CRRC Cool Surfaces Lesson Plan Teacher Guide

Cool Roof Rating Council

This document is a companion to the Cool Surfaces Lesson Plan published by the Cool Roof Rating Council (CRRC) available at https://coolroofs.org/resources/cool-surfaces-lesson-plan/. The CRRC is a 501(c)(3) nonprofit organization with a mission to bring objective, scientific information related to cool surfaces to critical discussions and informed decisions about the impacts of heat islands, extreme heat, and energy use in the built environment.

If you use the Cool Surfaces Lesson Plan in your classroom, please complete our short feedback form.

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Introduction and Learning Objectives

The Cool Surfaces Lesson Plan is designed for middle/junior high school level students (6th-9th grade), but may also be used for younger or older grades. After completing the Lesson Plan, students should be able to:

1. Describe the urban heat island effect
2. Explain the concepts of roof and wall surface solar reflectance and thermal emittance and how they relate to indoor air temperature, energy use, and the urban heat island effect
3. List at least two ways that the solar reflectance of a surface can be increased

4. Interpret the impact of less reflective and more reflective surfaces on interior air temperature of structures exposed to similar conditions

Lesson Plan Resources

The CRRC suggests completing the lesson plan over the course of 2-3 class periods, depending on the duration of the class periods. Example schedule:

1. **Class Period #1**: Watch Animated Video, have class discussions, and prepare materials for the Cool Surfaces Experiment.
2. **Class Period #2**: Develop hypotheses, conduct experiment, and record results. During experiment downtime (30-minutes), students can read supplemental resources or work on Cool Surfaces Impacts Assignment.
3. **Class Period #3**: Discuss experiment findings and work on projects for CRRC Competition.

The following Lesson Plan resources are publicly available for free at https://coolroofs.org/resources/cool-surfaces-lesson-plan/.

1. **Urban Heat Islands (UHI) and Cool Surfaces Animated Videos**
    a. **Link**: https://coolroofs.org/resources/cool-surfaces-lesson-plan#animated-videos
    b. **Format**: Approximately five minutes of narrated animated video content available in three short segments or as one video.
    c. **Purpose**: Videos provide general information about the urban heat island effect and solar reflective (“cool”) building surfaces as one mitigation strategy. They are designed to introduce these topics to students, prompt classroom discussions, and prepare them for the Cool Surfaces Experiment and other classroom and/or homework activities.
2. **Cool Surfaces Experiment Instructions and Tutorial**
    a. **Link**: https://coolroofs.org/resources/cool-surfaces-lesson-plan#cool-surfaces-experiment
    b. **Format**: Five-page document (including pictures) containing written experiment instructions and a narrated tutorial video explaining the instructions. Also see Experiment Modifications section of this Teacher Guide for modifications and additional information.
    c. **Purpose**: The experiment is designed to be conducted after watching the Animated Videos and engaging in some classroom discussion. Students will form a hypothesis based on what they learned from the Animated Videos and then create two “buildings” out of cardboard boxes that have been covered with different colored exteriors (paint or construction paper). Students will record the initial interior temperatures and then place the boxes under infrared heat lamps for a minimum of 30 minutes and observe the interior temperature difference for

the different surface colors. The written instructions and narrated tutorial video provide guidance on how to complete the experiment.

3. **Cool Surfaces Worksheet and Answer Key**
    a. **Link**: https://coolroofs.org/resources/cool-surfaces-lesson-plan#cool-surfaces-worksheet
    b. **Format**: Word document containing customizable short-answer, true/false, and multiple choice questions, along with an answer key.
    c. **Purpose**: This worksheet can be completed in class or as homework to check student's learning and help them think critically about the information presented in the Animated Videos. Teachers can add, remove, or revise the questions. If students are participating in the CRRC Student Competition, described below, the worksheet can be used as prep work for their competition submission.
4. **CRRC Student Competition Guidelines:**
    a. **Link:** https://coolroofs.org/resources/cool-surfaces-lesson-plan#student-competition
    b. **Format:** PDF of powerpoint slides
    c. **Purpose:** This document provides information about the opportunity for students to participate in an ongoing competition run by the CRRC. To participate, students may submit to the CRRC a creative or technical project completed in response to this Lesson Plan, which will be posted on the CRRC website if basic requirements are met. Twice a year, the CRRC will select first, second, and third-place projects that will receive top billing on the CRRC website and be featured in communications to the CRRC's membership.
5. **Opportunities for Support from CRRC Community**
    a. See Opportunities for Support section of this Teacher Guide

Defined Terms

The defined terms below are mentioned in the Animated Video or are closely related to the topics discussed throughout the Lesson Plan. The definitions are verbatim or adapted from the sources in parentheses.

Brownout: a period of reduced voltage of electricity caused especially by high demand and resulting in reduced illumination (Merriam-Webster).

Cool Exterior Wall: an exterior wall whose surface strongly reflects sunlight (i.e., solar energy) and cools itself by efficiently emitting any heat that was absorbed (CRRC).

Cool Pavement: paving materials that reflect more solar energy, enhance water evaporation, or have been otherwise modified to remain cooler than conventional pavements (US EPA).

Cool Roof: a roof whose surface strongly reflects sunlight (i.e., solar energy) and cools itself by efficiently emitting any heat that was absorbed (CRRC).

Cool Surface: a Cool Exterior Wall, Cool Roof, and/or Cool Pavement surface.

Infrared Radiation: the portion of the electromagnetic spectrum that extends from the long wavelength, or red, end of the visible-light range to the microwave range. Usually divided into three regions: near infrared (nearest the visible spectrum), with wavelengths 0.78 to about 2.5 micrometers (i.e., microns); middle infrared, with wavelengths 2.5 to about 50 micrometers; and far infrared, with wavelengths 50 to 1,000 micrometers (Britannica).

Infrared-Reflective Pigments: darker-colored pigments that are highly reflective in the near infrared portion of the solar spectrum (CRRC).

Peak Power Demand: The highest amount of electric demand within a particular period of time. Daily electric peaks on weekdays occur in late afternoon and early evening. Annual peaks occur on hot summer days (California Energy Commission).

Radiative Properties: Any measurement involving the scattering, absorption, or reflection of electromagnetic radiation at the land surface (NASA). Within this lesson plan, the term Radiative Properties is specifically used to refer to Solar Reflectance and Thermal Emittance.

Solar Absorptance: Ratio of the absorbed to the incident radiant power (IUPAC). In other words, the fraction of solar energy that is absorbed by a surface.

Solar Heat Gain: The increase in temperature of a building, object, or space caused by the absorption of solar radiation (Oxford English Dictionary).

Solar Reflectance: a Radiative Property that is the fraction of solar energy that is reflected by a surface (related term: Albedo) (CRRC).

Solar Spectrum: the electromagnetic radiation emitted by the sun (Britannica).

Thermal Emittance: a Radiative Property that is the relative ability of a surface to radiate heat (CRRC).

Urban Heat Island: an urbanized area that experiences higher temperatures than outlying areas (US EPA).

Elaboration on Animated Video Concepts

This section of the Teacher Guide offers elaboration on some of the high-level concepts that are introduced in the Animated Video, which can help provide context and assist with classroom discussions.

Video Segment 1

- Studies have shown that urban heat has a disproportionate impact on disadvantaged communities. Learn more at https://www.epa.gov/heatislands/heat-islands-and-equity.

Video Segment 2

- Air conditioners don't make heat go away. They just move it from inside a building to the air outside the building. This creates a positive feedback loop. Hotter outdoor temperatures drive up A/C use, which in turn expels more waste heat into the environment, driving up demand for A/C indoors, and so on.
- Solar reflectance (SR) and thermal emittance (TE) are the two radiative properties discussed in the video, but they are not the only radiative properties that exist. While a higher value (closer to 1) is cooler for SR and TE, the opposite is true for some other properties like solar absorptance and transmissivity.
- SR takes into account all of the solar radiation hitting a surface, not just visible light. Much of the heat from the sun (over 50%) is invisible infrared radiation.
- As discussed in the third segment of the video, it's important to understand that, while color has a large impact on solar reflectance and can be useful for understanding the concepts of reflectance and absorbance, high solar reflectance can also be achieved using special materials that reflect invisible infrared radiation but are visually dark.

Video Segment 3

- It may be helpful to think of cool roofs and walls as mirrors instead of shields—reflected heat goes into outer space, helping to reduce heat buildup in the local environment.
- Cool roofs and walls can be part of a larger plan for heat island reduction. They can be included with other cool community features like trees, vegetated roofs and cool pavements.

Experiment Modifications

The instructions for the Cool Surfaces Experiment can be found here. Below are some ideas for potential modifications if you would like to expand the scope of the experiment.

Surface Temperature Measurements

Using an infrared thermometer to measure the surface temperature of the boxes before turning on the lamps and after 30-minutes under the lamps is not required but is strongly encouraged. Recording the before and after surface temperatures creates additional data points for students to analyze and helps reinforce understanding of the concepts of reducing urban heat by keeping

surface temperatures lower. If you are not able to obtain an infrared thermometer, please see the opportunities for support in the below section.

Incorporating Additional Colors and Materials

If there is time and material availability, consider incorporating additional colored surfaces besides black and white. For example, how do red, green, blue, or gray materials compare?

If available, real roofing or exterior materials such as shingles, metal, exterior paints/coatings, roofing membranes, and more can be applied to boxes and tested. Members of the CRRC community may be able to donate such materials.

Students could also experiment with how insulation or other factors influence the interior air temperature. For example, what happens if the inside of the box is lined with foam or the box is filled with crumpled newspaper? What about if the box isn't completely sealed shut (e.g., ventilation)?

Thermometer Alternatives

The CRRC used basic, mercury-free classroom thermometers to design this experiment. To avoid cutting large holes in the boxes and be able to measure the interior temperature in the center of the box, using thermometers with probes such as this one may be a good alternative. Strip thermometers (e.g., for brewing or aquariums), dial thermometers, digital thermometers, or other types of thermometers may also be suitable, provided that the thermometers have relatively granular measurements (e.g, two degrees Fahrenheit or less) in order to accurately discern temperature differences. Please also ensure that two identical thermometers are used so that the results are directly comparable.

Using Natural Sunlight

This experiment was designed using electric heat lamps. However, if feasible, students can try conducting the experiment outside with natural sunlight. For best results, the experiment should be done on a clear, sunny day that is not too windy at a time of day when the sun is high in the sky and providing direct sunlight to the boxes. The exposure duration may need to be adjusted, and the results may be more or less dramatic compared to using heat lamps indoors. Designing an outdoor experiment could be an opportunity for the class to discuss the different factors (e.g., time of day, wind, shade, time of year, etc.) that may have an impact on the boxes interior and exterior temperatures.

Evaluating Results

While there may only be a one or two degree difference in the interior temperatures of the different boxes, this can have a big impact on the amount of energy needed to cool spaces.

After completing the experiment, students can find local utility data to see how much energy and/or money could be saved by keeping buildings a few degrees cooler.

Opportunities for Support from CRRC Community

The CRRC has numerous Members and other stakeholders that may be interested in supporting teachers through financial or in-kind donations or volunteer services. The CRRC has put together an information packet for members of the CRRC community that would like to provide support.

If your classroom would benefit from financial support to purchase the necessary materials and equipment to complete the Cool Surfaces Experiment, please fill out this form. The CRRC is able to provide a limited amount of financial support to teachers thanks to donations from our generous stakeholders. We cannot guarantee that support will be provided, but we will strive to meet your request.

If your classroom would benefit from in-kind donations of materials to expand the scope of the Cool Surfaces Experiment (e.g., infrared reflective roofing or wall materials), please fill out this form. The CRRC cannot not guarantee that support will be provided, but we will strive to match you with a sponsor from the CRRC community to provide the requested donations.

If you are interested in having a subject matter expert from the CRRC community visit your classroom in-person or virtually to provide a guest presentation, please fill out this form. The CRRC cannot not guarantee that a volunteer will be available, but we will strive to match you with a volunteer from the CRRC community.

Finally, if a student would like to receive technical review of a project related to cool surfaces, the CRRC will strive to match them with a subject matter expert to perform technical review and provide constructive feedback. If the student is participating in the CRRC Competition, they should check the box in the application form to request technical review. If the student is not participating in the CRRC Competition but still would like technical review, please reach out to the Lesson Plan contacts listed here.

Sources and Additional Resources

Scientifically backed information about cool surfaces can be found on the CRRC website at https://coolroofs.org/. Below are additional resources about urban heat islands, the effects of extreme heat, the impacts of cool surfaces, and more.

U.S. Environmental Protection Agency

- Learn about Heat Islands: https://www.epa.gov/heatislands/learn-about-heat-islands
- Heat Islands and Equity:https://www.epa.gov/heatislands/heat-islands-and-equity

- Climate Change and Heat Islands: https://www.epa.gov/heatislands/climate-change-and-heat-islands

World Health Organization

- Climate Change, Heat, and Health: https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health

Lawrence Berkeley National Laboratory Heat Island Group

- Cool Science: https://heatisland.lbl.gov/coolscience

National Integrated Heat Health Information System

- HEAT.gov: https://www.heat.gov/

Cool Roof Rating Council

- Resources for Home and Building Owners: https://coolroofs.org/resources/home-and-building-owners

CRRC Contact Information

- **Email:** education@coolroofs.org
- **Toll-free number:** (866) 465-2523
- **Mailing address:** 2435 N Lombard St., Portland, OR 97217
- **Website:** https://coolroofs.org/

Please don't hesitate to contact the CRRC with any questions or feedback about the lesson plan! The CRRC is actively seeking feedback in order to improve upon the lesson plan and make it as effective as possible.