



So You Want to Heat Your Home?

Students calculate the amount of energy needed to heat an average-sized home using different types of energy sources and different heating system efficiencies.

Grade Level: (5–8) 9–12

Subject Area: English Language Arts, Family and Consumer Science, Mathematics, Science, Technology Education

Setting: Classroom

Time:

Preparation: One hour

Activity: Two 50-minute periods

Vocabulary: Boiler, Btu (British thermal unit), Cord, Efficiency, Furnace

Major Concept Areas:

- Development of energy resources
- Quality of life

Getting Ready:

You could place the **Energy Sources Tally Chart** on the board before class. You may want to contact your local utility to get examples of actual home heating data in million Btu (British thermal unit). You may also want to find out the cost of natural gas, fuel oil, LPG, electricity, and wood in your area.

Objectives

Students will be able to:

- recognize how different energy sources and different heating system efficiencies contribute to the cost of home heating; and
- determine which heating system is most efficient and economical.

Rationale

Learning about the relationship between home heating system efficiency and energy costs provides students with background information to make decisions about the energy resources they will use in the future.

Materials

- Pictures of natural gas, fuel oil, liquid propane gas (LPG), electricity, or wood home heating systems (optional)
- Advertisements for furnaces, boilers, woodstoves, or other heating systems from print or online media (optional)
- Two cups filled with lemonade
- Copies of *Heating Your Home with a New Heating System*
- Calculators (optional)
- Find additional resources related to this activity on keepprogram.org > Curriculum & Resources

Background

It is no surprise to Wisconsinites that most of the energy they use in their homes or apartments is for keeping warm during the winter. The amount of money spent on heating is also significant. The average homeowner may spend \$485 to over \$2,400 on energy per heating season, depending on the efficiency of the heating system and the type of energy. Given such a cost range, it makes sense for homeowners who wish to replace their old heating system to compare the efficiency and energy costs of new systems before buying one.

The majority of homes in Wisconsin use furnaces or boilers that burn natural gas, fuel oil, or propane (also called liquid petroleum gas, or LPG). Electric baseboard heat is used in some houses and apartments. Wood-burning stoves are especially popular in rural areas and in the northern part of the state, where wood supplies are plentiful and access to other fuels is restricted (see **Information about Different Home Heating Systems**).

There are several important factors to consider when assessing a home heating system. The first factor is efficiency—the percentage of the energy that is converted into useful heat. For instance, a 15- to 20-year-old fuel oil or natural gas furnace may be 60 percent efficient, meaning that 60 percent of the energy from the oil or gas is transferred to the interior of the home. Most of the other 40 percent of the energy is lost when exhaust gases are vented up the chimney and outside, and the rest is lost warming up the furnace itself, or is used to restart the furnace after it has cycled off. The efficiency of new heating systems using natural gas, fuel oil, propane, and wood has improved considerably in recent years, and higher efficiency models are now widely available. Heating system efficiency does not vary much with the size of the system; the efficiency of a large-sized gas furnace used in a large house is not much different than that of a small-sized gas furnace used in a small house.

Energy cost is another important factor to consider when assessing a home heating system. Comparing energy costs requires thoughtful analysis because different energy types have different units of measurement and different price structures, as shown in the [Heating Your Home with a New Heating System Data Table](#). For example, the cost of fuel oil is set in dollars per gallon, while electricity is priced in cents per kilowatt-hour (kWh), and firewood is priced in dollars per cord.

In the United States, the commonly used unit of measure for space heating is the British Thermal Unit (Btu). One Btu is the amount of energy needed to raise the temperature of one pound of water by one degree Fahrenheit. A four-inch wooden kitchen match releases about one Btu of heat when it is burned. A typical Wisconsin home uses between 50 to 100 million Btu of heat each year (depending on the size of the home, quality of construction, and severity of winter weather). In order to compare different types of heating systems, it will be necessary to convert from Btu of heat into the units that are commonly used for sale of different energy sources.

A third important factor in assessing a home heating system is the cost of the system itself. High efficiency furnaces and boilers generally cost a few hundred dollars more than their less efficient counterparts. On the other hand, using a high-efficiency furnace or boiler often leads to noticeably lower energy bills during the course of Wisconsin's long heating season, and the savings in energy costs will often pay for the extra purchase cost of the high-efficiency systems after a few years. Electric baseboard systems are less expensive

than furnaces or boilers, but high electricity costs offset this advantage. There is no direct relationship between the cost of a woodstove and its efficiency. Because heating system costs vary widely, the best sources for cost information are local heating contractors, utilities, or woodstove distributors.

Other factors to consider when assessing a home heating system are availability of the energy source in a given locale and, if needed, the cost of air ducts, pipes, fuel tanks (fuel oil and propane), and other auxiliary equipment.

The recent trend toward high-efficiency heating systems benefits homeowners and the environment. By choosing the right combination of an efficient heating system and low-cost energy source, the homeowner can save money in the long-term. High-efficiency heating systems also reduce energy use, which reduces air emissions and contributes to prolonging the supply of energy resources.

Procedure

Orientation

One or two days before the activity, teachers may want to assign students to determine what type of energy source is used to heat their home (it is surprising how many students do not know this information).

Share the [Energy Sources Tally Chart](#) and ask students what type of energy source is used to heat their homes, and tally their answers.

Briefly discuss the advantages and disadvantages of each energy source (see [Information About Different Home Heating Systems](#)). To help with responses, show students pictures of furnaces, woodstoves, and other heating systems as well as advertisements for these systems and for local heating contractors.

Introduce the concept of efficiency through the analogy of making lemonade using two different juicers. Show the students two equally filled cups of lemonade.

Read the following:

The lemonade in both cups was made using two juicers. It took 17 lemons to make the lemonade in the first cup because the first juicer did not squeeze the lemons very well. The other cup of lemonade was made by the second juicer which only needed to squeeze 12 lemons to get the same amount of lemonade.

Have students tell you which juicer was more efficient in making lemonade.

Steps

1. Read the introduction from *Heating Your Home with a New Heating System*. Ask students which energy source discussed in the **Orientation** should be used to heat their home and have them tell why.
2. Hand out copies of *Heating Your Home with a New Heating System* to each student. In the space shown after the introduction on the first page, have students write down the energy source they have chosen. You may decide to let them use calculators to assist with worksheet calculations.
3. As a class, go over the concept of efficiency by completing **Part I** (Steps 1 through 5) of *Heating Your Home with a New Heating System*. If necessary, provide students with the definition of a Btu. Have them discuss their answers to Steps 3 and 4 of the activity sheet.
4. Divide the class into groups of five students. If students are left over, divide them up among the groups of five. Have each student in the group choose one of the five energy sources to investigate and complete the rest of the activity sheet for that energy source.
5. Have groups work on **Part III: Comparing New Heating Systems** to each group and ask students to summarize and compare energy cost savings using the different heating systems. When the students have finished, have them discuss the results among themselves. Based on their results, each group should determine:
 - the least efficient and most efficient heating system;
 - the heating system that saves the least and most energy;
 - the least expensive and most expensive energy sources; and
 - the heating system that saves the least and most money.
6. Have each group state which energy source they would use to heat their home based on their responses from **Part III**. How do their responses compare to the choices they made before they completed the activity sheet?

Additional steps for older or more advanced students (optional):

7. One-two days before starting the activity, ask students to take a photograph of their heating system. It may be interesting to post/share the

photos—either by pinning hardcopies on a bulletin board or digitally by using a cloud resource available to the class. It is often fun for students to see some of the more unique heating systems that can be found in some homes.

8. Have students use a computer to create a spreadsheet to complete the calculations. Rather than assigning a student a single heating system and energy source to analyze, task them with creating a spreadsheet to calculate data for all of them with the goal of producing a table similar to that shown on the **Answer Sheet**. Teachers may wish to provide students with the headings for each column in the table and have them perform the necessary calculations to produce the results and analyze their findings. This is a good exercise to teach the skill of spreadsheet data processing.
9. Teachers may wish to task students with creating a graph or chart to visually illustrate the differences in energy consumption and energy costs savings of each heating system type. These could be drawn by hand using square lined graph paper (to help students with creating and reading scales). Or, if a spreadsheet was created to facilitate the data analysis, then the graphs could be created electronically as well.

Closure

Ask students to list reasons why they would or would not use a particular energy source to heat their homes. Return students' attention to the chart drawn during the **Orientation**. Is there anything they want to add to the chart?

Encourage students to conduct research to complete the chart. For example, they may want to find out if certain energy sources are available in their area. Health and environmental effects for each energy source can also be investigated and compared. Students can then determine which source they think will affect human health and the environment the least.

Assessment

Formative

- Are students able to accurately complete the calculations on *Heating Your Home with a New Heating System*?
- Can students explain in their own words what it means when a boiler, furnace, or woodstove has a certain efficiency?
- Did students determine which heating system saves the most energy and has the lowest energy costs?

Summative

Show students the advertisements again. Have them comment on what information the ads include or do not include. Have students pretend that they are sales representatives for a heating equipment company. How would they design a sales pitch to sell a particular type of heating system that uses one of the five energy sources?

Extensions

Have students update the price information given on *Heating Your Home with a New Heating System Data Table* before doing this activity. Students could research the costs of each of the heating systems and compare them. They can call a heating contractor, the local utility, fuel oil or wood supplier. Energy prices and facts about energy sources used by Wisconsin residents for heating their homes can be found at the Wisconsin State Energy Office ([Public Service Commission](#) - PSC) website.

Invite someone who sells and installs heating equipment to class to talk about the costs, benefits, and limitations of heating a home using the different heating systems covered in this activity.

Related KEEP Activities

The activity “Exploring Heat” can be adapted for older students to introduce basic thermal energy concepts. Learning about the cost of home heating is also addressed in “Reading Utility Bills” and “Reading Utility Meters.” The activity “Advertising Energy” can be used by students to analyze how different companies sell their heating products. The ways homes were heated in the past can be investigated through the activity “Energy Use Then and Now.”

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Energy Sources Tally Chart

Energy Source Used to Heat Your Home	Tally	Advantages	Disadvantages
Natural Gas			
Fuel Oil			
Electricity			
Propane (LPG)			
Wood			
Coal			
Solar			
Other			

Information about Different Home Heating Systems

Natural gas and fuel oil are burned in furnaces or boilers. A furnace heats air, which is then distributed by air ducts throughout the house. A boiler may heat water to a high temperature or may turn it into steam. The hot water or steam is then piped to radiators located in different rooms of the house and piped back to the boiler after some of the heat is transferred to the rooms. The highest efficiency for natural gas furnaces is 96 percent, while high-efficiency oil furnaces and boilers, as well as natural gas boilers, achieve ratings of up to 86 percent.

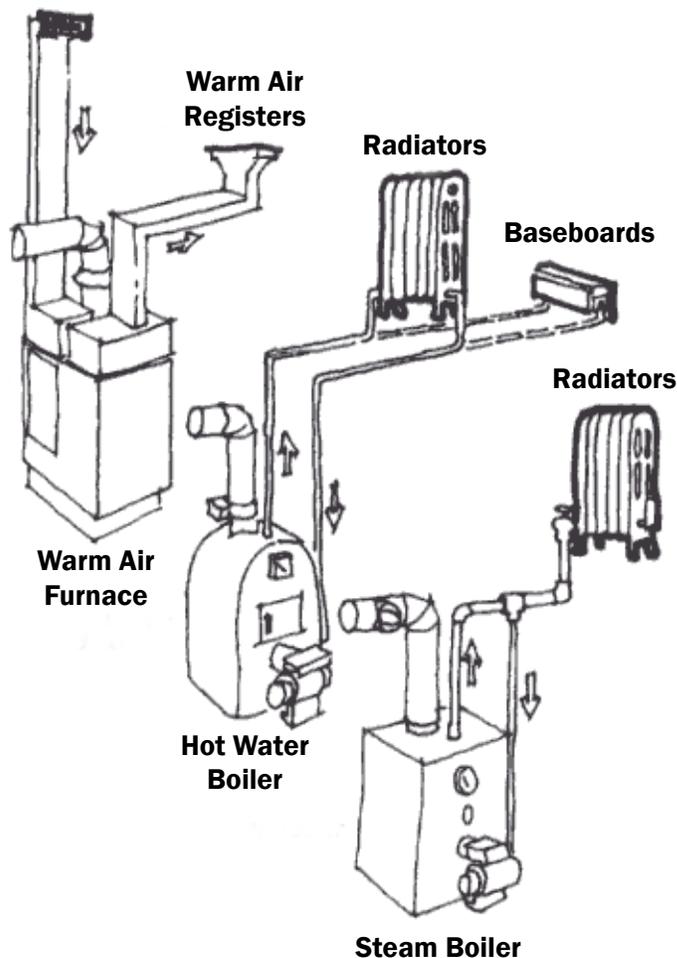
Propane is often used to heat rural homes that do not have access to natural gas lines. Similar in composition to natural gas, propane is stored in liquid form in pressurized tanks and converted to a gas when released for burning. Propane furnaces and boilers generally have the same efficiencies as those burning natural gas (as listed above).

Electric heating systems use baseboard heaters made of wire elements that heat up when current passes through them, much like portable electric space heaters used to warm individual rooms. Baseboard heating is 100 percent

efficient because all the electrical energy is converted into heat by the heating elements. On the other hand, when the efficiency of electric power plants and transmission lines are taken into account, electric heating is usually not as efficient as other heating systems. Because of its expense, electricity is not used as much for home heating. Very energy-efficient homes and apartments with small living areas use electric heat more often.

Woodstoves are preferred over fireplaces for heating a home with wood. High quality woodstoves achieve efficiencies of 90 percent. Despite their appeal, fireplaces in most houses are only 10 to 15 percent efficient at best, and many lose more heat than they provide. Therefore, using a fireplace to heat a home is not recommended, unless it is custom designed and operated specifically for efficient heating. Wood used for home heating is sold in units called cords; a cord is a stack of wood 8 feet long by 4 feet wide by 4 feet high, or 128 cubic feet. Wood may also be sold in face cords, which is about one-third of a cord. Since a cord of hardwood may yield up to twice as much heat energy as a cord of softwood, burning hardwoods like oak and maple is more economical.

Furnaces heat air, while boilers heat water



Answer Sheet

Answers to questions 3 and 4 of **Part I of Heating Your Home with a New Heating System:**

- Most of the 40 percent of energy that is not used to heat the home is lost when exhaust gases are vented up the chimney. The rest is either lost warming the furnace itself or is used to restart the furnace after it has cycled off.
- Efficiency is the percentage of energy in the fuel that is converted into useful heat. Another definition of efficiency is the useful heat delivered to the home from the heating system divided by the total amount of energy that is consumed by the heating system.
Amount of heat needed by house each year = 80.0 million Btu

Heating System	Efficiency %	Energy used by Heating System (million BTU/year)	Energy Source	Retail Unit	Retail Price per Unit (for Winter 2014-15) (\$ per unit)	BTU per Unit of Energy (BTU per unit)	Total Retail Units of Energy Used (units/year)	Annual Energy Cost (\$/year)	Energy Saved by the New Heating System (million BTU/year)	Energy Cost Savings or Expenses of the New Heating System (\$/year)
Old Fuel Oil Furnace	60%	133.3	Fuel Oil	gallons	\$2.80 per gallon	138,690 Btu per gallon	961 gallons	\$2,691	N/A	N/A
High Efficiency Gas Furnace	95%	84.2	Natural Gas	therms	\$0.74 per therm	100,000 Btu per therm	842 therms	\$623	49.1 BTU	\$2,068 Saved
High Efficiency Oil Furnace	85%	94.1	Fuel Oil	gallons	\$2.80 per gallon	138,690 Btu per gallon	679 gallons	\$1,901	39.2 BTU	\$790 Saved
Electric Baseboard Heaters	100%	80	Electricity	kilowatt hours	\$0.14 per kWh	3,413 Btu per kilowatt-hour	23,440 kWh	\$3,282	53.3 BTU	\$591 Extra Spent
High Efficiency Propane Furnace	95%	84.2	Propane (LPG)	gallons	\$1.79 per gallon	95,475 Btu per gallon	882 gallons	\$1,579	49.1 BTU	\$1,112 Saved
High Efficiency Woodstove	83%	96.4	Dry Hardwood Delivered	cords	\$315.00 per cord	21,000,000 Btu per cord	4.6 cords	\$1,449	36.9 BTU	\$1,242 Saved

Source: Wisconsin State Energy Office: Average Winter Prices for Heating Fuels 2014-2015. For updated retail price statistics see: psc.wi.gov.
Note: Students' answers may differ slightly due to rounding. introduction

Heating Your Home with a New Heating System

Introduction

You have just become the proud owner of an average-sized Wisconsin home. You learned from the previous owner that the old fuel oil furnace is unreliable and has a heating efficiency of 60 percent. In other words, only 60 percent of the energy the furnace uses to produce heat goes toward heating the home. You also found out that an average-sized Wisconsin home needs 80 million Btu (British thermal units) of heat each year. You want to see if getting a new, efficient heating system will save you energy and reduce your yearly fuel costs. Which fuel do you think should be used in the new heating system?

Heating Your Home with a New Heating System Data Table

Retail prices are Wisconsin averages for the winter of 2014-2015. Since prices vary regionally and change frequently, your teacher may provide updated data for your specific location.

Energy Source	New Heating System	Efficiency	Commonly Used Unit of Sale	Btu per Unit of Energy	Retail Price
Natural Gas	High Efficiency Gas Furnace	95%	therm	100,000 Btu per therm	\$0.74 per therm
Fuel Oil	High Efficiency Oil Furnace	85%	gallon	138,690 Btu per gallon	\$2.80 per gallon
Electricity	Baseboard Heaters	100%	kilowatt-hour	3,413 Btu per kilowatt-hour	\$0.14 per kilowatt-hour
Propane (LPG)	High Efficiency Propane Furnace	95%	gallon	94,475 Btu per gallon	\$1.79 per gallon
Wood (Dry Hardwood Delivered)	High Efficiency Woodstove	83%	cord	21,000,000 Btu per cord	\$315 per cord

Part I

To establish a basis for comparing new heating systems, you first need to figure out how much energy was needed to heat the home using the old furnace, and how much this cost each year.

- Let's say that X Btu is the total amount of energy used by the furnace each year. Of that total, 60 percent goes toward heating the house (60 percent of X = 80 million Btu, or 0.6 multiplied by X = 80 million Btu). To find the total amount of energy used by the furnace, divide 80 million Btu by 60 percent. (X = 80 million Btu / 0.6)

$$X = \underline{\hspace{2cm}} \text{ million Btu}$$

- Next, calculate the energy needed by the old furnace that was not used to heat the house. (The value for X minus 80 million Btu.)

$$\underline{\hspace{2cm}} \text{ million Btu}$$

Heating Your Home with a New Heating System

3. What do you think happened to the energy in Step 2? Where did it go?
4. Explain in your own words what heating efficiency means. (In other words, the furnace is efficient at doing what?)
5. Circle the commonly used retail unit for fuel oil that is used by the original heating system (see **Heating Your Home with a New Heating System Data Table**).

therm gallon kilowatt-hour cord

6. Calculate how many retail units of energy had to be purchased to provide the total annual energy required by the original heating system. (Multiply value for X_1 from Step 1 by one million, then divide by the number of Btu per unit of fuel found in the **Heating Your Home with a New Heating System Data Table**.)

Example: If 100 million Btu are needed to heat the home that uses a fuel oil furnace:
 $100,000,000 \text{ Btu} / 138,690 \text{ Btu per gallon} = 721 \text{ gallons of fuel oil}$

7. Calculate how much money was spent on fuel oil per year by the old furnace. Round your answer to the nearest dollar. (Multiply the value from Step 6 by the retail price of the energy source found in the **Heating Your Home with a New Heating System Data Table**.)

Example: If 721 gallons of fuel oil were needed: $721 \text{ gallons} \times \$2.80 \text{ per gallon} = \$2,019$

$Y_1 =$ _____ dollars

Part II

Now you will analyze a new heating system to replace the old one from Part I. To compare, you will need to figure out how much energy is needed by the new system, and how much this costs each year.

8. Write the name of the new energy source that you have been assigned. _____
9. Choose a new, efficient heating system that uses the fuel assigned to you and determine its efficiency (**Heating Your Home with a New Heating System Data Table**.)

System Type = _____ Efficiency = _____ %

10. Let's say that X_2 Btu is the total amount of energy used by the new heating system each year. Of that total, a certain percent, indicated by the efficiency, goes towards heating the house. To find the total amount of energy used by the new heating system, divide the 80 million Btu of heat required by the efficiency of the new system.

$X_2 =$ _____ million Btu
 ($X_2 = 80 \text{ million Btu} / \% \text{ efficiency expressed as a decimal}$)

Heating Your Home with a New Heating System

11. Circle the commonly used retail unit for the energy source that is used by the new heating system (see *Heating Your Home with a New Heating System Data Table*.)

therm

gallon

kilowatt-hour

cord

12. Calculate how many retail units of energy must be purchased to provide the total annual energy required by the new heating system. (Multiply value for X_2 from Step 10 by one million, then divide by the number of Btu per unit of energy found in the *Heating Your Home with a New Heating System Data Table*.)

13. Calculate how much money will be spent on energy per year for the new heating system. Round your answer to the nearest dollar. (Multiply the value from Step 12 by the retail price of the energy source found in the *Heating Your Home with a New Heating System Data Table*.)

$Y_2 =$ _____ dollars

Part III: Comparing New Heating Systems

Summarize your findings.

14. Does the new heating system save energy over the old fuel oil furnace? If so, how much energy is saved in million Btu? (Compare values for X_1 and X_2 .)

15. Does the new heating system save on fuel costs per year over the old fuel oil furnace? If so, how much money is saved? If not, how much more is being spent? (Compare for Y_1 and Y_2 .)

16. Summarize your answers using this table:

	Old Fuel Oil Furnace	New Heating System (list type)	Difference
Efficiency	60%	_____ %	
Energy Used per Year (million Btu)	$X_1 =$ _____	$X_2 =$ _____	
Total Energy Costs per year (\$)	$Y_1 =$ _____	$Y_2 =$ _____	

Heating Your Home with a New Heating System

Part IV

Divide into groups. Each member of your group has already compared the efficiency, energy savings, and cost savings between an old fuel oil furnace and a new heating system. Now your group needs to decide which of the five new heating systems and fuels would be best for your home.

To help answer this question, each member of your group should help fill in the table below for the energy source and heating system they considered.

Comparing New Heating Systems Table				
Energy Source	New Heating System	Efficiency (%)	Energy Saved by the New Heating System (million BTU/year)	Energy Cost Savings or Expenses of the New Heating System (\$/year)
Natural Gas	High Efficiency Gas Furnace			
Fuel Oil	High Efficiency Oil Furnace			
Electricity	Baseboard Heaters			
Propane (LGP)	High Efficiency Propane Furnace			
Wood (Dry Hardwood Delivered)	High Efficiency Woodstove			

Heating Your Home with a New Heating System

Answer these questions using information from the **Comparing New Heating Systems Table**:

1. Which new heating system is the most efficient? Which is the least efficient?
2. Which new heating system saves the most energy compared to the old fuel oil furnace? Which saves the least energy?
3. Would you say that the higher the efficiency of a new heating system, the more energy it saves?
4. Which heating system saves the most money in energy costs each year compared to the old fuel oil furnace? Which saves the least money or costs the most money in energy costs?
5. Would you say that the higher the efficiency of a new heating system, the greater the savings in energy costs? Is this true in all cases? Why or why not? Explain your answer.