Advancing cool roof coatings for urban heat resilience

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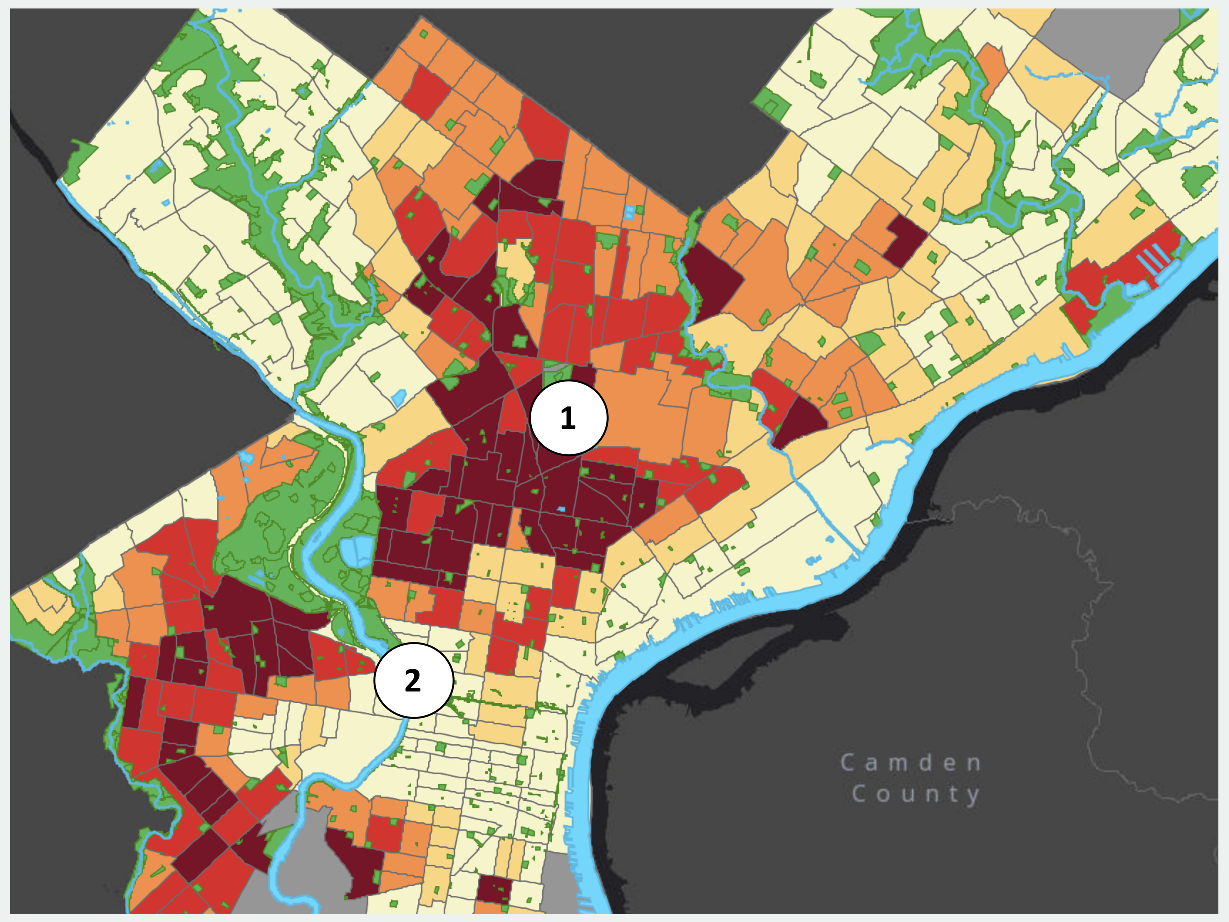
Urban Heat in Philadelphia

Human activity and the built environment of cities cause their temperatures to be much greater than those of nearby rural areas. This process, known as the urban heat island effect, leaves city residents vulnerable to dangerously high temperatures during the summer months.



Philadelphia Heat Vulnerability Index shows heat-vulnerable North and West Philadelphia. Circles #1 and #2 indicate the neighborhoods of Hunting Park and Fairmount, respectively.

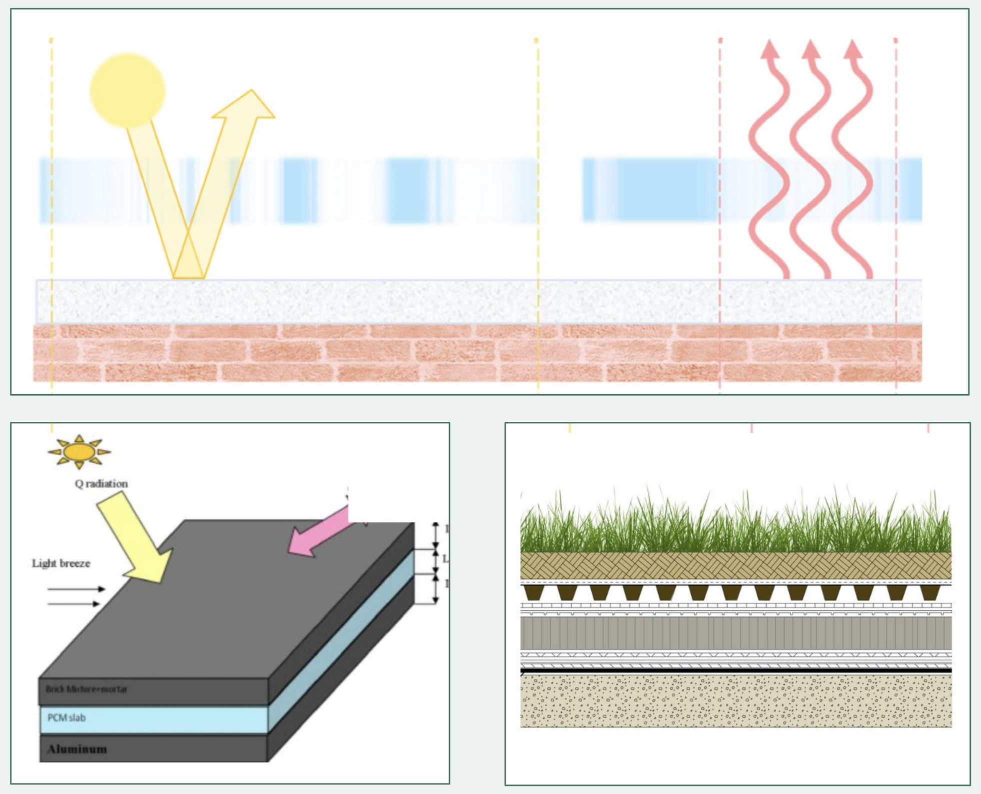
Roofing Materials Can Reduce Urban Heat

Dark-colored roofing materials that absorb a high fraction of solar radiation are a major cause of urban heat islands. Dark roofs contribute to the heat vulnerability of neighborhoods like Hunting Park (below). By replacing or covering these materials with coatings that prevent solar heat from entering the environment, we can passively cool buildings and cities. This project investigates existing approaches to cool roofing materials and demonstrates an experimental methodology for testing new materials.

Hunting Park: "Very high" vulnerability — Fairmount: "Very low" vulnerability

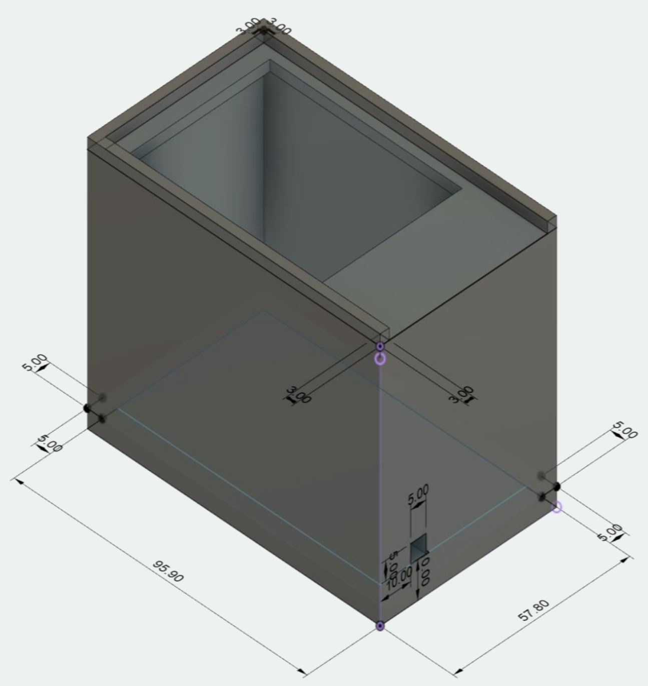
Dark roofing materials make Hunting Park more heat-vulnerable than Fairmount, its more affluent counterpart

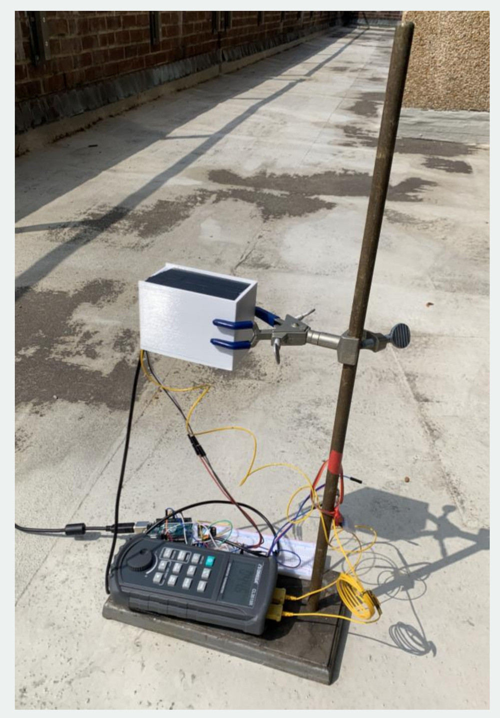
Cooling Cities: Current Technologies



- **Passive Radiative Cooling** (top) approaches maximize coatings' solar reflectivity and thermal emissivity. These coatings can stay cool in direct sunlight with no moving parts, making them a cost-effective solution.
- **Phase Change Materials** (bottom left) liquify as they absorb solar energy during the day and re-solidify as they emit energy at night. Storing energy as latent heat reduces the heat flux into buildings.
- **Green Roofs** (bottom right) harness natural evaporative cooling by covering buildings with vegetation. They share the benefits of phase change materials in addition to purifying the air but can be costly to maintain.

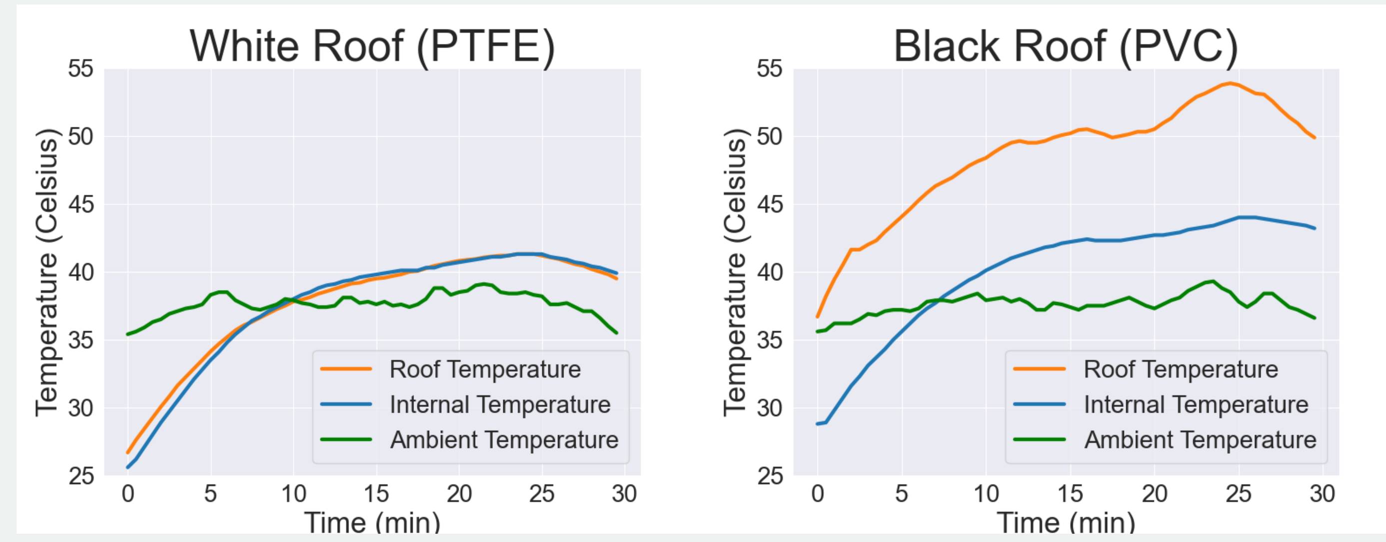
Methods

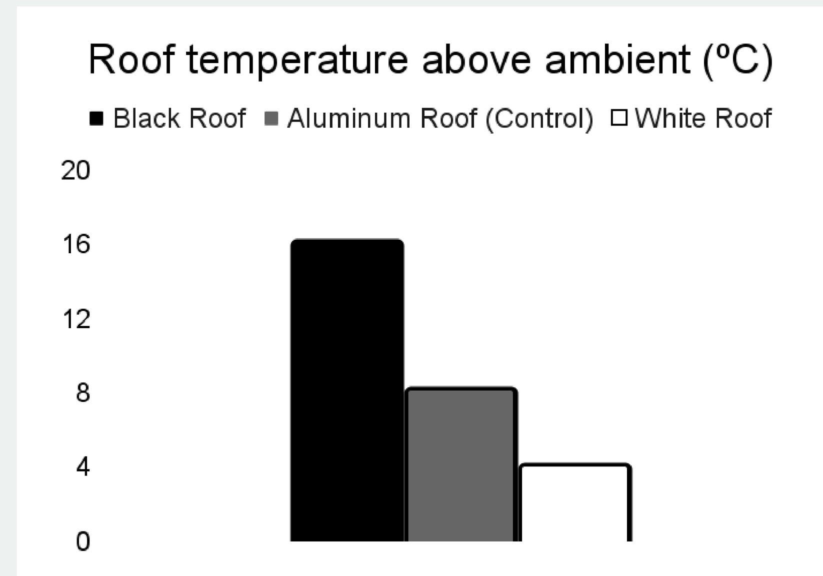




- **3-D printed PETG box** (2.5"x3.5") used to model indoor air temperatures
- **Aluminum panel** used as substrate to test different coatings
- **Arduino Uno** used to automate temperature measurement under direct sunlight

Reflective Coating Outperforms Dark Coating





Conclusions

- Passive radiative cooling is the most promising approach to advance global heat resilience in a cost-effective manner
- A simple white roof can reduce the difference between ambient temperature and roof temperature by 75%

Next Steps

Optimize Apparatus → Compare Promising Materials → Formulate Novel Coatings

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References

Philadelphia Division of Housing and Community Development (2022), Google Earth (2023), Mandal et al. (2020), Akeiber et al. (2015), Baldwin (2023).

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Adapting to Extreme Heat in Philadelphia to Increase Human Vitality

Environmental Innovations Initiative, University of Pennsylvania

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