$$Q = \frac{A \times \Delta T}{R}$$

How this equation helps us design energy efficient homes

Teacher Answer Key

Use the app to do the following questions:

1. When you play with the Q= AxΔT/R app, what happens to the energy consumption of the house when you turn down the thermostat? Why?

   The energy needed to heat the house goes down. Less energy is required to keep the house at a lower temperature. As ΔT is in the numerator, decreasing it decreases the result.

2. What two things make ΔT change?

   The indoor temperature setting and the outdoor temperature.

3. Calculate ΔT using these indoor and outdoor temperatures. Calculate ΔT by subtracting the outdoor temperature from the indoor temperature.
   a) Indoor 22°C, outdoor -23°C ΔT = *45*
   b) Indoor 17°C, outdoor -13°C ΔT = *30*
   c) Indoor 24°C, outdoor 15°C ΔT = *9*
   Apply these to the app. Which causes Q to be the highest?

   Example a), with a ΔT of 45 is the highest. Q is highest when the ΔT is highest, for example when the outdoor temperature is very low, and the indoor temperature is set very high.

4. Use the Reset button (bottom left) to return the app to the pre-set numbers. Write down the value of Q for the roof, walls, and the total.

   If RSI_{roof} = 3.50, then Q_{roof} = 2.13
   If RSI_{walls} = 3.50, then Q_{walls} = 1.52
   Q_{total} = 4.56kW

Now, double the RSI-value in the roof. What happens to Q_{roof}, and Q_{total}? Why? Now double the RSI-Value in the walls. Which has more impact? ***Think:*** Why do you think this is the case?

if RSI_{roof} = 7.00, then Q_{roof} = 1.06.
Q_{total} = 3.49kW
Q_{roof} and Q_{total} both went down when the roof insulation is doubled.

If RSI_{walls} = 7.00, then Q_{walls} = 0.76.
Q_{total} = 3.80kW

Doubling the roof insulation was more effective than doubling the wall insulation.
Doubling the roof insulation resulted in a Q_{total} of 3.49.
Doubling the wall insulation resulted in a Q_{total} of 3.80.
Why? This is where area makes a difference. In this case, there is more roof area than wall area. With more roof area, doubling roof insulation makes more of an impact in lowering Q.

5. If you add insulation to the roof, but not to the walls, does it still lower the home's energy consumption?

   Yes, although the same amount of heat would be lost through the walls, less heat would be lost through the roof, so with more roof insulation, there is overall less heat loss.

6. Why does a bigger house use more energy?

   A bigger house has more surface area to heat than a smaller house.

7. Use the Reset button to return the app to pre-set numbers. Use the app to calculate the Q_{total}, and Annual energy for heating for the four preset houses in the app. Create bar graphs comparing all these variables. What does this information show, and what does the annual energy say about how we build our homes?

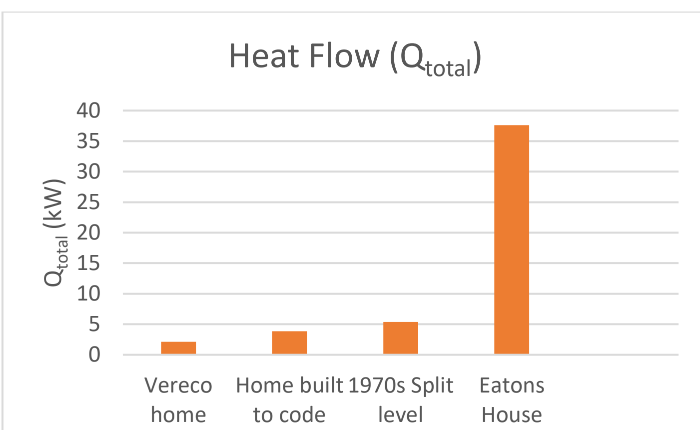
Sample houses	RSI			Q_{total}	Annual Energy
	Walls	Basement	Roof		
Vereco home	6.21 m^{2}°C/W	4.67 m^{2}°C/W	13.25 m^{2}°C/W	2.10GJ	26.3GJ
Home built to code	3.12 m^{2}°C/W	3.32 m^{2}°C/W	6.29 m^{2}°C/W	3.85GJ	48.1GJ
1970s Split level	2.17 m^{2}°C/W	2.31 m^{2}°C/W	4.84 m^{2}°C/W	5.37GJ	67.2GJ
Eatons House	0.71 m^{2}°C/W	0.60 m^{2}°C/W	0.30 m^{2}°C/W	37.61GJ	470.3GJ

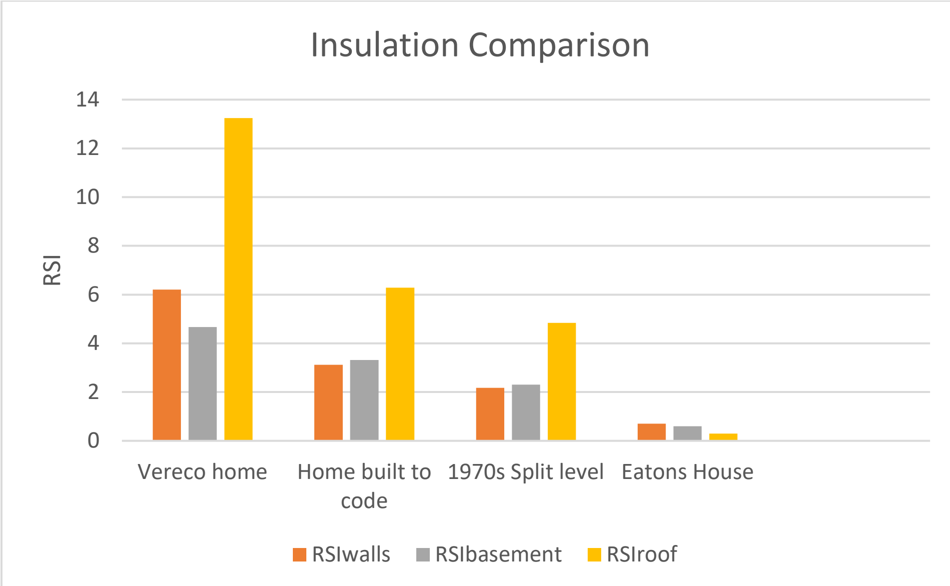
What does this information show, and what does the annual energy say about how we build our homes?

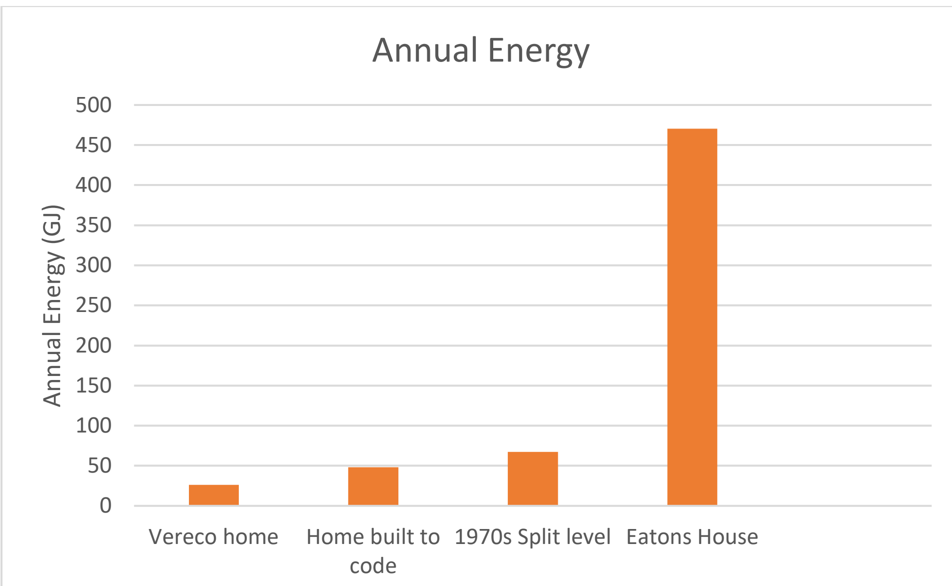
The greater the RSI insulation value of walls, basement and roof, the less Q_{total} and annual energy is used by the home. The Eaton's house had terrible insulation and uses a lot more energy than the others.

There is a medium sized increase in insulation from the 1970s Split level to the Home built to code, and a much bigger increase from the Home built to code to the Vereco home. A lot of energy could be saved by building homes with better insulation or building them to a higher standard.

Bar graphs:




Insulation Comparison
RSI
14
12
10
8
6
4
2
0
Vereco home
Home built to code
1970s Split level
Eatons House
RSIwalls
RSIbasement
RSIroof


Annual Energy
Annual Energy (GJ)
500
450
400
350
300
250
200
150
100
50
0
Vereco home
Home built to code
1970s Split level
Eatons House

8. Use the Reset button to return the app to pre-set numbers. Take the information for the Saskatoon passive house (page 3) and apply it to the app. Use the size of the house (90 m^2) and move the RSI buttons as close as possible to the passive house RSI values provided.
What is Q_{total} and the annual energy?

Q_{total} is 0.79GJ, annual energy is 9.9GJ

9. Looking at the Double Wall Construction information, and thinking about Q = A ΔT/R, how does double wall construction reduce the energy consumption of a house? ***Think:*** Why does thermal bridging lower the effective RSI value (see below) of a wall? How does reducing thermal bridging reduce the energy consumption of the house?

1. This wall has much more insulation than standard construction.
2. If you reduce thermal bridging by having an uninterrupted layer of insulation, you increase the effective R value. This reduces the amount of energy needed to heat the house, lowering Q.

10. Use the Reset button to return the app to pre-set numbers. Use the app to find Q_{total} for each of the 3 real estate listings below or look up others on your own.
    - For each listing, use the comparative size and age of the houses, with a constant thermostat setting to find Q. ***Note: Older homes in general, have less insulation and draftier windows. Set the RSI based on the age the home was built.***

If T_{in} at 20 and T_{out} at -20, then

- *Built to code house* — *Q_{total} = 3.78GJ*
- *Split level house* — *Q_{total} = 3.44GJ*
- *Similar to Eaton's house* — *Q_{total} = 32.72 GJ*

- Now apply the size of the 1970's split level home but choose the preset RSI values for the *Home Built to Code*. What is the difference in energy use (Q?) What does this information tell you?

If the Built to code house is the size of the Split-level house, then Q_{total} = 2.46.

Built to code house: Q_{total} 3.78
Split-level house: Q_{total} -2.46
1.32GJ less energy to heat the smaller home.

The smaller the house, the less energy needed to heat the building.

11. Use the Reset button to return the app to pre-set numbers. Use the app and the Building Materials R Values chart (page 2) to compare the heat flow (Q) of the following three ways to build a house. Keep the surface area (A) and thermostat setting (ΔT) constant for all three. Note: Use RSI and multiply by the number of millimeters, after converting inches to millimeters.

a) You build a house and insulate the walls with 5 ½" of fiberglass batt.

Convert from inches to mm: 1 inch=25.4mm

5.5" x 25.4mm = 139.7mm

RSI_{walls} =139.7mm x .022RSI/mm = 3.07_{walls}

Now the energy used by the house is:

Q_{walls}=1.73kW

Q_{total} = 4.77kW

b) You add 2" of Extruded Polystyrene to the exterior of the wall from "a".

Convert from inches to mm: 1 inch=25.4mm

2" x 25.4mm = 50.8mm

RSI_{walls} = 50.8mm x .035RSI/mm = 1.78_{walls}

1.78_{walls} + 3.07_{walls} = 4.85_{walls}

Now the energy used by the house is:

Q_{walls} = 1.10kW

Q_{total} = 4.13kW

c) You build a double wall with 10 ½" of cellulose blown insulation.

Convert from inches to mm: 1 inch=25.4mm

10.5" x 25.4mm= 266.7mm

RSI_{walls} = 266.7mm x .026RSI/mm = 6.93_{walls}

Now the energy used by the house is:

Q_{walls} = 0.77kW

Q_{total} = 3.81kW