Lesson 1.5: Climate Impact

Task	Page(s)	Learning Target
1	2-3	I can write a project summary that describes important criteria for successful roof modifications.
2	4-6	I can construct explanations for how each roof type functions to reduce climate impact.
3	7-9	I can isolate variables in the design tool to gather evidence for how roof modifications affect project criteria.
4	10-11	I can interactively test design solutions by observing how changes affect the outcome and communicate the strongest design solutions and trade-offs.
5	12	I can rank design solutions for each criterion in order to focus feedback for redesign strategies.

Task 1 Learning Target: I can write a project summary that describes important criteria for successful roof modifications.
https://sites.google.com/a/ps207tigers.org/207sci/roof-design-challenge
Welcome to your new engineering internship!
We will be working on a project for the city of Solton, Arizona. The people of this city want to reduce their climate impact. We believe we can develop a proposal that will accomplish this by making modifications to the roofs of some buildings in the city.

Solton is a city located in southern Arizona. Solton has thousands of buildings of many different sizes: homes, shops, schools, factories, office buildings, and other common buildings found in cities. Some of the buildings are very old and important to the history of the town. People travel to Solton to see these historic buildings. Solton's climate is hot and dry, with more than three hundred hot days each year. In some parts of the city, there are large trees and tall buildings that shade neighboring buildings. Because the weather is nearly always warm or hot, most buildings use air conditioners to keep cool year-round, especially in offices and hospitals where it is necessary to keep people and equipment cool.

Solton has requested proposals from Futura. The city wants to reduce its impact on Earth's climate. Futura is working with Solton to provide some proposals and has decided to look at roof modifications (in other words, making changes to the roofs of buildings) as a way to reduce Solton's climate impact.

Successful proposals will meet three criteria:

Reduce the city's climate impact
Many of Solton's buildings must run the air conditioning year-round. Air conditioning requires a lot of electricity, and most of the electricity we use is generated through combustion (burning) of fuels at power plants. The people of Solton want to reduce the city's overall use of fuels in order to cut down the amount of carbon dioxide in the atmosphere as much as possible. Carbon dioxide in the atmosphere contributes to Earth's increasing temperature.

Preserve the historic value of the city's buildings
The town of Solton is full of buildings that are important to its history. The buildings are very old, and the people of the city consider them both beautiful and valuable. People also visit the city to see the buildings, and this brings business to Solton. However, changing the roofs can affect the historic value of these buildings, especially when the buildings have pitched (slanted) roofs so that the changes are easy to see from street level.

Keep costs low
Roof modifications can be very expensive, and the people of Solton want to spend the town's money responsibly. Because of this, engineers need to be careful to keep costs as low as possible.

In addition to meeting the above criteria, the roof modification design for the city should take into account the constraints, or limits to the possible solutions. Some of these constraints include:
-The proposed design must not include any major structural changes to the buildings, such as changes in the shape or direction of the roof.
-The roof modifications include only white roofs and solar roofs.

Climate Impact and Roof Modifications

In the United States, we use a surprising amount of energy just to heat and cool buildings—about half of home energy use goes toward indoor temperature control. Most of our energy comes from combustion (burning fuel), and combustion puts carbon dioxide (CO2) into the atmosphere, which impacts Earth's climate by increasing the global temperature.

How can we make buildings more energy-efficient? One promising way is through roof modifications—making changes to the roofs of buildings. By changing roofs, U.S. communities can lower their energy use by more than 20% and significantly reduce their climate impact.

Futura will submit a proposal for building modifications that focuses on the roofs of Solton.
Futura has identified two promising roof modifications: solar roofs and white roofs.
Each of these roof modifications affects climate differently, and a combination may be the best plan. This is how each type of roof modification works:

Solar roof modification:

Solar panels installed on roofs absorb energy from sunlight and convert it into electrical energy. This energy can be used to cool the buildings, reducing the need for energy produced by combustion of fuels. This decreases the amount of carbon dioxide released into the atmosphere.

White roof modification:

Painting roofs with a type of white coating that reflects sunlight increases the city's albedo by a large amount and reduces the amount of energy needed to cool the city's buildings. This also decreases the amount of carbon dioxide released into the atmosphere.

The word *albedo* (al-BEE-doh) refers to how much sunlight is reflected away from a surface. The albedo scale is often referred to as a percentage, from 0% to 100%. A mirror reflects 100% of the light that hits it. A surface with an albedo of 80% reflects most sunlight. Dark colors tend to have a low albedo. Surfaces with an albedo of 15% reflect very little light. Instead, they absorb most energy from the sun and their temperature increases. This is why dark pavement feels hot on a sunny day—the pavement absorbs sunlight. In urban areas with lots of buildings and pavement, this temperature increase can be very large. By modifying rooftops to increase a city's albedo (so that it reflects more light and absorbs less heat), we can reduce the average temperature of the whole city and help keep global temperatures from rising higher.

Project Summary

Develop a **Project Summary** by responding to the following:

1. What is the engineering problem you are trying to solve?

2. Describe the first criteria—reduce the city's climate impact—and why it is important.

3. Describe the second criteria—preserve the historic value of the city's buildings—and why it is important.

4. Describe the third criteria—keep costs low—and why it is important.

5. Describe the two types of roof modifications that can impact climate.

Task 2 Learning Target: I can construct explanations for how each roof type functions to reduce climate impact.

Roof Modification: White Roofs WHAT ARE THEY?

White roofs, also known as cool roofs, are simply roofs that are painted white or covered with white plastic sheeting that reflects light from the sun.

HOW DO THEY WORK?

White roofs reflect more energy from sunlight than darker roofs do, so they have a higher albedo than dark roofs or solar panels. A white roof's albedo is usually 50-65%. Because of the high albedo, more energy is reflected away from the roof. That means the roof absorbs less energy and the temperature inside the building doesn't increase as much. Since buildings with white roofs don't get as hot on sunny days, less air conditioning is needed to keep them cool inside. Because of this, white roofs can save energy and reduce the amount of carbon dioxide being added to the Earth's atmosphere through combustion.

In addition, reflecting energy from sunlight away from the buildings in a city helps keep the air temperature in the whole city a little cooler. This kind of modification also improves local air quality by reducing air pollution in the form of smog. This is because the amount of smog can increase with higher temperatures (or decrease with lower temperatures).

ADDITIONAL INFORMATION

The energy savings from a white roof depend on how many hours of sunlight a building gets each day. The more hours of sunlight the building experiences, the more this modification can reduce climate impact. White roofs are one of the least expensive roof modifications because they use inexpensive materials and don't require much labor to install.

White roofs don't damage historic buildings in any permanent way. However, they do change the look of a building slightly if the roof is visible, such as on a pitched (slanted) roof. White roofs are less visible than solar panels, even on pitched roofs.

Summarize how this roof modification affects each of the criteria presented in the "Roof Types Organizer."

Roof Modification: Solar Roofs WHAT ARE THEY?

Solar roofs are covered with solar panels. These panels are made of metal frames, layers of glass, and many solar cells. The solar cells absorb energy from sunlight and convert it to electrical energy. Solar roofs provide an energy source that can cool buildings without burning fuels, so they reduce the amount of carbon dioxide added to the Earth's atmosphere through combustion.

HOW DO THEY WORK?

Most electrical energy comes from power plants that burn fuel such as coal or natural gas. Solar panels absorb energy from sunlight and convert it to electrical energy without producing carbon dioxide from combustion. When they receive many hours of sunlight, solar roofs often convert more energy than is needed to cool that one building, and that extra electrical energy can even be sold back to the power company! A study done in California showed that in 2010, all the solar programs there produced enough energy to provide electricity for more than 135,000 homes and reduced the amount of carbon dioxide produced from combustion by about 400,000 tons.

Solar panels have an albedo of around 30% because some of their parts are shiny, but most have dark surfaces with low albedo. Even though they don't have the highest albedo, solar panels on a roof can still reduce the energy from sunlight that is absorbed by the building. The energy from sunlight hits the solar panels instead of the roof's surface and keeps the building a little cooler in hot weather, reducing the need for air conditioning.

ADDITIONAL INFORMATION

In order to convert energy from sunlight into electrical energy effectively, solar panels need to be arranged so that they capture lots of sunlight. They must be facing in the direction of the sun as much as possible. Putting solar panels on a roof is somewhat expensive because the materials required to build solar panels cost a lot of money. Rooftops may also need extra modification in order to support the weight of the panels. Over a long period of time, however, solar panels can save people a lot of money they would have spent on electricity.

Solar roofs permanently change historical rooftops. They may also lower the historic value of old buildings because some people object to the way solar panels look compared to the original roofs. However, on historical buildings with flat roofs, solar panels can be placed out of view.

Summarize how this roof modification affects each of the criteria presented in the "Roof Types Organizer."

Roof Types Organizer

Summarize how each type of roof modification affects the criteria.

Criteria	White	Solar
Roof Modification Description		
Climate Impact Effect on CO_2 release from combustion		
Climate Impact Effect on Albedo		
Historic Value		
Cost		
Other Details		

1. How would the temperature inside a building with a solar panel on top compare to the temperature inside a building with an original dark roof?
2. How does the temperature inside a building with a white roof compare to the temperature inside a building with an original dark roof?
3. How does the temperature inside a building with a white roof compare to the temperature inside a building with a solar roof?
4. Why are solar roofs a useful roof modification for Solton?
5. Why are white roofs a useful roof modification for Solton?

Task 3 Learning Target: I can isolate variables in the design tool to gather evidence for how roof modifications affect project criteria.

1. To learn how to use RoofMod, play the RoofMod Demo video.
   https://sites.google.com/a/ps207tigers.org/207sci/roof-design-challenge-demo

Launch the Sim: https://apps.learning.amplify.com/roofmod/

Part 1: Table 1: Values for 100% of each type of roof

1. Fill in Table 1 using the original (default) roof data in the Design Tool. Before you start making changes to Solton's roofs, it's important to record what the city is like before any modifications, so you can compare your changes to the city to what it is currently. There is no cost because changes have not been made.

2. Just as you saw in the video, you will begin testing in RoofMod using the process of isolating variables. This means that you will only test one thing at a time. This careful process will help you understand how each change you make in the Design Tool affects your results.
   Play the Engineering Tip: Isolating Variables video to learn more:
   https://sites.google.com/a/ps207tigers.org/207sci/isolating-variables

Part 2: Table 2: Values from isolating the variable

1. Reset RoofMod to begin with all of the buildings in their original states.
2. Open the filter and select ROOF SHAPE: FLAT so you can see all of the flat roofs in Solton.
3. Change all flat roofs from original to white.
4. On the top of Table 2, write" Roof Shape" as the variable.
5. In the first row of Table 2, write "flat roof" on the line so it reads: "White with . . . flat roof." Record results in this row and include what percent of roofs in Solton now have flat white roofs.
6. Reset RoofMod to clear all changes.
7. Open the filter and select ROOF SHAPE: PITCHED.
8. Change all pitched roofs from original to white.
9. In the second row of Table 2, write "pitched roof" so it reads: "White with . . . pitched roof." Record results in this row and include what percent of roofs in Solton now have pitched white roofs.
10. Describe any differences in the results between flat and pitched roofs in the conclusion section of Table 2.

Part 3: Table 3: Values from isolating variable

1. Now test one of the other variables in the list: historic value, total roof area, or hours of sunlight.
2. Record your Data in Table 3. Isolating variables in this way will help you begin to determine how your roof specialty affects the design criteria.

Table 1: Values for 100% of each type of roof

	CO_2 from Combustion (tons)	Average Albedo (%)	Historic Value	Cost ($)
100% original roofs				
100% white roofs				
100% solar roofs				
Conclusions:				

Table 2: Values from isolating the variable of _____ (for both white roofs and solar roofs)

Variable: _____		CO_2 from Combustion (tons)	Average Albedo (%)	Historic Value	Cost ($)
White with...	white _____ %				
	white _____ %				
Solar with...	solar _____ %				
	solar _____ %				
Conclusions:					

Table 3: Values from isolating variable of _____ (for both white roofs and solar roofs)

Variable:		CO_2 from Combustion (tons)	Average Albedo (%)	Historic Value	Cost ($)
White with...	White ____ %				
	white ____ %				
	white ____ %				
Solar with...	solar ____ %				
	solar ____ %				
	solar ____ %				
Conclusions:					

Task 4 Learning Target: I can interactively test design solutions by observing how changes affect the outcome and communicate the strongest design solutions and trade-offs.
https://apps.learning.amplify.com/roofmod/
Use RoofMod to build and test various designs. When engineers conduct tests, they do so in an iterative process, which means they use the results from one test to help make decisions about the next design. Use the RoofMod Data organizer below to keep track of your roof modification designs and how each design affects the project criteria.

RoofMod Data

FUTURA

Design Team _____ Date _____

VERSION

PLAN

_____

_____

BUILD
Design Details

	% Original
	% Solar
	% White

TEST
Test Results

CO_2 from Combustion (tons)	Average Albedo (%)	Average Historic Value	Total Cost ($)

ANALYZE

VERSION

PLAN

_____

_____

BUILD
Design Details

	% Original
	% Solar
	% White

TEST
Test Results

CO_2 from Combustion (tons)	Average Albedo (%)	Average Historic Value	Total Cost ($)

ANALYZE

Was one design strong for one criterion, but not the others? How do you know?
The following criteria could be used for evaluating your model:

Reduce city's climate impact by minimizing the amount of carbon dioxide: carbon dioxide in the atmosphere increases the amount of energy absorbed by Earth's surface, making Earth's climate warm.

Reduce city's climate impact by increasing a city's albedo: reflecting more light and absorbing less heat can reduce the average temperature of the whole city and help keep global temperatures from rising higher.

Preserve the historic value of the city's buildings: The city of Solton wants to make sure that the roof modifications don't make the city so unattractive that people won't want to visit the city. Many people come to the city to see these historic buildings, and they would be disappointed if they all had solar roofs.

Minimize costs: The city of Solton wants to make these modifications as inexpensively as possible so that the city can spend its budget on other things.

You may notice that there is no "perfect plan." In order to more strongly address one criterion, you may have to make sacrifices in addressing the others. These are trade-offs between designs—strong in one criterion but weak in another. What is one criterion that you would prioritize over the others? Explain.
https://sites.google.com/a/ps207tigers.org/207sci/tradeoffs

Task 5 Learning Target: I can rank design solutions for each criterion in order to focus feedback for redesign strategies.

Complete the "Goal" portion of the organizer below by using the parameters below.

Notice that less than 11,000 tons of "CO2 from Combustion (tons)" would strongly address the criteria.

Remember: carbon dioxide in the atmosphere increases the amount of energy absorbed by Earth's surface, making Earth's climate warm. It is important to reduce the amount of carbon dioxide because is important to find ways to stop Earth's increasing temperature.

~~Less than 11,000~~	Less than 30	Less than 3.5	$12M-$18M
11,000-12,500	More than 45	3.5-3.9	Less than $12M
More than 12,500	30-45	More than 4.0	More than $18M

	Climate Impact		Historic Value	Cost ($)
	CO2 from Combustion (tons)	**Average Albedo (%)**		
Goal	Strongly addresses: Less than 11,000 Moderately addresses: Weakly addresses:	Strongly addresses: Moderately addresses: Weakly addresses:	Strongly addresses: Moderately addresses: Weakly addresses:	Strongly addresses: Moderately addresses: Weakly addresses:
Test Result				
Feedback				
Redesign Strategy				