



Center for Renewable Energy Advanced Technological Education

Sketchbox Lesson 2: Energy Codes and Measures

INSTRUCTOR'S GUIDE

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

- Students can explain what an energy code and how they are used by local governments
- Students can use the Sketchbox™ interface to model the energy use of a building built to different energy codes and report the impact of energy code on energy use and cost
- Students can use the Sketchbox™ interface to explore different energy efficiency measures and use the resulting data to describe relative energy savings from different measures

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, energy codes

The Activity:

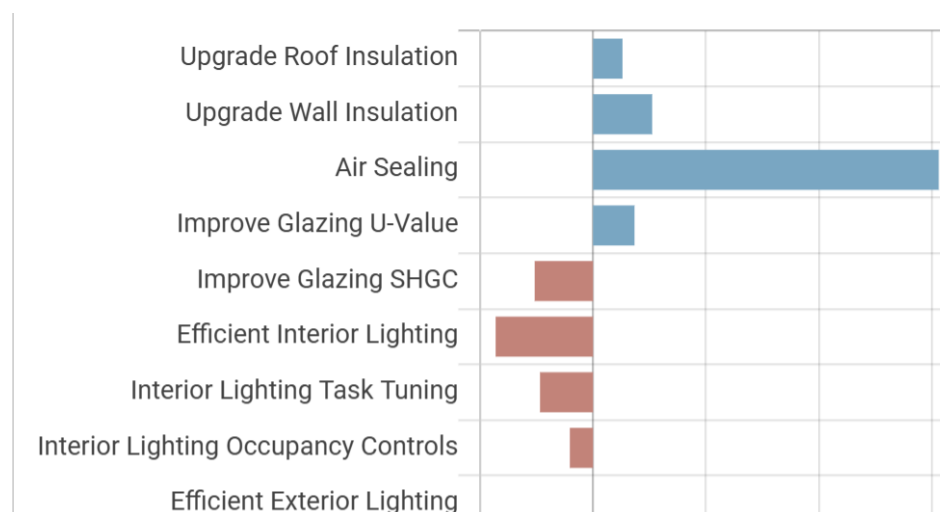
This activity involves the use of a computer model that calculates the energy use for a specific building in a given location. Sketchbox™ is a user interface to the energy modeling software DOE2 that uses typical industry values to make quick energy estimates for energy use in buildings. Sketchbox™ and 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.

Sample building data typical for different building sectors are included in Sketchbox™, and this data includes both ASHRAE and IECC energy codes. In this lesson students change to several different codes to examine how the same building built to different codes will use different amounts of energy and require different energy costs. After exploring the impact of energy code students use energy efficiency measures or sets of measures to improve the properties of a building to exceed code to see what reductions in energy use and cost are possible. Students also calculate the percentage of electricity and natural gas and cost savings for one of the building upgrades.

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.

1. How much energy cost does the 2018 IECC code save each year compared to the 2015 IECC code? What is the highest additional building cost that would make this a good investment?
2. Results from “best” values for a measures set show significant improvements above IECC energy code. Should the energy code require more efficiency? Why or why not?
3. Some measures increase use of natural gas when improved to a “best” value and others cause no change. Why does this happen? [See sample results below, reductions in natural gas use appear as bar graphs to the right of center, increases to the left]



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.

Try much earlier energy code or newest

Work out carbon emissions calculations by energy code

Re-order four selected measures

Analyze which measures apply to local school building

Switch to results other than cost (e.g. natural gas)

Study the data from the “Best” full measures case, which upgrades provide the most cost savings?

Copy of student handout with sample response begins on the next page

	Center for Renewable Energy Advanced Technological Education 	Name: SAMPLE STUDENT RESPONSE Date: ____ / ____ / ____ Class Hour: ____
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SKETCHBOX™ LESSON 2_v1.02: Energy Codes and Measures Sets

Student Activity and Response Guide

Introduction

Most buildings are built to meet a set of legal requirements called **building codes**. These standards ensure that electrical systems are safe, adequate fresh air is brought into the building, people are protected from dangerous falls, and that the building is as safe as possible for fire and other hazards. Buildings also often follow an **energy code**. Energy codes give guidance for different aspects of building construction such as how much insulation must be in a building's walls or roof, how efficient various mechanical systems must be, and what types of lighting are used. It is important to know that the U.S. does not have a national energy code for buildings, energy codes can be different from state to state or sometimes even from city to city.

What energy codes are used?

In the U.S. two energy codes are commonly used. One set is produced by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and the other by the International Code Council which creates the International Energy Conservation Code (IECC). An energy code is established as law when a city or state selects a code and then adopts it. A city or state does not need to adopt the ASHRAE or IECC standards, they can also write their own energy code. ASHRAE and IECC update codes on three-year cycles, but just because a new code exists does not mean that a state or city needs to implement it, the old code will be used until a new one is adopted.

Energy codes are built directly into Sketchbox

The amount of energy used by a building depends, in part, on the code it was designed to meet so energy code is important for energy modeling. Multiple energy codes are built directly into Sketchbox. In this activity you will switch between several energy codes and learn how buildings can also exceed the efficiency requirements of energy codes.

Exploring energy codes

1. Access the web address: <https://www.sketchbox.io/login>
2. Login to Sketchbox using the account you created in lesson 1
3. When Sketchbox opens you should see the “project” tab selected which was used to name your project and set the project location. Directly below the state and city of the project is the energy code. This starts as IECC 2018, but it can be changed to nine different options.

My Project

PROJECT DESIGN SCHEDULES BASELINE MEASURES RESULTS

General	Financial	Emissions				
Project Name My Project State Illinois Nearest City Chicago Energy Code IECC 2018	Rate Category Commercial Cost of Electricity 0.09 \$/kWh Cost of Natural Gas 0.693 \$/therm	Energy Source to Site Ratio <table><thead><tr><th>Electricity</th><th>Natural Gas</th></tr></thead><tbody><tr><td>2.8</td><td>1.05</td></tr></tbody></table> CO₂ Equivalence for Electricity 0.371 kg of CO₂e/kWh CO₂ Equivalence for Natural Gas 5.3 kg of CO₂e/therm	Electricity	Natural Gas	2.8	1.05
Electricity	Natural Gas					
2.8	1.05					

Leave the energy code set to IECC 2018 and switch to the design tab. Set the building type to school / university and make sure the area is 150000 ft².

PROJECT DESIGN SCHEDULES BASELINE

☒ School ☐ Site

Name

School

Color

Building Type

School/University

Parent Shell

None

Adjacency

Not Used

Area

150000 ft²

Aspect Ratio

1

Switch to the results tab and scroll to the bottom to find summary values for the top row in table 1:

Table 1

Building model	Annual electric use (kWh)	Annual natural gas use (therm)	Annual energy cost (USD, \$)
Baseline (IECC 2018)	* 1,023,333	* 36,149	* 117, 152
IECC 2015	* 1,102,508	* 35,481	* 123,815
ASHRAE 2016	* 1,057,115	* 35,068	* 119,443

4. The building modeled by these calculations was designed to meet the 2018 IECC standards. To see how building for the 2015 IECC standard is different, switch back to the project tab, change the code to IECC 2015, then return to the results tab to see the change (enter your results in the next line of table 1, “IECC 2015”).

My Project

[PROJECT](#) [DESIGN](#) [SCHEDULES](#) [BASELINE](#) [MEASURES](#) [RESULTS](#)

General

Project Name
My Project

State
Illinois

Nearest City
Chicago

Energy Code
IECC 2018
IECC 2006
IECC 2009
IECC 2012
IECC 2015
IECC 2018

Financial

Rate Category
Commercial

Cost of Electricity
0.09 \$/kWh

Cost of Natural Gas
0.693 \$/therm

Emissions

Energy Source to Site Ratio
Electricity: 2.8
Natural Gas: 1.05

CO₂ Equivalence for Electricity
0.371 kg of CO₂e/kWh

CO₂ Equivalence for Natural Gas
5.3 kg of CO₂e/therm



5. Now, return to the project tab and change the code one more time, this time selecting the 2016 ASHRAE code. Return once again to the results tab and add these additional data in the last row of table 1.

6. What differences did you notice in the energy performance of buildings designed to different codes? Describe several differences and use numbers from table 1 to support your answer.

Differences between codes: * Energy use and cost are slightly different between codes.

Support: * A building built to 2015 IECC code seems to use more energy than a building built to 2018 code, though it uses more electricity (1,102,508 kWh to 1,023,333 kWh) but slightly less natural gas (35,481 to 36,149).

Part 2 Using measures sets to improve building performance

A building designed to the 2018 IECC energy code is intended to meet specific requirements for building properties and mechanical system efficiencies. Sketchbox shows values for many of these characteristics in the “baseline” and “measures” tabs, and the values can be changed to exceed code if desired.

To begin, copy the values from the first line of table 1 above into table 2, these are the baseline values that will be compared to the next results.

Table 2

Building model	Annual electric use (kWh)	Annual natural gas use (therm)	Annual energy cost (USD, \$)
IECC 2018 “no change” (baseline- from table 1)	* 1,023,333	* 36,149	* 117,152
IECC 2018 Four selected improvements	* 940,829	* 35,877	* 109,538
IECC 2018 “best” measures set	* 680,520	* 11,698	* 69,353

7. We will examine four variables to reduce the energy utilization of our building: Roof U-value, solar heat gain coefficient (SHGC) for windows, interior lighting efficiency, and efficiency of heating equipment. U-value describes how easily thermal energy flows through a material, a low U-value is more energy efficient. Solar heat gain efficiency measures how easily solar radiation passes through window glass to an interior space.

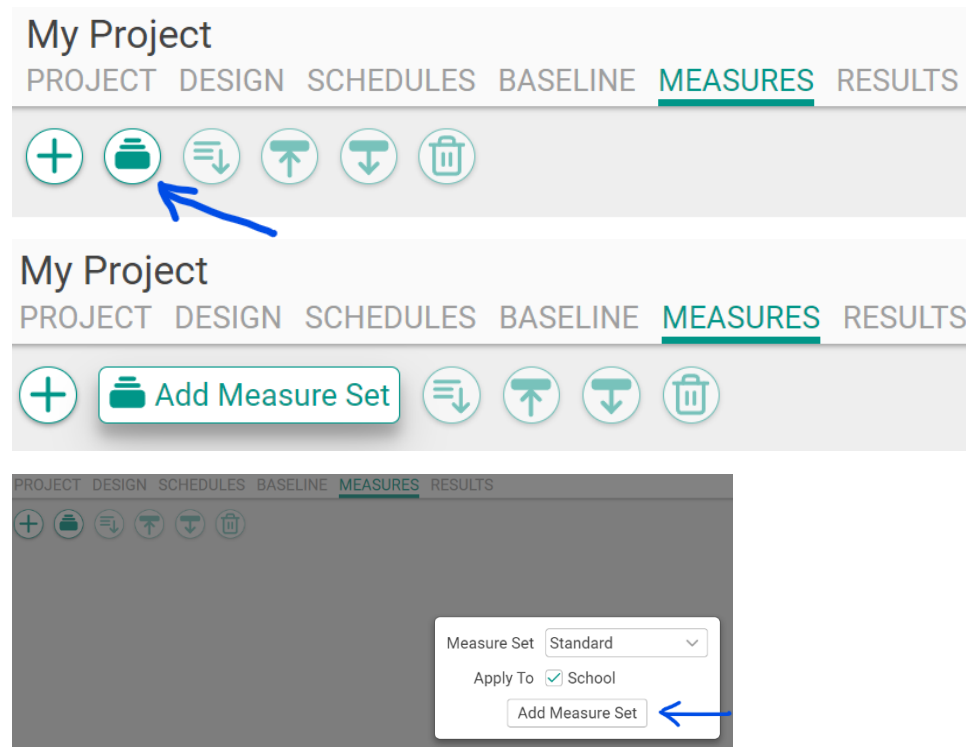
Each measure will be improved by an amount determined to be practical from a cost perspective. Predict how much energy cost these four upgrades will save. Rank them from largest to smallest energy cost savings, then explain your reasoning.

Ranking: (roof insulation, improved SHGC, efficient lights, efficient heating equipment)

*** Roof (most savings), heating equipment, lights, improved window SHGC (least savings)**

Reasoning: *** Students may suggest something like this: The roof is very large and will make a large difference, changing the windows will probably not make a significant change. The lights probably don’t use that much energy, so a change may not matter that much.**

8. Return to the project tab of your sketchbox model and be sure the energy code is set to IECC 2018. Now, switch to the measures tab and select the icon to the right of the plus symbol (+) to add a measures set (see image below). Use the standard measure set by clicking the “Add Measure Set” button that pops up.



9. After adding the measures set you should see values for sixteen different building characteristics. Each of these is important to energy use in a building and most have three values listed: “no change”, “better” and “best”. The “no change” value was used to model a building that would meet the energy code. The “better” value is an improvement that would save energy and lower the energy cost, but it would likely cost more as the building is constructed. The “best” value is the most energy efficient value determined to be possible without making the cost too large.

To explore the selected building upgrades change measures #1, 5, 6, and 13 to “better”, being sure to change all four directions (NSWE) for measure 5 (SHGC).

All other measures should be set to “no change” except for #14, demand control ventilation, which should be set to “no” (the following images show how to start).

1 – Upgrade Roof Insulation

Roof U-Value (BTU/hr-ft²·°F)

No Change 0.032 Better 0.03 **Best 0.028** Custom Office

2 – Upgrade Wall Insulation

Wall U-Value (BTU/hr-ft²·°F)

No Change 0.064 Better 0.043 **Best 0.036** Custom Office

3 – Air Sealing

Infiltration (ACH)

No Change 0.6 Better 0.45 **Best 0.3** Custom Office

4 – Improve Glazing U-Value

Glazing U-Value – North (BTU/hr-ft²·°F)

No Change 0.38 Better 0.34 **Best 0.3** Custom Office

10. Now, switch to the results tab and add summary values to the second line of **table 2**. You can find these values from the “proposed” column in the annual summary at the bottom of the results.

PROJECT	DESIGN	SCHEDULES	BASELINE	MEASURES	RESULTS
Annual Summary					ft ² ↑
			Baseline	Proposed	Absolute Savings
					Relative Savings

11. Continue to scroll down in the results to find the “Energy Cost Savings” graph. Note that you can hover over the bars to find a numerical value.



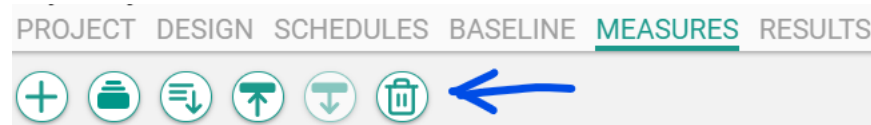
What is the actual ranking of the four measures? Comment on anything that surprises you in the ranking or in how different the measures are from each other.

(roof insulation, improved SHGC, efficient lights, efficient heating equipment)

* **Lights, heating, windows, roof**

It is amazing that the lights are that significant. Wasted energy from the lights then requires extra cooling at some times of the year, so that may be partly why this is so important. The roof and window changes did not matter much at all.

12. Return to the measures tab and select the trash can icon to remove the measures.



13. Add a measure set again, this time leaving every value at the “best” setting, except demand control ventilation, which should stay at “yes” (you should not need to make any changes). Then, switch to the results tab.

14. On the results tab find the “proposed” column in the annual summary and record the new values for energy cost, electric consumption, and natural gas consumption in the last row of table two (IECC 2018 “best” measures set).

15. What percent of electric consumption did the “best” upgrades save? To find this percent subtract the electric consumption after applying these measures (the bottom row in table two) from the baseline values (top row in table two) to find how much electricity was saved. Then, divide that number by the baseline value and multiply by 100. Show your calculations below.

Relative savings calculations:

$$* 1,023,333 \text{ kWh} - 680,520 \text{ kWh} = 342,813 \text{ kWh}$$

$$(342,813 \text{ kWh} / 1,023,333 \text{ kWh}) * 100 = 33.5\% \text{ savings}$$

16. To check your work, compare your answer to the “relative savings” for electric consumption in the annual summary table on the results tab.

Annual Summary				ft ² ↑
	Baseline	Proposed	Absolute Savings	Relative Savings



Summary of energy use reductions

17. Now, calculate relative savings for natural gas comparing the “best” upgrades to the baseline. Show your calculations and check your work with the annual summary.

*

$$36,149 \text{ therms} - 11,698 \text{ therms} = 24,451 \text{ therms}$$

$$(24,451 \text{ therms} / 36,149 \text{ therms}) * 100 = 67.6\% \text{ savings}$$

18. Finally, calculate relative savings for energy cost comparing the “best” upgrades to the baseline. Again, show calculations and check your work with the annual summary.

$$* \$117,152 - \$69,353 = \$47,799$$

$$(\$47,799 / \$117,152) = 40.8\% \text{ savings}$$

19. What additional measure would you be most interested in trying next? What measures have names that are unclear to you? * **Answers will vary**