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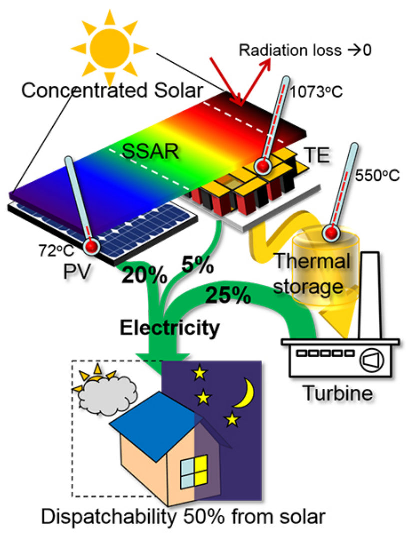
Hybrid system designed to harvest 'full spectrum' of solar energy

WEST LAFAYETTE, Ind. – A new concept could bring highly efficient solar power by combining three types of technologies that convert different parts of the light spectrum and also store energy for use after sundown.

Combining the technologies could make it possible to harness and store far more of the spectrum of sunlight than is possible using any one of the technologies separately.

"Harvesting the full spectrum of sunlight using a hybrid approach offers the potential for higher efficiencies, lower power production costs, and increased power grid compatibility than any single technology by itself," said **Peter Bermel (https://engineering.purdue.edu/Engr/People**



This schematic depicts a new concept that could bring highly efficient solar power by combining three types of technologies that convert different parts of the light spectrum and also store energy for use after sundown. (Purdue University image/Peter Bermel)
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/ptProfile?resource_id=75045), an assistant professor in Purdue University's **School of Electrical and Computer Engineering (https://engineering.purdue.edu/ECE)**. "The idea is to use technologies that, for the most part exist now, but to combine them in a creative way that allows us to get higher efficiencies than we normally would."

The approach combines solar photovoltaic cells, which convert visible and ultraviolet light into electricity, thermoelectric devices that convert heat into electricity, and steam turbines to generate electricity. The thermoelectric devices and steam turbines would be driven by heat collected and stored using mirrors to focus sunlight onto a newly designed "selective solar absorber and reflector."

"This is a spectrally selective system, so it is able to efficiently make use of as much of the spectrum as possible," he said. "The thermal storage allows for significant flexibility in the time of power generation, so the system can produce power for hours after sunset, providing a consistent source of power throughout the day."

Findings from the research are detailed in a paper with an advance online publication date of Aug. 15, and the paper is scheduled to appear in a future print issue of the journal Energy & Environmental Science. A YouTube video is available at **https://youtu.be/d__qNtVaDh4 (https://youtu.be/d__qNtVaDh4)**.

The hybrid system is designed to meet the changing demands for electricity at different times of the day.

"Typically for U.S. households, you have low usage overnight, then the demand goes up substantially in the morning, drops off a little during the day and then spikes upward around 5 p.m.," Bermel said. "Photovoltaics match very well with the load during the day, but not when it spikes. So the idea is to store energy just

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for a few hours, and that helps you address times of spiking demand."

Ideally, the system could achieve efficiencies of more than 50 percent using realistic materials, compared to 31 percent for photovoltaic cells alone.

The new selective solar absorber and reflector is the lynchpin of this approach and would perform two crucial roles: increase efficiency by reflecting visible light but absorbing near-infrared photons, and increase the temperature of the stored heat, which is then harnessed as electricity when it is needed throughout the course of the day.

Experimental research is still required to validate the theoretical design of the overall system.

"I think that this hybrid approach is doable," Bermel said. "In principle, we understand what needs to be done, but we need to do the experiments to validate the components and the whole system together."

The research paper was authored by Bermel; **Kazuaki Yazawa (https://nanohub.org/groups/bnc/people/details?id=277)**, a research associate professor at the Birck Nanotechnology Center in Purdue's Discovery Park; **Jeffery Gray (https://engineering.purdue.edu/Engr/People/ptProfile?resource_id=3049)**, an associate professor of electrical and computer engineering; **Xianfan Xu (https://engineering.purdue.edu/ME/People/ptProfile?id=11267)**, the James J. and Carol L. Shuttleworth Professor of Mechanical Engineering; and **Ali Shakouri (https://engineering.purdue.edu/Engr/ECE/People/ptProfile?resource_id=74115)**, the Mary Jo and Robert L. Kirk Director of the Birck Nanotechnology Center and a professor of electrical and computer engineering.

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Note to Journalists: A copy of the research paper is available from Emil Venere, Purdue News Service, at 765-494-4709, **venere@purdue.edu (mailto:venere@purdue.edu)**. A YouTube video is available at **https://youtu.be/d__qNtVaDh4 (https://youtu.be/d__qNtVaDh4)**, and other videos are available on Google Drive at **https://goo.gl/qNqCOr (https://goo.gl/qNqCOr)**.

ABSTRACT

Hybrid strategies and technologies for full spectrum solar conversion

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Harvesting the full spectrum of sunlight using a hybrid approach offers the potential for higher efficiencies, lower power production costs, and increased power grid compatibility than any single technology by itself. In this article, the base technologies for converting sunlight into electricity, including photovoltaics and solar thermal approaches are discussed. Then feasible strategies for combining them to utilize the various portions of the solar spectrum most effectively are discussed. In this study, we particularly focus on the advantages of a spectral splitting approach. This helps to convert higher energy photons (UV and visible) directly into electrons using optimized single or tandem

photovoltaic (PV) cells, while capturing lower energy photons as heat using a selective solar absorber, which absorbs photons within a range of energies, down to a cutoff in the mid-infrared. The solar heat is then thermally concentrated and driven through a high temperature thermoelectric generator on top of a high efficiency mechanical engine (e.g., a steam-driven Rankine cycle) through a heat exchanger, which connects to both thermal storage and the mechanical engine at 550 °C. The thermal storage allows for significant flexibility in the time of power generation (also known as dispatchability) at a modest cost. Hence, the system can produce power for hours after sunset. Ideally, the system can achieve efficiencies over 50% using a combination of an InAlAs/InGaP tandem photovoltaics, ErAs:$(InGaAs)_{1-x}(InAlAs)_x$ thermoelectrics, and mechanical Rankine cycles. The configuration and operating conditions can be optimized to minimize the levelized cost of energy (LCOE).

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