Efficiency: Energy Changes and Waste

C-8

2–3
40- to 50-minute sessions

ACTIVITY OVERVIEW

SUMMARY

Students continue to investigate energy transformations and explore the efficiency of these transformations. This activity explores the watt as a quantitative measure of the rate of energy use. Students measure the efficiency of a flashlight bulb in producing light by measuring how much energy is wasted in producing heat. They also compare the life-cycle costs for an incandescent bulb and a compact fluorescent bulb.

KEY CONCEPTS AND PROCESS SKILLS

The students will:

1. Describe the energy changes occurring in an incandescent light bulb (Understanding Concepts).
2. Identify the watt as a unit of power that measures how fast the energy is used (Understanding Concepts).
3. Assess the efficiency of a flashlight bulb in producing light (Designing and Conducting Investigations).
4. Relate energy transformations to useful energy output and lost energy output (Understanding Concepts).
5. Identify important factors to use when making decisions about purchasing light bulbs (Evidence and Trade-offs).

KEY VOCABULARY

energy efficiency

energy chain

filament

fluorescence

incandescent

MATERIALS AND ADVANCE PREPARATION

For the teacher:

Transparency Master C8.1, "The Laws of Energy"

* 2 incandescent bulbs: one 40 watt and one 75 watt

* 1 socket or lamp fixture for an incandescent bulb

* 1 compact fluorescent bulb in a socket or lamp fixture (optional)

For each group of four students:

1 9-volt battery, with harness and connection clips

1 flashlight bulb of known voltage and amperage rating (#50 bulb supplied), screwed into a metal socket and inserted into a black plastic cover

1 SEPUP tray

1 graduated cylinder

1 thermometer

**Not supplied in kit*

Obtain a 40-watt and a 75-watt light bulb (and optionally a compact fluorescent bulb) and a socket or desk lamp that holds these bulbs. Determine the local cost of electricity in your area in cents per kilowatt-hour (kwh). Find out the purchase price of both a 75-watt light bulb and an 18-watt compact fluorescent bulb. This information will be used for the student reading, "A Cool Energy Decision." If necessary, photocopy the student reading for use as homework.

SAFETY NOTE

The flashlight bulb used in this activity is inserted into a plastic cover to prevent contact between the bulb's metal base and water. Under no circumstances should students attempt to measure the heat production of light bulbs of other sizes by immersing them in water. Emphasize the extreme danger of shock or electrocution associated with such experiments. This experiment avoids those risks because it is conducted using a low-amperage, low-voltage system.

TEACHING SUMMARY

DAY ONE

1. Demonstrate the heat generation of two incandescent light bulbs of different wattage. Introduce the quantitative definition of the watt as a unit of power.
2. Students measure the heat production of a flashlight bulb, and calculate the efficiency of heat production for the bulb.
3. Introduce the concept of *energy efficiency.*

DAY TWO

4. Review the flashlight bulb efficiency calculations and discuss the results.
5. Investigate and discuss “A Cool Energy Decision.”
6. Discuss the laws of energy, using examples from observations in this activity as well as from earlier ones.

BACKGROUND INFORMATION
Efficiency: Energy Changes and Waste

This activity provides students with experiences related to three important energy concepts: energy transformations, the conservation of energy, and the idea that most energy transformations result in a “loss” of some of the energy as heat. This loss of energy may at first glance seem inconsistent with the law of energy conservation. In fact, the energy isn’t destroyed but is instead dissipated as heat that cannot be easily recovered for use.

The percent efficiency of any single energy transformation from one form to another, or a series of energy transformations, is determined by the equation:

$$(1)\quad \%\ \textit{efficiency} = \frac{\textit{useful energy output}}{\textit{energy output}} \times 100$$

where *energy output* refers to total energy, *useful energy output* is the amount of useful or available energy after the transformation(s), and *energy input* is the initial amount of energy being transformed.

The efficiency of many common energy transformations is very low. For example, a typical 40-watt incandescent light bulb is about 11% efficient at changing electrical energy to light energy. A significant amount of the energy output of the light bulb is heat energy, as the students will discover.

In this activity, students measure the efficiency of a flashlight bulb. Students calculate the *percent waste heat* using the following equation:

$$(2)\quad \%\ waste\ heat = \frac{heat\ energy\ output}{energy\ input} \times 100$$

Once you know how much waste heat the bulb produces, you can find the estimated efficiency of light production by subtracting the percent waste heat from 100%. The efficiency of energy transformed into useful light cannot be higher than the result of this calculation, and will be actually lower due to other small losses.

Both the heat energy output and the energy input are measured in calories. The heat energy output can be measured by the bulb's capacity to heat water. This allows students to use the same relationship developed in the calorimetry experiment in Activity C-3.

Students determine the heat energy output of their flashlight bulb using the following equation:

(3) heat energy output (in calories) = (vol. of water (mL) × (temperature change (°C))

Calculating the energy input to use in equation (2) involves a few steps. First, measure the electrical energy used (that is, the energy input) in watt-hours. If the appliance (hot plate, immersion heater, light bulb) has a power rating given in watts, use the following equation to calculate watt-hours:

(4) energy input = electricity used (in watt-hours) =
(power rating, in watts) × (time of operation, in hours)

If no power rating is available, use the standard relationship between volts and amperes and the labeled values that appear on the appliances to calculate the power in watts, as follows:

(5) volts × amperes = watts

Then use equation (4) to calculate the electricity used.
Next, convert the electricity measured in units of watt-hours to the unit of calories. Use the conversion factor of (860 calories/watt-hour). Thus,

(6) energy input (in calories) = watts × (hrs. of operation) × 860

For the #50 flashlight bulb used in the activity, the average power rating is 1.87 watts (8.5 volts × 0.22 mA) when used with one 9-volt battery. If the bulb is on for 3 minutes, the total electricity used (energy input) in calories is calculated by the equation:

energy input =

$$(1.87 \text{ watts}) \times \left(\frac{3}{60}\right) \times \left(\frac{860 \text{ calories}}{\text{watt-hour}}\right) = 82 \text{ calories}$$

This is the energy input value, which appears in the data table for heat efficiency of a flashlight bulb (see the Student Book, page C-65). Provide this energy input value for the students, or tell them the rating of the flashlight bulb is 1.87 watts and let them calculate the value.

NOTE: If you use a different size flashlight bulb, use the specific watt rating for that bulb to calculate the energy input value.

TEACHING SUGGESTIONS

■ DAY ONE

1. Demonstrating the heat generation of light bulbs and introducing the quantitative definition of watts

Introduce the lesson by reinforcing the concept of energy transfer that was developed in earlier activities. Remind students of the various energy transformations they participated in, including the conversion of potential energy to kinetic energy in the "Drive a Nail" activity (C-1), the conversion of chemical energy to light and heat energy in the calorimetry activity (C-3), and their work with batteries as chemical-to-energy converters (C-4).

Tell students we will now look at two common light bulbs and see what we can learn about their energy efficiency. Do not mention the power ratings of the bulbs, however. Using any standard desk lamp, table lamp, or socket, place the 40-watt light bulb into the socket. Now turn the bulb on, and ask, ***What kinds of energy are being produced?*** Student responses will certainly mention the light and probably the heat produced. If not, bring up light and heat and ask, ***How could we compare the amount of each kind of energy produced?*** After trying out student suggestions, have a student hold a thermometer two or three centimeters from the illuminated 40-watt bulb for one minute and make observations of any temperature change. The class should write the observations in their science notebooks. Now, repeat the demonstration using the 75-watt bulb, and again measure the temperature change after one minute. A temperature increase of approximately 5°C is typical for the 40-watt bulb, while a 10°C increase is typical for the 75-watt bulb. Have students also observe and comment on the brightness of each bulb. Reducing the room light and using the bulb and lamp assembly to illuminate a piece of paper or another object will help students see the difference in the amount of light produced by the two bulbs.

This demonstration suggests that the incandescent light bulb is a good source of heat energy in addition to light. Mention to students that architects use the fact that lights (both incandescent and, to a much lesser degree, fluorescent lights) also create heat. They now design new office buildings to get some of their space heating requirements from the lights in the building.

Ask students to list factors that may explain why one bulb produced more heat than the other bulb. They may suggest that one bulb uses more electricity and produces more energy than the other. Tell them that watts are a measure of power, which is how much energy (in the form of electricity) the bulb uses over a certain amount of time. The 75-watt bulb uses more energy than the 40-watt bulb (almost twice as much) over the same time period. Reinforce the following statements:

- Watts are a unit of power.
- The watt measures how much energy is used over a period of time.

Finally, relate the *calorie,* the unit of energy students used in previous activities, to the watt, by adding the following to the board or overhead:

860 calories per hour = 1 watt

2. Measuring heat production of a flashlight bulb

We can compare how much useful energy output we get from a light bulb with the energy input or energy used by the bulb. This comparison is called *efficiency* and tells us how "good" the light is at being a light! Reinforce the idea of efficiency by asking, ***If the light bulb were perfect at being a light, what percentage of the energy input would wind up as useful energy output, or light energy?*** The answer, of course, is 100%, or all of it. Ask, ***If the light bulb is less than 100% efficient, what happens to the rest of the energy?*** It is turned into heat; for our purposes, it is wasted. Explain that the goal of the students investigation is to measure the relative amount of useful energy produced by a small flashlight bulb and to use this measurement to determine the efficiency of the bulb.

Now tell students that it is easier to measure the heat energy produced by a light bulb by using water to collect the energy (just as the energy of the peanut was collected in the calorimetry experiments) than it is to directly measure the light bulb's light energy. Therefore, our experiment will measure the *heat* energy produced by the light bulb.

Make sure students realize that if they know the amount of energy lost (in this case heat) and the total amount of electrical energy input, they can find the useful energy output, which in this case is the light energy of the bulb.

Tell students we will measure how much heat a bulb produces in a specific amount of time, and then compare it with how much electrical energy was used during that same time period. The difference between the amount of heat energy produced and the total energy provided is a measure of the light energy obtained. Comparing the light energy obtained to the total energy provided will give us the efficiency of the bulb in producing light.

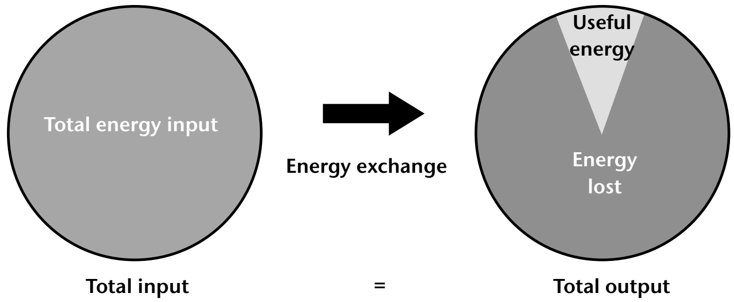
NOTE: This activity requires many student calculations to determine *percent efficiency*. Typical early secondary classes may have difficulty with all the arithmetic. We suggest providing the appropriate energy input value for the class to use in calculating the percent efficiency. High-ability groups could be asked to calculate the energy input. The energy input value used in the efficiency calculation is constant for any specific experiment and only depends on two factors: how long the bulb is on (specifically stated in the procedure), and the power rating, in watts, of the bulb.

Distribute the equipment and have students follow the directions in the "Hot Bulbs" activity on pages C-63 through C-65 of the Student Book. Students work in groups to conduct the experiment.

As students finish, help them with the calculations (see Background Information for details). Students will typically obtain a temperature change of 4°C to 5°C within 3 minutes.

3. Introducing the concept of energy efficiency

Begin the discussion on efficiency by asking students: ***What is the energy source or energy input for the light bulbs we just tested?*** Chemical energy from the battery is changed into electrical energy to power the light bulb. If we put a dollar's worth of energy into a light bulb, we get about a dollar's worth of energy out—but the problem is that some energy is available as light energy, and the other energy, as heat.We define *efficiency* in terms of how much useful energy we get out relative to the total amount of energy we put in. For example, if we put in a dollar's worth of energy, and only get 30 cents worth of light energy, then we might say the bulb is 30% efficient.



Ask students to examine the graphs on page C-66 of the Student Book. Summarize the results of the discussion, including these points:

- Energy input either becomes useful energy output or lost energy.
- If we want to use energy wisely, we should try to make the useful energy output as great as possible and the lost or wasted energy as small as possible.

Efficiency compares the useful energy output with the energy input. The equation for efficiency is:

$$\%\ \text{waste heat} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$$

Again refer to the pie graphs and energy relationships explored during this class to identify the components (useful energy output, energy input) of the efficiency equation. Help students understand the equation by asking***, What would the percent efficiency (that is, the percent waste heat) be if the useful energy output was 10 calories, and we had an energy input of 10 calories also?*** Have students use the equation, substitute the numbers, and come up with the answer. Tell students that, in fact, 100% efficiency is not possible in changing energy from one form to another. Most of the time efficiency is much less than 100%.

The table below (from page C-66 in the Student Book) provides some typical efficiency values for a

Some Typical Energy Efficiencies

Device	% Efficiency	% Waste Heat
Fluorescent light (20-watt, 24-inch)	50	50
Incandescent light (40-watt)	11	89
Auto engine (gas)	30	70
Auto engine (diesel)	35	65
Coal power plant	38	62
Nuclear power plant	31	69
High-efficiency gas furnace	90	10
Typical gas furnace	75	25
Typical oil furnace	63	37

variety of devices. In some cases, these represent a single energy transformation (for example, fluorescent or incandescent bulbs), while other values are the result of several energy transformations (for example, the generation of electricity in coal or nuclear power plants). Note the large amount of waste heat produced in many devices. As an extension, students can draw pie graphs using the data from the table.

■ DAY TWO

4. Reviewing flashlight bulb efficiency calculations and discussing results

Student results for the investigation will vary depending on battery condition and experimental technique. Here are some typical answers for the "Hot Bulbs" activity questions on page C-66 of the Student Book:

Question 1: What was the percentage of waste heat energy produced by your flashlight bulb? What do your results tell you about how efficiently these bulbs produce heat? Produce light?

The heat production for flashlight bulbs typically will vary widely. Students should report their experimental results. They should conclude that these bulbs produce considerable heat and the remainder (using the pie graph concept) is light energy.

NOTE: Some students might have the misconception that the light coming from the flashlight bulb "heated up" the water. To demonstrate that this is not the case, you might suggest another experiment, using the same bulb but painting it with black paint. In this case, much less light is visible, yet the water still warms up.

Question 2: Why should you use a control cup (in this experiment Cup B)? What did you place in the control cup, and what measurements did you take? Explain.

The control cup should contain 12 mL of water. Take initial and final temperature readings for the water. This will show that the observed change in temperature of the water in Cup A was due to the lighted flashlight bulb and not any other factor. Some students may suggest that as a better control setup, you should also leave the light bulb assembly in Cup B off over the 3-minute time period. Other students may suggest moving the control down to Cup C or D to minimize any heat energy transfer from Cup A.

Question 3: A typical light bulb is nearly 90% efficient at producing heat energy. Does your answer agree with the 90% figure? Why not? What problems did you have? What would you do differently?

Some statement of experimental errors should be made at this time. Some parts of the light bulb that were heating up were not surrounded by water, and thus some of the heat was not measured. Students might notice that the battery or the wire contacts were becoming slightly warm, another indication of heat production that was not measured in the experimental setup.

Determine the class result by finding the average of all group values for percent efficiency. Redraw the energy pie graph relationships, using the class result. The "% waste heat" should be labeled as the "Energy Lost" slice of the graph with the other section of the pie graph labeled as "Useful Energy Output." Adjust the size of each slice to reflect the class result.

Ask students if they think their class value for the percent heat efficiency is too high or too low compared with the "real" value? Students should be able to conclude that the heat measured by this experiment is underestimated, by relating their results to the results of the previous calorimetry experiment where some heat was also lost to the environment. Heat loss in the wires and other connections that carry the electricity to the bulb also contributes to the low experimental result.

Tell students the actual *light* production efficiency for a 40-watt incandescent light bulb is about 11%. This means that the flashlight bulb the students used, like the larger incandescent light bulb, is far more efficient at producing heat energy than in producing what we want: light energy.

5. Investigating and discussing "A Cool Energy Decision"

Ask students to investigate and discuss in groups "A Cool Energy Decision" on pages C-67 to C-70 of the Student Book. Provide the information students need to answer the questions that appear on pages C-69 and C-70. You will need to provide the local price of a 75-watt incandescent light bulb and an 18-watt compact fluorescent bulb, as well as the local cost of electricity in cents per kwh. Students should fill in the prices that you provide in their science notebooks.

This reading focuses on the concept of a life-cycle cost for an incandescent bulb vs. the same cost for a compact fluorescent bulb. (You may want to show or demonstrate a compact fluorescent bulb. See the Extensions at the end of this chapter.) While most consumers still make their purchase decisions based on initial cost of the item, the reading illustrates that there are other factors to include in this energy decision. In order to effectively compare the costs of the two bulbs, students need to have some understanding of how they pay for electrical energy.

If necessary, tell students that they can usually find the power rating in watts of any light bulb (it is usually stamped on the top of the bulb), and if they know how long the bulb was turned on, they can determine how much electrical energy was used. Explain that the right units have to be chosen for this relationship to work. The time must be in hours, and the power in *watts.*

Since the unit commonly used to measure electricity is the kilowatt-hour, abbreviated *kwh,* the power value should be expressed in *kilowatts*. Explain to students that dividing the watts by 1,000 changes the value to kilowatts.

Cite electric bills as an example of the use of kilowatt-hours. Mention that the electricity could also be measured in calories, as we did in this experiment, but that it is most often measured in kilowatt-hours. (The relationship between calories and kilowatt-hours is 860,000 calories = 1 kilowatt-hour, but this is not important for students to know.)

Use two examples for students: the 40-watt bulb and the 75-watt bulb tested in the demonstrations. To make the calculations easier, assume we had each light on all day for 10 hours.

To calculate the electricity used by the 40-watt light bulb, use this equation:

$$\text{40-watts} \times \text{10 hours} = \frac{\text{400 watt-hours}}{\text{1,000}} = \text{0.4 kilowatt-hours}$$

To calculate the electricity used by the 75-watt light bulb, use this equation:

$$\text{75-watts} \times \text{10 hours} = \frac{\text{750 watt-hours}}{\text{1,000}} = \text{0.75 kilowatt-hours}$$

Help students interpret these two numbers by noting that the 75-watt bulb transformed almost twice as much electricity as the 40-watt light bulb: 0.75 kwh compared with 0.4 kwh. That's why the temperature increase next to the 75-watt bulb was greater than that next to the 40-watt bulb.

Ask, ***Does anyone know how much money this amount of electricity would cost? How could we find out?*** Explain that if we knew the cost of electricity, we could find out how much money it would cost to operate both bulbs for 10 hours. Ask students if they can suggest how that could be calculated. Develop the relationship:

total cost of electricity = (energy in kilowatt-hours) × (electricity cost for each kilowatt hour)

Finish the two examples by calculating the electricity cost for a 40-watt and a 75-watt bulb used for 10 hours. Students should record the arithmetic calculations in their science notebooks.

40-watt light bulb (run for 10 hours):

total cost of electricity = 0.4 kilowatt-hours × (local cost of electricity)

75-watt light bulb (run for 10 hours):

total cost of electricity = 0.75 kilowatt-hours × (local cost of electricity)

If electricity costs 10 cents per kilowatt-hour, a 40-watt bulb costs 4 cents, while the 75-watt bulb costs 7.5 cents to operate for 10 hours. Go through additional examples, as necessary, to reinforce these concepts.

NOTE: Some students will have difficulty with the calculations in this exercise. You may need to discuss how to set up the calculations necessary to answer several of the questions.

The following are possible student responses to the questions on pages C-69 to C-70.

Question 1: Compare the cost of buying a 75-watt incandescent light bulb and an 18-watt compact fluorescent bulb. (Both bulbs provide about the same amount of light.) Based on this information, what decision would you make when replacing a burned out 75-watt light bulb? Would you buy a compact fluorescent light bulb or an incandescent one? Explain your choice.

People often make decisions about what item to buy based on the initial cost of the item. In this case, the compact fluorescent bulb costs so much more than the incandescent bulb that students will probably decide to buy the cheaper incandescent light bulb to save money.

Question 2: Now compare the average lifetime for each type of light bulb. One compact fluorescent bulb lasts as long as how many incandescent bulbs? Using this information, what energy decision would you now make? (Hint: Find out the total cost of these incandescent bulbs compared to the cost of one compact fluorescent.) Explain your decision.

The table on page C-69 indicates that a compact fluorescent light bulb lasts 10 times as long as an incandescent bulb. Students should multiply the cost of one incandescent bulb times 10 to compare the total purchase price for equivalent lifetimes of the two bulbs. The incandescent bulb will still appear to be a better value.

Question 3: Now let's look at another factor. Let's compare the amount of electricity both bulbs use in a specific amount of time. Use 7,500 hours (the lifetime of one compact fluorescent bulb) as the specified time.

a. *How many watt-hours of electricity would one compact fluorescent bulb use over its lifetime of 7,500 hours?*

b. *How many watt-hours of electricity would an equivalent number of incandescent light bulbs use over 7,500 hours?*

To calculate watt-hours of electricity, use the equation:

watts × time = watt-hours of electricity

For the 18-watt compact fluorescent bulb:

18 watts × 7,500 hours = 135,000 watt-hours of electricity

For the 75-watt incandescent bulb:

75 watts × 7,500 hours = 562,500 watt-hours of electricity

c. *Electricity is usually charged by the kilowatt-hour of use. Change your results in watt-hours to kilowatt-hours by dividing by 1,000.*

The results should be 135 kwh for the compact fluorescent bulb and 562.5 kwh for the incandescent bulb.

Question 4: Your teacher will tell you the cost of electricity in your area. Write it in your science notebook.

a. *What will be the total cost of electricity for the incandescent light bulbs?*

b. *What will be the total cost of electricity for the compact fluorescent bulb?*

Multiply the kilowatt-hours of electricity for each bulb times the local cost of electricity. The equation for the incandescent bulb is:

562.5 kwh × $.10/kwh = $56.25 of electricity

For example, if electricity costs $.10 per kwh, the equation for the compact fluorescent bulb is:

135 kwh × $.10/kwh = $13.50 of electricity

Thus, when you consider the cost of electricity for the two bulb types over a comparable time period, the compact fluorescent bulb is much more efficient.

Question 5: Find the total expense for using each type of bulb. Add together the cost of the bulb(s) and the cost of the electricity. Using all this information, which bulb is a better buy? Use your calculations to explain your decision.

Generally, the total expense for a compact fluorescent light bulb is about 40% of the total expense for 10 incandescent bulbs. This will vary depending on local purchase prices for each type of bulb. Students should be able to show the calculations that led them to their conclusion.

Question 6: What additional information would you like to know before making a final decision about which bulb to buy?

Here students may indicate the location of the bulb and type of light that they prefer, availability of the right type of fixture to be able to use a compact fluorescent, ease of maintenance for the compact fluorescent, or disposal problems related to the mercury content of the fluorescent bulb.

Question 7: Which bulb do you think most people buy when they go into a store? Why? If you were a manufacturer of compact fluorescent bulbs, what would you do to get people to buy your bulbs?

Most people buy such items based on price alone. They are unwilling (or unable) to spend the considerably greater amount of money initially required to save money over the longer time period. As a manufacturer of compact fluorescent bulbs, you could advertise their long-term savings and try to get the government or utility company to subsidize their purchase.

Discuss whether individuals in the class would want to use compact fluorescent bulbs in their homes. What would be the advantages and disadvantages of these bulbs? What factors might be most important in deciding?

6. Discussing the laws of energy

As closure for this activity, ask students what they have learned about energy. Typical answers might include, "There's a lot of energy wasted," or "Energy can change forms, but you lose some when it does." Tell students that for many years, scientists observed energy transformations and developed laws that describe these transformations. These are called the *laws of thermodynamics*, or, simply, the *laws of energy*. Using Transparency Master C8.1, discuss each of these with examples as indicated.

The Laws of Energy (The Rules of the Energy Game)

The First Law of Energy: Energy cannot be created or destroyed except in nuclear reactions.

The First Law of Energy is also called the *law of conservation of energy*. It is a difficult concept for early secondary students. You could explain it by saying that in studying falling objects, chemical changes, and changes in temperature in living and non-living systems, scientists have observed many transformations of energy from one form to another, but they have never been able to detect energy being created or destroyed. In nuclear interactions, such as the generation of power by a nuclear reactor, energy is created from matter.

To help students understand this concept, ask them, ***If you had a dollar bill and needed change to play a video game, would you ever expect to get five quarters for your dollar bill from a clerk?*** You can't get more out of this transformation (output) than you put into it (input). In explaining this concept, you might also want to use the popular paraphrase of the first law, which is: *You can't get something for nothing.*

Energy transformations are just like getting change. You won't get more out than you put in.

Ask, ***From our observations and discussions in this activity, would we ever get more useful energy output than the energy input we started with?*** The best we can do is 100% efficiency. The first law gives us the limits of what we can expect when energy transformations occur: we can never do more than "break even."

If energy is not created or destroyed, can we ever run out of energy? This brings us to the next point.

The Second Law of Energy: Energy can change form. When it does, some energy is lost or becomes unavailable for our future use.

The Second Law of Energy tells us that energy transformations never (or almost never) "break even." Whenever energy changes from one form to another, some of the energy—often as waste heat energy—is "lost" for future use. This lost energy is not destroyed but is often dissipated in the form of heat that becomes unavailable. The popular paraphrase of the second law is: *You can't break even.*

Ask students, ***What does the second law predict about the amount of light energy we obtained from our flashlight bulb?*** It will be less than the energy input or the electricity used. ***What happens to the "lost" energy?*** As heat energy, it spreads out into the room or is stored in the water. You could also use the exchange of U.S. dollars into foreign currency as a concrete analogy for the second law. Changing U.S. dollars into Canadian dollars or Mexican pesos results in getting slightly less money than you initially had because the bank or currency exchange charges a fee (keeps some of the money) for their service. Even in this "transformation" you can't break even!

These two laws of energy summarize what we know about energy and reinforce what we have discovered about energy transformations and efficiency in this activity.

EXTENSIONS

There are several optional exercises you may wish to try, depending on time.

- Show a compact fluorescent bulb and make the same set of observations (temperature change, etc.) as were made earlier with the incandescent lights. You may want to use a size of compact fluorescent that is equivalent in illumination to the incandescent light you used in the previous demonstration. For example, an 18-watt compact fluorescent bulb provides about the same illumination as a 75-watt incandescent bulb. The temperature increase over one minute for a thermometer placed about 2 cm or 3 cm from the compact fluorescent bulb should be considerably less than the temperature increase for the incandescent bulb. The fluorescent is more efficient at light production, as indicated in the table on page C-66 of the Student Book.
- Computer temperature probes can be used to measure and graph the temperature changes associated with incandescent light bulbs of various power (watt) ratings, as well as the compact fluorescent bulb. Light meters can also be used to make quantitative comparisons among bulbs.
- Students can write and illustrate their own energy ads for compact fluorescent bulbs. They can obtain and discuss current advertisements for various light bulbs appearing in newspapers and magazines, identifying the advantages highlighted in each ad.
- The waste heat produced by an electric immersion heater (used to heat one cup of water for coffee or tea), or the efficiency of heating water on a hot plate can be measured using a similar procedure. Have students suggest the procedure. In each case, the useful energy output is calculated by using the temperature change of a known amount of water. The energy input is calculated using the power rating of the appliance and the time of its operation. Discuss the efficiency of each appliance, and how the efficiency could be improved.

NOTE: Do not let the water come to a boil when using either the immersion heater or electric hot plate. If this happens, some of the electrical energy will be used to change water into steam, and will not continue to increase the temperature of the water. This, in turn, will make the efficiency calculation wrong. Ideally, you want to produce some measurable temperature change (5 degrees or more) in the water without having it come to a boil during the experiment.

The Laws of Energy
(The Rules of the Energy Game)

FIRST LAW

Energy cannot be created or destroyed (except in nuclear reactions).

You can't get something for nothing.

SECOND LAW

Energy can change form. When it does, some energy is lost or becomes unavailable for our future use.

You can't break even.

8 Efficiency: Energy Changes and Waste

Hot Bulbs

In this activity you will calculate how efficiently a flashlight bulb produces light energy. The more efficiently the bulb produces light energy, the less wasted energy it produces in the form of heat. Be sure to record and label all measurements and calculations in your science notebook. A chart similar to the one on page C-65 will help you keep organized.

How good is a flashlight bulb as a heater? Do the activity to find out!

MATERIALS

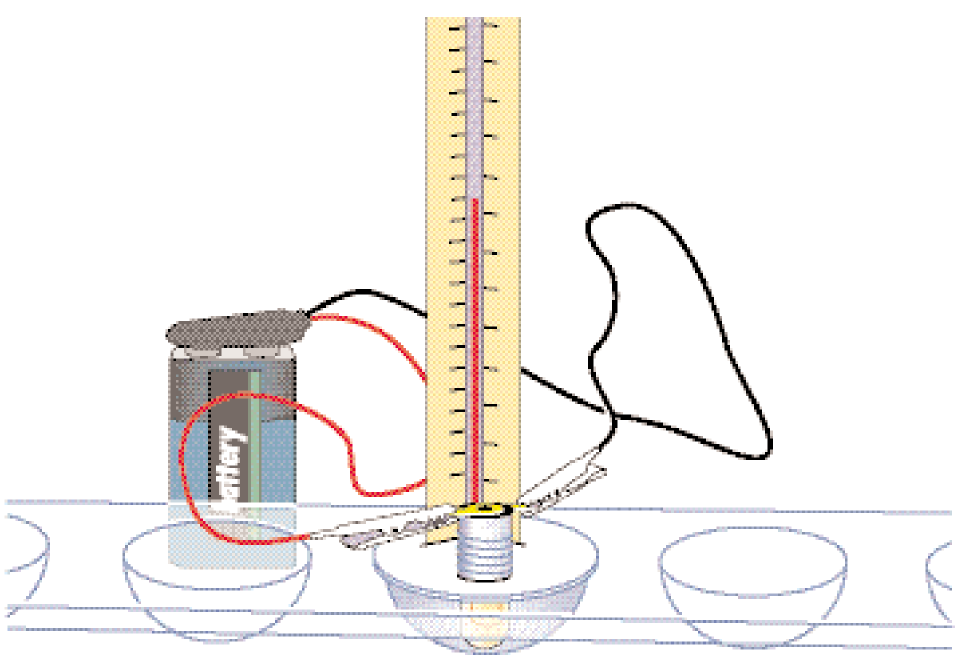
For each group of four students:

1 **9-volt battery, with harness and connection clips**
1 **flashlight bulb with socket and white plastic cover**
1 **SEPUP tray**
1 **graduated cylinder**
1 **thermometer**

SAFETY NOTE: Do not try this investigation with any other kind of battery without consulting your teacher. Never, under any circumstances, place plugged-in electrical appliances in or near water.

PROCEDURE

1. Using the graduated cylinder, carefully measure 12 mL of water into Cup A of the SEPUP tray. Measure the initial temperature of the water and record it in your science notebook.
2. Use Cup B as a control for this experiment. Decide in your group what should be placed in Cup B and what measurements should be taken for the control.
3. Insert the flashlight bulb into the white plastic cover. Be sure that the concave side of the plastic cover faces up and the bulb faces down. Screw the brass socket onto the bulb. Insert the thermometer into the plastic cover as shown.
4. Connect the 9-volt battery to the socket, using the connectors provided. Place the lighted bulb into the water in Cup A for exactly 3 minutes. Time this as precisely as you can.
5. After 3 minutes, remove the bulb from the cup. Measure the final temperature of the water and record it.



ANALYSIS

1. Calculate the temperature change of the water (final temperature minus the initial temperature).

2. Calculate the heat energy output of the flashlight bulb (in calories) using the equation:

   heat energy output (in calories) = volume of water × temperature change

3. Using the given energy input of 82 calories in 3 minutes, calculate the waste heat production of the flashlight bulb using the equation:

   % waste heat = (heat energy output / energy input) × 100

   Record and label the calculation in your science notebook.

4. Now use the heat efficiency calculation you just made to state the light bulb's light efficiency.

Heat Efficiency of a Flashlight Bulb

Measurements and Calculations	Experiment Cup A	Control Cup B
Volume of water (mL)	12 mL	
Initial temperature (°C)		
Final temperature (°C)		
Temperature change (°C)		
Time bulb was on	3 minutes	0 minutes
Heat output of bulb		
Energy input to bulb	82 calories	
% waste heat produced by bulb		
% light efficiency of bulb		

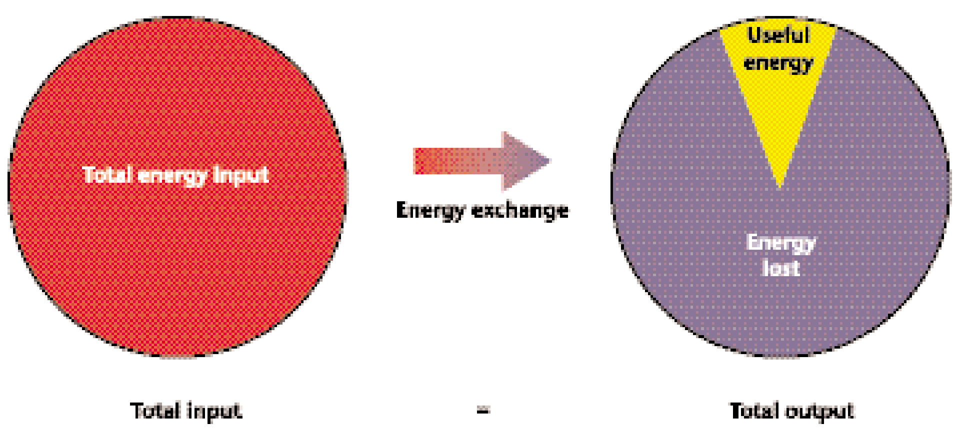
QUESTIONS

1. What was the percentage of waste heat energy produced by your flashlight bulb? What do your results tell you about how efficiently these bulbs produce heat energy? Produce light?

2. Why should you use a control cup (in this experiment Cup B)? What did you place in the control cup, and what measurements did you take? Explain.

3. A typical light bulb is nearly 90% efficient at producing heat energy. Does your answer agree with the 90% figure? Why not? What problems did you have? What would you do differently?

The pie chart below shows the efficiency of a light bulb. The table gives the efficiencies of other devices.



Device	% Efficiency	% Waste Heat
Fluorescent light (20-watt, 24-inch)	50	50
Incandescent light (40-watt)	11	89
Auto engine (gas)	30	70
Auto engine (diesel)	35	65
Coal power plant	38	62
Nuclear power plant	31	69
High-efficiency gas furnace	90	10
Typical gas furnace	75	25
Typical oil furnace	63	37