Energy Science in the Home:

Hands-on Activities for the Middle Grades

Student Guide

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Colorado Energy Science Center

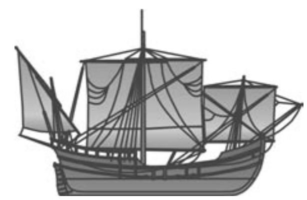
Unit One: Energy at Home

Energy History

A long time ago, the Native Americans (Indians) used **biomass** for energy. Biomass is anything that was alive a short time ago, like plants and animals. They burned wood (biomass) to cook food and warm their homes. Sometimes, they burned dried animal dung (biomass).

The sun gave them light in the day. Their fires and the moon and stars gave them some lights at night.

Some Indians lived in tents made of animal skins, called teepees. Others lived in rock and mud homes or in caves. Some of the caves were deep in the earth. These caves were warm in the winter. Heat from inside the earth—**geothermal energy**—kept them warm.



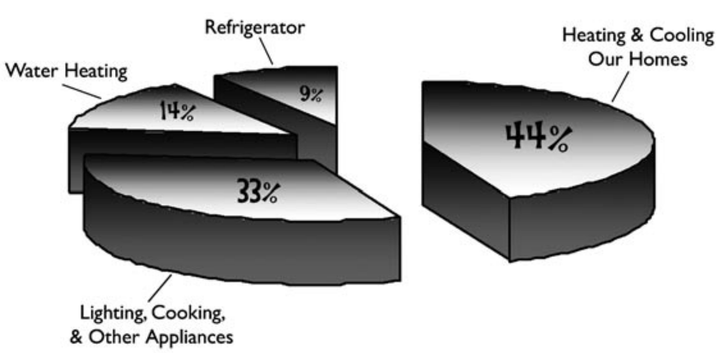
Then new people, known as the early settlers, arrived in America. They traveled on boats with sails. The sails captured the energy in the **wind** and pushed their boats to the New World.

The settlers built houses out of wood—**biomass**. They burned wood to keep warm and cook their food. They had no fans or air conditioners to keep them cool in hot weather.

The settlers didn't have light bulbs back then, so they made candles from animal fat to see in the dark. Most settlers rose at dawn and went to bed when the sun went down.

The settlers used water wheels to capture the energy in moving water—**hydropower**. They were able to run sawmills to cut wood by using hydropower.

As the nation grew and became more industrialized, people learned to use different energy sources, such as coal, oil, and natural gas to make heat and electricity. Electricity changed people's lives. For the first time they could use light bulbs to see at night. Later, scientists learned that uranium from inside the earth could be used to make **nuclear energy** by splitting atoms. Today, many different sources of energy are used to make electricity. We use electricity because it is a safe, easy way of using energy.



How Do We Use Energy?

We need energy to live. Think about what you did from the moment you woke up today until now. You probably used energy to turn on the lights, heat your shower water, listen to music on the radio, or cook your breakfast.

You use energy in the winter to heat your home, and energy in the summer to cool your home. Think about how much heat people in Alaska need to stay warm in the winter! Think about how much air conditioning people living in Florida need to stay cool in the summer!

The more energy you use, the more it costs. Energy bills show how much energy you use every month and how much money your family pays for that energy.

It takes a lot of energy to heat and cool our homes, and to heat water. Look at the pie chart to see how the average home in the United States uses energy.

Unit One: Energy at Home

Looking For the Energy Hogs in Your Home

The more energy you use at home, the more money you pay. An Energy Hog is anything that wastes a lot of energy, like an old refrigerator running in the garage or basement. If your family uses a lot of energy, you might have Energy Hogs in your home! An Energy Hog might also be a drafty window that lets cold air sneak in, or an attic that doesn't have enough insulation. There may be other things in your home that use energy all day long. Did you know that even when you are not using the DVD player and VCR, their little bright clocks still use energy? You can help your family save energy by learning about Energy Hogs and how you can bust them. When you save energy at home, your energy bills are lower, and this helps your family save money.

At home, this means doing things like turning off lights and appliances when you are not using them, and taking shorter showers. This also means setting the thermostat at 70 degrees Fahrenheit or lower during the colder seasons when you want to heat your home and setting it at 80 degrees Fahrenheit or higher in the warmer seasons when you want to cool your home. Using a programmable thermostat makes this job easy. You can also use energy-saving compact fluorescent light bulbs (CFLs) instead of the "old-fashioned" incandescent light bulbs. Your family can caulk or weatherstrip around windows to stop air leaks. Your home should have plenty of insulation in the walls and in the attic. Your family can replace old, worn-out appliances with energy efficient ones that have the ENERGY STAR® label on them.

Remember, watching out for the Energy Hogs in your home is easy and fun when you're energy smart. Saving energy will save your family money and help the environment too!

Where Do We Get Energy?

Before we can use energy in our homes, we need to get it from somewhere. So where do we get energy? Some is found underground and some is found above ground. There are two main categories of energy sources: nonrenewable and renewable.

NONRENEWABLE: Coal, oil, natural gas, and uranium are found underneath the ground. Coal, oil, and natural gas came from dead plants and animals that lived a long time ago, and decayed under pressure deep inside the earth. They take millions of years to form. We can dig them up or put a long pipe into the ground to remove them. We call these sources of energy nonrenewable because once we use them they are gone forever. In the United States, 92 percent of our energy comes from nonrenewable energy sources.

Unit One: Energy at Home

RENEWABLE: Scientists have figured out ways to make electricity from moving water (hydropower), the sun (solar power), the wind (wind power), and plants (biomass). We call these sources of energy renewable because we will never run out of sunshine, moving water, wind, or plants. The sun gives off energy that travels to the earth as light with a range of wavelengths. Long wavelengths turn into heat when they touch the earth. By using technology like solar panels, we can capture the energy from the sun and turn it into electricity. Wind turbines capture the energy in the blowing wind. Dams are used to get energy from moving water. You can feel the heat energy coming out of wood when it is burned. In the United States, 8 percent of our energy comes from renewable energy sources.

Some energy sources change the environment more than others. Coal and oil, for example, can pollute the air when they are burned. Wind turbines do not pollute. Some energy sources cost more than others. Some renewable energy sources can cost more money. For example, solar panels can be expensive, even though sunshine is free.

Can you find the seven sources of energy? Label each one!

The Home Energy Checkup

"How can you check the energy efficiency of your home?"

Objective:

To assess your home's energy efficiency and demonstrate the dollar savings that can be achieved by cutting back on energy use – without necessarily sacrificing comfort.

Supplies:

The **Home Energy Checkup** is a tool that lets you measure the energy efficiency of your home. It also helps you discover how you could improve its efficiency and how much this would save you on your annual energy bill. The **Checkup** is located at

http://www.ase.org/section/homeenergycheckup/

Procedure:

To complete this activity you must gather information about your home. In many cases you can find the information simply by making some observations or a few measurements. In other cases you may need the help of an adult. Get them to help you when you need them.

There are many sections to this activity, each with its own set of questions. **Doing it all in one sitting is not really practical.** The easiest approach is to tackle each section separately. For every section, first gather the relevant information, and then answer the questions. After completing a section, you will have to exit the Checkup and gather all the information you will need to work through the next section. Then re-enter the Checkup program and pick up where you left off. This procedure will require that you to re-enter some basic information (about the climate zone and fuel prices) every time you go back to the Checkup program, but it's short and easy. Now you are set to work on the first part of the Checkup.

Part 1: Climate and Fuel Prices

1. Click on the **Get Started**.

2. Choose the **Climate Zone** that fits the location of your home. Be sure to click on a spot on the map that's closest to the city you live in.

> Based on your answer to the question above, what sorts of energy efficiency measures do you predict will lower your annual energy budget the most? **Write your answer in your notebook.**

3. As soon as you have chosen your climate zone a "scorecard" appears at the bottom of the Home Energy Checkup screen. The scorecard gives the best estimate of your "current house" annual energy bill. At this point in the sequence, the estimate is an average for your climate zone, nothing more. You still have not made any efficiency changes, so the "efficient house" annual energy bill is just the same as for your current house and the savings are nil.

4. In your own notebook, record the current estimate of the annual energy bill (based just on your climate zone) for your home.

5. Now compare the annual energy bill from **different** climates. Do this by clicking on "file", and then on "reset values", then on "OK". You may have to exit and restart the program). Start again and this time choose a much ***warmer*** region of the country and record the annual energy bill in your own notebook. Next, repeat this procedure but this time choose a much ***colder*** region of the country and record that value in your own notebook.

Of the three different climate regions you explored, which had the highest annual energy bill? Which had the lowest bill? How do you explain the differences? **Write your answer in your notebook.**

6. Reset the values once again (you may have to cancel and restart the program to do this). Now start off by selecting the climate for where you live. Be sure to click on the spot closest to the city you live in. The next step asks you to set your energy prices. You need to choose "low", "medium", or "high" prices for the forms of energy you use in your home (electricity, natural gas, heating oil, propane, etc.).

In Colorado the rates are approximately as follows:

Natural gas:	$0.35/therm of natural gas	(in the "low" range)
Electricity:	$0.06/Kwh of electricity	(in the "low" range)
Propane:	$0.24/lb of propane	(in the "low" range)

7. As soon as you set the energy prices, your annual energy bill changes in the scorecard at the bottom of the screen. Now the bill reflects the cost of energy in your area as well as the climate. Record the current estimate of the annual energy bill in your own notebook. (***This is the baseline value that you will use to assess the impact of all the different energy efficiency measures you will explore in the Checkup program.)***

Compared to the national average, energy is relatively cheap in CO. What effect do you think this has had on motivating CO homeowners to make their homes more energy efficient? **Write your answer in your notebook.**

The remaining sections of the ***Checkup*** deal with energy efficiency improvements that you can make in your home and that will lower your annual energy bill. Before working each of these, exit the ***Checkup*** program (do that now) and collect the information you will need to complete the section. Then, re-enter the program, type in the climate and fuel prices information (you will do this every time you re-enter the program), and move on to the section you are currently working on. The first section deals with insulation.

Part 2: Insulation

The ***Checkup*** calls for you to find out if you have low, medium or high levels of insulation. To do this you will have to collect some information on the insulation in your house. Your parents may already know some of the numbers, or they can help you measure them.

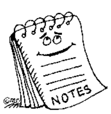
<u>In your own notebook answer the following questions:</u>

1. Thickness of insulation in the ceiling = (how many) inches.
2. Type of insulation in the walls is (name here).
3. My house is (how many) years old.
4. Type of insulation (if any) on the foundation walls is (name here) and it is (how many) inches thick.

<u>Use the guidelines below will help you rate the insulation level in your home in step 8</u>

<u>Ceilings:</u>

1. *<u>Low</u>*<u>:</u> six inches or less (equivalent to R-19 or less)
2. *<u>Medium</u>*: six to ten inches (R-19 to R-30)
3. *<u>High</u>*<u>:</u> twelve inches or more (R-35 or higher)



<u>The Department of Energy recommends R-38 for ceilings in Colorado</u>

<u>Walls:</u>

1. *<u>Low</u>*:
   a. if the house has no insulation in the walls
2. *<u>Medium</u>*:
   a. if the house is less than 10 years old and/or
   b. if the house has interior-insulated masonry walls
3. *<u>High</u>*:
   a. if the walls have R-19 (or higher) and/or
   b. if the house has exterior-insulated masonry walls
   c.

<u>The DOE recommends R-11 for walls in Colorado Foundation:</u>

1. *<u>Low</u>*: foundation walls (or concrete slab edges) have no insulation
2. *<u>Medium</u>*: walls have 2-inches (or less) of foam or fiberglass in or out
3. *<u>High</u>*: foam or fiberglass insulation is thicker than two inches

8. Startup the ***Checkup*** program. Re-enter the climate and fuel prices information. Click on the "Insulate…" button. Use the guidelines above to set the *current* level of insulation in your home. For the moment ignore the "new insulation" settings and just click "OK". Record the updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7. The value in step 7 assumed a "medium" / average level of insulation.

If the updated value is lower than the average, how much money is the current level of insulation in your home *saving* you every year. If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

Lets say that you live in the home for 20 years without changing its level of insulation. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook.**

9. Now click on the **insulation** button again and this time set the "New insulation" values to "high". Click OK and see what the annual energy cost would be if you boosted your insulation values to high. Record the "efficient house" energy cost in your own notebook. Exit the program.

How much money would you save over one year if you insulated to the "high" level? How much would you save over 20 years? **Write your answer in your notebook.**

Recently 22 homes in Denver had their level of insulation evaluated. Contractors submitted their estimates for improving the insulation levels in the ceiling, exterior walls, crawlspace, floor and foundation. The average home required about $1900 of work.

Using your estimate of the energy cost savings your home would achieve at the highest insulation levels (you calculated this above), how many years would it take for a $1900 insulation investment to pay for itself? **Write your answer in your notebook.**

Part 3: Air Leaks

The Checkup program calls for you to rate the current air tightness of your home as "leaky", "average" or "tight". To do this you will have to make some observations in your home.

<u>In your own notebook, record the following information:</u>

1. Is your home pretty drafty, especially around windows and doors?
2. Are the windows single or double-pane?
3. Does your home have storm windows?
4. Do the doors and windows have weather-stripping?

<u>Use these guidelines to rate the leakiness of your home in step 13.</u>

1. *Leaky*: Noticeable drafts; single-pane windows without storm windows or weather-stripping; door without weather-stripping.

2. Avg.: No obvious drafts, windows and doors less than 15 years old with storm windows and weather-stripping.

3. *Tight*: Home less than 10 years old with tight-sealing double pane windows and doors with weather-stripping

10. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the "Reduce air leaks" button and set the *current* level of air tightness in your home. For the moment ignore the "new air leaks" setting and just click "OK". Record the updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7 on page 3. The value in step 7 assumes a "medium" or average level of leakiness.

If the updated value is lower than the average, how much money is the current level of leakiness in your home *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

Let's say that you live in the home for 20 years without changing its level of leakiness. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answers in your notebook.**

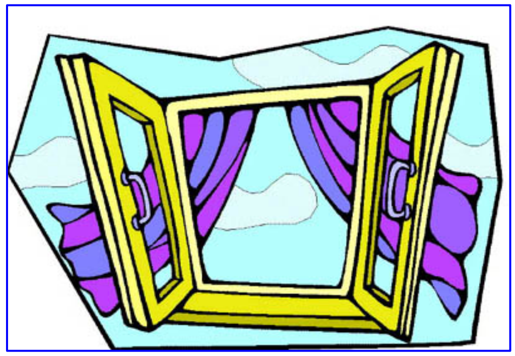
11. Now click on the "Reduce air leaks" button again and this time set the "new air leaks" values to "tight". Click OK and see what the annual energy cost would be if you really sealed up your home. Record the "efficient house" energy cost in your own notebook. Exit the program.

How much money would you save over one year if you sealed up enough leaks to make your home airtight? How much would you save over 20 years? **Write your answer in your notebook.**

Recently 22 homes in Denver had their leakiness level evaluated. Contractors submitted their estimates for improving the air tightness of the whole house. The average home required about $295 of work.

Using your estimate of the energy cost savings your home would achieve at the most airtight level (you calculated this above), how many years would it take for a $295 sealing investment to pay off? **Write your answer in your notebook**.

Part 4: Windows



Next you are asked to estimate the efficiency of your windows as “low”, “medium” or “high”.

In your own notebook, record this information first:

1. Are the windows in your home single or double-pane?
2. Does your house have storm windows in addition to the regular windows?
3. Are the window frames insulated (say with vinyl or some such material)?

Use these guidelines to rate the leakiness of your home in step 12.

1. *Low*: single-pane windows without storm windows
2. *Medium:* double-pane windows with insulated frames, or single–pane with tight-fitting storm windows
3. *High*: double-pane windows with low-e and/or solar control coatings

12. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the “Replace windows” button and set the *current* level of window efficiency in your home. For the moment ignore the “new efficiency” setting and just click “OK”. Record the updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7 on page 3. The value in step 7 assumes a “medium” or average level of window efficiency.

> If the updated value is lower than the average, how much money is the current level of window efficiency in your home *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

> Let’s say that you live in the home for 20 years without changing its windows. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook.**

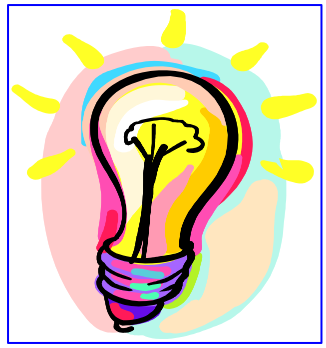
13. Now click on the “Replace windows” button again and this time set the “new efficiency” value to “high”. Click OK and see how the annual energy cost would change if you installed high efficiency windows in your home. Record the “efficient house” energy cost in your own notebook. Exit the program.

How much money would you save over one year if you installed highly efficient windows? How much would you save over 20 years? **Write you answer in your notebook.**

Recently 22 homes in Denver had their window efficiency evaluated. Contractors submitted their estimates for improving window efficiency. The average home required about $3719 of work.

Using your estimate of the energy cost savings your home would achieve with the most efficient windows (you calculated this above), how many years would it take for a $3719 window investment to pay off? **Write your answer in your notebook.**

Part 5: Lighting



Next you are asked to estimate the efficiency of the lights in your house as "low", "medium" or "high".

In your own notebook, record this information first:

1. How many light fixtures in your home have compact fluorescent lights (CFLs) in them?

Use these guidelines to rate the lighting efficiency of your home in step 12.

1. *Low*: No CFLs installed
2. *Medium*: 1 to 4 CFLs installed
3. *High*: 5 or more CFLs installed

14. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the "Install compact fluorescent lights" button and set the *current* level of lighting efficiency in your home. For the moment ignore the "new efficiency" setting and just click "OK". Record the updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7. The value in step 7 assumes a "medium" or average level of lighting efficiency.

> If the updated value is lower than the average, how much money is the current level of lighting efficiency in your home *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

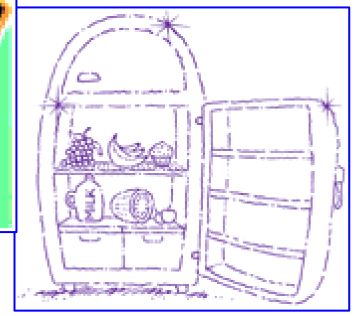
> Let's say that you live in the home for 20 years without changing its lighting. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook**.

15. Now click on the "Install CFLs" button again and this time set the "new efficiency" value to "high". Click "OK" and see how the annual energy cost would change if you installed more than 5 CFLs in your home. Record the "efficient house" energy cost in your own notebook. Exit the program.

How much money would you save over one year if you installed more than 5 CFLs? How much would you save over 20 years? **Write your answer in your notebook.**

An average CFL costs about $9. If you installed just five of these you would pay $45. Using your estimate of the energy cost savings your home would achieve for a $45 CFL investment to pay off? Note that estimate does not account for the cost of replacing the incandescent bulbs, which have to be replaced about ten times more often than CFLs. **Write your answer in your notebook**.

Part 6: Refrigerator and Dishwasher



Next you are asked to estimate the efficiency of the refrigerator in your house as “low”, “medium” or “high”.

<u>In your own notebook, record this information first:</u>

1. My refrigerator is (how many) years old?
2. My dishwasher is (how many) years old?

<u>Use these guidelines to rate the efficiency of the refrigerator and dishwasher in your home in step 16.</u>

1. <u>*Low*</u>: unit is more than 10 years old
2. <u>*Medium*</u>: unit is less than 10 years old but made before 1993
3. <u>*High*</u>: unit is newer than 1993

16. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the “Install high-efficiency refrigerator” button and set the *current* refrigerator efficiency in your home. For the moment ignore the “new efficiency” setting and just click “OK”. Now click on the “Install high-efficiency dishwasher” button and set the *current* dishwasher efficiency in your home. Again ignore the “new efficiency setting”. Record the combined updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7. The value in step 7 assumes a “medium” or average efficiency refrigerator and dishwasher.

If the updated value is lower than the average, how much money is the current combined refrigerator + dishwasher efficiency *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

Let’s say that you live in the home for 20 years without changing its refrigerator and dishwasher. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook.**

17. Now click on the “Install high-efficiency refrigerator” button again and this time set the “new efficiency” value to “high”. Click “OK”. Do the same for the dishwasher settings. See how the annual energy cost would change if you installed a high efficient refrigerator and dishwasher in your home. Record the “efficient house” energy cost in your own notebook.

How much money would you save over one year if you replaced your current refrigerator and dishwasher with a high-efficiency refrigerator and dishwasher? How much would you save over 20 years? **Write your answer in your notebook**.

Part 7: Showerheads

Next you are asked to estimate the efficiency of your showerheads as “low”, “medium” or “high”. Showerhead efficiency is measured in gallons per minute (gpm). You will estimate the efficiency yourself with a bucket and a watch. Place a one gallon bucket (or a bucket where you have marked the one gallon level) under the showerhead, turn on your shower to its usual pressure and use the watch to see how long it takes to fill the bucket. The number of seconds tells you how many gallons per minute you are using.

1. In your own notebook, record how many seconds did it take to fill the bucket to the one gallon level.

<u>**Use these guidelines to rate the showerhead efficiency of your home in step 18.**</u>

1. *<u>Low</u>*: 20 seconds or less. This amounts to 3 gpm
2. *<u>Medium</u>*: 20-30 seconds. This amounts to 2-3 gpm
3. *<u>High</u>*: 30 seconds or more. This amounts to 2 gpm or less.

18. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the “Install efficient showerheads” button and set the *current* showerhead efficiency in your home. For the moment ignore the “new efficiency” setting and just click “OK”. Record the updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7.

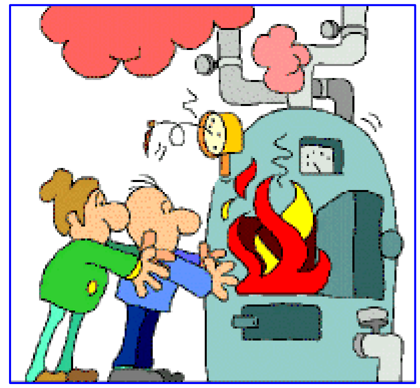
If the updated value is lower than the average, how much money is the current showerhead efficiency in your home *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

Let’s say that you live in the home for 20 years without changing its showerheads. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook**.

19. Now click on the “Install efficient showerheads” button again and this time set the “new efficiency” value to “high”. Click “OK” and see how the annual energy cost would change if you installed highly efficient showerheads in your home. Record the “efficient house” energy cost in your own notebook. Exit the program.

How much money would you save over one year if you replaced your current showerheads with high-efficiency showerheads? How much would you save over 20 years? **Write your answer in your notebook**.

Part 8: Furnace



Next you are asked to estimate the efficiency of your furnace. Your furnace could be one of several different types. If it burns gas or propane or oil its efficiency is measured by its Annual Fuel Use Efficiency (AFUE) percentage. If it's an electric heat pump then its Heating Seasonal Performance Factor (HSPF) gauges the efficiency. The AFUE or HSPF values may be printed on the side of the units. If none of this information is available you can use the furnace age to estimate current efficiency.

<u>In your own notebook, record this information first:</u>

1. My furnace uses (gas, propane, oil, electricity) to heat the house.
2. The furnace AFUE or HSPF value is (answer here).
3. My furnace is (how many) years old.

Use the guidelines below to rate the furnace efficiency of your home in step 20.

<u>1. Gas/Propane Furnace</u>

1. *<u>Low</u>*: 70% AFUE or less (or 20+ years old)
2. *<u>Medium</u>*: 7—77% AFUE (or 5-20 years old)
3. *<u>High</u>*: 78% AFUE or higher (or less than 5 years old)

<u>2. Oil Furnace or Boiler</u>

1. *<u>Low</u>*: 6.0 HSPF or less (or 20+ years old)
2. *<u>Medium</u>*: 70-77% AFUE (or 5-20 years old)
3. <u>High</u>: 78% AFUE or higher (or less than 5 years old)

<u>3. Electric Heat Pump</u>

1. *<u>Low</u>*: 70% AFUE or less (or 20+ years old)
2. *<u>Medium</u>*: 6.0-6.7 HSPF (or 5-20 years old)
3. *<u>High</u>*: 6.8 HSPF or higher (or less than 5 years old)

20. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the “Install high-efficiency furnace” button and set BOTH the type of furnace equipment you have, AND its *current* efficiency level. For the moment ignore the “new efficiency” setting and just click “OK”. Record the updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7.

> If the updated value is lower than the average, how much money is the current furnace efficiency in your home *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write answer in notebook**.

> Try selecting among the different type of furnaces. Which turns out to be the most energy efficient? Which is the least energy efficient? **Write your answer in your notebook.**

> Lets say that you live in the home) for 20 years without changing its furnace. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook.**

21. Now click on the “Install high-efficiency” button again and this time set the “new efficiency” value to “high”. Click “OK” and see how the annual energy cost would change if you installed a highly efficient furnace in your home. Record the “efficient house” energy cost in your own notebook. Exit the program.

> How much money would you save over one year if you replaced your current furnace with a high-efficiency furnace? How much would you save over 20 years? **Write your answer in your notebook**.

Part 9: Air Conditioning

Next you are asked to estimate the efficiency of your home cooling system (if your home has no air conditioning then move on to the next section). The efficiency of central air conditioners is measured by the Seasonal Energy Efficiency Ratio (SEER). Window AC unit efficiency is measured by the Energy Efficiency Ratio (EER). These values may be printed on the side of the units. If they don't appear you will have to use the age of the unit to gauge efficiency.

In your own notebook, record this information:

My home is cooled by (central air conditioner; window AC units). Choose one.

1. The SEER or EER of the unit is (answer here)
2. The age of the cooling system is (how many) years old.

Use these guidelines to rate the air conditioning efficiency of your home in step 22.

1. Central air conditioning
    1. *Low*: SEER 7 or less (more than 15 years old)
    2. *Medium*: SEER 7.1 to 10 (5-15 years old)
    3. *High*: SEER 11 or higher (less than 10 years old)

2. Window AC units
    1. *Low*: EER less than 8 (more than 10 years old)
    2. *Medium*: EER 8 to 9 (newer than 1990)
    3. *High*: EER 10 or higher (less than 5 years old)

22. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the "Install high-efficiency AC" button and set BOTH the type of equipment you have, AND its *current* efficiency level. For the moment ignore the "new efficiency" setting and just click "OK". Record the updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7.

If the updated value is lower than the average, how much money is the current air conditioning efficiency in your home *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

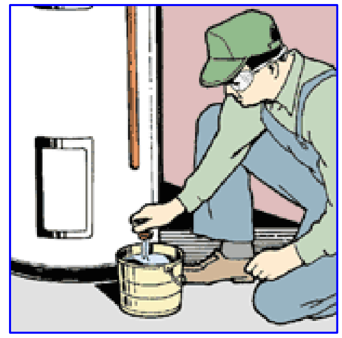
Let's say that you live in the home for 20 years without changing its air conditioner. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook**.

Try selecting among the different type of air conditioners. Which turns out to be the most energy efficient? Which is the least energy efficient? **Write your answer in your notebook.**

23. Now click on the "Install high-efficiency AC" button again and this time set the "new efficiency" value to "high". Click "OK" and see how the annual energy cost would change if you installed a highly efficient air conditioner in your home. Record the "efficient house" energy cost in your own notebook. Exit the program.

How much money would you save over one year if you replaced your current air conditioner with a high-efficiency air conditioner? How much would you save over 20 years? **Write your answer in your notebook**.

Part 10: Water Heater



Next you are asked to estimate the efficiency of your home water heater. Water heaters run on gas, oil, propane or electricity. The Energy Factor (EF) measures their efficiency. You can also use their age to gauge their efficiency.

In your own notebook collect this data:

My home hot water heater runs on (gas; electricity; oil; propane). Choose one.

1. The water heater has an EF of (answer here).
2. The water heater is (how many) years old

Use these guidelines to rate the water heater efficiency of your home in step 24.

Gas/Propane/Oil water heaters	
1. Low: EF 0.5 or less	(more than 7 years old)
2. *Medium*: EF 0.51 to 0.56	(3-7 years old)
3. *High:* EF 0.6 or higher	(less than 3 years old)

Electric water heater	
1. *Low:* EF 0.85 or less	(more than 7 years old)
2. *Medium:* EF 0.86 to 0.89	(3-7 years old)
3. *High:* EF 0.94 or higher	(less than 3 years old)

24. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the "Install high-efficiency water heater" button and set BOTH the type of equipment you have, AND its *current* efficiency level. For the moment ignore the "new efficiency" setting and just click "OK". Record the updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7.

If the updated value is lower than the average, how much money is the current water heater efficiency in your home *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

Try selecting among the different type of water heaters. Which turns out to be the most energy efficient? Which is the least energy efficient? **Write your answer in your notebook.**

Let's say that you live in the home for 20 years without changing its water heater. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook**.

25. Now click on the "Install high-efficiency water heater" button again and this time set the "new efficiency" value to "high". Click "OK" and see how the annual energy cost would change if you installed a highly efficient water heater in your home. Record the "efficient house" energy cost in your own notebook. **Exit** the program.

How much money would you save over one year if you replaced your current water heater with a high-efficiency water heater? How much would you save over 20 years? **Write your answer in your notebook.**

Part 11: Washer and Dryer

Next you are asked to estimate the efficiency of your home clothes washer and dryer. You can estimate their efficiency by their age and style.

<u>In your own notebook, collect this information first:</u>

1. My home clothes washer is (how many) years old.
2. My clothes washer is (top; front) loading. (circle one).
3. My clothes dryer is (how many) years old.
4. My clothes dryer has a "dryness sensor" (yes or no).

<u>Use the guidelines below to rate the washer and dryer efficiency of your home in step 26.</u>

1. <u>Clothes Dryer</u>
    1. *<u>Low</u>*: more than 15 years old; no dryness sensor
    2. *<u>Medium</u>*: 5-15 years old; no dryness sensor
    3. *<u>High</u>*: less than 3 years old; has dryness sensor
2. <u>Clothes Washer</u>
    1. *<u>Low:</u>* more than 15 years old, top loading
    2. *<u>Medium:</u>* 3-15 years old, top loading
    3. *<u>High:</u>* less than 3 years old, OR front loading

26. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the "Install high-efficiency clothes washer" button and set the *current* washer efficiency in your home. For the moment ignore the "new efficiency" setting and just click "OK". Now click on the "Install high-efficiency clothes dryer" button and set the *current* dryer efficiency in your home. Again ignore the "new efficiency setting". Record the combined updated annual energy cost in your notebook. Compare this value to the one you recorded in step 7. The value in step 7 assumes a "medium" or average efficiency clothes washer and dryer.

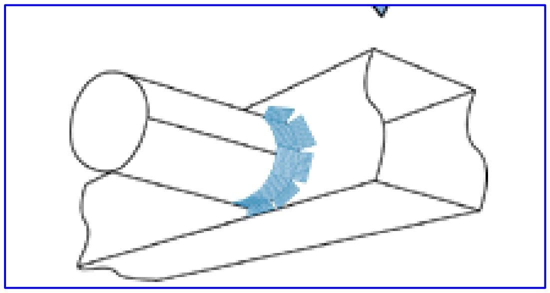
If the updated value is lower than the average, how much money is the current combined washer and dryer efficiency *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook.**

Let’s say that you live in the home for 20 years without changing its washer and dryer. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in your notebook**.

27. Now click on the “Install high-efficiency washer” button again and this time set the “new efficiency” value to “high”. Click “OK”. Do the same for the dryer settings. See how the annual energy cost would change if you installed a highly efficient washer and dryer in your home. Record the “efficient house” energy cost in your own notebook.

How much money would you save over one year if you replaced your current washer/dryer with a high-efficiency washer and dryer? How much would you save over 20 years? **Write your answer in your notebook**.

Part 12: Air Ducts



Next you are asked to estimate the leakiness of your home's air ducts that deliver hot or cold air from your furnace or air conditioner. If your home has no air ducts skip this section. The easiest way for you to estimate the leakiness of your air ducts is to look at them and see if they are insulated (or not), and if they are located in spaces that are not heated in winter and not cooled in summer.

Record these observations in your own notebook:

1. Are the ducts uninsulated?
2. Do they pass through unconditioned spaces?
3. Are the duct joints sealed with tape?

Use these guidelines to rate the leakiness of your air ducts in step 28.

1. *Leaky*: long uninsulated duct runs in unconditioned spaces such as attics or crawl spaces; no tape on duct joints
2. *Average*: some uninsulated duct runs in unconditioned spaces; duct joints sealed with tape
3. *Tight*: no ducts in unconditioned spaces; duct joints sealed with tape

If the updated value is lower than the average, how much money is the current duct leakiness *saving* you every year? If the updated value is higher, how much is it *costing* you every year? **Write your answer in your notebook**.

Let's say that you live in the home for 20 years without changing the duct leakiness. How much money would you save on energy over those 20 years, OR, if your energy cost exceeds the average, how much additional money will you spend on energy over those 20 years? **Write your answer in notebook**.

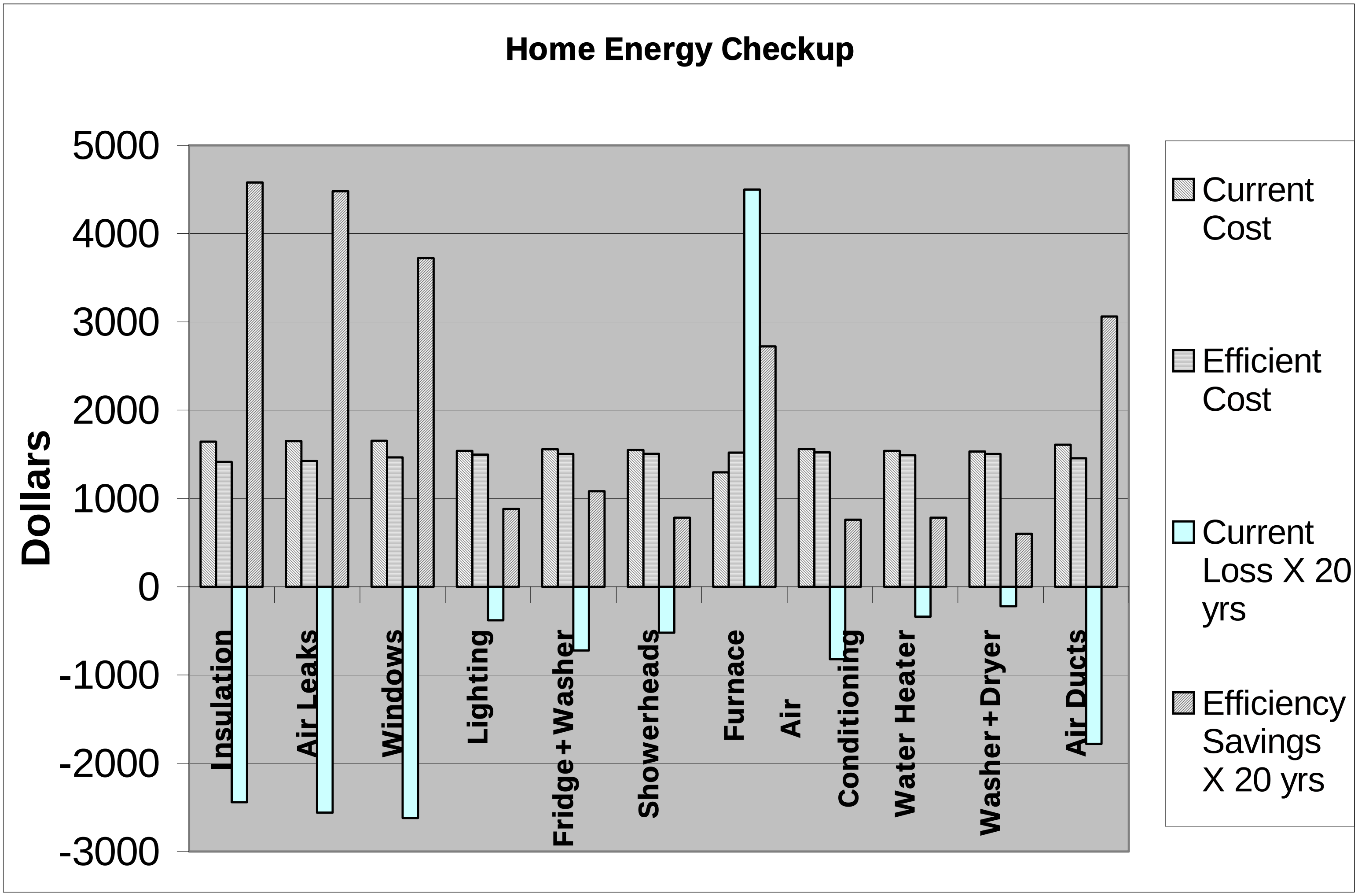
28. Startup the Checkup program. Re-enter the climate and fuel prices information. Click on the "Seal heating and cooling ducts" button and set the *current* duct leakiness in your home. For the moment ignore the "new seals" setting and just click "OK". Record the combined updated annual energy cost in your own notebook. Compare this value to the one you recorded in step 7. The value in step 7 assumes a "medium" or average duct leakiness.

29. Now click on the “Seal heating and cooling ducts” button again and this time set the “new seals” value to “high”. Click “OK”. See how the annual energy cost would change if you sealed the ducts. Record the “efficient house” energy cost in your own notebook.

> How much money would you save over one year if you sealed the ducts to block all leaks? How much would you save over 20 years? **Write your answer in your notebook.**

MAKING A BAR GRAPH:

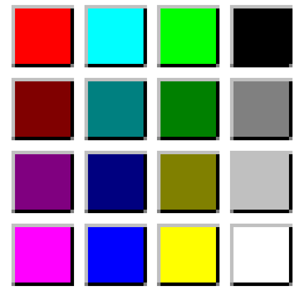
Now that you have answered all the questions you can make a bar graph that will make it easier to view all the information you have compiled. It should look something like this:



- **Current Cost**: the energy cost associated with the current level of … (insulation, lighting, etc.)
- **Efficient Cost:** the energy cost associated with the energy-efficient level of … (insulation, lighting, etc.)
- **Current Loss X 20 yrs:** [current cost – average cost] X 20 years
- **Efficiency savings X 20 yrs:** [current cost – energy efficient cost] X 20 years

The Color Competition

"How does color affect the temperature of a house?"



Objectives:

- To measure the heat absorption characteristics of different colors.
- To make predictions for each color and compare predictions to observations.
- To make the connection between roof /home color and the size of your energy bill.

PROCEDURE:

1. Each team will have 2 soda cans. These soda cans will become your adopted cylindrical "houses".

2. Paint your cans using two of the colors provided.

3. Predict which of your "houses" will experience the greatest gain in temperature and write those predictions on the board after your team name and the colors of your "houses". Explain your reason for your prediction. You will compete with the other teams to see who is able to make the most accurate predictions.

4. Place all the "houses" together in a single location with direct sunlight, but away from any drafts.

5. Insert the thermometer through the roof hole (i.e. can opening) and monitor the temperature by taking readings in Celsius **every minute for 8 continuous minutes**. Remember to take an initial temperature reading when you first place the thermometer in each can. This will be the starting temperature, Ts.

6. Record data on the data sheet. Calculate the change in temperature after 8 minutes.

7. Once collected, plot the data on a graph and label the axes. The purpose behind plotting the data is to see which home heats the fastest.

8. Use your data sheet to record the change in temperature for your cans on the class data chart on the board.

9. Compare your predictions to the actual change in temperature for each can.

Analysis Questions: In your own notebooks, answer the following:

1. Which color can experienced the greatest gain in temperature? The least? How many degrees separate the two?

2. How did these values compare to your predictions?

3. Why was it important to place the cans together in a single location?

4. Based on the data collected, which color of roof do you think would be the most energy efficient? Explain.

5. The values below represent typical reflectivity percentages (the percentage of light striking the surface that is reflected for various common colors. Choose the colors that closely match those of your "houses". How do these values help to explain your results?

Reflective Value	Color	Reflective Value	Color
5%	Black	54%	Gold
8%	Dark Blue	59%	Apricot
10%	Walnut	61%	Aqua
15%	Brown	63%	Powder Blue
20%	Forest Green	64%	Yellow
21%	Red	65%	Gray
25%	Kelly Green	69%	Beige
28%	Coffee	70%	Pink
35%	Orange	75%	Yellow
45%	Gray	78%	Ivory
46%	Rose	82%	White

STUDENT PAGE

The Insulation Race

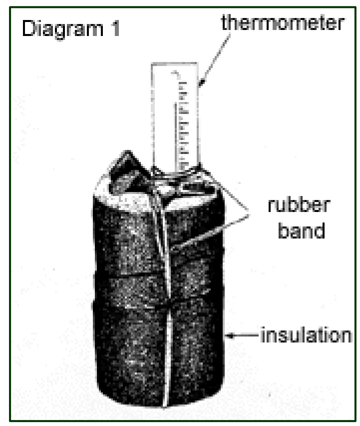
"Which insulating material is best at stopping the flow of heat?"

Objective:

To analyze various insulating materials to determine how the type of insulation used in a home affects its internal temperature and thus its energy costs.

Supplies:

- two identical soda cans for each team, a total of 6 teams
- two glass lab thermometers (graduated up to 100 C) for each team
- timer to measure minutes
- hot water (50 - 80 C)
- Graduated cylinder or measuring cup with milliliters
- Measuring cup with handle
- insulating materials (enough of each to fully wrap a can ONCE), such as steel wool; cotton; styrofoam; bubble wrap; newspaper; aluminum foil and cloth
- rubber bands, tape
- Scissors, X-acto knife
- funnel
- Hot pot/coffee maker/anything that heats water



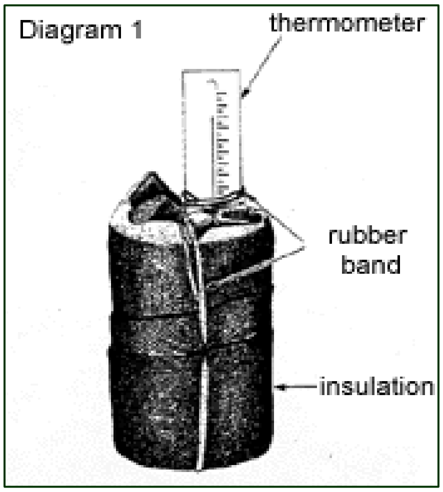
Procedure:

1. Completely wrap one cylindrical "house" (soda can) with one layer of the insulating materials you are given to choose from. Make sure you wrap the roofs (i.e. can tops) and bottoms, but leave a small hole above the pop-top opening for the thermometer. Hold the insulation in place with rubber bands and small strips of tape.

2. Use a second soda can and do not insulate it with any material. This will serve as your control.

3. Wrap rubber bands around the tops of the thermometers to suspend the thermometer in each can. **Make sure that the thermometer does not touch any part of the can**. You can also try suspending the thermometers in the cans with tape.

4. Using a funnel to fill your houses with exactly 200 milliliters of hot water.
5. Insert the thermometer through the insulation and pop-top openings. Adjust the rubber bands (or modeling clay) so that the thermometer is about halfway into the can and is not touching any part of the can. Measure **and record** the starting temperature of the water in each of your "houses" and then every minute for exactly 20 minutes. Stop recording the temperature when the time is up.
6. Calculate the change in temperature of the water for each can.
7. Using this formula: **Heat Loss (in calories) = Mass of water (in grams) x ΔT (in Celsius)**, calculate the calories of heat lost from each "house".
8. Construct a graph to plot your data for each "house".



Analysis Questions: In your own notebook answer the following:

1. How did your group's results compare with other groups?
2. Compare your results with the entire class data. Which insulating material best prevented the loss of heat?
3. What were sources of differences (errors) in the data/procedure?
4. Which material most resembles actual home insulating materials?
5. How might your home's insulation affect your energy bill?

STUDENT PAGE

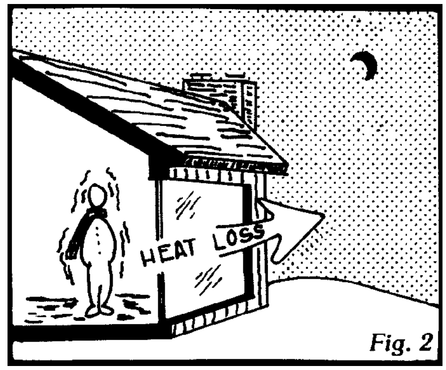


Fig. 2

Heat Conduction

"How much heat is lost through windows in the winter?"

Objective:

To use simple physics to estimate the energy lost through a window over time.

Buildings with windows lose heat through those windows in the winter. The warmth inside the building is **conducted** through the glass to the cool air outside. The heat lost through windows represents dollars spent on wasted energy. We can calculate how much energy is lost through a window over a month, and the related cost of that waste.

To do this we first need the heat conduction equation, originally derived by the French mathematician J. Fourier. Here it is:

$$Q = U \times A \times T \times (t_1 - t_2)$$

Where:

Q = Total heat lost in units of British Thermal Units (Btu)
U = U-value, a measure of how well the material conducts heat in units of Btu/(ft^2·hr·°F)
A = surface area measured in ft^2
T = time measured in hours
t_1 = inside temperature in degrees Fahrenheit.
t_2 = outside temperature in degrees Fahrenheit.

Window Type	U-value [Btu / (ft^2·hr·°F)]
Single pane with aluminum frame	1.1
Double pane, wood frame, ½" air space	0.49
Double pane, wood frame, ½" argon-filled air space, low-e coating	0.38
"Superwindow"	0.22

Supplies:

- Tape measure – one for each team
- Fahrenheit Thermometer – one for each team

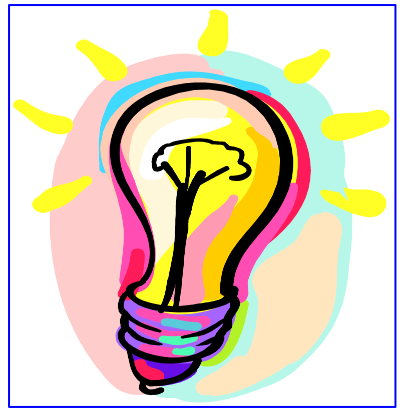
Procedure:

1. Measure the window area of a classroom in units of ft^2. This is the value of **A**
2. Measure the inside temperature in °F. This is the value of $\mathbf{t_1}$
3. Measure the outside temperature in °F. This is the value of $\mathbf{t_2}$
4. Select a time span (**T**) during which you are reasonably sure the values of $\mathbf{t_1}$ **and** $\mathbf{t_2}$ do not change significantly
5. Look up the U-value that corresponds to the type of windows in the classroom (see table above).
6. Plug in the quantities ***U,*** **A, T,** $\mathbf{t_1}$, $\mathbf{t_2}$ into the Fourier heat equation to calculate Q in units of Btu.
7. Once you've calculated the heat lost through conduction through the window in units of Btu, then you can proceed to calculate the energy dollars lost in the process. First convert Btu into therms of natural gas by dividing your Btu value by 100,000. The typical charge per therm of natural gas is $0.35. So, multiply your therms by $0.35 to find the dollar value of the heat lost by conduction through the window during the time T.

Analysis Questions: In your own notebook, answer the following:

1. Which type of window (see table) conducts the most heat? The least?
2. Why do manufacturers use the "U-value" of their products in advertising?
3. Which U-value is the most efficient at conserving energy? How did you decide this?
4. Show your work for Step 7.
5. How would you decide if the replacement of high U-value with low U-value windows is cost effective?

STUDENT PAGE



Light Bulbs or Heat Bulbs

"Which is more efficient: an incandescent light bulb or a compact fluorescent light bulb?"

Objective:

To compare the different heating effects of incandescent and fluorescent bulbs.

Lighting accounts for 20% to 25% of all electricity consumed in the United States. An average household dedicates 5% to 10% of its energy budget to lighting, while commercial establishments consume 20% to 30% of their total energy just for lighting. In a typical residential or commercial lighting installation, 50% or more of the energy is *wasted by obsolete equipment, inadequate maintenance, or inefficient use*. Saving lighting energy requires either reducing electricity consumed by the light source or reducing the length of time the light source is on. In this activity you will compare an incandescent bulb to a compact fluorescent light bulb (CFL) to see which of the two really saves both energy AND money.

Supplies:

- ❑ Incandescent bulbs (60, 75 or 100-watt)
- ❑ CFLs (of equivalent light output to the incandescent bulbs selected above.) For example, an 18-watt CFL is equivalent to a 75-watt incandescent)
- ❑ Thermometers (the remote wire type work best)
- ❑ Two light sockets

Procedure:

You will compare the different heating effects of incandescent and fluorescent bulbs.

1. Set the thermometer 4" from the CFL and turn the light on. In your own notebook , record the starting temperature and the final temperature after 10 minutes.

   Starting Temperature (Ts) = (answer)   Final Temperature (Tf) = (answer)

2. Let the thermometer cool down to close to the initial temperature (i.e. room temp.)

3. Repeat step 1 using the incandescent bulb. Be sure to have the same bulb-thermometer distance and to conduct the test for the SAME amount of time. Also record the starting and final temperatures.

   Starting Temperature (Ts) = (answer)   Final Temperature (Tf) = (answer)

4. For both cases compute the net change in temperature, ΔT (ΔT= final T – initial T) and compare them.
   ΔT for CFL = (answer) ΔT for incandescent = (answer)

At this point you have probably concluded which light bulb is the most energy efficient. But most homeowners are not only interested in saving energy, but also in saving **money.** Incandescent bulbs are very cheap (about 75 cents per bulb), while a CFL costs between $8 and $20. In that case it sounds like the incandescent bulbs are the best choice. Is that right? It's true that CFLs are not cheap, but are they ***cost-effective***?

To answer that question you will need the following facts about a 75-watt incandescent bulb and an 18-watt CFL, which yields the same amount of light.

	Incandescent	**CFL**
Watts consumed	75 W	18 W
Rated lamp life	750 hours	10,000 hours
No. bulbs used over 10,000 hours	13	1
Electricity cost per kWh	$0.083	$0.083
Cost per bulb	$0.75	$14.00 (average)

With this information you will need to calculate the three quantities listed below. Write your answers in your own notebook.

1. The amount of electricity consumed by each bulb type over a 10,000 hour period in kilowatt-hours (kWh).
   Total electricity consumed by incandescent bulbs = (answer) kWh
   Total electricity consumed by CFL bulb = (answer) kWh

2. The electricity cost per 10,000 hours of use for each bulb type.

   Total cost of electricity consumed by incandescent bulbs = (answer)
   Total cost of electricity consumed by CFL bulb = (answer)

3. The **total** cost of the bulb (or bulbs) used during the 10,000 hours.

   Total Incandescent bulb cost = (answer)
   Total CFL cost = $ (answer)

Now you are set to calculate the **Total Life-Cycle Cost** for each bulb type over a 10,000 hour usage period. That value is just the sum of the total cost of the bulbs used during the 10,000 hour period, and the cost of the electricity consumed by each bulb type during that time.

Incandescent bulb life-cycle cost = $ (answer)
CFL life-cycle cost = $ (answer)

Compare the life-cycle cost for each bulb type. Over a 10,000 hour usage period, which bulb would you buy to save money? (answer)

How much money would you save by your choice?

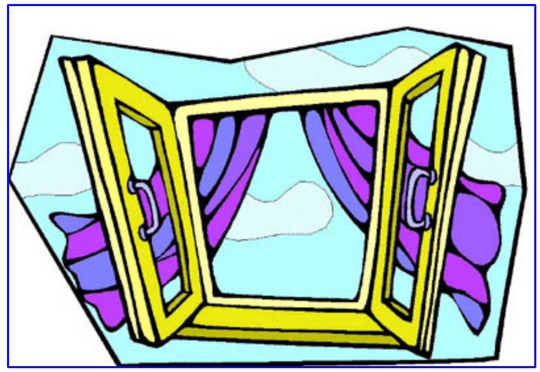
Money saved = $ (answer)

The life cycle cost you just calculated applies to your choice of bulb for a single lamp. To gauge the effect of your choice of bulbs for your entire home use the cost savings calculator located at **http://www.sdearthtimes.com/ET_Lighting_Work.html** . There you will enter information on the number of bulbs, amount of use, watt-rating etc. for your home and calculate the savings achieved by your choice of bulb type.

Analysis Questions: In your own notebook, answer the following:

1. Which bulb heats up the most?
2. Why is it important to keep the distance from the light source the same for both types of bulbs?
3. Based on your calculations of the Total Life-Cycle Cost for each bulb type, over a 10,000 hour usage period, which bulb would save you money? How much money would you save by your choice?
4. How would the use of CFLs reduce the cooling costs of your home?
5. Develop a cost-effective plan to replace incandescent bulbs in your home with CFLs. Which bulbs would you replace first and why?

STUDENT PAGE



Windows

"How do the insulating abilities of single-pane windows compare to double-paned windows?"

Objective:

To compare the insulating abilities of single-pane and double-pane windows in a model home.

Supplies:

- Cardboard box that can be entirely closed up. A large shoebox works best.
- X-acto knife to cut a window in the box
- 5.5" diameter plastic Petri dish (to serve as window)
- Styrofoam wrap (comes in sheets that look like thin foam paper)
- Double stick tape (glues on both sides)
- Scotch or masking tape (for sealing up the box)
- 100-watt incandescent bulb **AND** clamp-on lamp to light it
- Digital thermometer with wire sensor

Procedure:

You will conduct two heating/cooling trials, one with a single pane window and the second with a double pane window.

1. Use the **larger** half of the Petri dish to trace out a circle on one of the long sides of the rectangular cardboard box. Trace carefully.

2. Use the X-acto knife to cut along the traced curve. Cut SLOWLY to be accurate.

3. To assess the quality of your cut, fit the Petri dish into the window frame. It should make a fairly snug fit.

4. To compensate for possible gaps, first put double stick tape along the edge of the Petri dish that comes in contact with the window hole. Next, cut an inch-wide strip of the Styrofoam wrap about 15" long and stick it onto the edge of the taped-up Petri dish. This will act as weather-stripping.

5. Carefully fit the weather-stripped window into the hole making sure that the foam is wedged between the Petri dish and the cardboard – the way weather-stripping should be.

6. Now cut small holes in each of the short sides of the rectangular box. One hole allows you to insert the temperature sensor and cable from the digital thermometer. The second hole is an exit for the clamp-on lamp cord that must be plugged into a wall outlet.

7. Place the clamp-on lamp with a 100-watt bulb facing **AWAY** from the window and facing **AWAY** from the remote temperature sensor (see picture below).

8. Be sure the temperature sensor is hanging in the air without touching any surface and far from the lamp.

9. Make sure the lamp is turned on, but not yet plugged in. Then close up the box using regular tape. Tape up any places that might cause the box to leak.

10. Now plug in the lamp lighting the bulb and record the starting temperature. Record the temperature every minute for the next 17 minutes. Note that the temperature in the box will be the temperature recorded by the remote sensor – i.e. what the digital thermometer calls the "outside temperature", even though it's inside the box.

11. After the 17^{th} minute unplug the lamp **but continue recording** the temperature every minute for the next 17 minutes.

12. To prepare for the second trial put double stick tape along the outer edge of the smaller half of the Petri dish (the unused half). Cut another strip of the foam paper and stick it along the edge of the dish. This weather stripping will ensure that the double pane window is well sealed.

13. Fit the smaller half of the Petri dish into the large half. You may have to open up the box to do this. If so then reseal the box after everything is in place.

14. Repeat the heating and cooling trial with the double pane window making sure to repeat all the steps EXACTLY.

15. Plot the temperature curves and compare the results.

Analysis Questions: In your own notebook, answer the following:

1. Why is it important for the temperature sensor not to be directly in the light?
2. What were the differences (if any) between the single-pane window and the double-pane window?
3. Explain the importance of repeating the heating and cooling trial with the double-paned window using the EXACT same steps.
4. What are the differences you see between the two types of windows?
5. How would you use this information to conserve energy?