Outline — Salvadori After-School: *Building Green*

This 12-week program focuses on the fundamentals of green design in relation to the built environment. In 2012, buildings were the greatest contributors to greenhouse gas emissions[1] in the US (44.6%) – greater even than emissions produced by industry and transportation. By identifying and studying sustainable ways of heating, cooling, lighting, and powering buildings, students will learn how to reduce their environmental impact and understand the value of green design. For their final project, students will work in teams to design and construct a scale model of an energy-efficient building.

Objectives

Students will be able to:

1. understand how the built environment can impact the natural environment.
2. identify the main sources of energy consumption in buildings.
3. investigate sustainable methods of heating, cooling, lighting, and powering a building.
4. conduct scientific experiments to verify hypotheses and draw conclusions.
5. work in cooperative groups to translate ideas and concepts from a two dimensional design to a three dimensional model.
6. design and construct a scale model of an energy-efficient building.

Outline

Session 1 Intro to Building Green
Session 2 Energy Consumption
Session 3 Energy-Efficient Lighting
Session 4 Building Orientation
Session 5 Solar Energy – Passive Solar Heating
Session 6 Solar Energy – Passive Cooling
Session 7 Solar Energy – Active Solar Power
Session 8 Energy Transfer – Testing Insulation
Session 9 Designing a Green Building, Part 1
Session 10 Designing a Green Building, Part 2
Session 11 Constructing a Scale Model, Part 1
Session 12 Constructing a Scale Model, Part 2

Sample Vocabulary

- **built environment:** the structures made by people, that are designed and built around us (i.e., houses, bridges, roads, parks hospitals, schools, churches, etc.)
- **green:** something that attempts to preserve or enhance environmental quality (by being recyclable, biodegradable, nonpolluting, etc.)
- **green design:** an approach to building that reduces harmful effects on the environment and on human health, and conserves energy
- **energy-efficient:** using less energy to provide the same service
- **non-renewable energy:** energy from any natural resource from the earth that exists in limited supply and cannot be replaced if it is used up; also, any natural resource that cannot be replenished by natural means at the same rates that it is consumed
- **renewable energy:** energy from fuel sources that restore themselves over short periods of time and do not diminish; such fuel sources include the sun, wind, and moving water (hydropower)
- **scale:** an indication of the relationship between the distances on a map (or diagram/model) and the corresponding actual distances
- **solar power:** heat radiation from the sun converted into electrical power

Session 3 Energy-Efficient Lighting – OUTLINE

Lesson Theme

Students will understand the environmental impact of different types of lighting sources.

Objectives	Students will be able to:

1. understand how their school uses energy.
2. identify steps they can take to reduce the carbon footprint of their classroom. (Extension)
3. categorize building energy consumption into four main categories (heating, cooling, lighting, and power)
4. identify energy-efficient design alternatives to traditional methods of heating, cooling, lighting and powering a building.
5. understand the heat generation and energy consumption relationship between four different lighting sources (incandescent, compact florescent, halogen, and LED).

20 min. **Re-Cap: *Using Energy at School***

- Students will speak with school administration about how their school uses energy and why it's important.

25 min. **Intro to Primary Activity: *Green Buildings***

- Students will sort their classroom's energy consumption into four main categories (lighting, heating, cooling, and power).
- Students will play a matching game to identify green design alternatives to traditional methods of lighting, heating, cooling, and powering a building.

35 min. **Primary Activity: *Energy-Efficient Lighting***

- Students will work in groups to test the energy-efficiency of different light bulb types (incandescent, fluorescent, halogen, and LED).

10 min. **Wrap-Up**

- Commit to incorporating two principles from the *Green Classroom Pledge* into their weekly routine at school.

Vocabulary

- **green design:** an approach to building that reduces harmful effects on the environment and on human health, and conserves energy
- **energy-efficient:** using less energy to provide the same service
- **incandescent:** producing bright light when heated
- **fluorescent:** producing light when electricity flows through a tube that is filled with a type of gas
- **halogen:** an incandescent light bulb filled with halogen gas allowing it to run at higher temperatures, which produces greater brightness and efficiency
- **LED:** light-emitting diode; an electronic device that emits light when a voltage is applied to it
- **wattage:** the amount of electrical power measured in watts that something (such as a light bulb) uses
- **lumen:** a measure of the total light emitted by a light bulb
- **watt:** a unit for measuring electrical power
- **luminous efficiency:** a measure of the brightness of a light in comparison to its energy consumption; expressed in lumens-per-watt (lm/W)

Session 3 Standards Addressed

New York State Standards for Math, Science, and Technology

Standard 6 **Interconnectedness: Common Themes**

Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

MODELS: *Key Idea 2*

Models are simplified representations of objects, structures, or systems, used in analysis, explanation, or design.

- Use different types of models, such as graphs, sketches, diagrams, and maps, to represent various aspects of the real world

Common Core Standards for Mathematics

5.MD.2.	Make a line plot to display a data set of measurements in fractions of a unit (1/2, 1/4, 1/8)
5.G.2.	Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation
6.NS.6c.	Find and position integers and other rational numbers on a horizontal or vertical number line diagram
6.SP.4.	Display numerical data in plots on a number line, including dot plots, histograms, and box plots
7.RP.2b.	Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships
MP #4	Model with mathematics.
MP #6	Attend to precision.

LESSON 3

NOTE: THIS IS LESSON 3 OF
A 12-WEEK RESIDENCY.

Salvadori After-School

Building Green

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see it. build it. know it.

Session 3 Energy-Efficient Lighting

Lesson Theme

Students will understand the environmental impact of different types of lighting sources.

Objectives **Students will be able to:**

1. understand how their school uses energy.
2. identify steps they can take to reduce the carbon footprint of their classroom. (Extension)
3. categorize building energy consumption into four main categories (heating, cooling, lighting, and power)
4. identify energy-efficient design alternatives to traditional methods of heating, cooling, lighting and powering a building.
5. understand the heat generation and energy consumption relationship between four different lighting sources (incandescent, compact florescent, halogen, and LED).

20 min. **Re-Cap: *Using Energy at School***

- Have the school's custodian engineer or an administrative staff person (like the Principal or Vice Principal) talk to the students about how the school uses energy, what they do to help the school use energy wisely, and why they believe it's important to do so.
- Before the speaker comes in, distribute the index cards with the questions created by the students the previous week. Students should sit next to the partner they worked with. Use the sample energy questions listed at the end of Session 2 if there are not enough student questions.
- When the speaker comes in, have them introduce themselves and explain their role in relation to the school's energy use. Allow enough time for the students to ask their questions. Record important facts on chart paper and/or assign one of the students to take notes.

  Note: If a visit from the school's staff is not possible, lead a discussion with the students about the list of questions they created last week and the findings that they made during the week, or how to go about finding the answers to their questions (schedule to meet with the Principal, write a letter, etc.).
- If time allows, have students, read, modify, and sign the *Green Classroom Pledge*.

Lesson Prep

1. Post charts/pictures:
   1. Salvadori Student Agreement
   2. Green Classroom Pledge (*Extension*)
   3. Experimental Procedure (2)
   4. set of built environment pictures from Session 1 (5 total)

✓ Coordinate a visit from the school's custodian engineer or administrative staff

✓ Set up testing stations for Primary Activity

Materials

- ☐ pencils, yellow student folders
- ☐ blue tape, chart paper, markers, dry-erase markers and dry-erase eraser
- ☐ index cards with student energy questions from Session 2
- ☐ *Classroom Energy Survey* activity sheets from Sessions 1 and 2 (one per group)
- ☐ *What Do Buildings Use Energy for?* activity sheet (one per group)
- ☐ set of *Green Design Alternatives Matching Game* cards (one card per student)
  - ☐ 6 picture cards
  - ☐ 18 to 26 clue cards -depending on class size
- ☐ *Green Design Alternatives Matching Game* answer key (for Educator)
- ☐ large set of *Green Design Alternatives* picture cards (for Educator – for reviewing)
- ☐ *What Am I Game poster* and description cards set (optional - per group, for smaller classes)
- ☐ Primary Activity Setup:
- ☐ 2" masking tape
- ☐ 8 extension cords
- ☐ 8 outlet power strips
- ☐ 8 light socket adapters
- ☐ 8 incandescent light bulbs
- ☐ 8 compact fluorescent bulbs
- ☐ 8 halogen light bulbs
- ☐ 8 LED light bulbs
- ☐ 4 clear plastic bins
- ☐ light bulb station signs (4)
- ☐ Primary Activity (per group):
- ☐ *Group Roles* handout (half-sheet)
- ☐ thermometer gun
- ☐ safety gloves
- ☐ stopwatch
- ☐ calculator
- ☐ *Energy-Efficient Lighting* activity sheets (one per student)

Vocabulary

- ☆ green design
- ☆ energy-efficient
- ☆ incandescent
- ☆ fluorescent
- ☆ halogen
- ☆ LED
- ☆ wattage
- ☆ lumen
- ☆ watt
- ☆ hypothesis
- ☆ luminous efficiency

25 min. **Intro to Primary Activity: *Green Buildings***

- Review the types of devices and systems that use energy in a school. ***How could consuming too much energy be harmful to the environment?*** (can cause greenhouse gases, land pollution, air pollution, acid rain, health hazards, etc.) ***What did we say is one of biggest impacts that humans have on the natural environment?*** (destruction of the natural environment through the building and maintenance of the houses and buildings we live and work in) Show the laminated pictures of the built environment.

  There are four main things that buildings use energy for. ***What do you think those four things are?*** Record student answers on chart paper. *Buildings use energy to provide* ***lighting****, to maintain a comfortable indoor temperature (****heating*** *and* ***cooling****), and to* ***power*** *electronics, appliances, and other technologies (i.e., things that are plugged into the outlet).*

- Ask students to find the *Classroom Energy Survey* activity sheet in their yellow folders. **Note:** Not all the students will have it since it was a group activity. *You are going to work with the same group to sort the list you created into these categories: lighting, heating, cooling, and power.*

- Do one or two examples together as a class so that students understand how to sort their list on the *What Do Buildings Use Energy for? activity* sheet. **Note:** Some items on students' lists may fall under more than one category – i.e., electric fan, air conditioner, desk lamp, etc.

- Distribute the *What Do Buildings Use Energy for?* activity sheets. Have students form groups with the same students they worked with in Session 1 to create the list. When students are finished sorting, review the categories together as a class.

  Let's take a look at some traditional ways in which buildings provide heating, cooling, lighting, and power, and some alternative ways (green design alternatives) *that save energy. It's okay if there are some you don't know or have never heard of before. This is just an introduction. Whatever we learn about today, we'll keep exploring over the next few weeks.*

- ***Who remembers what green design is?*** Record the students' answers on chart paper. *Green design is an approach to building that reduces harmful effects on the environment and on human health, and conserves energy.*

- *To learn more about green design and how we can incorporate it into our building, we are going to play a matching game. Everyone is going to get one card. The card will either have a picture on it or a clue. The picture cards show an image of a type of green design alternative. Each clue card has a description of one of those green design alternatives. There are a total of* ***6*** *green design alternatives. There are at least 3 clue cards for each green design alternative. The goal is to create a group with one green design alternative and all the clues that go with it.*

- *When I say "Go!" you will have five minutes to find your group. After receiving a card, your job will be to find the people with the picture and clue cards that match the one you have. Each group should have at least three people, so once you find one match keep looking for the other members of your group. If you are confused by the card you receive, use your classmates' help to figure it out. Let's do one example together.*

✪ Extension ✪

How can we reduce our classroom's carbon footprint?

Draw the students' attention to the *Green Classroom Pledge* poster. Read the pledge together as a class. Ask the students if there is anything else they would like to add. Have students come up to sign the pledge.

If time is limited, students can sign at another time. If more time is available, guide the class to create their own pledge on chart paper.

Leave the poster up where it is clearly visible to the students, teacher, and visitors.

***What Do Buildings Use Energy for? activity* sheet**

***What Am I Game* version with poster board and description cards:**

35 min.

Primary Activity: *Energy-Efficient Lighting*

- Do an example together as a class by showing the students the large set of *Green Design Alternatives* picture cards and reading one of the clues on a clue card. Ask students to match the clue to the correct green design alternative. Once, students understand how to play, distribute one card to each student and start the game.

  Note: Larger classes will need to repeat clue cards in order to have enough cards for all the students. For smaller classes, use the *What Am I Game* version with the laminated poster board and Velcro description cards – one per group.

- Once everyone has found a group, have groups share what green design alternative they were, and read their clues. ***Which of these green design alternatives have you heard of or seen before?*** *These alternative design choices can be described as being energy-efficient because they use less energy to provide the same service.*

- Hold up an incandescent light bulb and a compact fluorescent light bulb (CFL). ***What do you notice that is the same about these two light bulbs? What do you notice that is different?***

  One of the Green Design Alternatives we talked about is replacing regular incandescent light bulbs, with compact fluorescent light bulbs or CFLs. There are other types of light bulbs too, like halogens and LEDs (hold them up)*. The difference between these four types of light bulbs is the way in which they produce light. Some require more energy than others to produce the same amount of light.*

  Today we're going to test each of these types of light bulbs to find out which is the most energy-efficient. We are going to do this by collecting data about how much energy each one consumes (wattage), how much light each one gives off (lumens), and how much heat each one produces.

- *Each group is going to test at least one type of light bulb and share their results with the rest of the class.* Distribute an *Energy-Efficient Lighting* activity sheet and a pencil to each student and have them make a hypothesis about which light bulb (incandescent, compact fluorescent, halogen, or LED) will be the most energy-efficient. Remind students that energy-efficiency means using less energy to provide the same service.

  Note: In the case of the light bulb, the most energy-efficient one will be the one that provides the most amount of light using the least amount of energy. The lumen information is provided on the activity sheets (in blue ink).

- Once students have made their hypothesis, read the *Experimental Procedure* poster together as a class and use the materials to demonstrate each step. ***Did you…***

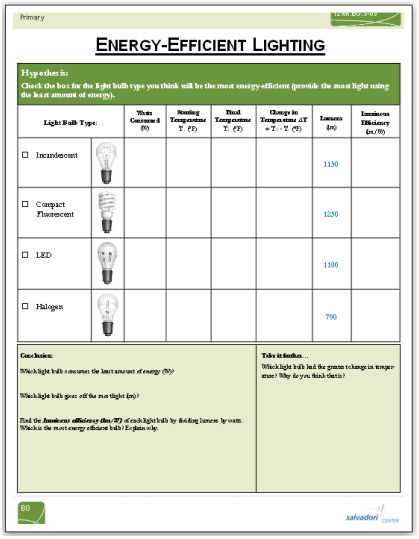
  - ☐ *Take the light bulb **starting temperature** before turning on the power strip and **record it in your chart**?*
  - ☐ *Record the light bulb wattage?*
  - ☐ *Reset the stopwatch to **0:00**?*
  - ☐ ***Turn on the power strip** and **start stopwatch** at the same time?*
  - ☐ *Retake the temperature at **3:00** (take the temperature while the light bulb is still on)?*
  - ☐ ***Record the final temperature** on your chart?*
  - ☐ ***Turn off** the power strip?*

✪ Learning Resource ✪

Energy-efficient means using less energy to provide the same service.

Energy efficiency is different than energy conservation. Energy conservation is reducing or going without a service to save energy. For example: Turning off a light is energy conservation. Replacing an incandescent lamp with a compact fluorescent lamp (which uses much less energy to produce the same amount of light) is energy efficiency.

Source: http://eetd.lbl.gov/ee/ee-1.html



ENERGY-EFFICIENT LIGHTING

Hypothesis:
Check the box for the light bulb type you think will be the most energy-efficient (provide the most light using the least amount of energy).

Light Bulb Type:		Watts Consumed (W)	Starting Temperature T_i (°F)	Final Temperature T_f (°F)	Change in Temperature $\Delta T = T_f - T_i$ (°F)	Lumens (lm)	Luminous Efficiency (lm/W)
☐ Incandescent						1150	
☐ Compact Fluorescent						1250	
☐ LED						1100	
☐ Halogen						790	

Conclusion:
Which light bulb consumes the least amount of energy (W)?
Which light bulb gives off the most light (lm)?
Find the *luminous efficiency (lm/W)* of each light bulb by dividing lumens by watts. Which is the most energy efficient bulb? Explain why.

Take it further…
Which light bulb had the greatest change in temperature? Why do you think that is?

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***Energy-Efficient Lighting* activity sheet**

✪ Group Roles ✪

Starter (collects the group's materials at the beginning and at the end of the experiment; turns power switch on and off; reads out data from the infrared thermometer)

Time Keeper (uses the stopwatch to keep time)

Recorder (records experiment data on activity sheet)

Temperature Reader (holds the infrared thermometer; ensures that the laser is steadily centered on light bulb; must wear safety gloves)

Primary Activity (Cont.)

- **Note:** The wattage information can be found at the top of the incandescent, halogen and LED light bulbs. It is located on the side of the compact florescent light bulb. The infrared thermometer takes the surface temperature of the light bulb. To use it, point it directly at the light bulb, holding it about an inch away. Hold the orange trigger. Release the trigger and the reading will hold for 7 seconds. Warn students to not stare into the laser beam or point it at anyone's eyes. The laser should be ON and the temperature set to °F.
- Distribute the *Group Roles* handouts. Give students 2-3 minutes to choose their group role. Have one person from each group (the Starter) gather the materials and bring them back to the group.
- Each group will begin by testing one of the light bulbs. Have each group test a different type of light bulb, in case there is not enough time for the class to do more than one round of the experiment. Once groups have tested their first lightbulb and recorded their data, they may choose another lightbulb to test.
- After 25 minutes, ask for groups to share their data. Students will work on the *Conclusion* and *Take it Further* sections at the bottom of the activity sheets using the class's data.
- Review the students' conclusions. Record on chart paper.
- Guiding questions:
  - Which light bulb is the most energy-efficient? (LED)
  - Which light bulb had the greatest change in temperature? (incandescent)
  - Why do you think the incandescent light bulb had the greatest temperature change? How is the heat produced by a light bulb related to the amount of light it produces? (most of the energy consumed by the incandescent light is used to produce heat instead of light)
  - If LEDs are the most energy-efficient of the four types of light bulbs we tested today, why aren't they more common? Why don't more people use LEDs instead of incandescent? (e.g., lack of consumer education, availability, technology, cost, habit)
  - When or where would it be useful to use incandescent light bulbs? (as heat lamps in the food industry, for animals in cages and tanks – like lizards and turtles)

10 min.

Wrap-Up

- **Optional:** Ask students to choose two things from the *Green Classroom Pledge* that they will focus on doing during the week.

✪ Learning Resource ✪

A lumen is a measure of the total light emitted by a light bulb. It differs from wattage, which is the measure of energy going into the bulb. **Lumen-per-watt** (LPW) indicates how much light comes out of a lamp in terms of how much is going in. The higher the LPW, the more efficient the light bulb.

Source: http://kids.britannica.com/comptons/article-9315622/Lumen

✪ Learning Resource ✪

Incandescent bulbs contain a long, coiled, piece of metal called a filament. In fact, an average 60 watt bulb has over 6 feet of filament wire inside of it! When you turn on a light bulb, electricity flows through the filament. As the filament heats up it produces light.

Incandescent bulbs are simple but fairly inefficient. Most of the electricity flowing through the filament generates heat while a small percentage actually produces light. That's why light bulbs get quite hot to the touch. They're essentially heaters generating a small amount of light. This low level of efficiency is also why there's a huge push to switch to more efficient fluorescent and LED lighting.

Video: http://www.wydea.com/topic/lightbulb

energy-efficient	using less energy to provide the same service Source: http://eetd.lbl.gov/ee/ee-1.html
fluorescent	producing light when electricity flows through a tube that is filled with a type of gas
green design	an approach to building that reduces harmful effects on the environment and on human health, and conserves energy
halogen	an incandescent light bulb filled with halogen gas allowing it to run at higher temperatures, which produces greater brightness and efficiency Source: http://encyclopedia.kids.net.au/page/li/Light_bulb
hypothesis	an idea or theory that is not proven but that leads to further study or discussion
incandescent	producing bright light when heated
LED	light-emitting diode; an electronic device that emits light when a voltage is applied to it
lumen	a measure of the total light emitted by a light bulb Source: http://kids.britannica.com/comptons/article-9315622/Lumen
luminous efficiency	a measure of the brightness of a light in comparison to its energy consumption; expressed in lumens-per-watt (lm/W)
watt	a unit for measuring electrical power
wattage	the amount of electrical power measured in watts that something (such as a light bulb) uses

Next Generation Science Standards (NGSS)

HS-ESS2 Earth's Systems

HS-ESS2-2 Analyze data using tools, technologies, and/or models in order to make valid and reliable scientific claims or determine an optimal design solution.

HS-ESS3 Earth and Human Activity

HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

EXPERIMENTAL PROCEDURE:

Did you…

☑ Take the light blub **starting temperature** before turning on the power strip and **record it in your chart**?

☑ Record the light bulb wattage?

☑ Reset the stopwatch to **0:00**?

☑ **Turn on the power strip** and **start the stopwatch** at the same time?

☑ Retake the temperature at **3:00** (take the temperature while the bulb is still on)?

☑ **Record the final temperature** on your chart?

☑ **Turn off** the power strip?

Energy-Efficient Lighting

Check the box for the light bulb type you think will be the most energy-efficient (provide the most light using the least amount of energy).

Hypothesis: I think that the _____ bulb is the most energy-efficient because _____

_____.

Light Bulb Type:		Watts Consumed (W)	Starting Temperature T_S (°F)	Final Temperature T_F (°F)	Change in Temperature $\Delta T = T_F - T_S$ (°F)	Lumens (lm)	Luminous Efficiency (lm/W)
☐ Incandescent						1170	
☐ Compact Fluorescent						1250	
☐ LED						1100	
☐ Halogen						790	

Conclusion:

Which light bulb consumes the least amount of energy (W)?

Which light bulb gives off the most light (lm)?

Find the ***luminous efficiency (lm/W)*** of each light bulb by dividing lumens by watts. Which is the most energy efficient bulb? Explain why.

Take it further…

Which light bulb had the greatest change in temperature? Why do you think that is?