



Center for Renewable Energy Advanced Technological Education

Sketchbox Lesson 1: Introduction to building modeling

INSTRUCTOR'S GUIDE

Grade Level: High School, Technical College, Community College
Lesson Length: 1-2 hours
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Learning Goals:

- Students can describe the scale of the amount of energy used in buildings and some ways in which this energy is used
- Students can use the Sketchbox™ interface to model the energy use of a building with specific characteristics and report their results
- Students can list several factors that affect energy use in buildings

Technology Required:

- Internet-accessible digital device to use Sketchbox™, Sketchbox user account (free)

Standards related to this lesson

Next Generation Science Standards (<https://www.nextgenscience.org/>)

Content Standards

HS-ETS1-4 Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Science and Engineering Practices

2. Developing and using models
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Lesson metatags

building design, computer model, data analysis, efficiency, electricity, energy, energy conservation, energy economics, heating and cooling, HVAC, kwh, natural gas, NG, simulation, utility rates

The Activity:

This activity involves the use of a computer model that calculates the energy use for a specific building in a given location. Sketchbox™ is a user interface to the energy modeling software DOE2 that uses typical industry values to make quick energy estimates for energy use in buildings. Sketchbox™ and DOE2 use historical weather input data for the location selected in the model along with location specific CO₂ equivalent emissions data for electricity and cost data for electricity and natural gas.

While Sketchbox™ allows changes to many parameters that affect energy use in buildings this lesson focuses on building size, window to wall ratio, and location. Students first run a model for a 150,000 square foot school building in Chicago, IL, and recording those data as a baseline. Students then make three separate changes to the building to study the impact of those changes and become familiar with operating the simulation. Students generally find Sketchbox™ easy to use and can independently collect this data. However, it is helpful to remind students to undo the change they have made in each part of the exercise before making the next modification to the model. This can be emphasized as changing only one variable at a time, while controlling all other variables, to determine the separate impact of each variable.

Discussion ideas

Post lesson discussion questions are included with the teacher slides and copied here. Slides containing these questions also have related sample data to aid in discussion.

Discussion questions for lesson 1, Introduction to building models:

1. The smaller building uses less energy- explain why.
2. Does a building only half the size use only half the energy?
3. Does doubling window area increase or decrease electricity use? Why?
4. Does doubling window area increase or decrease natural gas use? Why?
5. Why does moving to LA increase electricity use?
6. Why is some natural gas still needed in LA even though the climate is much warmer?

Especially if you do not plan to use lesson 4, carbon emissions, there are additional notes in the teacher slides for introducing the impact of different means of generating electricity, in different locations, on carbon emissions.

Extension activities and questions

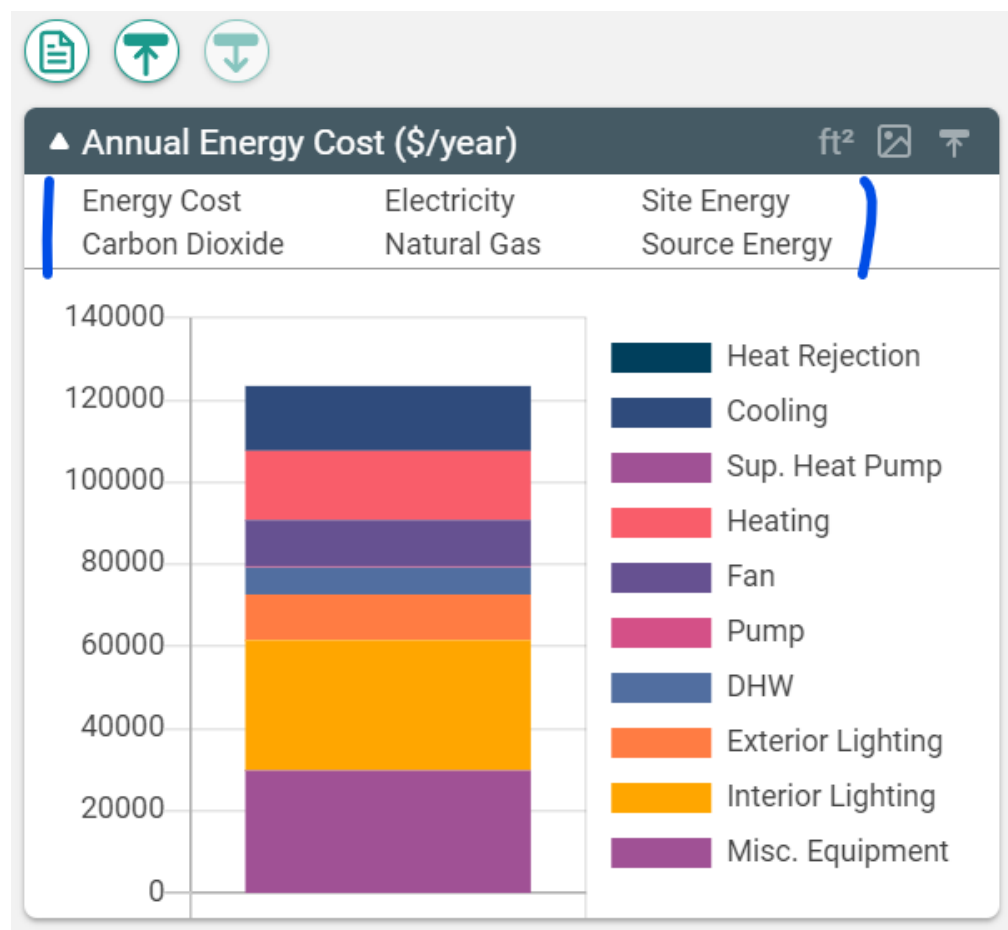
These ideas are included in the teacher slides but copied here for reference. They are intended as additional learning activities, especially for students of student groups that complete other parts of the lessons before their peers.

Students can select an additional city of their choice for comparison to Chicago and Los Angeles

Students can reduce window percentage on north wall but increase window percentage on south wall, keeping total window area constant

Students can change another parameter of interest (additional lessons study energy codes, schedules, measures sets, set points, carbon emissions, and building shape)

Students can also explore other data beyond energy cost using options in the results tab, as shown in the image below:



Copy of student handout with sample answers begins on next page

	Center for Renewable Energy Advanced Technological Education 	Name: _____ Date: ____ / ____ / ____ Class Hour: ____
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SKETCHBOX™ LESSON 1 (v1.02): Introduction to Building Models

Student Activity and Response Guide

INTRODUCTION:

Energy use in school buildings

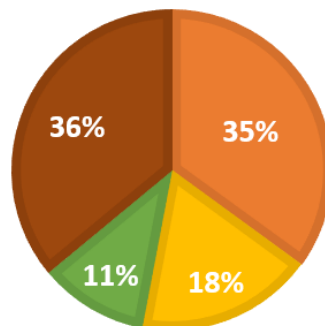
The US department of energy reported in 2015 that buildings use 40% of all energy in the U.S. and about 75 percent of the electricity. This energy has a significant cost, and the EnergyStar program estimates U.S. schools spend roughly \$162 per student each year for energy (it can be more than spending for computers and textbooks combined!). Energy use also produces significant emissions of air pollution and other environmental impacts. These effects can be reduced by making buildings, including school buildings, more efficient. The goal of this lesson is to learn ways this is done and to explore a computer model that estimates the impact of specific changes to a building.

Reducing energy use in buildings

To understand how to reduce the energy used by buildings it helps to understand what equipment uses this energy. In schools, the largest use of energy is heating, ventilation, and air conditioning, or HVAC; this is about 35% of all energy used in a school building. Major appliances like refrigerators, freezers, dryers, and hot water heaters (18%) and lights (11%) also use a lot of energy. All other devices together account for the rest (36%).

ENERGY USE IN SCHOOLS

■ HVAC
 ■ Appliances
 ■ Lighting
 ■ Other



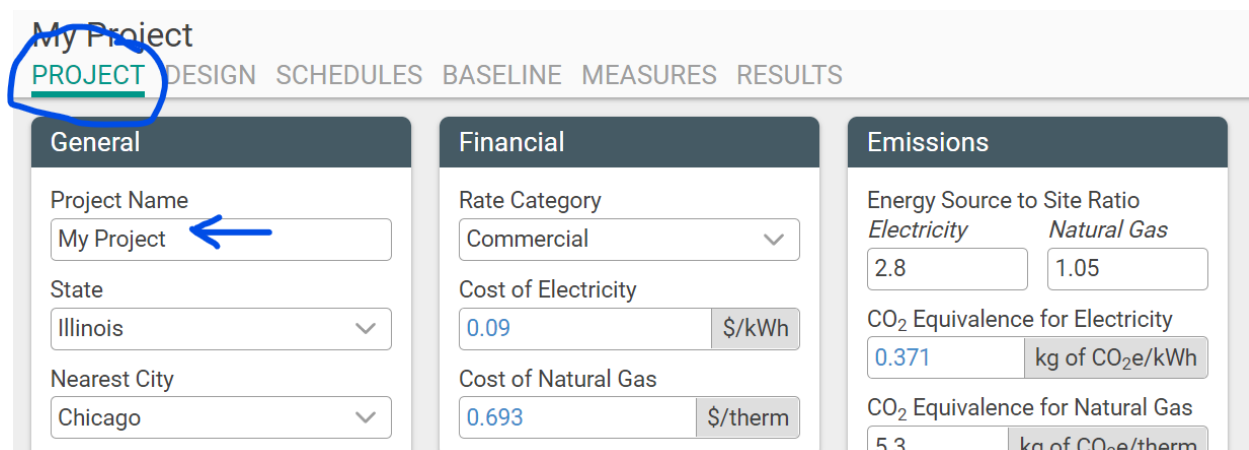
Using models to evaluate potential upgrades

There are many ways to reduce the energy used by a building such as installing more efficient lights, changing temperature settings when people are not in the building, and upgrading outdated heating and cooling systems. Choosing which upgrades to make can be difficult, but that is exactly where building energy modeling can help!

This lesson introduces a building model interface called Sketchbox™, created by Slipstream, to analyze energy use in buildings. To get started, follow these steps:

1. Access the web address: <https://www.sketchbox.io/login>
2. Create an account and then log in
3. When Sketchbox™ opens the “**project**” tab should be selected. This tab lets you name your project, choose its location, and enter data about energy code, energy cost, and emissions. Energy code is a legal framework that guides how buildings are designed and built and is presented in a later lesson.

Give your project a new name and keep the state set to Illinois and the city to Chicago.



My Project

PROJECT DESIGN SCHEDULES BASELINE MEASURES RESULTS

General	Financial	Emissions
Project Name My Project	Rate Category Commercial	Energy Source to Site Ratio <i>Electricity</i> 2.8 <i>Natural Gas</i> 1.05
State Illinois	Cost of Electricity 0.09 \$/kWh	CO₂ Equivalence for Electricity 0.371 kg of CO ₂ e/kWh
Nearest City Chicago	Cost of Natural Gas 0.693 \$/therm	CO₂ Equivalence for Natural Gas 5.3 kg of CO ₂ e/therm

4. Now, switch to the “**design**” tab.

My Project

PROJECT **DESIGN** SCHEDULES BASELINE MEASURES RESULTS

☒ School ☐ Site

Name

Color

Building Type



From the design tab you can change the size, shape, and layout of your building and choose equipment for heating and cooling. For now, leave everything as a default EXCEPT to change the building type to “**School/University**”. Once you have done this, make sure the building has 150,000 square feet of space (this is the size of a middle school or a small high school) and that the number of floors is 2.

5. Now you are ready to model how much energy this building will use! Select the “**Results**” tab and look for the table that looks like the one shown here:

Results Table 						
	Peak Cooling (kBtu/hr)	Peak Heating (kBtu/hr)	Peak Electric Demand (kW)	Annual Electric Consumption (kWh)	Annual Natural Gas Consumption (therm)	Annual Energy Cost (\$)
Baseline	878.1	751.8	127.9	326919	8539	35339

R1 Note the **annual energy cost** and record that value here: * 117,152

Check the annual energy cost with the value from your instructor- they should match.

Now, record the annual energy cost, the annual electric consumption (kWh), and the annual natural gas consumption (therm) in the **table on the next page (table 1)** in the “Baseline” row. We will compare to these values later.

Table 1

Building model	Annual electric consumption (kWh)	Annual natural gas consumption (therm)	Annual energy cost (\$)
Baseline (data from part one) 150,000 sq ft, Chicago, 22% window to wall ratio	* 1,023,333	* 36,149	* 117,152
L1* 75,000 square feet Half area	* 510,622	* 18,792	* 58,978
L2* Double window area	* 1,058,548	* 36,736	* 120,727
L3* California	* 1,038,341	* 9853	* 164,809

Part Two

Now that you have seen inputs and results in sketchbox let's explore how changes to the building affect predicted energy use.

6. Make a prediction about how the energy use will change if the building size is cut in half (be sure to add one or two reasons to support your prediction).

R2 Prediction: * Energy use will decrease

R3 Support: * Since there is less building area less energy will be needed to heat and cool, and there are few people to operate equipment

7. To test your prediction, navigate back to the "design" tab in sketchbox then change the building area from 150000 ft² (square feet) to 75000 ft².

My Project

PROJECT **DESIGN** SCHEDULES BASELINE MEASURES RESULTS

☒ School ☐ Site

Name Color

Building Type

Parent Shell Adjacency

Area Aspect Ratio



8. Return to the results tab to view the new results. Find the space in table 1 on the previous page marked “L1” and add the label “75,000 sq ft, half area”. In the three spaces after the L1 label enter the new results for the half-area model.

R4 9. Was your prediction correct? How does the new energy use and energy cost compare to the original building?

*** Energy cost is lower but not exactly half.**

10. Now let’s explore how windows affect energy use in buildings. Make a prediction about how the energy use will change if more windows are added to the building (be sure to add one or two reasons to support your prediction).

R5 Prediction: * Students may expect cost to increase or decrease.

R6 Support: * Adding windows should reduce energy for lighting which reduces cost but adding windows also increases cost for heating and cooling, total change is an increase.

11. To make the next change select the “design” tab in sketchbox and change the building area back to 150000 ft². Then, increase the “**window-to-wall-ratio**” from 22 to 44 for the walls facing in each direction.

My Project

PROJECT DESIGN SCHEDULES BASELINE MEASURES RESULTS

☒ School ☐ Site

Wall Type

Metal framed

Glazing Type

Fixed fenestration

Window-to-Wall Ratio (%)

North	South	East	West
44	44	44	44

Skylight Type

Plastic Curb

Skylight-to-Roof Ratio

0 %



Scroll
bar

←

12. Return to the results tab to view the new data. Find the space in table 1 on the previous page marked “L2” and add the label “double window area”. Then, in the three spaces after the L2 label, enter the new results for the double window area model.

R7 13. Was your prediction correct? How do the energy use and energy cost with more windows compare to the original building?

*** Energy use and cost increase a little. Students could explore by what percent electricity and natural gas each change.**

14. Finally, let’s examine how location affects energy use in buildings. Make a prediction about how the electricity and natural gas use for this building will change if it were moved to Los Angeles, California (be sure to add one or two reasons to support your prediction).

R8 Prediction: * Electricity cost will be more for more cooling but natural gas use will be less.

R9 Support: * The warmer climate will require more cooling so more electricity for air conditioning. The warmer climate will require less heating from natural gas.

15. Return to the “design” tab in sketchbox and change the “window-to-wall-ratio” from 44 back to 22 for each wall.

16. Switch to the “project” tab and record natural gas and electricity cost in Chicago (Chi).

R10 Natural gas cost Chi (\$/therm): * 0.693

R11 Electricity cost Chi (\$/kWh): * 0.09

17. Now, change the **state to California** and the **city to Los Angeles**. Record the cost of natural gas and electricity in Los Angeles (LA).

R12 Natural gas cost LA (\$/therm): * 0.814

R13 Electricity cost LA (\$/kWh): * 0.151

18. Return to the results tab to see the new data. Find the space in table 1 marked “L3” in the bottom row and add the label “California”. In the three spaces after the L3 label enter the new results for the California model.

R14 Was your prediction correct? How does the new energy use in Los Angeles compare to the same building located in Chicago?

*** Yes, energy use was last, though electricity only slightly increased while natural gas use is much smaller.**

R15 How does the new energy COST in Los Angeles compare to the same building located in Chicago? Explain how this relates to your answer about energy use.

*** Energy use is less but the cost is higher. At first this seems contradictory, but this happens because the cost of electricity and natural gas (per kWh and therm) are both much higher in Los Angeles than Chicago.**