How cool are cool roofs? PPPL serves as the laboratory to find the answer

December 11 2012, by Jeanne Jackson Devoe

Keith Rule and a team of interns felt the heat when they installed a weather station on top of the LSB roof last summer as part of the cool roofs project. From left to right, Keith Rule; Jessica Sponaugle, a summer intern from Monmouth University in West Long Branch; and Hannah Capponi, a summer intern from Council Rock High School North in Newtown, Pa.

When Keith Rule and a team of interns walked onto the black and white roof of the main building of the U.S. Department of Energy's Princeton Plasma Physics Laboratory one sweltering day last summer, they could feel the temperature difference between the two different colored areas in the soles of their feet.

The white roof was tolerable but the black roof was too hot to stand on. "You could feel it coming through your shoes," recalls Rule, a senior project engineer in the Environment, Safety, Health & Security Department, who is heading the project at PPPL.

Rule and his team installed equipment for a study that will give researchers a precise picture of what kinds of roofs work best in what kinds of weather and examine how so-called "cool roofs" can affect energy use and energy costs. Or as puts it, "The question is: What gives you the most savings for the buck?" said Elie Bou-Zeid, a professor of civil and environmental engineering at Princeton University who is the lead researcher on the project.

Researchers aim to find out whether cool roofs—white roofs that reflect the sun—are the best way to save energy and money in areas like New Jersey, where it's icy cold in winter and steaming hot in summer.

Early data shows dramatic temperature difference between black and white roofs

Early data from the project supports what Rule and his team's feet were telling them back in the summer: White roofs are much cooler than black roofs. When temperatures were in the 90s during the third week of August, for example, sensors measured the temperature on the black roofs at 130 degrees to 170 degrees Fahrenheit – hot enough to fry an egg. Rule's team needed sunglasses to work on the highly reflective white roofs but they were much cooler – ranging from 90 to 100 degrees.

However, the data also indicates that the thickness of the roof's insulation, called the R-value, could be the most crucial factor in determining whether the building will absorb the heat. A thicker roof seems to eliminate the differences between the black and white roofs and it works in all seasons, Bou-Zeid said. But more insulation costs more money than painting a roof white and the difference in cost will be another factor the study will consider.

Walking on the black side of the roof. From left to right: Hannah Capponi, Jessica Sponaugle and Keith Rule.

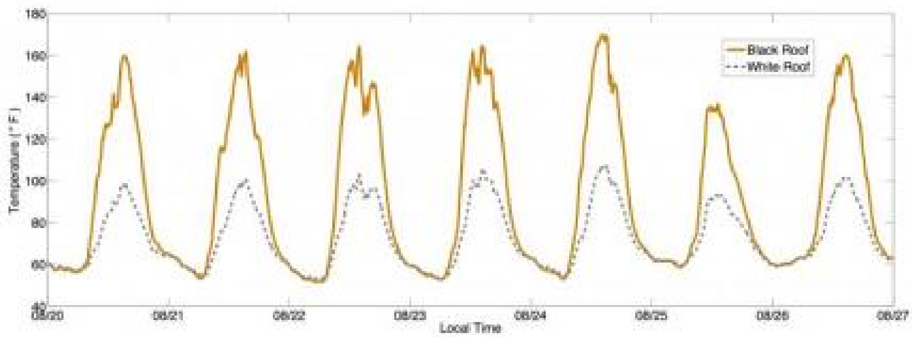
Adam Cohen, PPPL's deputy director for operations, said the study has also demonstrated the value of PPPL's infrastructure for sustainability research: There are a large number of buildings at the site that can be used in a study and the Lab staff has shown itself to be an enthusiastic participant in sustainability research studies. "We showed that we could use this facility as a test bed to evaluate sustainability projects in a real working environment," Cohen said.

A constant stream of information

PPPL timed the project to take advantage of the fact that the Laboratory was replacing roofs and agreed to make PPPL a live laboratory for the cool roofs project. The team installed not just black and white colored roofs but also roofs of different thicknesses between March and early September.

The group installed four weather stations on five PPPL roofs that resemble wire tripods fitted with oddly-shaped contraptions. They measure all kinds of weather from solar radiation, better known as sunshine, during the sweltering days of the summer to the 85-mile-an-hour winds during Hurricane Sandy in October. The team also installed 25 sensors at five locations inside the roofs to measure heat absorption.

Every 15 minutes a data logger above the ceiling in each of the five buildings sends this information to Bou-Zeid, who is five miles away at Princeton's School of Engineering and Applied Science. Meanwhile, PPPL's automatic building systems feed Bou-Zeid data on how much electricity and fuel is being used for heating and air conditioning. He and Prathap Ramurthy, a postdoctoral research associate, plug the data into a computer model that will accurately predict the cheapest and most-energy efficient roof for every temperature and weather condition.



Temperature Chart: This chart shows the temperature fluctuations on a white roof compared to a black roof at PPPL during the last week of August. The black roof reached 170 degrees Fahrenheit, while the top temperature of the white roof was just over 100 degrees.

The cool roofs study at PPPL and Princeton stands out from previous studies, Bou-Zeid explained, because it is based on extremely detailed, minute-to-minute information on weather and heat absorption, and will therefore result in more accurate predictions.

Another significant difference, he said, is that this study is the only one to compare how the thickness of a roof affects heat absorption compared with cool roofs. "Our data will be much more exact," Bou-Zeid said.

Preventing pollution and saving energy

Many researchers believe that reflective white roofs earn the "cool roofs" title by reflecting the sun's rays to keep buildings' interiors cooler and reducing the need for air conditioning. Black roofs, on the other hand, absorb heat – making buildings warmer year-round and potentially reducing heating costs in the winter.

The main effect cool roofs could have on the environment is to reduce greenhouse gas emissions by reducing the amount of energy used to cool buildings. A 2010 study by the Lawrence Berkeley National Laboratory in Berkeley, Calif. predicted that making roofs and pavements more reflective in all cities with populations of more than 1 million people in the northern hemisphere would offset 57 billion tons of CO_2 emissions –far more than the 36.4 billion tons of carbon dioxide released worldwide in one year in 2010.

Black roofs absorb solar radiation from the sun and when that heat escapes, the building emits heat or long-wave radiation some of which may be trapped by the greenhouse gases in the atmosphere that cause the greenhouse effect, which is linked to global warming. By contrast, white roofs reflect solar radiation. The short waves of solar radiation or sunlight are not trapped by greenhouse gases and therefore do not contribute to global warming, Bou-Zeid said.

However, the main impact of white roofs on the environment would be to reduce energy consumption. Another 2010 Berkeley study on the potential benefits of cool roofs for commercial buildings in 236 U.S. cities estimated that commercial building owners who installed cool roofs in warm areas could reduce the amount of energy used for air conditioning by 10 to 30 percent. The study concluded that commercial building owners in cooler areas would pay more for heating in winter but would still realize a net decrease in energy costs.

Provided by Princeton Plasma Physics Laboratory