ENERGY FOR EVERYONE
propane

Measurements and Calculations with Propane

LESSON 5
UNIT: PROPANE
PROBLEM AREA: PROPANE USE IN AGRICULTURE

Propane Education & Research Council

STUDENT LEARNING OBJECTIVES

Instruction in this lesson should result in students achieving the following objectives:

1. Outline the measurement and pricing of select energy sources.
2. Describe factors that influence the pricing of select energy sources.
3. Explain cylinder capacity and fill by weight and volume.
4. Compare the costs of various energy and fuel sources.
5. Evaluate EnergyGuide labels on consumer appliances.

NATIONAL SCIENCE STANDARDS ADDRESSED IN THIS LESSON

All students should develop an understanding of:

Science and Technology: Content Standard E

- Abilities of technological design
- Understandings about science and technology

Science in Personal and Social Perspectives: Content Standard F

- Natural resources
- Science and technology in local, national, and global challenges

NATIONAL MATHEMATICS STANDARDS (NCTM) ADDRESSED IN THIS LESSON

- Compute fluently and make reasonable estimates
- Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more complicated cases

LIST OF RESOURCES

The following resources may be useful in teaching this lesson:

- Propane.com/Agriculture
- Energy.gov
- NPGA.org
- PropaneSafety.com

LIST OF EQUIPMENT, TOOLS, SUPPLIES, AND FACILITIES

- Two coins (quarters work best)
- Piece of cloth
- Two pieces of same metal, large enough to hold coins
- Copies of sample test
- Visuals from accompanying masters
- Copies of student lab sheet

TERMS

The following terms are presented in this lesson *(shown in bold italics throughout the lesson):*

1. AFUE rating
2. cylinder gas
3. BTU
4. Energy Star label
5. EnergyGuide label
6. overfill prevention device (OPD)
7. tare weight
8. water capacity

TELL STUDENTS...

"Today's lesson focuses on measurements and calculations with propane. You will be asked to outline how propane is measured and priced, calculate weight and volume of propane, compare costs of using various types of fuels, and evaluate energy labels on various types of appliances."

INTEREST APPROACH

Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. Two possible interest approaches are included here.

This interest approach illustrates heat loss and the ***BTU (British thermal unit)*** as a measurement of heat; however, do not reveal this information to the class until the trick has been performed. **VM-A** shows pictures of the materials and procedure for your reference.

Materials: Two coins (quarters work best), thick cloth or napkin, two flat pieces of metal

DEMONSTRATION

1. Arrange the class so everyone can see the demonstration.
2. Place two coins (quarters work well) side by side on a thick cloth.
3. Lay two flat pieces of metal near the coins displayed on the cloth.
4. Tell the students that you can smell the DNA from a human hand that touches the coins and that you have washed these coins to remove previous DNA.
5. Select a student to assist you.
6. Turn with your back to the coins, preferably facing the class so that everyone can see you are not observing your student assistant or the coins.
7. Ask the student to pick up one of the coins and hold it tightly in the hand of his or her choice. Then, ask the student to close both hands tightly.
8. Ask the student to concentrate on which hand the coin is in. The key is to stall until heat can transfer from the student's hand to the coin. Lead the class in a discussion to
   - Define DNA
   - Tell where they have heard about DNA
   - Explain if they think they have DNA and how they got it
9. After two or three minutes, ask the student to place the coin back on the cloth and to move both coins around so you cannot tell which coin was held by its placement.
10. Pick up one of the coins, and lay it gently against your top lip and under your nose for a few seconds. Pretend to sniff the coin. Note the temperature of the coin on your lip.
11. Repeat Step 10 with the other coin. Although the students think you are sniffing the coins, you are really selecting the coin by temperature. The coin the student was holding will feel warmer.
12. Determine which coin was warmer — therefore supposedly containing the student assistant's DNA — and announce your conclusion to the class.

DEMONSTRATION BREAKDOWN:

Tell the students that the demonstration was a trick — that your ability to select the right coin had nothing to do with DNA.

- Ask the students for the secret behind the trick. If they cannot guess it, tell them the trick was related to heat. They should realize that the coin held in the hand was warmer — thus, the key to the trick.
- Ask the class what might have happened if the coins had been laid on the metal plates instead of on the cloth after one had been held in the hand.
- Lead the class to recognize that heat would have been lost much more quickly on the metal than on the cloth and that the trick might not have worked.

Explain that the ***BTU*** is the unit used to measure heat and the loss of heat in applications.

- Ask the class what the words "30,000 BTU" on a greenhouse heater mean.
- *Answer: The heater puts out 30,000 BTU per pound of fuel burned (usually calculated on a per hour basis).*

Summary of Content and Teaching Strategies

OBJECTIVE 1

Outline the measurement and pricing of select energy sources.

ANTICIPATED PROBLEM

How are energy sources measured and priced?

Energy sources are usually measured in pounds, gallons, or cubic feet. These units are converted to BTU for comparison purposes.

A. Sources of energy include water, anthracite coal, bituminous coal, coke, diesel, electricity, fuel oil, kerosene, liquid propane, natural gas, propane, steam, wood, and many others. Because the physical state of these substances varies (Are they solid, liquid, or gaseous?), they are not all measured in the same way.

B. Propane can be measured in gallons, for example, while electricity can be measured in watt-hours and wood can be measured in cords.

C. In the United States, the standard unit for the measurement and comparison of energy sources is the BTU (British thermal unit). One BTU is the amount of heat needed to raise the temperature of 1 pound of water by 1 degree Fahrenheit. This is approximately the amount of heat generated by one match. BTU measurements of common energy sources are:

   1. Natural gas — 1,050 BTU per cubic foot
   2. Propane — 2,500 BTU per cubic foot
   3. Kerosene — 135,000 BTU per gallon vs. propane at 91,000 BTU per gallon and gasoline at 125,000 BTU per gallon
   4. Wood — 7,870 BTU per pound

OBJECTIVE 2

Describe factors that influence the pricing of select energy sources.

ANTICIPATED PROBLEM

What factors influence the pricing of select energy sources?

Various factors can influence the pricing of propane. In recent years, virtually every source has experienced an increase in price.

A. Three main factors contribute to higher fuel prices:
   1. Higher crude oil and natural gas prices
      a. Propane, butane, kerosene, and gasoline are derived from crude oil, so the prices of these fuels track the price of crude oil. Propane costs are especially affected because propane competes mostly with crude-oil-based fuels for heating. Additionally, as with the prices of all energy sources, propane prices are influenced by the systems required to transport the energy source from production facilities to where it is used, whether by pipeline, ship, or truck.
      b. Propane and butane are both also derived from natural gas, so the price of natural gas determines the costs of propane and butane.
   2. Seasonal weather conditions and location
      a. Colder temperatures during the winter months increase the demand for energy for heating, particularly in the northern part of the country. The increase in demand reduces supplies and leads to higher prices. Fuel retailers are prepared to meet the demand, but predictions of long-term weather trends are difficult.
      b. Warmer temperatures during the summer months increase the demand for energy for cooling, also reducing supplies and creating high demand on the electric grids.
      c. Fuel prices are also influenced by proximity of the customer to the supply. In an area such as the Gulf Coast, customers are close to major suppliers and shipping ports, so the effort needed to get propane or other fuels to customers is minimal. Those customers who live farther away usually pay additional prices when transportation costs are added.
   3. International influences. The global propane market is constantly changing. An increasing number of new customers are turning to propane all over the world, particularly in Asian markets, such as China. Labor and political unrest elsewhere, including the Middle East, also contributes to higher energy prices. As a result, competition for propane increases, meaning higher prices.

B. The propane industry helps consumers meet the challenges of increasing fuel costs. Retailers of other fuels conduct many of the same activities to assist their customers in dealing with cost fluctuations
   1. Propane wholesalers and retailers work hard to protect consumers from "sticker shock." Many retailers purchase advance supplies of propane at lower contract prices to protect themselves and their customers from higher seasonal prices. Many propane retailers also offer balanced-billing payment plans that allow customers to spread their yearly cost of propane over many months, leveling out seasonally higher bills.
   2. Retailers also encourage customers to consider filling their tanks before the start of the heating season rather than waiting until their tanks are empty. A regular delivery schedule can help offset higher seasonal pricing.

C. Even during times of increasing energy costs, propane provides excellent value and comfort, besides being a clean, safe, and reliable energy source. In 2007, propane costs were $22.39 per million BTU as compared with electricity costs of $31.15 per million BTU (based on the Department of Energy's national average of 2007 residential retail prices)

SUGGESTED TECHNIQUES TO HELP STUDENTS MASTER THIS OBJECTIVE

1. Begin the lesson with an interest approach, state the objectives, and introduce key terms.
2. Have the students research why gas prices are rising.
3. Use **LS-A** to allow students to calculate the cost to heat an average home with propane for one year.

OBJECTIVE 3

Explain cylinder capacity and fill by weight and volume.

ANTICIPATED PROBLEM

How is cylinder capacity determined, and how are cylinders filled?

Bottled gas is a term used to describe substances that are gaseous at standard temperature and pressure (STP) and have been compressed in carbon steel, stainless steel, aluminum, or composite bottles known as gas cylinders. In the United States, bottled gas usually refers to liquefied petroleum (LP) gas. The capacity of gas cylinders is usually described by volume (gallons or cubic feet). Cylinders are usually filled by weight. Cylinders such as those for forklifts, however, are not required to be filled by weight.

A. The filling process depends on the requirements of the individual cylinder, because there are different sizes and kinds of cylinders. The methods and policies for filling bottles also depend on the company. Some companies charge by the gallon, whereas others charge by the cylinder.

B. After visually inspecting the cylinder for safety, the filler will look for the cylinder's water capacity and tare weight

   1. The ***water capacity*** in pounds is indicated by "WC" on the bottle and stands for the amount of water that the bottle can hold. The filling station will have a cylinder filling chart that will convert WC to pounds of propane. For example, a WC of 47.8 pounds converts to 20 pounds of propane.
   2. The ***tare weight***, indicated by "TW," stands for the number of pounds that the empty bottle weighs. Thus, if the TW is 18 pounds, then the filler needs to set the scale to slightly more than 38 pounds (18 lb. TW + 20 lb. propane = 38 lb.) to fill the bottle to capacity.

C. A propane cylinder should be equipped with an overfill prevention device. An ***overfill prevention device (OPD)*** is a safety feature that helps prevent a small propane cylinder from being overfilled, so it has enough space left for liquid expansion during warmer temperatures. Without adequate space, an increase in cylinder pressure may occur, creating potentially hazardous conditions. Most cylinders with OPDs have special triangular hand wheels with the letters "OPD" on them. In many states, cylinders without OPDs cannot be refilled.

D. To fill a forklift cylinder or similar propane bottle, the filler will use the liquid level gauge, also known as the bleeder valve, to determine when the cylinder is at capacity.

SUGGESTED TECHNIQUES TO HELP STUDENTS MASTER THIS OBJECTIVE

1. Show students **VM-B** for approximate dimensions of common propane cylinders.
2. Show students **VM-C** for an example of a cylinder-filling capacity chart.

OBJECTIVE 4

Compare the costs of various energy and fuel sources.

ANTICIPATED PROBLEM

What are the costs of comparative energy and fuel sources?

Consumers must weigh several important factors when choosing a fuel source, whether for home heating or use on the farm: cost per BTU, heating capacity, availability, and overall efficiency. For example, propane generally is less expensive per BTU than electricity but more expensive than natural gas. The homeowner or farmer must carefully consider all factors before making a choice of fuel. These include:

A. Energy costs

B. Realization that a choice made on cost alone would most likely eliminate any fuel but natural gas or heating oil

C. Comparison of propane to other fuels

   1. Propane provides great value because it burns hotter and more efficiently than many other energy sources, powering a variety of high-performance and energy-efficient appliances.

      a. A propane furnace can heat air up to 25 degrees warmer than electricity.

      b. Propane tankless water heaters can reduce standby energy loss by up to 20 percent and cost approximately 60 percent less to operate than electric water heaters.

      c. A propane appliance has a shorter energy savings payback period, which is the time the appliance takes to pay for itself via energy savings (appliance cost based on average consumption for a family of five).

   2. Propane gives off less than half the greenhouse emissions that electricity gives off.

   3. Propane is sometimes known as bottled gas, since it can be put into convenient cylinders and moved to where it is needed. Use of natural gas, however, requires the user or facility to be near a natural gas pipeline. In rural areas and most agricultural facilities, natural gas pipelines are not available.

SUGGESTED TECHNIQUES TO HELP STUDENTS MASTER THIS OBJECTIVE

1. Show **VM-D**, and discuss with students the comparative costs of different energy sources per BTU.
2. Have students brainstorm about which situations would necessitate use of some of the more expensive fuels. Hints: availability, location, convenience, pollution considerations.
3. Use **LS-A** to allow students to compare the estimated costs of agricultural and residential applications across various energy sources.

OBJECTIVE 5

Evaluate EnergyGuide labels on consumer appliances.

ANTICIPATED PROBLEM

What information do EnergyGuide labels provide, and how can this information be used?

An ***EnergyGuide label*** is a label on every major home appliance that estimates energy use of the appliance and annual energy cost and that compares energy use of similar products. This label is required by the U.S. Department of Energy (DOE).

A. The manufacturer's EnergyGuide label gives consumers two important pieces of information to compare different brands and models when shopping for a new appliance:
    1. Estimated energy consumption on a scale showing a range for similar models
    2. Estimated yearly operating cost based on the national average cost of electricity

B. An AFUE rating (Annual Fuel Utilization Efficiency rating) on an EnergyGuide label indicates how efficient an appliance is. This is expressed as a percentage. For example, an AFUE rating of 80 percent for a gas furnace means that more than 80 percent of the heat generated is usable.

C. Don't confuse the EnergyGuide label with the ***Energy Star label***. The EnergyGuide label features energy use and operating cost information to help shoppers compare appliance models, while the Energy Star label marks an appliance with superior energy efficiency. However, the Energy Star label may appear on the EnergyGuide label if a particular model qualifies.

SUGGESTED TECHNIQUE TO HELP STUDENTS MASTER THIS OBJECTIVE

1. Show students **VM-E**, which illustrates how to read the EnergyGuide label. The Department of Energy provides a guide for consumers to understand how appliances are rated for efficiency, what the ratings mean, and what to look for while shopping for new appliances: Energy.gov/EnergySaver/Appliances-And-Electronics/Shopping-Appliances

SUGGESTED RESOURCE FOR OBJECTIVE 5

1. Energy Star Label information: SRPNet.com/Energy/EnergyStar.aspx

REVIEW/SUMMARY

Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle. The anticipated problems can be used as review questions.

APPLICATION

Use the included visual masters to apply the information presented in the lesson.

EVALUATION

Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is provided.

ANSWERS TO SAMPLE TEST

Use the included lab sheets to apply the information presented in the lesson.

PART ONE: MATCHING

1. c
2. a
3. f
4. d
5. b
6. e

PART TWO: SHORT ANSWER

1. We measure energy sources in BTU because this gives us a standard way to compare all energy sources, whether they are solid, liquid, gas, or electricity.
2. The three factors are higher crude oil and natural gas prices, seasonal weather conditions and location, and international influences.
3. Cylinders are filled by weight or volume. To fill by weight, the WC is converted to pounds of propane, and this is added to the TW. Cylinders such as those for forklifts are filled by volume using a liquid level gauge (bleeder valve).
4. Portability of propane gas in containers allows people not near natural gas pipelines to have ready access to gas fuel.
5. A rating of 70 percent means that more than 70 percent of the energy generated is usable.

PART THREE: COMPLETION

1. 91,000
2. match
3. 38
4. $731.64
5. Steps:

   a. Propane provides 91,000 BTU per gallon, so propane at $1.90 per gallon costs about $0.00002088 per BTU (since $1.90/gal. ÷ 91,000 BTU/gal. = $0.00002088/BTU).

   b. The house uses 4,000 BTU per hour, so it uses $0.08352 per hour (since $0.00002088/BTU x 4,000 BTU/hr. = $0.08352/hr.).

   c. The cost to heat the home for one year using propane is $731.64 (since $0.08352/hr. x 24 hr./day x 365 days/yr. = $731.6352/yr.).

NAME: _____

Measurements and Calculations with Propane

PART ONE: MATCHING

INSTRUCTIONS: Match the term with the correct definition.

a. BTU
b. water capacity
c. tare weight
d. EnergyGuide label
e. Energy Star label
f. AFUE rating

_____ 1. The weight of an empty cylinder, in pounds

_____ 2. The amount of heat needed to raise the temperature of 1 pound of water by 1 degree Fahrenheit

3. An indicator of the efficiency of an appliance expressed as a percentage

_____ 4. A way of displaying an appliance's estimated total energy use and estimated yearly operating cost

_____ 5. The amount of water a cylinder can hold, in pounds

_____ 6. A way to indicate that an appliance is energy efficient

_____

PART TWO: SHORT ANSWER

INSTRUCTIONS: Provide a short written answer to the following questions.

1. Why do we measure energy sources by BTU?

2. What three factors contribute to higher fuel prices?

3. What are the two ways to fill cylinders to capacity? Explain.

4. Why is propane sometimes more convenient to use in rural areas than natural gas?

5. What does an AFUE rating of 70 percent mean?

PART THREE: COMPLETION

INSTRUCTIONS: Provide the word or words to complete the following statements.

1. There are _____ BTU per gallon of propane.

2. A BTU is approximately the amount of heat generated by one _____.

3. If the TW is 18 pounds and the WC converts to 20 pounds of propane, the filler needs to set the scale to _____ pound(s) to fill the bottle to capacity.

4. If propane costs $1.90 per gallon, and your house uses 4,000 BTU per hour, then propane would cost $_____ per year for your house. Show your work.

Interest Approach

STEP 1
Two coins on a cloth

STEP 2
Two flat pieces of metal displayed near the coins on the cloth

STEP 3
"Smelling" the coin and feeling the temperature

STEP 4
Coins placed on top of metal

Propane Cylinder Dimensions

Below are approximate dimensions of common propane cylinders.
Contact your container manufacturer or propane dealer for precise cylinder measurements.

CYLINDER	20#	30#	40#	100#
Capacity	4.7 gal	7.1 gal	9.4 gal	23.6 gal
Weight (empty)	18 lb	24 lb	29 lb	68 lb
Weight (full)	38 lb	54 lb	70 lb	170 lb
Overall Height	18 in	24 in	29 in	48 in
Diameter	12.5 in	12.5 in	12.5 in	12.5 in
BTU Capacity	430,270	649,980	860,542	2,160,509

Cylinder Filling Capacity Chart

W.C.	LBS. PROPANE	W.C.	LBS. PROPANE
2.39	1	35.8	15
4.78	2	38.2	16
7.17	3	40.6	17
9.56	4	43.0	18
11.9	5	45.4	19
14.3	6	47.8	20
16.7	7	59.7	25
19.1	8	71.7	30
21.5	9	78.8	33
23.9	10	83.6	35
26.2	11	95.6	40
28.6	12	105.1	44
31.0	13	119.5	50
33.4	14	239	100

Cost Comparison Charts

FIVE YEAR AVERAGE DATA (2014-2018)

Based on the U.S Energy Information Administration's national five-year average of residential retail prices through 2018.

ENERGY SOURCE	AVERAGE RETAIL PRICE	COST PER MILLION BTU
Electricity	$0.13 per kilowatt-hour	$37.21
Propane	$2.39 per gallon	$33.56
No. 2 Heating Oil	$2.92 per gallon	$27.14
Natural Gas	$10.57 per thousand cu ft.	$13.22

Chart assumes 78% appliance efficiency for all fuels except electric.

COST COMPARISON CHART (2018 PRICES)

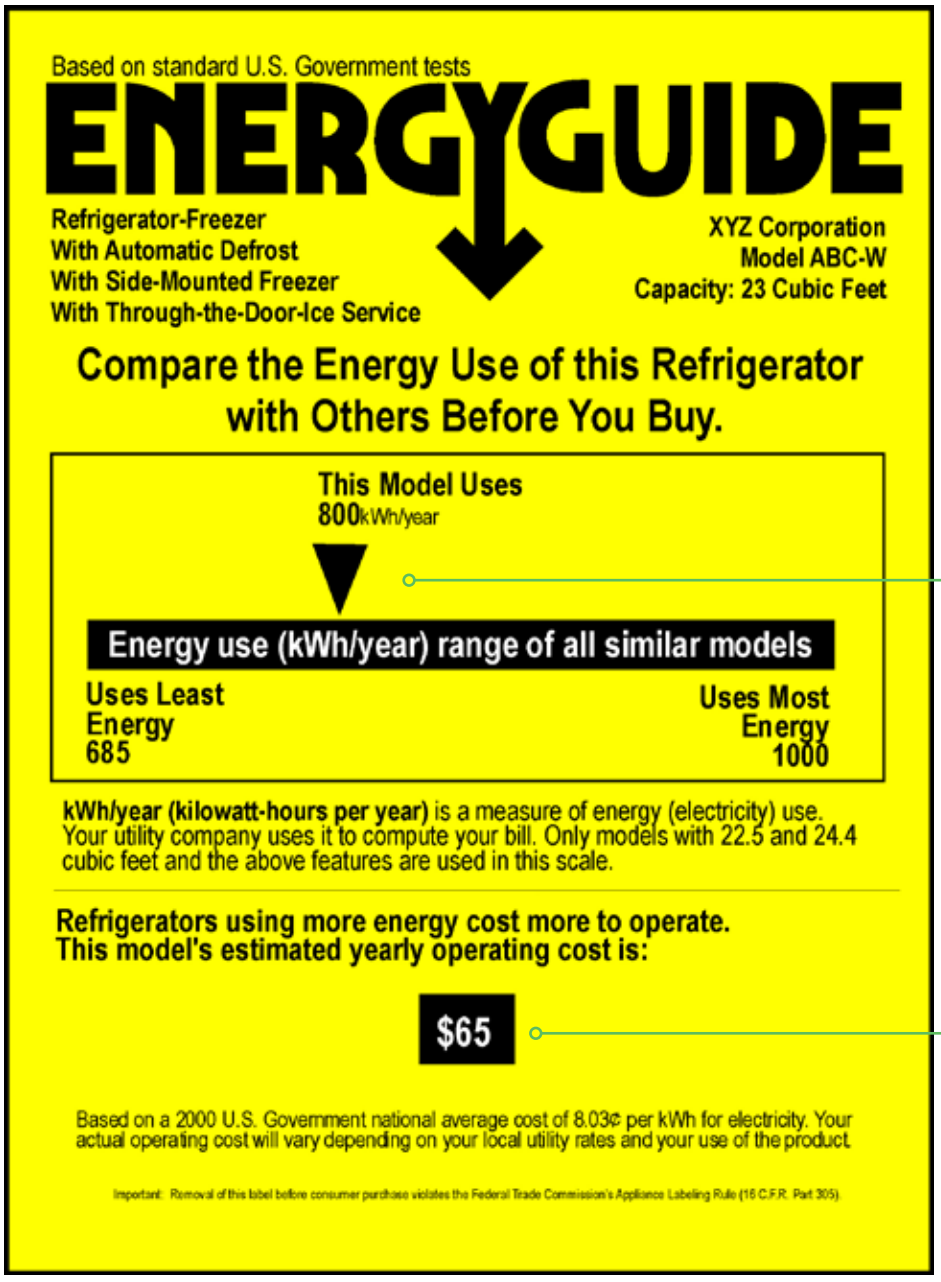
Based on the U.S Energy Information Administration's national average of 2018 residential retail prices.

ENERGY SOURCE	AVERAGE RETAIL PRICE	COST PER MILLION BTU
Electricity	$0.13 per kilowatt-hour	$37.72
Propane	$2.48 per gallon	$34.86
No. 2 Heating Oil	$3.20 per gallon	$29.77
Natural Gas	$10.52 per thousand cu ft.	$13.16

Chart assumes 78% appliance efficiency for all fuels except electric.

How to Read the EnergyGuide Label

The EnergyGuide label gives you two important pieces of information you can use to compare different brands and models when shopping for a new appliance:



Estimated energy consumption on a scale showing a range for similar models

Estimated yearly operating cost based on the national average cost of electricity

NAME: _____

Calculating and Comparing Cost of Energy

PURPOSE

The purpose of this activity is to practice calculations that deal with the measurement and pricing of propane and to make cost comparisons of various energy and fuel sources.

OBJECTIVE

Calculate an estimated annual cost of energy for agricultural operations and consumer appliances.

MATERIALS

- Computer with internet access
- Basic-function calculator

PROCEDURE

1. **APPLICATION PROBLEM**: If propane costs $2.05 per gallon and the average use for your home is 3,000 BTU per hour, how much would propane cost for your home for one year? Propane provides 91,000 BTU per gallon.
2. Visit Propane.Com/For-My-Business/Agriculture/Irrigation-Cost-Calculator/ for the Irrigation Cost Calculator. The calculator allows you to quickly compare the cost of using propane gas to the cost of using other energy sources for irrigation. Experiment with the calculator to see how using propane for irrigation compares with using diesel. Write down which values you entered for each input, as well as your final answers. Do this a total of three times. Enter different values each time so that you will have different results.

ANSWER TO APPLICATION PROBLEM

1. Propane provides 91,000 BTU per gallon, so propane at $2.05 per gallon costs about $0.00002253 per BTU (since $2.05/gal. ÷ 91,000 BTU/gal. = $0.00002253/BTU).
2. The house uses 3,000 BTU per hour, so it uses $0.06759 per hour (since $0.00002253/BTU x 3,000 BTU/hr. = $0.06759/hr.).
3. Thus, the cost to heat the home for one year using propane is $592.09 (since $0.06759/hr. x 24 hr./day x 365 days/yr. = $592.0884/yr.).

You may choose to allow students to write a short report on their procedure and results.