14 Hot Bulbs

LABORATORY

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students apply their understanding of the concepts of energy transfer and transformation to compare the efficiencies of two different types of light bulbs. They do so by measuring the amount of thermal energy produced by the two bulbs, applying the law of conservation of energy, and calculating how much of the electrical energy supplied was converted into light energy.

NGSS CORRELATIONS

Performance Expectations

Applying MS-PS3-4: Plan an investigation to determine the relationship among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

Applying MS-PS3-5: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Disciplinary Core Ideas

MS-PS3.A Definitions of Energy:

Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.

MS-PS3.B Conservation of Energy:

The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.

Science and Engineering Practices

Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

Planning and Carrying Out Investigations: Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of the investigation.

Crosscutting Concepts

Energy and Matter: The transfer of energy can be tracked as energy flows through a designed or natural system.

Connections to Nature of Science: Science Addresses Questions About the Natural and Material World: Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Common Core State Standards—Mathematics

MP.2: Reason abstractly and quantitatively.

6.EE.A.2: Write, read, and evaluate expressions in which letters stand for numbers.

Common Core State Standards—ELA/Literacy

RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

WHAT STUDENTS DO

Students compare the amount of thermal energy transferred by a small incandescent bulb and an LED. They use their measurements to calculate the efficiency of the bulbs to produce light by measuring how much "wasted" energy is "lost" in the unwanted production of thermal energy. They also compare "lifetime" costs for different types of bulbs. Finally, students consider the trade-offs involved when deciding which type of bulb to purchase.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*

  1 Scoring Guide: EVIDENCE AND TRADE-OFFS (E&T)

- *For each group of four students*

  1 9-volt battery harness with an LED and an incandescent bulb
  * 1 9-volt battery
  2 bulb socket and thermometer holders
  2 hot bulb trays
  1 graduated cylinder (10-mL)
  2 metal-backed thermometers
  1 timer
  * access to water

- *For each student*

  1 Scoring Guide: EVIDENCE AND TRADE-OFFS (E&T) (optional)

**not included in kit*

Obtain eight 9-volt batteries for the activity. It is recommended that you fully assemble the battery harness and bulb setups by inserting each bulb through the round hole in each bulb socket and thermometer holder. Ensure that the incandescent bulb is securely screwed into its socket. Make sure you have a supply of room-temperature water available for students to use. Tap water is often colder than room temperature, and its use will cause the data collected to be inaccurate.

SAFETY NOTE

This experiment avoids risks associated with water and electricity by using a low-amperage, low-voltage system. In addition, the insulating-foam covers also serve to prevent metal parts of the bulbs from contact with water.

Under no circumstances should students attempt to measure the heat production of 120-volt "house-current" light bulbs by immersing them in water. Emphasize the extreme danger of shock or electrocution associated with such experiments.

TEACHING SUMMARY

GET STARTED

1. The class discusses energy efficiency in relation to light bulbs.

   a. Use the scenario in the introduction to begin a discussion of energy transformations in light bulbs.

b. Introduce ways of describing the brightness and energy consumption of light bulbs.

c. Discuss the efficiency of light bulbs.

d. Discuss how to measure the efficiency of a light bulb.

DO THE ACTIVITY

2. Students measure the amount of thermal energy emitted by a light bulb.

   a. Introduce the experimental process used in the activity.

   b. Facilitate the completion of Parts A and B of the Procedure.

3. Students calculate the light efficiency of the bulbs.

   a. Assist students with the energy calculations as needed.

   b. Have students calculate how much of the energy was "wasted" as thermal energy.

   c. Use the law of conservation of energy to calculate the amount of light energy emitted by the light bulb.

   d. Assist students with the efficiency calculations as needed.

BUILD UNDERSTANDING

4. The class reviews results and the concept of energy efficiency.

   a. Have each student group report its experimental results.

   b. Compare the energy efficiencies of the two bulbs.

5. Assign and then review the Analysis items.

   a. Analyze why experimental efficiencies are higher than actual efficiencies.

   b. Relate results of this activity to designing energy-efficient homes.

   c. (E&T ASSESSMENT) Compare the trade-offs between using several different types of light bulbs.

TEACHING STEPS

GET STARTED

1. The class discusses energy efficiency in relation to light bulbs.

   a. Use the scenario in the introduction to begin a discussion of energy transformations in light bulbs.

   Allow students time to read the scenario in the introduction. Ask if anyone in the class has had a similar experience of feeling heat when touching or being close to a light bulb. Follow up by asking what type of energy is supplied to a bulb (electrical) and what type of energy is desired from a light bulb (light energy). Point out that if the bulb is hot, some of the electrical energy supplied to the bulb must have been transformed into something other than visible light.

b. Introduce ways of describing the brightness and energy consumption of light bulbs.

Ask students if all light bulbs produce the same amount of light or if some are dimmer than others. Allow students to share their thoughts. Tell them that two pieces of information are usually associated with a light bulb. They are the power that it uses (the rate at which it uses electrical energy) and the amount of light (brightness) provided by the bulb. Explain that power is the rate at which the light bulb transforms electrical energy and is usually measured in watts (W). Brightness is usually measured in lumens. Point out that typical bulbs found in a home may range from 10 to 100 W and 400 to 1,600 lumens, depending on the type of bulb. Encourage students to check the range of bulbs that they have at home.

c. Discuss the efficiency of light bulbs.

Refer students back to the introduction, and ask, "Are light bulbs 100% efficient?" Emphasize that the light efficiency of a light bulb is a ratio of the amount of useful energy (visible light) we get from it to the amount of electrical energy put into it. Students should be able to state that the bulb in the introduction was not 100% efficient, as some of the energy supplied to the bulb must have ended up as thermal energy.

d. Discuss how to measure the efficiency of a light bulb.

Pose the question, "How efficient do you think light bulbs are?" Allow students to suggest answers before following up by asking, "How do you think we could measure the efficiency of a light bulb?" Allow groups a few minutes to discuss this, and select a few groups to share their ideas. Make sure that students come to the conclusion that if they know how much energy is supplied, and they compare it to how much energy is transformed to useful energy (light) or wasted energy (thermal energy), they should be able to calculate the efficiency. Remind students that they already know how to measure thermal energy since they did this in the activity "Thermal Energy Storage." Explain that the goal of the investigation is for students to measure the amount of thermal energy produced by an incandescent bulb and an LED (light emitting diode) and use this measurement to determine the efficiency of the bulbs.

DO THE ACTIVITY

2. Students measure the amount of thermal energy emitted by a light bulb.

   a. Introduce the experimental process used in the activity.

   Ask students, "Which do you think will more accurately measure the thermal energy produced—submerging a light bulb in water or holding a thermometer next to the bulb?" Point out that a thermometer held in the air will only receive a small portion of the thermal energy being released from all portions of the bulb and that the water will collect the energy that comes from all sides of the bulb. Therefore, our experiment will measure the thermal energy produced by the light bulb by measuring the temperature change of the water. If appropriate, review the relationship between temperature and thermal energy, and review the joule as a unit for measuring energy.

   b. Facilitate the completion of Parts A and B of the Procedure.

   Distribute the equipment to each group, and point out the location of the room-temperature water. Emphasize that there are two light bulb setups: one using an incandescent bulb and the other using an LED. Explain that groups are going to compare the efficiency of the two bulbs at producing light. Demonstrate how to connect the bulbs to the battery.

   Have students work in groups of four to conduct Parts A and B of the experiment. Circulate between groups to check on their progress and provide guidance and assistance when needed.

   Student results may vary considerably, depending on the "freshness" of the batteries. A sample data table is shown below.

LIGHT BULB DATA

Bulb	Water volume (mL)	Time (min)	Initial temperature (°C)	Final temperature (°C)	Temperature change (°C)
Incandescent	*9*	*3*	*23*	*30.5*	*7.5*
LED	*9*	*3*	*23*	*23*	*0*

3. Students calculate the light efficiency of the bulbs.

   a. Assist students with the energy calculations as needed.

   Part C of the Procedure requires students to calculate the efficiency of the bulbs using various equations. Depending on the mathematical proficiency of your students, you may choose to model one or more of the calculations before students do these steps. Alternatively, you can review these calculations after students have finished.

First have students calculate the amount of electrical energy that was supplied to the light bulb.

PROCEDURE STEP 12 SAMPLE STUDENT RESPONSE (INCANDESCENT BULB)

electrical energy supplied (joules) =
time bulb is lit (min) × number of joules/min

= 3 × 114

= 342 joules

b. Have students calculate how much of the energy was "wasted" as thermal energy.

Remind students that in the activity "Storing Thermal Energy," they found that the amount of thermal energy emitted or absorbed depended on the mass, type of substance, and temperature change. The equation in Procedure Step 13 reflects this relationship.

PROCEDURE STEP 13 SAMPLE STUDENT RESPONSE (INCANDESCENT BULB)

thermal energy released (joules) =
Δ temperature (°C) × mass of water (g) × 4.2 (joules/(g × °C))

= 7.5 × 9 × 4.2

= 284 joules

c. Use the law of conservation of energy to calculate the amount of light energy emitted by the light bulb.

Remind students of the law of conservation of energy. In this case, they can assume that the electrical energy supplied is equal to the light energy emitted plus the thermal ("wasted") energy produced.

PROCEDURE STEP 14 SAMPLE STUDENT RESPONSE (INCANDESCENT BULB)

light energy emitted (joules) =
electrical energy supplied (joules) – thermal energy released (joules)

light energy emitted (joules) = 342 – 284 = 58 joules

d. Assist students with the efficiency calculations as needed.

Explain that efficiency is usually expressed as a percentage found by comparing the amount of "useful" energy to the total energy supplied. In this case, the useful energy is the light energy from the light bulb.

PROCEDURE STEP 15 SAMPLE STUDENT RESPONSE (INCANDESCENT BULB)

light efficiency of bulb (%) =
(light energy emitted/electrical energy supplied) × 100(%)

light efficiency of bulb (%) = (58/342) × 100(%) = 17%

Teacher's note: In this experiment, a significant amount of thermal energy is transferred ("lost") to the environment (through wires, air, plastic, etc.); therefore, the calculated thermal energy transfer of the bulb is significantly less than the actual value. This results in an overestimation of the efficiency of light production. For example, the efficiency of most incandescent bulbs is actually only about 5%; LEDs can be up to 90% efficient.

BUILD UNDERSTANDING

4. The class reviews results and the concept of energy efficiency.

   a. Have each student group report its experimental results.

   Write each group's calculated efficiencies on the board. If you haven't yet done so, review the calculations from Procedure Steps 11–15. A sample data table is shown below:

   LIGHT BULB CALCULATIONS

Bulb	Electrical energy supplied (joules)	Thermal energy released (joules)	Visible light energy emitted (joules)	Efficiency (%)
Incandescent	*342*	*284*	*58*	*17*
LED	*54*	*0*	*54*	*100*

   Hold a class discussion about the range of values obtained by the groups. Comment on any results that significantly vary from the others, and discuss why groups should have similar values.

   b. Compare the energy efficiencies of the two bulbs.

   Use the calculated values for efficiency to compare the two bulbs. Discuss factors that could have affected the results (e.g., whether the light bulbs were of equal brightness, whether there may have been errors in the data collection). Emphasize that even though there may be inaccuracies in the results, LEDs are much more efficient at producing visible light than incandescent bulbs.

   If students detected no thermal energy released by the LED, have a class discussion about whether LEDs are actually 100% efficient. Encourage students to think about sources of error that might have affected the outcome. One possibility is that the thermometer was not sensitive or accurate enough to detect very small increases in temperature.

5. Assign and then review the Analysis items.

   a. Analyze why experimental efficiencies are higher than actual efficiencies.

      Review students' responses to Analysis item 1, which asks them to reflect on their results. Discuss possible sources of error that would make values not match the 5% revealed in the question. It could be caused by inconsistent heat production of the bulbs due to differences in the bulbs or batteries, not timing for exactly 3 min, and thermal energy loss to the surrounding air and tray. Thermal energy loss in the wires and other connections that carry the electricity to the bulb also contributes to a percentage lower than ideal.

      Students should be able to conclude that the "wasted thermal energy" measured by this experiment is underestimated because not all of the thermal energy was trapped by the water. Some thermal energy was transferred ("lost") to the environment.

   b. Relate results of this activity to designing energy-efficient homes.

      Analysis item 4 asks students to consider how the use of some devices may be more efficient when used in some settings and less efficient in others. This is particularly pertinent to the design of energy-efficient buildings used for different purposes or built in different environments.

   c. (E&T ASSESSMENT) Compare the trade-offs between using several different types of light bulbs.

      Analysis item 4 provides an opportunity for you to apply the E&T Scoring Guide. Give students a copy of the E&T Scoring Guide, if appropriate, and review your expectations for a complete and correct response.

      Analysis item 4 asks students to analyze data in a table and choose a type of light bulb. Since LED bulbs have the highest efficiency, use the least energy per second, have the longest lifetimes, and have the lowest total cost per 100 hours, many students will select them. Students who forget to take into account the large number of incandescent bulbs they would need to purchase over the long run compared with LED or compact fluorescent may choose incandescent bulbs because they have the lowest initial costs. Some students may choose another bulb and explain how they like the quality of the light they give off, their size or shape, or that they prefer not to have the "upfront" cost of the LED, fluorescent, or halogen bulbs.

      A sample Level-4 response to Analysis item 4 can be found in the Sample Responses to Analysis section.

SAMPLE RESPONSES TO ANALYSIS

1. A typical incandescent light bulb is about 5% efficient at producing light energy. Does your calculation for light efficiency agree with this? Explain why you think your result is or is not close to 5%.

   We calculated that our incandescent bulb had an efficiency of 22%. This is much higher than 5%. We think that some of the thermal energy got transferred to the cup and the cap instead of just the water.

2. Are light bulbs better at emitting light energy or thermal energy? Explain using results from this experiment.

   The answer depends on which light bulb you are using. Based on the experimental results of this activity, the LED didn't raise the water temperature and had >90% light efficiency, which makes LEDs much better at emitting light than thermal energy. The incandescent bulb increased the water temperature and had <30% light efficiency, which makes it better at emitting thermal energy than light.

3. Do you think you would be more concerned about inefficient bulbs in a home that is in a hotter climate or a colder one? Explain.

   Inefficient bulbs are more of a problem in hotter climates because the "wasted" thermal energy from a bulb increases the temperature inside the home. This makes it more uncomfortable, and if the house is air conditioned, the air conditioner(s) would have to work harder. In colder climates, the thermal energy from the bulb would increase the inside temperature, and the heater would not have to work as hard, so it wouldn't really be "wasted."

4. (E&T ASSESSMENT) Look at the table below, which compares an incandescent light bulb with other kinds of bulbs that are about the same brightness. Answer the following questions:

   a. Which is the best light bulb? Using the table, explain the evidence that helped you decide.

   b. What are the trade-offs of buying the light bulb that you identified in Step 4a?

COMPARISON OF EQUALLY BRIGHT (1600 LUMENS) LIGHT BULBS

Characteristics	Incandescent	Compact flourescent	Halogen	LED
Efficiency	*5%*	*20%*	*9%*	*38%*
Rate of energy use (W)	*100*	*23*	*60*	*13*
Cost per bulb	*$1.00*	*$3.00*	*$2.00*	*$5.00*
Electricity cost per 100 hours	*$1.20*	*$0.28*	*$0.72*	*$0.16*
Average lifetime (hours)	*1,000*	*12,000*	*2,000*	*15,000*
Total cost per 100 hours	*$1.30*	*$0.31*	*$0.82*	*$0.19*

SAMPLE LEVEL-4 RESPONSE

a. *Based on the energy efficiencies given in the table, the LED is between 2 and 8 times more efficient than other bulbs. LEDs cost the most to buy, and their price is 10 times more than an incandescent. But, since it lasts more hours and uses less electricity, it is still the most economical bulb over its lifetime. The total cost for the LED is $0.19 per 100 hours, about one and a half times more economical than the fluorescent and more than 4 times cheaper than the incandescent or halogen bulb. This makes it the best bulb, based on energy efficiency and overall lifetime cost.*

b. *LEDS are the best light bulbs to choose out of the four types in the table. They will save money over the long term but the trade-off of buying the LED instead of one of the other light bulbs is that it is initially more expensive. I will have less money to spend on things after buying LEDs to light the house. It may take years before I get that money back from using less electricity and having to buy fewer replacement light bulbs.*

REVISIT THE GUIDING QUESTION

How can we measure the efficiency of a light bulb?

The purpose of a light bulb is to produce visible light. Most light bulbs use electrical energy as the source of energy. In the case of a light bulb, any energy changed into a form other than visible light can be considered "wasted" energy. The more energy that a bulb wastes, the less efficient it is. The most common form of wasted energy in a light bulb is thermal energy. Since it is easier to quantify thermal energy than light energy, we can use an indirect method to estimate the efficiency of a light bulb by measuring how much of the electrical energy is transformed into thermal energy. We can then apply the law of conservation of energy to calculate the amount of "useful" energy emitted by the bulb in the form of visible light. The ratio of light energy output to electrical energy input, expressed as a percentage, is a measure of the efficiency of the light bulb.

ACTIVITY RESOURCES

KEY VOCABULARY

energy efficiency

law of conservation of energy

temperature

BACKGROUND INFORMATION

TYPES OF LIGHT BULBS

Incandescent bulbs use a thin metal filament inside an evacuated space. Electrical energy flowing through the filament heats the metal, and the hot metal radiates visible and infrared light energy. When lit, the hot filament slowly evaporates until it becomes so thin that it breaks, causing the light to "burn out." To prolong the life of the filament, it is contained within a bulb that has had most of the air removed. Halogen lights are special incandescent bulbs that contain a halogen gas within their bulb to increase the brightness and extend the life of the filament. Fluorescent bulbs do not have filaments and, instead, create visible light in a series of steps during which electrical energy causes a gas inside the bulb to emit light energy. LED (light emitting diode) bulbs have no filaments or trapped gases but, instead, pass an electric current through a solid semiconductor. As electric energy is transferred to electrons within the semiconductor, the electrons move through the material and emit light. LEDs can produce light about 90% more efficiently than incandescent bulbs. In this activity, the provided small incandescent flashlight bulb is rated at approximately 1.9 W (joule/s), and the LED provided is rated at approximately 0.3 W. (These rated wattages produce the values of 114 and 18 joules of electrical energy supplied per minute used in the Student Book.)

Lumens produced	Typical wattage for this amount of lumens*			
	Incandescent	Compact Fluorescent	Halogen	LED
1,600	*100 W*	*26 W*	*72 W*	*22 W*
1,100	*75 W*	*23 W*	*53 W*	*20 W*
800	*60 W*	*15 W*	*43 W*	*12 W*
450	*40 W*	*11 W*	*29 W*	*9 W*

*Data based on commonly available bulbs of each type

MEASURING POWER

Power is the concept of "energy per time," a rate typically measured in watts. Watts is a measure of how much energy, in joules, is used per second. For example, a 100-watt bulb requires 2.5 times more electrical energy than a 40-watt bulb over the same time period. In other words, the electrical energy required by a 100-watt bulb during 1 min of use will keep a 40-watt bulb lit for 2.5 min.

EVIDENCE AND TRADE-OFFS (E&T)

When to use this Scoring Guide:
This Scoring Guide is used when students are making a choice or developing an argument about a socioscientific issue, where arguments may include judgments based on nonscientific factors.

What to look for:

- Response uses relevant evidence, ideas, and concepts to compare multiple options in order to make a choice.
- Response takes a position supported by evidence and describes what is given up (traded off) for the chosen option.

Level	Description
Level 4 Complete and correct	The student provides a clear and relevant choice with appropriate evidence and reasoning, including BOTH of the following: • a thorough description of the trade-offs of the decision • reasons why an alternative choice was rejected
Level 3 Almost there	The student provides a clear and relevant choice with appropriate and sufficient evidence and reasoning, BUT one or both of the following are insufficient: • the description of the trade-offs • reasons why an alternate choice was rejected
Level 2 On the way	The student provides a clear and relevant choice BUT evidence and reasoning are incomplete.
Level 1 Getting started	The student provides a clear and relevant choice BUT provides reasons that are subjective, inaccurate, or unscientific.
Level 0	The student's response is missing, illegible, or irrelevant.
x	The student had no opportunity to respond.

NGSS UNIT OVERVIEW

ENERGY

Performance Expectation MS-PS3-3: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Performance Expectation MS-PS3-4: Plan an investigation to determine the relationship among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

Performance Expectation MS-PS3-5: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Performance Expectation MS-ETS1-4: Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **Investigation: Home Energy Use** Students begin exploring concepts about energy transfer by analyzing qualitative data on energy use in two hypothetical homes in different environments. They consider how certain features of a home may cause the homeowner to use more or less energy. This introduces them to the idea of energy efficiency. They begin tracking their understanding about energy transfer and developing a plan to increase home energy efficiency. They will finalize and present that plan in the final activity in this unit.	MS-PS3.A MS-PS3.B	Analyzing and Interpreting Data	Cause and Effect Energy and Matter	ELA/Literacy: WHST.6-8.9
2. **Laboratory: Drive a Nail** Students learn that there are two basic types of energy: kinetic and potential. Students plan and carry out an investigation to examine the relationship between gravitational potential energy and kinetic energy of motion. They analyze and interpret the data to quantify the transfer of energy from a falling object (metal rod) to a stationary object (nail). They expand on their understanding of energy efficiency by considering whether all of the gravitational potential energy has been transferred to the nail.	MS-PS3.B MS-PS3.A MS-PS3.C	Planning and Carrying Out Investigations Analyzing and Interpreting Data	Patterns Cause and Effect Energy and Matter	Mathematics: MP.2 6.EE.C.9 ELA/Literacy: RST. 6-8.3
3. **Role Play: Roller Coaster Energy** Students expand on their understanding of energy transfer and transformations by exploring what is happening to energy during a roller coaster ride. Students use a model to help them explain the repeated transformations of gravitational potential and kinetic energy along the ride, and the transfer of kinetic energy from the roller coaster cars to thermal energy and sound in the tracks.	MS-PS3.B MS-PS3.A	Constructing Explanations and Designing Solutions Developing and Using Models	Energy and Matter	Mathematics: MP.2 ELA/Literacy: WHST.6-8.9

ENERGY (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
4. **Investigation: Shake the Shot** Students continue their exploration of energy transformation and transfer by analyzing and interpreting data from an investigation. This investigation involves transferring kinetic energy from a moving arm to moving metal pellets and then transforming that energy into thermal energy in the metal pellets inside the container. Students measure the rise in temperature of the metal pellets as evidence of the amount of thermal energy transferred.	MS-PS3.B MS-PS3.A MS-PS3.C	Analyzing and Interpreting Data Planning and Carrying Out Investigations	Energy and Matter Patterns Cause and Effect Systems and System Models Scale, Proportion, and Quantity	Mathematics: MP.2 6.EE.C.9 ELA/Literacy: RST. 6-8.3
5. **Reading: Conservation of Energy** Students obtain information from a reading on the behavior of energy. In particular, they develop an initial understanding of the conservation of energy during energy transformations. Students develop arguments to explain that energy cannot be "lost" during energy transformations, arguments that are informed by their growing understanding of systems and system models. They apply this understanding to the topic of energy efficiency, and use the information to inform their home energy efficiency plans.	MS-PS3.B MS-PS3.A	Engaging in Argument from Evidence Obtaining, Evaluating, and Communicating Information Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Energy and Matter Systems and System Models	ELA/Literacy: WHST.6-8.1 WHST.6-8.9
6. **Investigation: Follow the Energy** Students explore many types of energy transformations and transfers that people encounter regularly in their everyday lives. The ubiquity of energy transfers and transformations reinforces the crosscutting nature of energy. Students present arguments that a change in the kinetic energy of an object results in an energy transfer either to or from that object. This activity provides an opportunity to assess student work related to Performance Expectation MS-PS3-5.	MS-PS3.B MS-PS3.A	Engaging in Argument from Evidence Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Energy and Matter	ELA/Literacy: WHST.6-8.1 WHST.6-8.9

ENERGY (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
7. **Laboratory: Mixing Hot and Cold Water** Students conduct an investigation on thermal energy transfer in water, documenting this transfer by measuring temperature changes. They observe the effects of thermal energy being spontaneously transferred from a hot region into a cold one until thermal equilibrium is reached. Students analyze and interpret the data that they collect as they explain the relationship between changes in temperature and thermal energy transfer.	MS-PS3.A MS-PS3.B	Constructing Explanations and Designing Solutions Analyzing and Interpreting Data Planning and Carrying Out Investigations Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Energy and Matter Scale, Proportion, and Quantity	Mathematics: MP.2 6.EE.C.9 ELA/Literacy: RST.6-8.3
8. **Laboratory: Thermal Energy Storage** Students apply their understanding of energy transfer to plan and carry out an investigation to determine the factors that influence the change in temperature of cold water when a hot object is immersed in it. This activity provides an opportunity to assess Performance Expectation MS-PS3-4.	MS-PS3.A MS-PS3.B	Planning and Carrying Out Investigations Analyzing and Interpreting Data	Energy and Matter Scale, Proportion, and Quantity Connections to Nature of Science: Science Is a Human Endeavor	Mathematics: MP.2
9. **Reading: Energy Across the Sciences** Students obtain information from text about how scientists in several different disciplines use their understanding of energy to explain scientific phenomena. They read about energy transfers and transformations in examples from the life sciences, earth sciences, and physical sciences. In doing so, students develop an understanding of the crosscutting nature of energy. Students communicate their understanding about the universal nature of energy to others.	MS-PS3.B MS-PS3.A	Obtaining, Evaluating, and Communicating Information	Energy and Matter Systems and System Models	ELA/Literacy: RST.6-8.1 WHST.6-8.9
10. **Design: Energy Transfer Challenge** Students are introduced to the idea that thermal energy transfer can be maximized and minimized by engineering systems that are either good thermal conductors or insulators. They use an engineering design process to design, construct, and test their systems.	MS-PS3.A MS-PS3.B MS-ETS1.A MS-ETS1.B	Constructing Explanations and Designing Solutions Analyzing and Interpreting Data	Energy and Matter Structure and Function	ELA/Literacy: RST.6-8.3

ENERGY (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
11. **Laboratory: Energy in Light** Students investigate the behavior of electromagnetic energy when it hits a surface. They see that the energy can be transmitted, reflected, and absorbed. By conducting an investigation they find that shiny surfaces reflect much of the energy while dark surfaces absorb, transforming some of the light energy into thermal energy.	MS-PS3.B MS-PS3.A	Analyzing and Interpreting Data Constructing Explanations and Designing Solutions	Energy and Matter Patterns	Mathematics: MP.2 6.EE.A.2 ELA/Literacy: RST.6-8.3
12. **Reading: Conduction, Convection, and Radiation** Students are formally introduced to the three types of thermal energy transfer: conduction, convection, and radiation. This knowledge enables students to be able to look at a system and understand how thermal energy enters or exits that system through these different methods of energy transfer, thus reinforcing the idea that when energy is transferred, it can be transferred out of the observed system into a larger system.	MS-PS3.A MS-PS3.B	Constructing Explanations and Designing Solutions	Energy and Matter	ELA/Literacy: WHST.6-8.9
13. **Design: Maximizing Solar Energy Transfer** From the previous two activities, students should now have a better understanding of how solar energy is transferred from the sun to Earth and that different materials absorb, reflect, or transmit this energy in different proportions. In this activity, students design, build, test, and optimize a device to maximize thermal energy transfer: a solar heater. The success of their devices is determined by how well students apply what they have learned about thermal energy transfer and how well students are able to redesign the devices based on performance evaluations in early tests. Students present their final designs to the class and use their results to explain their design process. This activity provides an opportunity to assess Performance Expectations MS-PS3-3 and MS-ETS1-4.	MS-PS3.A MS-PS3.B MS-ETS1.A MS-ETS1.B MS-ETS1.C	Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Developing and Using Models	Energy and Matter	ELA/Literacy: SL.8.4

ENERGY (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
14. **Laboratory: Hot Bulbs** Students apply their understanding of the concepts of energy transfer and transformation to compare the efficiencies of two different types of light bulbs. They do so by measuring the amount of thermal energy produced by the two bulbs, applying the law of conservation of energy, and calculating how much of the electrical energy supplied was converted into light energy.	MS-PS3.A MS-PS3.B	Analyzing and Interpreting Data Planning and Carrying Out Investigations	Energy and Matter Connections to Nature of Science: Science Addresses Questions About the Natural and Material World	Mathematics: MP.2 6.EE.A.2 ELA/Literacy: RST.6-8.3
15. **Problem Solving: Improving Home Energy Efficiency** Students obtain more information about factors that can affect energy use in the home. They apply their understanding of energy transfer and energy transformation to develop a home energy efficiency plan to use less energy. Students communicate their plan be preparing a report to present to the hypothetical homeowners.	MS-PS3.B	Obtaining, Evaluating and Communicating Information	Energy and Matter Connections to Nature of Science: Science Addresses Questions About the Natural and Material World	Mathematics: MP.2 ELA/Literacy: WHST.6-8.9

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

ENERGY

This is a work in progress. Please check the Tools and Resources opening page in the online Teacher Portal for future updates.

This unit explores the anchoring phenomenon: Some energy transfers and transformations are more efficient than others. When a device uses energy, some of the energy is changed into a form that is not useful. This "wasted" energy reduces the efficiency of the device. Examples: Some appliances (such as refrigerators) and devices (such as certain light bulbs) use less energy than others; some devices transform energy from the sun. Students generate and answer questions such as: Why are some devices more efficient than others? What can people do to reduce energy use? How can people manipulate energy transfer and transformation to use energy more efficiently?

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Some devices are less efficient than others. For example, some light bulbs are hotter than others.	Why do light bulbs produce different amounts of heat?	What does it take to reduce energy use in a home? (Activity 1)	1 (10, 11, 12, 13, 14, 15)	MS-PS3-3 MS-ETS1-4	If we want to be able to use energy more efficiently, we need to understand how it behaves.
Objects are more likely to break if they are dropped from higher up.	Why does my cell phone break when it falls from my hand while I am walking but is less likely to break when it falls from my pocket when I am sitting?	How does the height and mass of an object affect its gravitational potential energy? (Activity 2)	2, 3, 4	MS-PS3-5	All types of energy can be classified as either kinetic (energy of motion) or potential (energy of position)—a simple system helps us understand how energy can be transformed.
		How is energy transformed on a roller coaster? (Activity 3)			Energy can be transformed over and over again.
		How can kinetic energy be transformed into another energy type: thermal energy? (Activity 4)			One kind of kinetic energy can be transformed into another kind of kinetic energy—thermal energy.
There are many types of energy that we encounter on a daily basis.	What are the similarities and differences among these different types of energy?	How can you use the law of conservation of energy to describe energy transformations? (Activity 5)	5, 6		Energy is conserved—whenever it is transferred or transformed, the total energy at the start is the same as the total energy at the end.
		How can you use the law of conservation of energy to describe energy transformations? (Activity 6)			There are many kinds of energy transformations, and all of them follow the law of conservation of energy.

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

ENERGY (continued)

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Substances get warmer or colder depending on their environment.	What is happening when a substance gets warmer or cooler?	What happens to thermal energy when hot and cold water are combined? (Activity 7)	7, 8	MS-PS3-4	Energy can be transferred from one object to another.
		What affects how much thermal energy can be stored in or released from an object? (Activity 8)			We can quantify the transfer of energy.
There is energy in food, fuel, weather systems, and many other situations.	Do we mean the same thing when we talk about energy transfer and transformation in other fields of science?	How does an understanding of energy help scientists explain phenomena in all fields of science? (Activity 9)	9	MS-PS3-4 MS-PS3-5	Energy in living systems is the same as energy in physical systems and has the same behavior—it can be transformed and transferred.
Some devices are more efficient than others.	If energy is conserved, why do people say it is produced or used?	How can you increase or decrease the rate of thermal energy transfer? (Activity 10)	(1) 10, 11, 12, 13, 14, 15	MS-PS3-3 MS-ETS1-4	We can do things to speed up or slow down energy transfer.
		What properties of matter affect how it interacts with solar energy? (Activity 11)			The sun's energy is transferred to materials differently depending on their properties.
		What are the different ways that thermal energy is transferred? (Activity 12)			Thermal energy can be transferred three different ways.
		How can you engineer a device to maximize its ability to transfer solar energy? (Activity 13)			We can use different materials to maximize energy transfer from the sun to serve a purpose.
		How can we measure the efficiency of a light bulb? (Activity 14)			Sometimes energy transformations are not useful to us.
		How can features in a home affect the energy efficiency of the home? (Activity 15)			We can do things to change the efficiency of desirable energy transformations.

UNIT OVERVIEW

ENERGY

This unit explores issues around energy efficiency and energy use. Listed below is a summary of the activities in this unit. Note that the total teaching time is listed as 23-35 periods of approximately 45 to 50 minutes (approximately 5-7 weeks).

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
1. **Investigation: Home Energy Use** Students brainstorm the uses of energy in the home and become aware of everyday energy consumption. They compare the features of two homes and suggest which one consumes less energy. Students then develop an operational definition of energy efficiency.	Energy, energy use, energy efficiency, trade-off LITERACY	Prepare Student Sheets.	E&T QC A5	1–2
2. **Laboratory: Drive a Nail** Students are introduced to the concepts of kinetic and gravitational potential energy. They design and conduct an experiment to drop metal rods of different masses from different heights to drive a nail into a foam block. This activity allows students to explore energy transfer, the relationship of gravitational potential energy to mass and height, and the transformation of gravitational potential energy to kinetic energy.	Kinetic energy, potential energy, gravitational potential energy, energy transfer and transformation, variables LITERACY		PCI Proc.	2–3
3. **Role Play: Roller Coaster Energy** Students further examine energy transformations between gravitational potential energy and kinetic energy in the context of a common experience—namely, roller coasters. Students are introduced to the idea that some energy is transformed into thermal energy and sound during energy transformations.	Kinetic energy, potential energy, energy transfer and transformation	Prepare Student Sheet.	EXP A1	1–2
4. **Investigation: Shake the Shot** Students further investigate energy transfer and transformation. They transfer kinetic energy to a system of metal shot in a container and explore the resulting energy transformation by measuring temperature change. The investigation introduces the relationships between motion, temperature, and thermal energy.	Energy transfer and transformation, heat, temperature, thermal energy	Fill shakers.	AID A3	1–2

ENERGY (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
5. **Reading: Conservation of Energy** Students are introduced to the fundamental principle of energy—the law of conservation of energy. They learn that almost all energy transformations involve the process of heating, in which some energy is transformed to thermal energy. People usually consider this energy as "lost" since it is often no longer useful to them. Students are introduced to the idea of efficiency in a transformation.	Absorption and release of energy, law of conservation of energy, energy efficiency, conserving energy LITERACY	Prepare Student Sheet.	ARG QC A3	1–2
6. **Investigation: Follow the Energy** Students continue to explore the consequences of the law of conservation of energy by analyzing specific energy transfers and transformations. Students focus on different energy types through examples of transformations that either absorb or release energy.	Energy types, following energy transformation and transfer LITERACY	Prepare Student Sheet.	ARG A3 (Assessment of PE MS-PS3-5)	2–3
7. **Laboratory: Mixing Hot and Cold Water** Students investigate thermal energy transfer between water samples of different volumes and temperatures. To start, students predict the results of mixing water samples of different temperatures. They then test their predictions through experimental measurement of the temperatures of the mixtures as they reach thermal equilibrium. Lastly, students explain their results by applying their understanding of thermal energy transfer.	Energy transfer	Provide supply of hot and cold water.	EXP A2	2
8. **Laboratory: Thermal Energy Storage** Students design and conduct an investigation to determine the relationship between the mass, type of material, and temperature change when substances at different initial temperatures are combined.	Energy transfer, storage and release of thermal energy	Provide supply of hot and cold water.	PCI Proc. (Assessment of PE MS-PS3-4)	2
9. **Reading: Energy Across the Sciences** Students read about energy transfers and energy transformation in several different examples, keeping track of this information as they read. They summarize what all of the examples have in common by writing a blurb that could go on the back of a science textbook about energy.	Energy transformation and transfer (and efficiency) LITERACY	Prepare Student Sheet.	COM QC A2	1–2

ENERGY (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
10. **Design: Energy Transfer Challenge** Students explore thermal energy transfer (heat) by coming up with, designing, and testing one process and structure to melt as much ice as possible and another to allow as little ice to melt. They then use the data collected to compare and analyze the effectiveness of their designs and analyze variables that affect the transfer of thermal energy.	Energy transfer, transformation (and efficiency), engineering design	Gather ice cubes and optional insulating materials.	ENG Proc.	2–3
11. **Laboratory: Energy in Light** Students measure, compare, and analyze the temperature change experienced by different materials when exposed to the same amount of sunlight.	Energy transfer, transformation, absorption, (and efficiency)	Gather graph paper and trays.	AID A1	1–2
12. **Reading: Conduction, Convection, and Radiation** Students read about thermal energy transfer. They are introduced to the terms convection and radiation and compare the three methods of thermal energy transfer. The Listen, Stop, and Write literacy strategy helps students comprehend the ideas presented in the text.	Energy transfer, conduction, convection, radiation, insulation LITERACY		EXP A3	1–2
13. **Design: Maximizing Solar Energy Transfer** Students design, test, evaluate, and redesign a solar heater.	Energy transfer, transformation, reflection, (and efficiency), engineering design	Prepare a supply of room temperature water, gather optional materials.	ENG Proc. (Assessment of PE MS-PS3-3 and MS-ETS1-4)	2–3
14. **Laboratory: Hot Bulbs** Students compare the amount of thermal energy transferred by a small incandescent and LED light bulb. They use their measurements to calculate the efficiency of the bulbs to produce light by measuring how much "wasted" energy is "lost" in producing thermal energy. They also compare "lifetime" costs for different types of bulbs. Finally, students consider the trade-offs involved when deciding which type of bulb to purchase.	Energy transfer, transformation, and efficiency	Obtain fresh 9–volt batteries, check bulb harness setups, and prepare a supply of room temperature water.	E&T A4	1–2

ENERGY (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
15. **Problem Solving: Improving Home Efficiency** Students gather more information about the factors that affect energy use and efficiency because of how they affect energy transformation. They use their knowledge of energy concepts and an economic analysis to make energy-saving recommendations that meet the needs of families in fictional scenarios. Their analyses calculate the time it takes for energy improvements to pay for themselves and the savings over 10 years. Students present the trade-offs of their home energy efficiency plans in their recommendations.	Energy efficiency, home improvements	Prepare Student Sheets.	COM A1 E&T A1	2–3