# The relationship between a building's rooftop materials and inside temperature

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**Christa McAuliffe Center for Integrated Science Learning, Framingham State University, Perspectives of Earth Team Mentorship, Metrowest Stem Education Network, 2023 Summer Internship**

In Summer 2023, the Christa McAuliffe Center commissioned a group of high school interns to design, prototype, test and build a model to demonstrate the impact that various rooftop types have on the mitigation of extreme temperatures in a building.

The interns were asked to create scaled-down models of identical buildings with four different rooftop types and gather indoor temperature data. These models will be used by the McAuliffe Center in the context of its educational programs and outreach activities.

The temperature data will be used to support proposals to mitigate extreme heat effects suffered by the population of Framingham, especially the City's marginalized populations.

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We, the interns at the McAuliffe Center, were commissioned to evaluate strategies to mitigate the impact of extreme heat. The impact of extreme heat is especially felt in urban areas where large infrastructure, such as buildings, parking lots, and roads, absorb and retain heat at a higher rate than surrounding rural areas.[1] These structures are made with materials that have low albedo, which measures how well a surface can reflect sunlight. Low albedo surfaces absorb a significant amount of heat during the day and release it at night.[2]

Many urban areas also have a significant lack of greenery. Trees are needed to combat urban heat islands due to a process called evapotranspiration, in which trees absorb heat and cool themselves using the water inside of them, similar to how humans sweat to cool off.[3] A lack of greenery means more heat will be absorbed by low albedo surfaces such as buildings and roads. If no action is taken, everyone - but especially older adults, children, athletes, outdoor workers, homeless people, and low-income individuals - will be greatly affected by extreme heat.[4]

In the Summer of 2023, our team was asked to build models to demonstrate the impact that various rooftop materials have on the mitigation of extreme temperatures inside a building.

To accomplish this, we created four models with four different roof materials. These models were designed to simulate a building using a wood cube with a door. We created a white roof, black roof, rooftop garden (a green roof), and a roof covered with solar cells. The models needed to allow simultaneous temperature collection of both the roof itself and the inside of the model. The models had also to be portable, which is important because it allows the models to be shown at outreach events in different locations in the community.

At first, our prototypes varied in size, number of floors, and thermometer placement. Through our measurements with these prototypes, we would adjust our models to isolate the impact of each kind of roof. Through these adjustments, we found that we needed to limit the air that went into the model during data collection. We also needed some insulation as this is present in real buildings. These prototypes were effective and gave valuable insight into what elements our final models should have.

Our final design is a “Frankenstein” combination of each of the prototypes of the four teams. We incorporated insulation in the form of the wooden “walls” of the model. We used linoleum tiles spray-painted black and white to represent commonly used roofing types. On the door, we included a small dual-layered plate glass window and a thermometer to measure indoor temperatures. To simulate a green rooftop, we plant sedum in a [box] layered with a mesh and rubber base to allow roots to expand and water not to be absorbed by the wood. To simulate roofs with solar panels, we used solar cells tilted at a 10º angle. This angle is used in many actual solar installations. Linoleum tiles were secured to the base of the roof using Velcro to make the rooftops interchangeable.

We found that the surface temperature of black and white roofs differed by almost 40ºF. We found white roofs consistently had the lowest surface temperature at various times during the day, while green roofs had the second lowest and solar roofs had the second highest surface temperature.

For inside temperatures, we found that green roofs had the lowest temperature of all four models, while black roofs consistently produced the highest indoor temperature. White roofs had the second lowest indoor temperature, while solar roofs produced the second highest indoor temperature, though there was not a major difference between the two. Models with black and solar roofs showed a consistent 6-10ºF difference in inside temperature when compared. (See Fig

1) This difference can be easily felt by those living inside a building with these roof materials. Continuous testing shows a consistent trend between the different rooftop models, with white and green being significantly cooler than black roofs.

Using alternative roof materials provides many benefits to those inside. In addition, green roofs cool off the environment through evapotranspiration and absorb $CO_2$. Solar roofs, while not extremely effective at keeping the inside of the building cool, create clean energy which decreases the building's use of fossil fuels. Because of their cooling properties, white roofs are a good option if solar or green roofs are not possible. These three roof types keep the temperature inside a building low, meaning less demand for air conditioning, more money saved, and less risk of heat-related health problems.

Individuals, city governments, and companies should consider green roofs because of the cooling effects they provide to those inside the building, along with other benefits. Solar roofs should also be considered to cut reliance on fossil fuels and provide some cooling benefits in comparison to black roofs. White roofs are recommended due to their enhanced cooling effects if green roofs are not possible, while black roofs should not be used for new buildings and existing roofs should be replaced with white ones.

Our findings show a significant correlation between roof material and inside temperature. All alternatives to black roofs also save money because they maintain lower temperatures inside buildings reducing the demand for air conditioning. The McAuliffe Center can use these findings to recommend homeowners and city governments to look towards switching out and fitting new constructions and existing buildings with alternatives to black roofs that will keep people inside the building comfortable, save money, and will reduce $CO_2$ production.

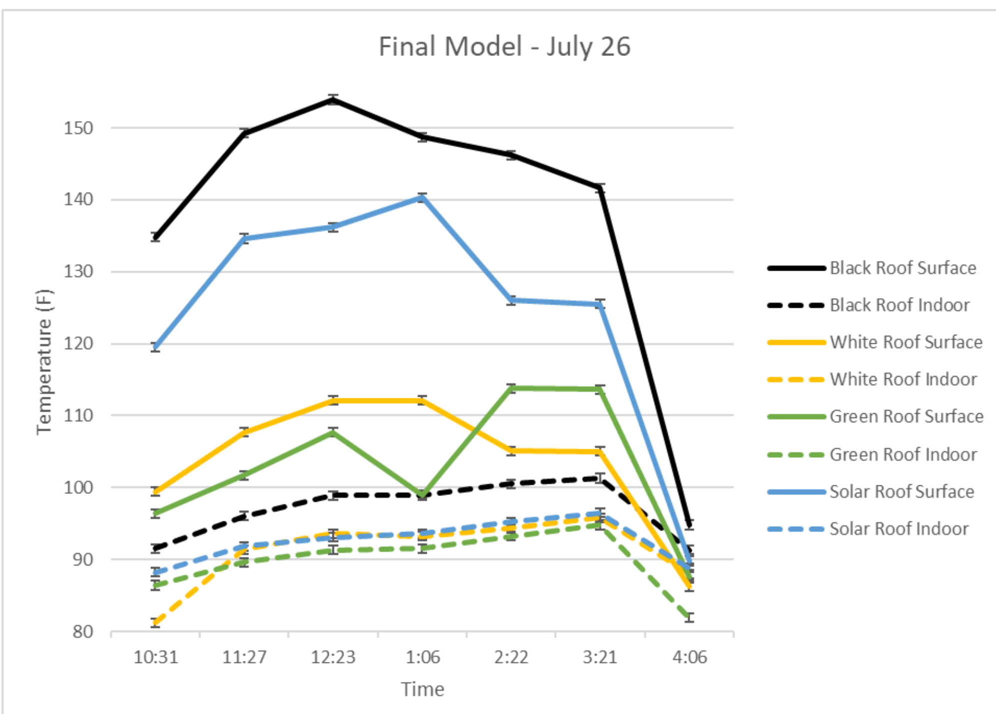


Figure 1

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