by roughly 2,250 kilograms. Andraka highlights one example of the upgrade: in the original engines, he points out, gas passed over the outside of the engine, with pieces of tubes and fittings at either end, requiring a total of approximately 20 parts. "On the new engine, the gas passage is a part of the block with no external parts. It's much more reliable, much cheaper to assemble, with fewer parts and fewer places to leak," Andraka says. The new systems have been running on test sites for more than 100,000 hours.

Maricopa Solar also represents just one scalable module; each multi-megawatt field will be grouped first in 60-engine units that come together to generate 1.5 MW, then those larger units are linked to each other to produce up to 9 MW. Explains Coates, "With the large 750 MW commissions, we won't have to wait until we have 750 MW of dishes before we start producing power. This means that the utility can get the power prior to the full build-out, which can take years to complete." This is in comparison to parabolic trough or tower CSP technology, which doesn't generate electricity until the entire system is complete.

Meanwhile, Tessera Solar, SES's sister company in charge of development, is renegotiating contracts with utilities in California but expects to supply power at or below the cost of other solar technologies, and they plan to break ground on bigger solar Stirling engine power plants in Texas and California in 2010. Tisdale says he remains somewhat skeptical, but also optimistic: "This 1.5 MW site is key to demonstrating that it works."