How does the <u>SHAPE</u> of the building affect the <u>EFFICIENCY</u> of a building

> ***Synopsis:*** *Using a computer simulation, Sketchbox, students will determine how the shape of a building will affect the efficiency of that building. Using the results of the computer simulation students will draw real-world inferences about how design influences the efficiency of a building and how the efficiency of a building influences the design.*

NGSS Content Standards

HS-ETS 1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS 1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

HS-ETS 1-4 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.

Instructor's notes:

- *The first section students calculate the perimeter of specific shapes. The teacher may choose to do this as a class lesson. Or for additional help with math there are many online calculators available to assist students.*
- *Minimal changes are made in the parameters of the building resulting in what looks like major changes in the building footprint. Teachers may choose to discuss what other factors architects consider when designing a building.*
- *The results for these calculations look very similar. Teachers may choose to discuss long-term cost savings overall in different building types. Teachers may also choose to discuss how a less expensive design to build may prove to be a more expensive option to operate. Discussion could be generated through this thought process.*
- *On the "Results" tab the two graphs show a visual breakdown of the annual energy cost. Looking at the specific details of the energy cost teachers can discuss with students what elements wouldn't be affected by a building's footprint.*

How does the <u>SHAPE</u> of the building affect the <u>EFFICIENCY</u> of a building

Name: _____Date: _____ / _____ / _____ class hour: _____

Lesson Objectives:

- **Determine how, if at all, a building's shape affects its overall efficiency.**
- **What role does a building's calculated efficiency play in the design of that building?**

Introduction:
It is often said that a triangle is the *strongest* shape. We see this in structural design the world over. What is never mentioned is what is the most *efficient* shape – the circle. While a round building is impractical in building construction a square is the next most efficient shape in terms of its building footprint. First, You are going to do a few math calculations showing just how efficient different shapes can be. Then you are going to test how those shapes impact the energy efficiency of a building.

Step1: Proving what the most efficient shape is…

What do we mean by the efficiency of a shape? For the same area a circle has the smallest perimeter, or building footprint, of any other shape. How does that relate to building construction? If a building has a smaller perimeter then it will also need less exterior materials, i.e. siding, sheathing, etc... The savings can grow quite exponentially when we also consider the size of a building.

Let's do some math… the AREA of all of our shapes are going to be 100,000 square feet.

The perimeter (circumference) of a 100,000 sf circular building would be 1,121 feet

The perimeter of a 100,000 square foot square building would be how many feet? Show your work.

$$P = 4\sqrt{A}$$

What would the perimeter of a 100,000 square foot rectangular building be if its sides were 500 feet by 200 feet? (Approximately a 2.5:1 ratio) Show your work.

What would the perimeter of a 100,000 square foot rectangular building be if its sides were 400 feet by 250 feet? (Approximately a 2:1 ratio) Show your work.

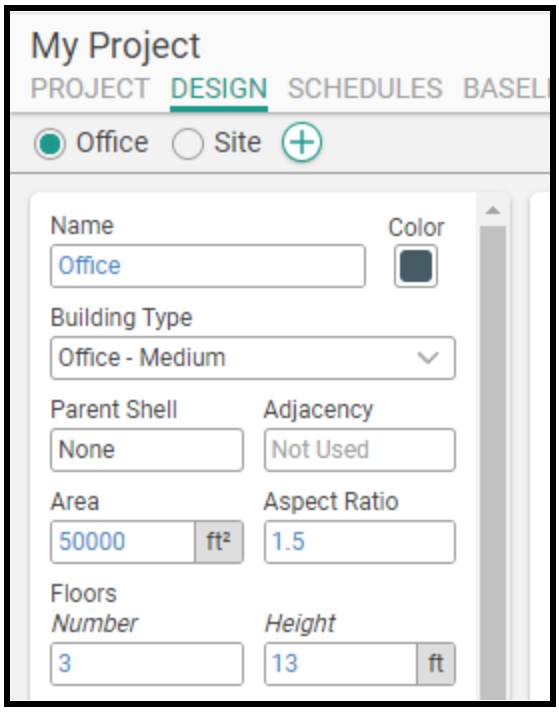
What would the perimeter of a 100,000 square foot rectangular building be if its sides were 600 feet by 166 feet? (Approximately a 3:1 ratio) Show your work.

What did the results of your calculations tell you? How could this impact the design and construction of a building PRE-construction? How could this impact the performance of the building POST-construction?

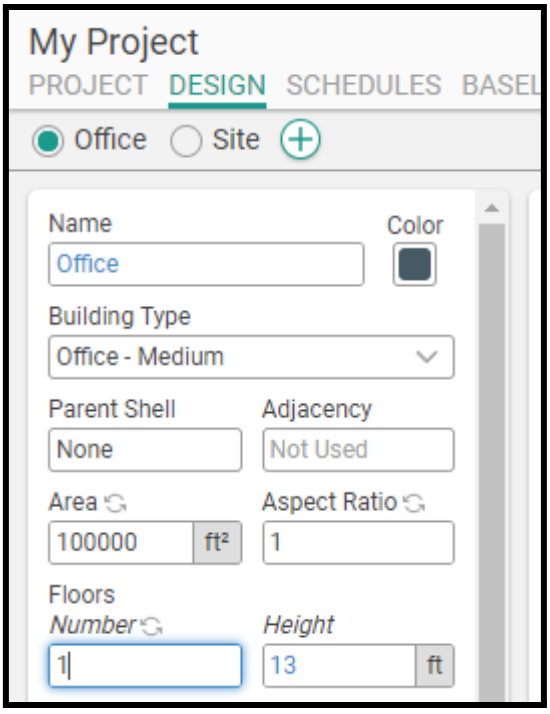
Now you will test how the performance of these buildings is affected by its shape. You will have two building types to assess: a Single-story 100,000 sf building and a 5 story 100,000 sf building. Note: The 5-story building has a total square footage of 100,000 or 20,000 sf per floor.

1. Access the web address: https://www.sketchbox.io/login

2. Log in to existing account or create an account and log in



Default Settings



Altered Settings

- ***Area is changed to 100000***
- ***Aspect Ratio will change to 1, 2, or 3***
- ***Floors will be changed to 1 or 5***

For each scenario navigate to the Results tab and analyze the results.

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 ($)	Annual Water Consumption (gal/yr)
Baseline	1580.7	1313.8	248.1	647069	14671	68403	1400000

The Results tab will show two graphs and a table at the bottom like the one shown above.

Before testing, hypothesize how you believe a building's footprint will impact its efficiency. Does the shape matter? Does the number of stories play an additional role in determining its efficiency?

By altering the aspect ratio and the number of floors calculate how the building's annual electric consumption and annual energy cost will change

Scenario Aspect ratio, stories	Estimated Annual Electric Consumption	Estimated Annual Energy Cost
1:1, 1 story building		
2:1, 1 story building		
3:1, 1 story building		
1:1, 5 story building		
2:1, 5 story building		
3:1, 5 story building		

Looking at the results of your investigation, what conclusions have you drawn?

How do the estimated results differ from your hypothesis?

What part of the data would surprise someone when interpreting the results?

Using this information how will this inform the design team when designing other new buildings?

Do you think the results of this data will influence a design team to design buildings in a certain way?