Lesson 6: Energy Transfers and Efficiency in Large-Scale Energy Generation

Overview

Students analyze the way they personally use energy and begin to examine energy use on a much larger scale. Students discover how reliant all sectors (residential, commercial, industrial, transportation) are on electricity and fossil fuels as energy sources. As they investigate the energy transfers involved in the generation of electricity, students consider the efficiency of the transfers involved in the process.

Teacher Background

The United States has 5% of the world's population; yet America accounts for 30% of the energy used worldwide. Several industrialized countries support a similar standard of living yet use far less energy per capita than Americans do. This data seems to beg the question: how can we use energy in the most efficient ways possible?

In this lesson, students initially reflect upon their own energy use by reviewing their Energy Snapshots assigned at the end of Lesson 1. They discover that much of the energy they rely on and use is electrical. Their personal use is compared first to energy use in Maine and then to the United States. What should become clear to students is that Americans are increasingly dependent on energy and a large portion of the energy we rely on is electrical. Many students recognize that high levels of electricity consumption have environmental and economic impacts and that conserving energy is a critical endeavor. With their knowledge of energy transfers/transformations, students can more fully understand their role in energy conservation.

Electricity is considered a secondary energy source because its generation requires the use (often combustion) of a primary energy source such as coal or natural gas (which are nonrenewable fossil fuels). Many of the techniques used to generate electricity on a wide-scale basis have not changed since they became part of power infrastructure in the late 1950's; it follows that the efficiency of power plants hasn't improved much since then either. Currently, the United States converts fossil fuel into electricity at 33% efficiency. This translates into about two-thirds of every unit of fuel burned going toward "unintended" effects (in cooling towers and up smoke stacks). Many facilities have taken measures to make their operations "cleaner" and more efficient by reducing these emissions and waste. Students will consider inefficiency as they become familiar with the basic operations involved in electrical production. Students will also begin to recognize that even the small choices they make everyday impact energy consumption.

It is worth noting here that Maine has significant renewable energy resources. Maine presently obtains 22% of its electric power from conventional hydroelectric plants. With thousands of miles of coastline Maine is recognized as one of the most promising sites for tidal and wave powered turbines in the world. Maine's numerous forests and windy areas also hold the potential for wood-fired and wind-powered electrical generation. A complete energy summary for Maine, including consumption and production statistics for fossil fuels can be found on the U.S. Department of Energy's Energy Information Administration (EIA), Maine Energy Profile. Maine is the only New England State in which industry is the leading energy-consuming sector. http://apps1.eere.energy.gov/states/energy_summary.cfm/state=ME

Take time to become familiar with the various components of this lesson. The lesson contains a number of suggestions and alternative components which allow teachers to customize instruction as they consider students' prior knowledge, skill levels, and time available. The lesson also has a number of opportunities to make connections with other disciplines such as mathematics and social studies.

Key Ideas

- In order to meet increasing energy demands, people in Maine must utilize the potential energy in various sources in the most efficient ways they can.
- Examining the efficiency of the transfers and transformations involved in electrical generation methods further supports the notion that the energy decisions people make have benefits and drawbacks.

Lesson Goals

Students will:

- analyze and determine energy use trends for themselves, on Maine, and the nation.
- examine the efficiency of the energy transfers and transformations common to prominent electrical generation methods.
- begin to consider the cumulative effects of the energy decisions people make daily.

Vocabulary

generator: a device that converts mechanical/motion energy into electrical energy usually by passing magnets through an electric field (electromagnetic induction).

nonrenewable resource: resources that do not replenish as part of natural ecological cycles in a short period of time.

renewable resource: resources that replenish in a short period of time as part of natural ecological cycles.

turbine: a device made up of a series of blades that is turned by a fluid (gas or liquid) and as it turns, transfers mechanical energy to a generator.

Preparation

- (Optional) If students took digital photographs documenting their 15-20 minutes of energy use; (See Lesson 1, Step 6 "Energy Snapshots") gather and assemble these into a slideshow.
- Preview the Palmer Putnam podcast. This can be accessed from the PowerSleuth website (www.powersleuth.org). Click on Energy for Maine, Teacher Zone, Lesson 6.
- Download and review the most current Maine energy consumption data by visiting the *PowerSleuth* website (www.powersleuth.org), *Energy for Maine*, Lesson 6. Consider what support students will need in analyzing the data available.
- Download and review the NEED article "Energy Consumption." Identify and prepare to pre-teach vocabulary that may be unfamiliar to students. Decide whether students will be reading the article independently, as a class, or in groups using a jigsaw reading strategy (See Step 4). Article found at: http://www.need.org/needpdf/infobook_activities/IntInfo/ConsI.pdf
- Download, review, and copy enough PowerSleuth power puzzle sets and their descriptions for pairs of students. Download the puzzle versions without lines for this activity. Available from: www.powersleuth.org
- Consider making overheads of the Maine Energy Consumption data and the coal power puzzle diagram.
- (Optional) Preview, if using, the video clip: http://www.iptv.org/video/detail.cfm/3788/exm_20030905_energy_part01/format:wmv

Materials

Item	Quantity
Scientist's Notebook	1 per student
Computer, LCD projector, speakers, internet connection	1 per class
Counters (100 pennies or beans in small paper cups)	1 set per pair
Chart paper and markers	1 per pair
Maine Energy Consumption Data available from www.powersleuth.org, Energy for Maine, Lesson 6 or http://www.eia.doe.gov/emeu/states/state.html?q_state_a=me&q_state=MAINE	1 per student and/or an overhead of this information
"Energy Consumption" article Energy Consumption from NEED (National Energy Education Project) http://www.need.org/needpdf/infobook_activities/IntInfo/ConsI.pdf	1 per student
Teacher Resource 6.1: *PowerSleuth* puzzle sets and Teacher Resource 6.2: *PowerSleuth* puzzle descriptions	1 per pair
Cup, container, or picture of "boiling" water (optional, prop)	1
Student Handout 6.1: Advance Organizer for Energy Consumption Article	1 per student
Student Handout 6.2: Calculating the Efficiency of Selected) Components of an Electrical Power Plant	1 per student
Calculator (optional)	1 per student

Time Required: 3-4 sessions

Session 1: review energy snapshots, view podcast, make visual representation of energy consumption prediction, examine Maine energy consumption data

Session 2: read and debrief energy consumption article

Session 3-4: investigate electrical generation methods; consider power plant efficiencies

Connection to *Maine Learning Results (MLR)* and *Benchmarks for Science Literacy (BSL)*:

- Transformations and transfers of energy within a system usually result in some energy escaping into its surrounding environment. Some systems transfer less energy to their environment than others during these transformations and transfers. BSL 8C/M1* (6-8)
- Different ways of obtaining, transforming, and distributing energy

have different environmental consequences. BSL 8C/M2 (6-8)

- Electrical energy can be generated from a variety of energy resources and can be transformed into almost any other form of energy. Electric circuits are used to distribute energy quickly and conveniently to distant locations. BSL 8C/M4* (6-8)
- Energy from the sun (and the wind and water energy derived from it) is available indefinitely. Because the transfer of energy from these resources is weak and variable, systems are needed to collect and concentrate the energy. BSL 8C/M5* (6-8)
- Some resources are not renewable or renew very slowly. Fuels already accumulated in the earth, for instance, will become more difficult to obtain as the most readily available resources run out. How long the resources will last, however, is difficult to predict. The ultimate limit may be the prohibitive cost of obtaining them. BSL (SFAA) 8C/M10** (6-8)
- By burning fuels, people are releasing large amounts of carbon dioxide into the atmosphere and transforming chemical energy into thermal energy which spreads throughout the environment. BSL 8C/M11** (6-8)

Teaching The Lesson

Engage

1 Examination and discussion of students' energy snapshots.

Working in small groups of 3-4, students share their snapshots. Once all students have had the opportunity to share, ask the group to select 3 specific instances (discrete activities within their collective snapshots) and focus on identifying what provides the energy (the energy source), what is receiving the energy (the energy receiver), and what forms are involved as energy is transferred between objects. Students should also discuss what energy transfers they think are "intended" and suggest transfers are "unintended."

If students were given the option of documenting their energy use with digital photographs, show students the slideshow of the assembled images. As students watch the slideshow, have them make note of energy sources, energy receivers, forms, transfers, and transformations, intended and unintended transfers/transformations. List these categories on the board or have students write them down before they watch the slideshow so they can categorize what they see in the images efficiently.

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Once students have finished examining their snapshots, briefly discuss with students the following:

- *What patterns or commonalities did you notice about energy receivers in your snapshots?* Answers will vary but students may find that many of the receivers were electronic or mechanical devices.
- *What patterns or commonalities did you notice about the forms of energy involved in the transfers you monitored?* Answers will vary but students will likely notice that the tasks frequently involved electrical energy.
- *What patterns or commonalities did you notice about the sources of energy involved in the various activities you monitored?* Answers will vary but students often notice the prominence of mechanical and/or electrical energy.
- *How do you think the way humans have used energy has changed over time? For example, if this were 1950, what might be different about the energy snapshots? What do you think would be the same?* Answers will vary but students will most likely recognize that energy use has increased, especially our dependence on electricity.

- *If this were 1900, what do you think your energy snapshots would include? If it were 2050? What do you think accounts for these differences?* Answers will vary but the point is that students should recognize that the way energy is used has changed and is due to a number of factors including increased population and increased sophistication in the types and availability of devices that have been engineered to utilize energy in many different ways.

2 Consider changes in energy use through history.

Have students view, either individually or as a class using an LCD projector, the Palmer Putnam podcast. The podcast can be accessed from the *PowerSleuth* website (**www.powersleuth.org**). Click on *Energy for Maine*, Teacher Zone, Lesson 6.

Set the context and focus for viewing the podcast by asking students to consider as they listen:

- *How has the amount of energy people use changed throughout time and what explains these changes?* Students should recognize that energy use worldwide dramatically changed with the discovery and use of petroleum in the 1860's.
- *Do you think your snapshots are representative of how people in Maine, across the United States, and the world use energy? What are some of the other ways energy is used by people in our society?* The point of this question is two fold; initially, to get students thinking about energy beyond their own personal use and second, to help students recognize people's use of energy (in all sectors) is heavily reliant on petroleum and nonrenewable energy sources. They have most likely recognized people's reliance on electricity but probably have not considered the energy sources for electricity.

3 (Optional) Introduce different sectors of energy use.

Introduce students to different categories of energy use: transportation, residential, industrial, and commercial. List the different sectors on the board and briefly describe each category. Students may have limited knowledge of how energy is used by other sectors such as business, industry, and transportation. All of these activities require an energy source. Differentiate between "commercial," (referring to businesses- those engaged in buying and selling good and services), and "industrial," (referring to occupations that involve the manufacture or production of a product). Provide local examples of commercial, industrial, and transportation to help students understand the differences. Give students a few minutes, to first, with their partner to brainstorm all the ways they think each sector uses energy and make a list in their scientists' notebooks.

After a few minutes, discuss some of the items on students' lists. Give each pair 100 counters (pennies or beans), a piece of chart paper, and markers. Explain to students that they will be using their 100 counters to predict the percentage of energy they think each sector uses. Explain that each counter represents 1% of the total energy used by the different groups (sectors). Students should think about what percentage of total energy they think each sector uses and create a visual on chart paper showing the percentages for each sector in Maine. Students may create a pie chart, bar graph, or come up with some other way of representing their prediction.

Monitor students as they work. Talk with students about the reasons behind their predictions. Visit each pair and make note of the trends in students' displays. After a few minutes, call the class together and share the similarities and differences in the percentages displayed in students' predictions.

4 (Optional) Examine Maine energy consumption data.

Distribute a copy of Maine Energy Consumption data to students and/or share the information by displaying an overhead of this information. Discuss with students how the actual data compares to their predictions. Discuss with students what might account for any differences.

Distribute a copy of the reading "Energy Consumption" to each student and Student Handout 6.1: Advance Organizer for Energy Consumption Article. Explain to students that this reading describes more specifically what each each sector uses energy and the energy sources are most commonly used to fuel various tasks.

Encourage students to mark up the article by underlining, circling, or highlighting parts of the article that pertain to the focus areas. Give students time to read the article silently or read the information together as a class.

Alternatively, use a jigsaw reading strategy with the article. Divide the class into "home groups" of three. One person reads the Residential and Commercial section (point out that these two categories are grouped together in the reading), another person in the home group reads the Industrial Sector, and the last person is assigned the Transportation Sector. All students in the class assigned to read the Residential and Commercial section (or Industrial, or Residential respectively) gather to read and discuss their section in preparation for sharing their "expert" knowledge about their section with their home group. Experts return to their home group and take turns sharing their findings with the other members of their home group.

Once students have completed the article, make certain that students know that each sector relies heavily on electricity and fossil fuels as energy sources. Students may not yet realize that some of the methods of generating electricity stem from fossil fuels. This will be clarified in the next phase of this lesson.

Explore

5 Introduce different methods of generating electricity.

Segue into an examination of the methods of electrical generation. Connect the trends students already noticed about their personal reliance (through the examination of their snapshots on energy) to the use across Maine and the rest of the country.

Ask students in the manner of a riddle: *What does the boiling of water have to do with the generation of most electrical energy in the United States?* (Consider setting up a small electric tea kettle or use another prop to catch students' attention to this question.) Don't answer the riddle but explain to students they will be exploring this in more detail.

Give each pair of students a set of PowerSleuth power puzzle diagrams and their descriptions. Sets include: coal, natural gas, wind, water (hydro), and solar.

> **Note:** PowerSleuth *puzzle diagrams can be downloaded without puzzle lines from:* ***http://www.powersleuth.org***.

Make certain to call students' attention to the diagram that shows water being used to generate electricity and relate this to the water wheel models they designed in Lesson 5. Ask students to work in pairs, reviewing the various ways electricity can be generated by examining the different components of each process and reading the accompanying descriptions. As students review the diagrams, ask them to pay particular attention to the energy sources, energy receivers, and types of energy transfers and transformations that are taking place throughout the various steps of the process. Encourage pairs to map the transfers and transformations of energy by marking the diagrams with arrows and words. Let students know that energy transfers and transformations are complex in this process but that they should do their best in mapping what they can.

As pairs work, circulate among students providing assistance, addressing questions, and encouraging students to examine the transfers and transformations of energy in depth.

Call students together and discuss the similarities and differences they've noticed in the electrical generation methods. Explore the following points by asking questions such as:

- *What do the various methods of electrical generation have in common?* (Several of the components of electrical generation are quite similar or the same. For example, all methods require an energy source that, which students may note, can be traced back to the sun. Several involve the burning of some sort of fuel for the purpose of generating steam. Steam is used to turn turbines which are connected to generators. All methods include distribution components (transmission lines, transformers, etc.).
- *What are some of the differences in the methods of electrical generation?* (Some energy sources are renewable and some are nonrenewable. Students may or may not refer to the sources using these terms and even if they do, it is worth identifying what sources each refers to. Renewable energy sources are those that can renew themselves or be replenished by natural processes. Energy from the sun, wind, and water are examples of renewable energy sources. Nonrenewable energy sources are those that cannot be replaced in a practical amount of time, making their amount limited to what is on the earth right now. Fossil fuels (such as coal, petroleum, and natural gas) take millions of years to form. Explain that electricity is considered a secondary energy source because as they have just examined, it is generated by transferring the energy of coal, natural gas, oil, water, and other natural sources, which are called primary sources. While the energy sources used to make electricity can be renewable or non-renewable, electricity itself is neither renewable nor non-renewable.)

Point out to students that the final energy "receiver" depicted in these diagrams is labeled as "you." Based on what students have been discussing earlier in this lesson, students should recognize that the receiver might be a business such as a restaurant or store, a manufacturing facility, a hospital, a school, an airport, a movie theater, and so on. The receiver could be further traced to a specific device and even traced through the components of the specific device. The number and types of energy transfers and transformations that occur to make something such as a TV work are mind-boggling!

Revisit: *What does boiling water have to do with the generation of electricity?*

Clarify the connection of boiling water to the generation of electricity in terms of the transformation of chemical energy (released by burning a fuel such as coal or natural gas) into heat. Heat is transferred to the water that boils to produce steam (heat to mechanical/motion). As the steam expands, it turns the blades of a turbine (mechanical/motion). The turbine is connected to a generator that transfers mechanical/motion energy into electrical energy.

(Optional) Consider showing students all or part of this 6 minute video clip which describes personal energy use, talks about efficiency being the key to meeting the energy demands of the future, and reviews the different steps and resources involved in electricity generation. All or part of the clip can be used to reinforce Step 5 and/or used to segue into looking at the energy efficiency focus in Step 6. http://www.iptv.org/video/detail.cfm/3788/exm_20030905_energy_part01/format:wmv

6 Consider efficiency in large-scale electrical production.

Encourage students to re-examine the power generation diagrams to consider the efficiency of the energy transformations and transfers in each step of the process. For simplicity's sake, it might be most useful to direct students to view the same diagram (either coal or natural gas) and display an overhead of the same diagram.

Ask student to think back to the Interaction Stations and the discussion about what happens to energy as it is transferred to one object to another. Use a specific example, such as the spool racer, for comparison. Explain to students that the energy transfers and transformations that occur in a power plant are much like those that occur in the racer. Some of the energy is transferred to places and forms that are unintentional.

Provide each student with a copy of Student Handout 6.2: Calculating the Efficiency of (Selected) Components of an Electrical Power Plant. Model the efficiency of transfers and transformations for the various components of the electricity generating process by directing students to place their cup of 100 counters (pennies or beans) just above the picture of the boiler in the coal diagram.

Explain that the number of counters (in this case 100) represents the energy units available to boil the water in the boiler. Direct students to fill in 100 in the "Energy Input" column on the handout. Explain that the boiler is 77% efficient. Help students recognize that if the boiler is 77%, 77 units are going toward the "intended" effects, and 23 units of the 100 energy units are being transferred to places in ways that are unintended. Ask students to comment on what they think some of those unintended transfers might be. Students should suggest that some of the energy units get transferred and transformed to friction (thermal), radiant (light) and mechanical/motion energy.

Have students enter “23” in the “energy transferred and transformed to unintended effects and have students remove 23 counters from their cups and place them aside. Have students fill in the number of energy units available for the next device in the electrical generation process. Have students move their cup to the turbine in the diagram.

Continue to model the change in the units of energy available through the next few components of the electrical generation power plant. Have students complete the handout as the number of energy units for each device is calculated. Students may need additional instruction on how to calculate the number of units available to the next device, depending on their familiarity with percentages. Use the efficiency figures in the completed table to help guide students:

Device	**Energy Input** (Number of energy units transferred as intended.)	**Efficiency**	**Energy Output** (Number of energy units available for next device.)	**“Unavailable Energy”** (Number of energy units transferred to unintended effects.)
Boiler (in a power plant)	100 units	77%	**77 units**	**23 units**
Turbine	77 units	45%	**35 units**	**42 units**
Generator	35 units	99%	**34 units**	**1 unit**
Transmission lines	34 units	91%	**31 units**	**3 units**
Water heater	31 units	79%	**25 units**	**6 units**

As an alternative to demonstrating the energy units that become unavailable at each step as described above, assign one device to each of the five student volunteers. Give each student a sign that identifies which device they are representing and notes its efficiency.

Note: *The entire transmission system for electricity consists of wires, transformers, and switches each involving various unintended transfers and transformations. Students may wonder what types of unintended effects occur as energy is transferred through transmission lines. One example that students should be able to relate to is an earlier interaction station involving some transformation to heat due to the resistance of electricity moving through a wire.*

Reflect And Discuss

7 Summarize learnings and bring lesson to a close.

Spend some time discussing the overall efficiency of the power plant. Compare the overall efficiency to the efficiency of some of the system parts. After completing the final step, ask students: *How much of the initial 100 units of energy actually gets used to heat hot water in the electric water heater?* (25 units of energy)

If students viewed the video clip in Step 5, ask students how this relates to the comment made by the narrator in the video "… efficiency being the key to meeting the energy demands of the future?" Discuss how the last exercise illuminates the narrator's assertion. Ask students what impact even small improvements in efficiency in each of the steps would have on meeting energy demands.

Discuss with students that even though they may not at this point be able to personally improve the efficiency of transfers and transformations that occur in electricity generating power plants, make certain they recognize the things they can do. For example, students can make conscious choices about how, when, and in what quantity they use electricity. As the "receivers" of energy from an electricity-generating power plant, people can choose to reduce the amount of energy wasted by unplugging devices, using energy-efficient appliances (examined in Lesson 7), and adopting energy-conserving practices (the focus of Lesson 8). Students should also recognize that they can get their local, state, and federal leaders to raise awareness of the issues around efficient energy use.

Extensions

Students may:

- find out how power plants across the world are capturing "waste" heat and using other traditionally unwanted "by-products" to increase efficiency and reduce costs. Cogeneration plants are one example. Take a virtual field trip to learn more using EIA Energy Kids "Field Trips" http://tonto.eia.doe.gov/kids/energy.cfm?page=Trips
- research and compare the efficiencies of different electrical power generation methods.

- investigate "efficiency" in the transportation sector. Find out how the automobile industry is working to improve the efficiency of vehicles. Examine trends in efficiency in this sector. http://www.fueleconomy.gov/ (Additional classroom exploration ideas can be found at: http://www.uwsp.edu/cnr/wcee/keep/HSSupplement/transportation/MPG.htm and GM's The Energy Highway: Solutions Ahead: http://www.gm.com/experience/education/teachers/energy_highway.jsp
- examine a satellite "photo" of the Earth at night. The "photo" is actually a compiled image using data from the Defense Meteorological Satellite Program and shows the location of permanent lights on Earth's surface. http://geology.com/articles/satellite-photo-earth-at-night.shtml. This image of the United States at night is a composite of over 200 images made by satellites orbiting the Earth. http://apod.nasa.gov/apod/ap970830.html
- learn more about Climate Change by visting the EPA's Climate Change for Kids site: http://www.epa.gov/climatechange/kids/index.html

References:

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Advance Organizer for Energy Consumption Article

Residential and Commercial

1. What do these sectors use energy for?

2. What energy sources are most commonly used to fuel the various tasks in these sectors?

Industrial

1. What does this sector use energy for?

2. What energy sources are most commonly used to fuel the various tasks in this sector?

Transportation

1. What does this sector use energy for?

2. What energy sources are most commonly used to fuel the various tasks in this sector?

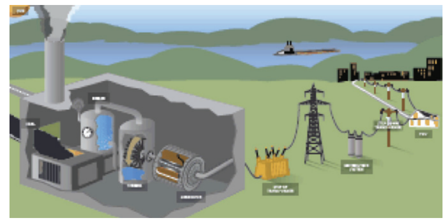
What do all of the sectors seem to have in common?

Calculating the Efficiency of (Selected) Components of an Electrical Power Plant

Device	**Energy Input** (Number of energy units transferred as intended.)	**Efficiency**	**Energy Output** (Number of energy units available for next device.)	**"Unavailable Energy"** (Number of energy units transferred to unintended effects.)
Boiler (in a power plant)				
Turbine				
Generator				
Transmission lines				
Water heater				

PowerSleuth Puzzle Descriptions:

Coal *PowerSleuth* Puzzle



Coal

1. Coal is delivered to the power plant to be burned.

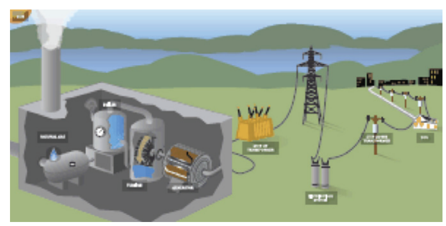
2. The burning coal creates heat which boils the water in the boiler and turns the water into "steam." This steam turns the blades of huge turbines.

3. The turbines spin a generator, creating electricity.

4. The electricity moves through power lines to a "step up" transformer. The step up transformer increases the voltage or "push" needed to send the electricity further down a network of power lines.

5. The electricity moves through local "step down" transformers that reduce the voltage to a correct level for homes, schools, and businesses.

Natural Gas *PowerSleuth* Puzzle



Natural Gas

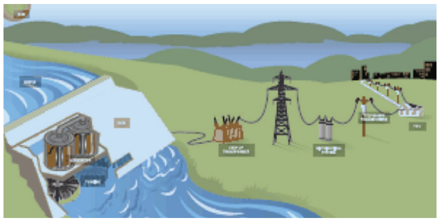
1. Natural gas is piped in to the power plant to be burned.

2. The burning gas creates heat which boils the water in the boiler and turns the water into "steam." This steam turns the blades of huge turbines.

3. The turbines spin a generator, creating electricity.

4. The electricity moves through power lines to a "step up" transformer. The step up transformer increases the voltage or "push" needed to send the electricity further down a network of power lines.

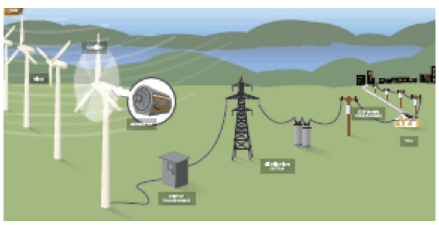
5. The electricity moves through local "step down" transformers that reduce the voltage to a correct level for homes, schools, and businesses.



Hydro

Hydro Power *PowerSleuth* Puzzle

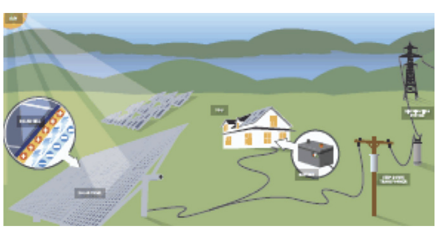
1. Water is backed up behind a dam. The water falls through an opening in the dam.
2. The falling water spins the blades of huge turbines. The turbines spin a generator, creating electricity.
3. The electricity moves through power lines to a "step up" transformer, which increases the voltage or "push" needed to move the electricity through more power lines.
4. The electricity moves further down a network of power lines.
5. The electricity moves through local "step down" transformers that reduce the voltage to a correct level for homes, schools, and businesses.



Wind

Wind Power *PowerSleuth* Puzzle

1. The air moves creating wind. As the wind blows, it turns the blades of the wind turbines.
2. The turbines spin a generator, creating electricity.
3. The electricity moves through power lines to a "step up" transformer, which increases the voltage or "push" needed to move the electricity through more power lines.
4. The electricity moves further down a network of power lines.
5. The electricity moves through local "step down" transformers that reduce the voltage to a correct level for homes, schools, and businesses.



Solar

Solar Power *PowerSleuth* Puzzle

1. When the sun shines, the sunlight hits the solar cells of solar panels, creating electricity.
2. Electricity is delivered through wires to the house and may be used immediately.
3. Unused electricity is stored in wall-sized batteries, which are located inside the house.
4. Sometimes solar panels produce extra electricity that may be delivered through power lines to the electricity company for other homes, schools, and businesses to use.

Lesson 7: Watt's in a Name(plate)?

Overview

In this lesson, students determine how much electricity a particular device uses by reading electric nameplates and using Kill A Watt meters that monitor electrical energy consumption. They discuss the cumulative effects of parasitic or phantom loads and strategies to minimize and/or eliminate them.

Teacher Background

Appliances and devices use electrical energy by transforming it into other forms of energy. People believe that when an appliance is plugged in but turned off it isn't using energy. This is not true! Many household appliances use small amounts of energy in "stand by mode" even when turned "off." TVs, DVD's, coffee makers, telephones, computers, printers, and a number of other gadgets constantly draw electrical energy as they "wait" to be used. This constant electrical use is referred to as "parasitic" or "phantom" load. Devices such as TVs and DVD players consume as much as 10-15 watts powering built-in remote control functions and digital clocks. AC power adapters and battery chargers also consume standby power even when they are not charging appliances. While this may not seem like a lot of energy, collectively this draw of "on demand" electricity adds up.

Measuring the amount of electricity that different appliances use can seem challenging because 1) we cannot "see" electricity as it is being used and 2) although we may be familiar with terms such as watt, volt, and amp, we are not clear on what they mean in terms of measuring electrical energy. If we consider how electricity travels, how it is measured may become clearer.

Current electricity is produced by electrons on the move. Current electricity requires an unbroken pathway or closed loop (a complete circuit) to flow and undergo transformations. Without a complete pathway electrons cannot flow and electrical devices do not work. Electrical devices house the components of (simple) circuits.

In order to make electrons move, an energy source is needed. Batteries and electricity from a power plant (generator) are most typically the energy sources for household electrical devices. The source pushes electrons through a particular device with a certain amount of force. The pressure applied to electrons to make them move through a device is known as voltage (V) and its strength is measured in volts (V). A 12-volt energy source (such as a car battery) would apply greater pressure than a 1.5-volt AA battery. In the United States, standard household voltage is 120-volts and certain household devices such as electric ovens and clothes dryers are wired for 240-volts.

The rate at which electrons flow is another aspect of electricity that can be measured. The number of electrons flowing between two fixed points (electrical current) is measured in amps or amperes (A). One amp is 6.25 x 1018 electrons per second passing through a circuit. Electricity can flow through wires with wider diameters faster than wires with smaller diameters. A related property, resistance (R), is one that slows down the flow of electrons. Resistance in electrical devices is anything that slows down the flow of electrons (material that the wire is made of, diameter of the wire, etc.) and is measured in ohms (Ω). Devices called resistors can be placed in circuits to regulate the flow of current.

Watts (W) are used to measure electrical power. Electrical power is defined as the amount of electric current flowing due to a given voltage being applied. Electrical power can also be thought of as the amount of electricity required to start or operate an electrical device for one second. Electrical power can be calculated using the following formula:

$$\text{Power} = \text{voltage} \times \text{current}$$

$$W = V \times A$$

Monthly electricity bills list the number of kilowatts (1000W = 1kW) residents have used and charges homeowners a certain amount of money using the utility company's kilowatt hour rate (in Maine this ranges from 8¢ to 12¢ per kWh). Small appliances (hair dryers, radios, and toasters) and other electrical devices such as incandescent light bulbs are rated by watts.

To operate properly, appliances and other devices need to receive the right amount of electrical energy. If they receive too little energy, the appliance will not operate properly; too much, and the appliance may burn out. Most appliances have the information about its electricity requirements stamped directly on the bottom or back of the appliance or engraved on its electrical nameplate. The wattage listed is the maximum power drawn by the appliance. Many appliances have a range of settings (for example, the volume on a radio) so the actual amount of power consumed depends on the setting. Other appliances, such as refrigerators and electric heaters, cycle on and off so the amount of energy used is based on an average.

In this lesson, students will use an appliance's electrical nameplate to find the number of watts a device uses and then use a Kill A Watt meter to measure its actual use. While it is not expected that students comprehensively understand the different aspects of electrical energy measurement, they will encounter values for amps, volts, and watts and may have questions about their meanings. Use students' background knowledge of electricity as a guide for how much information is provided about these measurements. Because consumers are charged for their electricity use based on the number of kilowatt hours used, watts are the units chosen for comparison. For those that would like additional information on how electricity is measured, review pages 39-41 of the National Energy Education Development (NEED) Project's Intermediate Energy Information book. This resource can be viewed or downloaded at **www.need.org**.

Be certain to become familiar with how to use the Kill A Watt meter. Included in this lesson is Teacher Resource 7.1: Using A Kill A Watt meter. This handout, from the Maine Energy Education Program (MEEP) **www.meepnews.org**, provides operation tips and offers additional suggestions as to how to use the meter in the classroom. There are also a number of online videos that show how Kill A Watt meters work and can be used. A couple are suggested in the Preparation section of this lesson and can be found on the PowerSleuth website (**www.powersleuth.org**).

Key Ideas

- Many devices have parasitic or phantom loads even when switched "off."
- Parasitic or phantom loads cumulatively have a significant impact on overall energy consumption.
- Connecting devices that have parasitic/phantom loads to power strips and turning the strip completely off when a device is not in use and purchasing Energy Star certified appliances are two strategies that can be used to reduce energy use.

Lesson Goals

Students will:

- be able to determine the number of Watts an electrical device uses by reading the device's electric nameplate.
- give an example of a parasitic or phantom load.
- describe the cumulative effects of parasitic or phantom loads.
- suggest strategies to eliminate or minimize parasitic or phantom loads.

Vocabulary

parasitic or phantom load: electricity used by a device even when the appliance is turned "off."

Watt: a unit of power used to measure electricity.

Preparation

- Obtain a set of Kill A Watt meters from your school's library. A set of four meters was mailed (November 2009) to all middle and high school libraries in Maine. Kill A Watt meters are also available at Maine public libraries and can be checked out free of charge. The Maine Energy Education Program (MEEP) may also have additional meters available for classroom use.
- Become familiar with operating the Kill A Watt meters. Tips for using the meter are included in Teacher Resource 7.1: Using the Kill A Watt meter. The following online video clips provide additional information and tips on using the meters:
  http://www.youtube.com/watch?v=1l_mo1jwh8Y
  http://vimeo.com/2924444 (Note: This clip shows Kill A Watt meters that have a "calculate cost" feature built in unlike the ones students will be using.)
- Gather a variety of household electrical devices. Try to find some that have a "stand by" power feature and others that have on/off switches. Utilize electrical devices such as computers, printers, speakers, pencil sharpeners, TVs, VCR/DVD players, radios, digital clocks, desk lamps, and overhead projectors that are readily available in the school to minimize preparation time. Consider including older appliances and their newer version counterparts. Have 3-4 appliances for each student group to test and a set of 2-3 items for the opening demonstration. Be sure to gather items that, when activated, will not burn or otherwise be harmful to students. Alternatively, consider setting up appliances in stations around the room and have student groups move from station to station.
- Locate the electric nameplate on each of the items. If the nameplate does not have Watts listed, make certain that the amps (A) and volts (V) are listed. Students can calculate the Watts (W) using the other two values.
- Make certain students have easy access to an electrical outlet. Use power strips or extension cords, if necessary.

Note: *Consult the school's custodian to make certain that the activation of multiple devices will not overload the school's electrical system and blow a fuse. If uncertain, carry out this investigation as a demonstration.*

Materials

Item	Quantity
Scientist's Notebook	1 per student
Variety of household electric devices Include devices that have a "stand by" power feature and others that have on/off switches. Utilize electrical devices such as computers, printers, speakers, pencil sharpeners, TVs, VCR/DVD players, digital clocks, desk lamps, and overhead projectors that are readily a vailable in the school to minimize preparation time.	3-4 appliances for each student group and one set for the opening demon-stration
Hand lens	One for each group
Power strips or extension cords	One power strip for opening demonstration / additional power strips or exten-sion cords, as needed
Kill A Watt meters from the school and/or local public library	4 (one for each group)
Student Handout 7.1: Kill A Watt Challenge	1 per student
Student Handout 7.2: Nameplate Data	1 per student
Student Handout 7.3: Kill A Watt Data	1 per student
Student Handout 7.4 (optional): Calculating Annual Energy Costs	1 per student
Calculator (optional)	1 per student
Teacher Resource 7.1: Using the Kill A Watt meter	1 for teacher review

Safety

Review guidelines for using electrical devices safely.

Connection to *Maine Learning Results (MLR)* and *Bench-marks for Science Literacy (BSL)*:

- All technologies have effects other than those intended by the design, some of which may have been predictable and some not. BSL 3B/M2a (6-8)
- Use statistics to summarize, describe, analyze, and interpret re-sults. MLR B1(6-8) c
- Use a variety of tools and technologies to improve investigations and communications. MLR B1 (6-8) e

Teaching The Lesson

Engage

1 Make predictions about energy use.

Prior to the start of class, gather a coffee maker with a digital clock, TV, radio, and power strip. Place these items in a place visible to all students. Ask students to predict which one of these devices they think uses the most electrical energy and why. Mention that students may want to take into consideration what they know about the energy transfers and transformations that take place in these devices. Have students record their predictions in their scientists' notebooks.

2 Introduce electric nameplates.

Provide each student with a copy of Student Handout 7.1: Electric Nameplates. Explain to students that every device that uses electricity has an electric nameplate on it. The nameplate is usually a sticker, but is sometimes engraved into the device. It has information about where the device was manufactured, whether it has been tested for safety, and how much energy it uses. Show students the location of information on the nameplate of one of the demonstration devices. Include:

- wattage (a unit of power used to measure electricity)
- current (the rate at which electric current flows, measured in amps)
- voltage (the force, measured in volts, with which a source of electric current moves) Note: Students may see VAC, power from an outlet, and VDC, power from a battery.

Point out to students that sometimes the nameplates do not contain these three values but the following mathematical equation can be used to calculate the missing information:

$$\text{Watts (W)} = \text{Amps (A)} \times \text{Volts (V)}.$$

Explain that during this investigation, we will be focusing on how many Watts particular devices use because this value can be used to calculate how much it costs to use a particular device.

Have student volunteers assist in locating and/or calculating the number of Watts, using amps and voltage, each of the demonstration devices uses. Have a few hand lenses available to read nameplates that have small print. Students can compare the nameplate information to their predictions made at the beginning of the lesson. On the board, write the number of Watts, amps, and volts for the different devices on the board. Ask students how many Watts of electricity would be used if these devices were used at the same time. (Add the number of Watts together.)

Students may notice that some household devices, in addition to their nameplate, have an Energy Star sticker. Devices that are most efficient receive this label from the U.S. Environmental Protection Agency.

3 Introduce the idea of phantom loads.

Plug the coffee maker, TV, and radio into the power strip. Show students the Kill A Watt meter and explain that the meter measures and displays the same information found on electric nameplates. For this demonstration plug the Kill A Watt meter into the wall, select the Watt setting, and plug the power strip into the wall. Plug the devices into the power strip. Turn the various devices on one at a time and ask students to notice what happens to the number of Watts. Students should notice that the number of Watts increases and decreases as devices are switched on and off. Click off the power strip. Students should notice that the Kill A Watt meter registers zero Watts. Explain to students that this is because the power strip has a switch that completely shuts off the flow of electricity to all of the devices.

Click the power strip back on. The devices should be on and students will once again notice how many Watts the devices are using collectively. Switch off the radio. Ask students what they notice about the number of Watts the meter shows. (The number of Watts should decrease by the number of Watts listed on the nameplate or calculated for the radio.) Switch off the coffee maker. Ask students what they notice. They may notice that the number of Watts decreases by an amount close to but not exactly equal to the number of Watts listed on the coffee makers' nameplate. Lastly, switch off the TV. Ask students what they notice about the number of Watts being used. They should notice that the number of Watts being used has decreased but that the meter is still showing that electricity is being used. Ask students "What's going on?" (or "Watt's going on?") Are these devices "off?" Why does the Kill A Watt meter still show electricity being used?

Explain to students that one thing nameplates do not tell us is whether the device has what is known as a parasitic or phantom load. Parasitic or phantom load refers to electricity used by a device when it is turned "off." Devices that have parasitic or phantom loads often have built in clocks, glowing lights, or remote controls associated with them. Unless these devices are completely disconnected from their power supplies, they continue to "draw" or use electricity.

Ask students how they could use the Kill A Watt meter to determine whether a device has a parasitic or phantom load. Students may suggest that if the Kill A Watt meter reads wattage when the device is "off" then it has a parasitic or phantom load.

Demonstrate the parasitic/phantom load of the coffee maker and/or the TV by plugging the device into a Kill A Watt meter that is plugged into a wall outlet or power switch and switching it "off." Switch the power strip completely off or unplug the device to emphasize the complete termination of electricity.

Discuss with students the impact of parasitic/phantom loads. Students should begin to recognize the cumulative impact of parasitic/phantom loads used by multiple devices over the course of a year.

Explore

4 Investigate electrical use of various electronic devices and appliances.

Students work in small groups of 4 or 5 to investigate the amount of energy used by different devices. Encourage them to first make a prediction as to which devices use the greatest number of Watts and whether or not the device has a parasitic/phantom load. Students can make predictions and collect their data using Student Handout 7.2: Nameplate Data or develop their own method of keeping track of the information in their scientists' notebooks.

Have students find the number of Watts the different devices use by locating the values on the devices' nameplates. Remind students how to calculate any of the values that are not listed on the nameplate by using the formula. (Write the formula on the board.)

Once students have found the number of Watts using the nameplates, have them test the device to determine if it has a parasitic/phantom load. Remind students how to plug in and operate devices safely. Show students how to plug the Kill A Watt meter into the power strip. Use of a power strip or extension cord makes testing easier. To test a device, students will plug it into the Kill A Watt meter. Again, students may use Student Handout 7.3: Kill A Watt Data or use their scientists' notebooks to record their data. Explain to students that using the meters to find the actual energy used is similar to using a calculator after they've learned how to add and subtract; the meters are a tool but not the only way to find out if a device has a phantom load.

> **Note:** *Have students complete the nameplate activity before providing the Kill A Watt meters. By doing the nameplate portion separate from the Kill A Watt part, students are more likely to spend more time examining the information on the nameplate and will be less prone to taking shortcuts.*

Circulate among student groups and provide assistance as needed. Ask guiding questions and listen to students' ideas about energy use as they work.

Reflect And Discuss

5 Conduct a scientists' meeting.

Ask students to share what they learned about the devices they surveyed. Discuss the following:

- *What similarities and differences did you notice about the nameplate data and the Kill A Watt data?*
- *Which devices use the most energy?*
- *What do these devices have in common?* (Relate to energy transfers and transformations that may be occurring in the device. Students often notice that devices that make heat use more energy.)
- *Which devices have parasitic or phantom loads?*
- *What do they have in common? Why might these devices "need" to use energy even when they are turned "off?"* (Relate to energy transfers and transformations that may be occurring in the device.)
- *What cumulative effect do you think parasitic/phantom loads have on overall energy consumption? What strategies can be employed to decrease this effect?*

(Optional) Students can calculate the amount of energy various devices will use in one year using the formulas found on Student Handout 7.4: Calculating Annual Energy Cost.

6 (Optional) Investigate devices at home.

As a follow up homework assignment give students the task of locating the nameplates for the devices identified in their snapshots. Allow students to sign out the Kill A Watt meters on a rotating basis so that each can test various devices in their homes for phantom loads.

Extensions

Students may:

- look up the typical wattages of various household devices and use this information to estimate their overall electricity use. This information can also be used to determine whether to invest in a more energy-efficient appliance. http://www.energysavers.gov/your_home/appliances/index.cfm/mytopic=10040
- find out more about Energy Star appliances: http://www.energystar.gov/
- investigate the connection between the Environmental Protection Agency (EPA) and Energy Star labels. Why do you think the EPA is the "issuer" of Energy Star labels?
- predict which room in their house uses the most energy and then use the meters to check their predictions.

Connections to Maine Agencies

MEEP (Maine Energy Education Program) is a no cost resource for schools and teachers in Maine. MEEP representatives will come to interested schools, free of charge, to guide and support the concepts in this lesson and have programs that supplement concepts in this lesson:

- School Energy Efficiency Investigation: Students use tools to see how their school uses energy and where energy is wasted. Tools include an infrared thermometer, a temperature/humidity datalogger, a light meter, and Kill A Watt meter. Students can then make recommendations on how energy can be conserved in their school. This project can also be combined with the Greenhouse Gas Surveys being offered by Maine DEP. More information can be found on the MEEP website: www.meepnews.org/classroomactivities.

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of this site. To schedule a presentation, contact Nancy Chandler at 207.760.2556 or nchandler@mainepublicservice.com.

Online References and Resources :

Lesson modified from the Maine Energy Education Program (MEEP)'s Kill A Watt Challenge Activity.

Energy Efficiency in the Home by Wyatt Wilcox
http://energyseeds.com/2007/10/11/go-solar-and-kill-a-watt/

National Energy Education Development (NEED) Project's Intermediate Energy Information Book (pages 39-41). The NEED Project, PO Box 10101, Manasas, VA 20108. www.need.org

Macaulay, D. (1988). *The Way Things Work*. London: Dorling Kindersley Limited.

Energy For Maine

Kill A Watt Challenge

Electric Nameplates

Knowing how to read an Electric Nameplate is an important skill to have. It enables you to quickly compare the energy usage of multiple appliances. The electric nameplate includes the following energy information:

- Maximum watts used,
- Voltage needed, and
- Maximum Amps consumed

Not all nameplates include all three of these pieces of information. If you're missing something, you can figure it out using this equation:

Amps x Volts = Watts

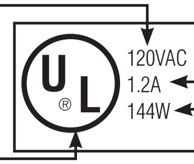
Take the nameplate at right for example.

1.2A x 120V = 144W

If we didn't already know the wattage, we could easily figure it out!

What's on an electric nameplate?

Voltage: AC denotes alternating current (from an outlet). DC means direct current (battery power).



Amperage

Wattage: The most important number we need to know.

Safety Testing: This device was tested by Underwriters Laboratories.

Kill a Watt Meter

The Kill A Watt meter is a tool that tells you the same energy information you can learn from reading an electric nameplate, but it can also tell you whether or not a device has a

parasitic load. A parasitic load is the energy a device uses when you think it's turned "off". Computers, TVs and some stereos have parasitic loads. You can search for parasitic loads by plugging devices into the Kill A Watt meter and seeing if they use any Watts or Amps while they are turned off. The Kill A Watt meter has buttons for Amps, Volts, Watts, and Kilowatt-Hours. If you plug an appliance into the meter for an extended period of time, it will keep track of how many KwH the device used for that time period. You can then calculate how much money it costs you to run that machine!

Energy Star

The US Environmental Protection Agency recognizes the most efficient devices with the Energy Star label. Do any of your appliances have this distinction?

ENERGY STAR

How Much Energy do your Appliances Use?

Now it's time for you to learn more about your electronic devices and appliances. Which ones use the most energy? Which ones use the least? Do any of them have parasitic loads? Use the table on the following page to track energy consumption of your appliances.

Nameplate Data

Prediction: Which appliance do you think will use the most energy? Why?

____

____

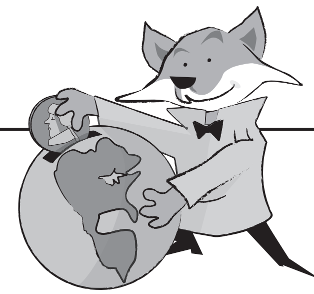
____

Appliance	Volts (V)	Amps (A)	Watts (Volts x Amps)	Energy Star (yes or no)

Kill A Watt Data

Appliance	Volts (V)	Amps (A)	Watts	Phantom load? (yes/no)	Watts pulled by “phantom”

Energy For Maine



Calculating Annual Energy Cost

How much energy will this device use in one year?

Wattage (W) × Hours "on" per day × 365 days per year = Watt Hours per year

________ (W) × ___________ hours × 365 = ______________ Watt hours

Parasitic load (W) × (24 hours – hours turned on) × 365 days per year = parasitic load per year (watt hours)

________ (W) × __________________ hours × 365 = ____________ Watt hours

Add the two numbers above to calculate Total Watts per year

________ (W) + ___________ (W) = _______________ Total Watt hours

Total Watt hours per year / 1000 = Total kilowatt hours per year

_____________ (W) / 1000 = ___________ Total kilowatt hours (kWh)

How much will that cost?

Total kWh × $0.15 = Cost per year

__________ (kWh) × $0.15 = ___________ Dollars

Consider this:

Can you determine how these numbers might change if the device is unplugged or completely switched off when it is not in use?

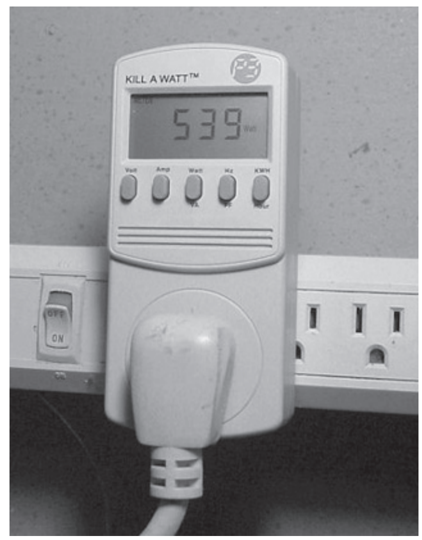
How would the numbers change if the device was used only half as much per year?

Using a Kill A Watt Meter

Courtesy of the Maine Energy Education Program (MEEP) www.meepnews.org.

The Kill A Watt meter measures the electricity usage of various electronics and appliances. It can tell consumers how much energy is used at that instant or over time. Once familiar with how to use it, the Kill A Watt meter can be a valuable tool in helping schools and families reduce their energy use.

Setting up the Kill A Watt meter



The meter requires a 3-pronged outlet. Orient the outlet so that the round hole is on the bottom, as shown in the photo. This orientation makes it easier to read the meter. If necessary, plug the meter into a power strip or extension cord.

Plug the meter into the outlet, and then plug an electronic device or appliance into the meter. Numbers will be displayed on the digital screen.

Features of the Kill A Watt meter

The Kill A Watt meter's LCD displays various measurements of electrical power as different buttons are selected:

- Pressing one of the gray buttons on the meter will show the voltage (V), amperage (A), wattage (W), and hertz (Hz). Wattage is the most pertinent of these four units for measuring electricity usage. Notice that the number of volts multiplied by the number of amps calculates the number of watts.
- The pink button is a toggle function. Press the KWH/Hour key one time to show the cumulative number of kilowatt hours of energy used when the device plugged in over a period of time. This kilowatt hour (kWh) function reads electrical use in the same way as a power company measures the amount of electricity people use. If we can figure out how many kWh a device uses, we can then calculate how much money it costs to run that machine for a much longer period of time, such as a year.
- Press the pink button twice to see how many hours that device has been plugged in (KWH Time). Important note: Unplug the Kill A Watt meter to reset it.
- When monitoring electrical use over time, be sure to put the Kill A Watt meter in a place where it will be left undisturbed!

Ideas for using the Kill A Watt meter

Here are some of the ways Kill A Watt meters can be used:

- **Measure Phantom Loads.** Some electronic devices and appliances use energy even when they are "off!" TVs, VCRs and microwaves are good examples of this. Press the Watt button on the Kill A Watt meter to see how much energy these "vampires" are consuming!
- **Measure the electricity a device uses over time.** Vending machines are big energy users! Press the kWh button on the Kill A Watt meter to see how much electricity a vending machine uses for a few days, and then calculate how much it would use in a year! Special tools, called Vending Misers, can reduce the energy used by a vending machine. Is your school interested in taking the Vending Miser Challenge? Contact MEEP (www.meepnews.org) for project details.
- **Discover devices "energy-saving" mode.** Photocopiers use a lot of energy. Many photocopiers have an energy-saving mode that people are often unaware of or forget to use. See how much energy can be saved by using the "Energy-Saver" mode, and then figure out ways to encourage people to push the "Energy-Saver" button when they're done copying!
- **Compare two similar devices.** Compare the energy use of a flat-screen computer monitor versus the older boxier style. Compare a laptop's energy use to a desk top computer. See how much less energy is used when a computer is in stand by mode!
- **Laptop charging carts.** How much energy is used when all of the classroom laptops are charging?
- **How "energy" smart are Smart boards?** Smart boards are becoming more and more common in Maine classrooms. How much energy do they use?
- **What's your idea?** Tell us how the Kill A Watt meter was used in the classroom or at home. Send your idea to MEEP (www.meepnews.org).