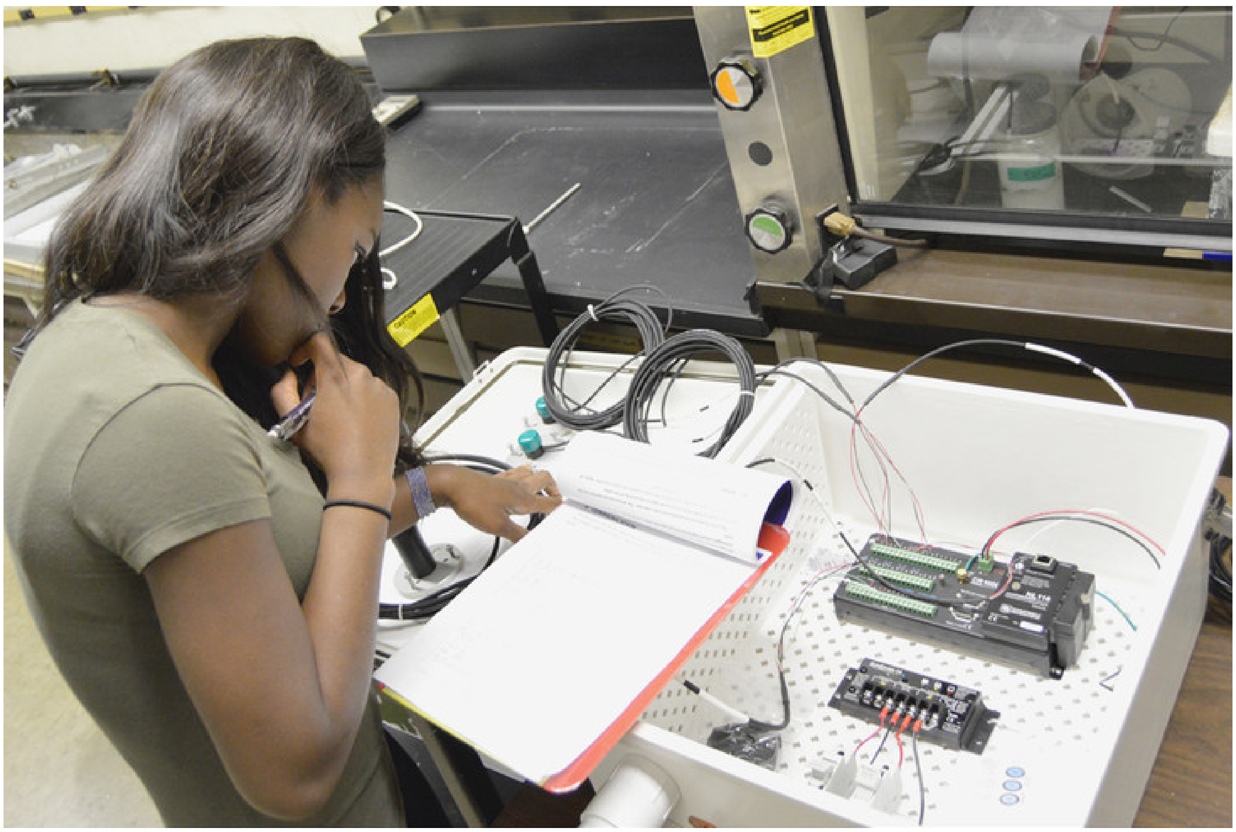
New device could unlock information potential of sunlight

June 24 2016, by Liam Jackson



Energy engineering undergraduate student Worlasie Djameh inspects the wiring configuration of the All-Seeing Eye device prior to installation. The device was created to collect more baseline information about sunlight, which can be used to inform a variety of industries. Credit: Penn State

People rely on sunlight for heat, light, and energy every day, but three

Penn State researchers believe we're missing a valuable piece of information that sunlight itself could provide—the dynamic directions of incoming light.

"In the solar industry, you typically see people measuring the power potential of sunlight, which is important for energy production," says Jeffrey Brownson, associate professor of energy and mineral engineering. "But very few people are using sunlight for information, and this baseline data could help improve a number of industries. If you can start collecting the right information, you can use it to inform crop yields, assess fire risk of sloped surfaces such as mountains, and predict home heating patterns and solar energy generation."

This information is missing now, says Brownson, because existing technology to capture sunlight's directionality on a regular basis is expensive. A pyrheliometer, which is like a paper towel roll attached to a sensor that tracks the sun across the sky, can measure the angle of direct sunlight accurately, but it commonly costs between $20,000 and $30,000. The device also includes moving parts that can break, and it requires regular maintenance.

So Brownson, along with two other Penn State researchers—Vivek Srikrishnan, a doctoral student in energy and mineral engineering, and George Young, professor of meteorology and atmospheric science—set out to create a device that was cheaper and required less maintenance than a pyrheliometer. They've finished a prototype of their new device, which they've dubbed the "All-Seeing Eye" (ASE). Now, with help from a seed grant from the Penn State Institutes of Energy and the Environment, the team is installing two models of their device in central Pennsylvania. They have set up one at the Russell E. Larson Agricultural Research Center at Rock Springs and plan to install another in the State College area in fall 2016.

The first All-Seeing Eye was installed near a suite of National Weather Service instruments that are maintained by the Department of Meteorology. The team plans to build a second All-Seeing Eye in the State College area in the fall of 2016. Credit: Jeffrey Brownson

Like a bug's eye with a simple human brain

The project first came about when the researchers were investigating the power generated by sunlight, or solar irradiance, needed to heat buildings.

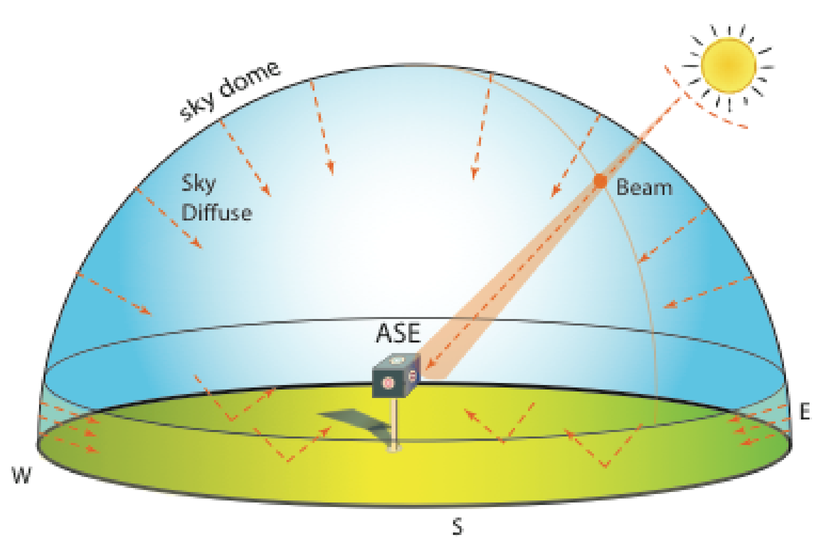
"If you stand in the sun in the summer, you get hotter than if you're standing in the shade. That heating should affect heating in buildings," says Srikrishnan. "We realized that there was a flaw in the standard way solar irradiance is measured. Typically, a flat sensor is used, but this has limitations. You can't pick up on nuances like whether there is cloudiness to the east versus the west or north, or whether sunlight is reflected off a nearby building or coming directly from the sun."

Energy and mineral engineering graduate student Vivek Srikrishnan holds a metal pole while cement sets in the ground. The group's All-Seeing Eye is attached to the pole and is located at Penn State's Agricultural Research Farm, located six miles southwest of State College, Pennsylvania. Credit: Jeffrey Brownson

Their device works similarly to an insect's eye with a simplified human brain.

"There are five sensors that point in different directions: upward, as well as cardinal north, east, south, and west. These are like faceted bug's eyes that work together to build an image," says Young.

But the team wasn't interested in all the sunlight hitting those sensors. They wanted to find out a specific kind of sunlight, known as direct or "beam" sunlight. This light travels directly from the sun to the ASE's sensors without hitting anything on its way. They needed to filter out diffuse sunlight, which changes direction as it goes through the sky and clouds in the atmosphere, and reflected light, which is direct light that bounces off nearby objects and the ground before hitting the sensor.



Depiction of how the All-Seeing Eye works. The device collects all types of sunlight, then uses artificial intelligence to isolate beam, or direct, sunlight. Credit: Jeffrey Brownson

Tracking only the direct sunlight hitting the ASE sensors on a given day could seem like an insurmountable task, considering the countless ways light travels from the sun before hitting the sensors.

To filter through this mass of data, the team tapped into a sophisticated, yet simple, model of artificial intelligence known as a neural network. Neural networks are used in other industries for robotics, character recognition, and data processing. Google even uses neural networks to recognize images in its Image Search and Photos applications. For the ASE, neural networks help the device learn to recognize direct sunlight.

"To use the All-Seeing Eye, you input a year's worth of data on direct sunlight, enough so that you've sampled lots and lots of cloud and snowfall conditions. This data set serves as the 'truth' against which we can compare what our ASE is detecting," says Young. "Then, we can compare the data received by the sensors against this truth value, and make adjustments after every comparison."

Jeffrey Brownson and energy engineering student Corryn Klien discuss logistics of installing the frame for a solar panel that will power the group's All-Seeing Eye device. Credit: Penn State

After thousands or even tens of thousands of adjustments—which take only a minute or two with today's computing power—the machine has learned what direct sunlight is, and it can track that moving forward.

It turns out that the team's approach is incredibly accurate. For his Penn State master's thesis, Srikrishnan obtained useful data from the National Renewable Energy Laboratory (NREL) in Boulder, Colorado, which regularly tests the effectiveness of energy technology and posts this data publicly as a service to the energy community. Srikrishnan gathered data from low-cost sensors, then ran it through the team's neural network and compared the results to present-day data collected by NREL. This approach showed promise that the ASE could be much more accurate than sunlight models used in the market today.

"For all weather conditions, existing models to estimate direct sunlight had between 20 and 30 percent error. Ours had less than 10 percent error. In snowy conditions, existing models had a 48 percent error, while ours had 15 percent," Srikrishnan says.

All the components for the All-Seeing Eye are laid out prior to installation at Penn State's Agricultural Research Farm, located six miles southwest of State College, Pennsylvania. Credit: Penn State

Providing a service to a community of information gatherers

One of the biggest draws of the ASE is its cost-effectiveness. Brownson estimates that the ASE costs around $4,000, making it a fraction of the price of a pyrheliometer. The team hopes that, by creating an economical device, they can provide a service to the solar community. The more people who install the device, the more sunlight information will be available to various industries.

"There's a whole untapped potential in measuring sunlight. One of our main goals in this project is trying to recognize—and help others recognize—that the sun is an important economic driver, and we don't measure the value of sunlight today in a way that we could pretty easily do," Brownson says. "There's so little discussion today about the enormous potential for collecting and applying sunlight as data for decision making. We're just excited to take a step toward figuring out more about the possibilities of using sunlight for information."

Provided by Pennsylvania State University

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