



Green Inside, Outside and Above: Green and Cool Roofs

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INTRODUCTION

This lesson will introduce students to the heat trapping characteristics of roofs and how the sun's heat increases the urban "heat island" effect, substantially heating buildings. Students will learn the benefits of green roofs - how they save cooling costs for buildings, provide habitat for wildlife, filter pollutants, and drain rainwater.

Grade Level & Subject: Grades 9-12: Science, Social Studies/Civics

Length: One 45-90 minute class period.

Objectives:

- Understand how a roof traps heat
- Identify the characteristics of the urban heat island effect
- Recognize the environmental benefits of green roofs
- Create a plan to install a green roof at school

National Standards Addressed:¹

- **Content Standard:** [NSS-G.K-12.5 ENVIRONMENT AND SOCIETY](#)
As a result of activities in grades K-12, all students should
 - Understand how human actions modify the physical environment.
 - Understand how physical systems affect human systems.
 - Understand the changes that occur in the meaning, use, distribution, and importance of resources.
- **Content Standard:** [NS.9-12.6 PERSONAL AND SOCIAL PERSPECTIVES](#)
As a result of activities in grades 9-12, all students should develop understanding of
 - Personal and community health
 - Population growth
 - Natural resources
 - Environmental quality
 - Natural and human-induced hazards
 - Science and technology in local, national, and global challenges
- **Content Standard:** [NL-ENG.K-12.8 DEVELOPING RESEARCH SKILLS](#)

¹ Education World (2008) *U.S. National Education Standards*. Retrieved January 21, 2009, from <http://www.education-world.com/standards/national/index.shtml>.

- Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.
- **Content Standard:** [NT.K-12.2 SOCIAL, ETHICAL, AND HUMAN ISSUES](#)
 - Students understand the ethical, cultural, and societal issues related to technology.
 - Students practice responsible use of technology systems, information, and software.
 - Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.

Materials Needed:

- Copies of Reproducible #1- **With Grants and Other Incentives, Chicago Leads the Nation in Installing Green Roofs.**
- Copies of Reproducible #2- **Article Reflection Questions**
- Copies of Reproducible #3- **Worksheet for Cool Roofing Research**
- Access to computer lab for student research

Assessment: Students will be assessed through the following activities:

- Completion of Reproducible #2- **Article Reflection Questions**
- Completion of Reproducible #3- **Worksheet for Cool Roofing Research**
- Research and discussion of cool roofing
- Completion of optional extension assignment

LESSON BACKGROUND

Relevant Vocabulary:

- **Albedo:** *Albedo*, or solar reflectance, is a measure of a material's ability to reflect sunlight (including the visible, infrared, and ultraviolet wavelengths) on a scale of 0 to 1. An albedo value of 0.0 indicates that the surface absorbs all solar radiation, and a 1.0 albedo value represents total reflectivity.
- **Green Roof:** *Green roofs* are rooftops planted with vegetation. Intensive green roofs have thick layers of soil (6 to 12 inches or more) that can support a broad variety of plant or even tree species. Extensive roofs are simpler green roofs with a soil layer of 6 inches or less to support turf, grass, or other ground cover.
- **Cool Roof:** The term *cool roof* is used to describe roofing material that has high solar reflectance. This characteristic can reduce heat transfer to the indoors and enhance roof durability. Cool roofs may also be highly emissive, releasing a large percentage of the solar energy they absorb.
- **Urban Heat Island Effect:** The *urban heat island effect* is a measurable increase in ambient urban air temperatures resulting primarily from the replacement of vegetation with buildings, roads, and other heat-absorbing infrastructure. The heat island effect can result in significant temperature differences between rural and urban areas.

Information: Cities are showing signs of rising temperatures due to buildings and other

infrastructure that absorb heat instead of reflecting it. This heating is caused by the types of materials and colors used in construction, and leads to an increase in the amount of energy used to control the temperatures of buildings. This causes a greater impact on our natural resources, and can also lead to health hazards due to high temperatures and increased pollution.

Green roofs replace the concrete of pavements and buildings with trees and vegetation. This cooling provides benefits to the environment, as well as the building itself. Green roofs promote clean air by removing pollution and adding oxygen into the atmosphere. They also improve water quality by filtering and reducing runoff, and provide a habitat for animals such as birds and insects. Green roofs improve building conditions by insulating in the winter and shading in the summer. They also help to increase roof life expectancy by reducing the impact of UV rays.

Resources:

- *Green Roofs* Background and Student Action Plan, Earth Day Network, 2009.
- *Heat Island Effect*, U.S. Environmental Protection Agency (2008) - <http://www.epa.gov/heatisland/index.htm>
- *Glossary*, U.S. Environmental Protection Agency (2008) - <http://www.epa.gov/hiri/resources/glossary.htm>

LESSON STEPS

Warm-up: *Green Roofs in Chicago*

1. Have students read the article from the *Christian Science Monitor*, **Reproducible #1- “With grants and other incentives, Chicago leads the nation in installing green roofs.”**
2. Students should read the article and answer the questions listed below and in **Reproducible #2- Article Reflection Questions** independently. After all students have completely finished reading and answering questions, have them organize themselves in partners or small groups to share answers.
3. Have students share their answers with the class in a general discussion about why green roofs are important and any other issues your students are interested in talking about. Ask the following questions:
 - a) What are the benefits of green roofs?
 - b) Are green roofs a modern invention?
 - c) Why do you think Chicago is subsidizing the cost of green roofs?
 - d) What are some famous buildings that have green roofs? Have you ever been to any buildings with green roofs? Where?
 - e) What is the Urban Heat Island Effect?

Activity One: *Urban Heat Island Effect*

1. As the earth is warming, its cities are warming even faster. Tell students that most urban areas have a temperature that is 10°F higher than surrounding areas.² Since most of the world's population lives in cities, we need to be very concerned about this situation.
2. Have your students brainstorm with their partner reasons why cities are warmer than more natural landscapes. Solicit students to share responses to class.
3. Explain that trees and vegetation provide natural shading and cooling by filtering the air. Since urban areas are covered in man-made structures and not green life, the natural air conditioning that plants provide us with is lost. The buildings and pavement in a city automatically absorb more heat than any sort of vegetation because of the materials and colors that we choose to build with. Additionally, waste heat released from engines and machinery (cars, air conditioning, factories, etc) heats up the city even more.
4. Have your students brainstorm on their own why this effect might be harmful to humans and the natural environment. Share with the class that most importantly, the heat island effect amplifies a city's energy needs. This causes both an economic burden, and a further drain on our earth's resources. The increased heat also intensifies smog problems and can be a health hazard.
5. Ask your class if they have any examples of how the Urban Heat Island Effect has affected their lives. Green roofs are really necessary in a city not only because they will cool it down, but because they provide green spaces in a place where concrete and metal are unnaturally commonplace. The elevated temperature in the city is yet another reason why urban life can be more difficult than life in the suburbs.
6. Green roofs also have other benefits including providing a habitat for plants, insects and other wildlife, reducing runoff, and filtering pollution from water. Although it seems that environmental activism might make more sense in a place where there are trees and natural spaces, it is really more necessary in cities, where people are less connected with the earth but often more threatened by their environment.

Activity Two: *A Rainbow of Roofs*

1. According to the EPA, 90% of the roofs in the U.S. are dark colored. Your students should know that dark colors absorb heat from the sun. Black, the most common color of a rooftop, absorbs red, yellow, green and blue light and reflects almost no light. This absorbed light is transferred into heat energy, making black rooftop temperatures reach up to 190 degrees Fahrenheit. This increases cooling costs in buildings and contributes to the Urban Heat Island Effect.³

² U.S. Environmental Protection Agency (2008) *Heat Island Effect*. Retrieved January 20, 2008 from <http://www.epa.gov/heatisland/index.htm>

³ U.S. Environmental Protection Agency (2008) *Heat Island Effect*. Retrieved January 21, 2009 from <http://www.epa.gov/heatisland/index.htm>

2. White, on the other hand, reflects all the colors of light that black absorbs, making it a much better color to use if you want things to stay cooler; including the visible, infrared, and ultraviolet wavelengths on a scale of 0 to 1.
3. **Albedo**, or solar reflectance, is a measure of a material's ability to reflect sunlight. An albedo of 0.0 indicates that the surface absorbs all solar radiation, and a 1.0 albedo value represents total reflectivity.⁴ Although roofs covered with vegetation are one alternative to a dark rooftop, another solution is to find a material with a higher albedo than a conventional black roof. These are called “cool roofs” and are becoming more popular alternatives. This activity is designed for students to practice their researching skills and get a broader idea about what alternatives there are to conventional roofing.
4. Split your students up into several teams and assign them each one type of “cool roof” to research (besides a conventional green roof). Some options include metal, white paint, tar and gravel, and red/brown tile. Also, one group should research the type of roof that your school has. Have them fill out **Reproducible #3- Worksheet for cool roofing research**, and then prepare the information for a presentation to the rest of the class. Have the students prepare their topics together, and then have a discussion about which options might be the best for your school, for a home, or for a commercial building.

Activity Three: *Cooling Down YOUR School!*

1. Now that your students are knowledgeable about green roofs, they should begin to consider what type of roof their school has. What benefits could a green roof bring to the educational environment at your school? A green roof on your school would have the same economic and environmental benefits as discussed earlier in this lesson, but could it offer more? The plants and wildlife on the roof could be an outdoor classroom for science lessons and other classes. Lunchtime or school events could be held on the roof, and school clubs could use it for various activities. If an intensive green roof is able to hold produce, then your environmental club could manage the gardens and sell the produce. Furthermore, a green roof would serve as a physical reminder of your school's commitment to environmental innovation and to a greener future and set the example for other institutions in your area to take action.
2. Public and private high schools, middle schools and universities around the nation have chosen to invest in green roof technologies for these reasons. In May 2005, the **Calhoun School** (a private K-12 school in NYC) installed a Green Roof on the top of their building. The roof has been used as an herb garden for the cafeteria and is also used for biology classes. The space has been used for art installations, receptions, and has earned the school a number of awards. **Mission San Jose High School** replaced their gravel roofs with smooth-tops ones covered with white acrylic elastometric coating. These new “cool roofs”

⁴ U.S. Environmental Protection Agency (2008) *Glossary*. Retrieved January 21, 2009 from <http://www.epa.gov/hiri/resources/glossary.htm>

helped to reduce heating and cooling costs and helped their old building comply with California's regulations for energy efficient buildings. **Carnegie Mellon University** has installed green roofs in four locations around campus.

3. If all these places have explored greener roofing options, then yours can too. Have your students brainstorm what type of roofing option might be the best for your school district. Please refer to Earth Day Network's *Green Roofs* Student Action Plan. There you can find more information about what green roofs are, why they are good for your school, and how to convince your school to get one.

Wrap Up: *Roof Discussion*

Ask students to name the different types of roofs they have learned about in this lesson, and how their characteristics determine the amount of heat they absorb or reflect. Discuss the importance of green roofs and how they could improve buildings in their communities. Encourage advocacy for green roofs in their neighborhood and at school, and discuss steps that they can take to become involved. Ask your students if they would be interested in pursuing a campaign to get a green rooftop at your school.

Extension: *Raise the Roof! Student Roof Campaign*

For homework, have your students draft a letter to your school principal or the president of the school board explaining why your school should get a green roof. This should be a convincing formal letter that draws together information that was reviewed in this lesson plan and/or Earth Day Network's *Green Roofs* Student Action Plan. Students may include outside research if they need statistics for their letter. This assignment should be assessed not only on the accuracy of the content of the letter, but on grammar, style, and fluidity of the letter. Using these letters as a foundation, have the students select the one(s) that best reflects their interests, or draft an official letter from the entire class, and deliver to the principal or school administrators.

CONCLUSION

In this lesson, students will learn how roofing options can affect the environment in many ways. In urban areas especially, green roofing and cool roofing choices can have a positive impact on the community. Through these activities the students have learned the importance behind green roofs, and how they can advocate for better roofing options at their schools.

With grants and other incentives, Chicago leads the nation in installing green roofs.⁵

By [Amanda Paulson](#) | Staff writer of *The Christian Science Monitor*

In the center of downtown Chicago lies an oasis of green. Monarch butterflies flit past little bluestem. Bees fly from prairie clover to purple coneflowers. A small hawthorn tree rises from a mound.

The expanse of native plants and grasses isn't a park, but the top of City Hall, the premier green roof in a city that is making green building a civic cornerstone.

Six years ago, when Mayor Richard Daley had the roof installed, it was an oddity. Today, more than 200 green roofs in the city have been constructed or are under way, covering some 2-1/2 million square feet of tar with plants - by far the most of any American city.

Now other cities, hoping to cool and clean their air and help with storm drainage, are beginning to emulate Chicago, and the city is taking key steps to encourage - and in some cases require - private developers to follow City Hall's example.

Chicago's City Council just announced a pilot program that will provide up to \$100,000 in matching funds for developers who retrofit existing downtown buildings with green roofs, out of a \$500,000 pool of financing. Last year, the city began awarding small \$5,000 grants to smaller projects, many residential. A green permitting process is designed to expedite requests. And Chicago has started requiring green roofs on new buildings that receive city financing.

"You look down on the prime real estate areas of this country - downtown Chicago, Manhattan - and so much is unutilized, all these rooftops," says Sadhu Johnston, Chicago's environment commissioner. The green-roof push, he says, is just one piece of a larger plan for the city that has included adding hundreds of thousands of trees, increasing energy efficiency, and replacing some traffic lanes with planted medians. "It's about a comprehensive strategy of making Chicago a better place to live."

Green roofs may be surprising in a city still more known for manufacturing than composting, but they are relatively common in Europe. Germany - the country that gave Mayor Daley the idea - has green roofs on about 20 percent of all flat roofs, according to one estimate. With a history dating back to the hanging gardens of Babylon, green roofs range from simple trays filled with hardy plants like sedum, to complex systems like the City Hall roof, which features some 150 plant species, a small apiary, and two trees.

In Chicago, they sit atop the Apple store, a Target, and a McDonald's. Even Chicago's soon-to-open Wal-Mart will have one - the company's first.

⁵ <http://www.csmonitor.com/2006/0710/p02s02-ussc.html>

Nationally, green roofs grace the Gap headquarters in San Bruno, Calif.; a Ford Motor plant in Dearborn, Mich.; and the American Society of Landscape Architects building in Washington.

The idea is simple: bring back some of the organic material displaced by buildings, streets, and parking lots. Advocates tout benefits that range from reducing the urban "heat island" effect - which makes cities several degrees warmer than surrounding areas and can translate into millions of dollars in energy costs - to lengthening the life span of a roof, providing community garden or recreation space, and contributing to a building's energy efficiency.

"Cities are just going to keep getting hotter," says Steven Peck, president of Green Roofs for Healthy Cities. "So you take away hot surfaces and turn them into air conditioners. Green roofs do that very, very well."

On City Hall, for instance, the ambient temperature on the planted, city side of the roof is often 50 to 70 degrees cooler than that on the county side, still traditional black tar. Commissioner Johnston acknowledges that it's hard to know how many such roofs are needed before the effects become felt throughout the city, but he's determined to keep encouraging them until Chicago gets there.

"It's like turning off the water when you brush your teeth," he says. "Every building that does it this way has an effect."

This is why Chicago is doing its best to push private developers to follow City Hall's example. Every new roof in the city is already required to be reflective - another step to minimize urban heat island - but the latest matching-funds initiative is designed to show existing buildings that they, too, can establish green roofs.

"There are certain preconceived notions that it's easier to do it with new construction than with existing construction," says Constance Buscemi, spokeswoman for the city's Office of Planning and Development.

But there can be drawbacks. It's often twice as expensive to install a green roof, though experts say that's usually recouped through the roof's lengthened life span (they can last 40 or 50 years instead of the typical 20 or 25) and energy savings for the building. And some buildings simply aren't designed for the additional load, even when that's just a few inches of lightweight soil.

In a recent survey by Green Roofs for Healthy Cities, Chicago was followed by Washington and Suitland, Md. (home of a huge green-topped National Oceanic and Atmospheric Administration building) in green-roof square footage. But the amount of space is increasing rapidly - up 80 percent in the US between 2004 and 2005.

"What we've seen in Europe is that once the technology was understood and people saw that it worked, combined with incentives from the regulatory side, it really blossomed as an idea," says David Yocca, a senior partner at the Conservation Design Forum in Elmhurst, Ill., who has designed a number of green roofs. "It's the sort of idea that makes a lot of sense."

Article Reflection Questions:

1. What are the benefits of green roofs?

2. Are green roofs a modern invention?

3. Why do you think Chicago is subsidizing the cost of green roofs?

4. What are some famous buildings that have green roofs? Have you ever been to any buildings with green roofs? Where?

5. What is the Urban Heat Island Effect?

Worksheet for Cool Roofing Research

Names: _____

Date: _____

Type of Roof: _____

DIRECTIONS: Please answer the following questions in two to three (2-3) complete sentences using as much detail as possible.

1. What material is your type of roof made out of? What is its solar reflectance, or albedo?
2. How much does this material cost per square foot? How long will it hold up before it needs to be replaced?
3. What type of building is this roof most suited for? Where has it most often been used?
4. Why is this type of rooftop better than a conventional roof?
5. Would you recommend this type of rooftop for our school? For your home?