New approach to solar power with hybrid solar-thermoelectric systems

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This laboratory setup was used to test the principles behind Wang and Miljkovic's concept for a hybrid solar thermoelectric system that could deliver both electricity and heat. Photo: Dominick Reuter

Systems to harness the sun's energy typically generate either electricity or heat in the form of steam or hot water. But a new analysis by researchers at MIT shows that there could be significant advantages to systems that produce both electricity and heat simultaneously.

The new study incorporates thermoelectrics — devices that can produce an electric current from a temperature gradient — into a concentrating solar thermal system, also called a parabolic trough. Such systems use long, curved mirrors (the trough) to focus sunlight onto a glass tube running along the centerline of the trough. A liquid pumped through that tube gets heated by the sun, and then can be used to produce steam to drive a turbine, or used directly for space heating or industrial processes that require heat.

The new MIT study "shows a unique opportunity for thermoelectrics integrated within solar thermal systems," says Evelyn Wang, associate professor of mechanical engineering at MIT, who was co-author of a paper describing the potential for such hybrid systems in the journal *Solar Energy*.

The novel arrangement proposed by Wang and graduate student Nenad Miljkovic embeds a thermoelectric system in the central tube of a parabolic-trough system so that it produces both hot water and electricity at the same time. The key to making this work is a device called a thermosiphon that draws heat away from the "cold" part of a thermoelectric system, maintaining its temperature gradient.

Wang and Miljkovic's system would modify a parabolic-trough system's central tube into a series of concentric tubes: A narrower tube inside the first would contain the thermoelectric material, with an even narrower tube at the center of the apparatus housing the thermosiphon, passively transferring heat from the thermoelectric cold side and alleviating the need to pump cooling fluid as in a conventional parabolic-trough system. The heat carried away by the thermosiphon could then be used to heat water for space heating, industrial processes or hot water.

One advantage such a system has over traditional photovoltaics (devices that generate electricity from sunlight), Wang says, is that "thermoelectrics can be much cheaper than photovoltaics." Also, conventional solar cells do not operate well at high temperatures. But, she explains, thermoelectrics thrive in hot conditions, which allow them to build up a greater temperature gradient.

"There really is no solar system now to do combined electricity and heat production at high temperature," Miljkovic says. But, he adds, "there are companies actively trying to pursue this."

"There's an opportunity for bringing together different technologies," Wang says. The thermosiphon, which draws heat from one place to another just as a siphon draws liquid, is "a passive way to transfer heat … and can be low cost as well," she says.

Thermosiphons are typically filled with materials that undergo a phase change (usually from liquid to vapor) as they heat up, and can achieve a thermal conductivity — a capacity for transferring heat from one place to another — "much higher than any solid material," Wang says. "It's an efficient way to carry away the heat, to whatever you want to deliver it to."

Wang and Miljkovic devised a computer model to search for optimal combinations of existing materials for the thermoelectrics and the thermosiphon. This model allows different combinations to be tested at varying operating conditions to make the overall system as efficient as possible.

A system for a single house could provide both heat and electricity, Wang says. "In a house, you need a lot of heat, but you only need so much electricity," she says. While the thermoelectric efficiency of such a system is relatively low, "in a household system you don't need that much power" relative to heat, she says.

Abraham Kribus, a professor of mechanical engineering at Tel Aviv University in Israel who was not involved in this research, says this paper "describes a fresh approach to solar energy conversion, with optimistic results showing high theoretical conversion efficiency."

Kribus adds that because this is still an early stage of analysis, it's not yet clear how such a system would stack up to traditional solar systems on cost and reliability. But that's not a criticism, he says: "This is the situation at early stage with every nonconventional idea. … Overall, the paper shows a nice start and a very capable team behind it."

Wang agrees that it is likely to take a few years to develop a practical implementation of these ideas. She and Miljkovic are going ahead with "working on building a system to demonstrate" how the combination could work, she says.

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