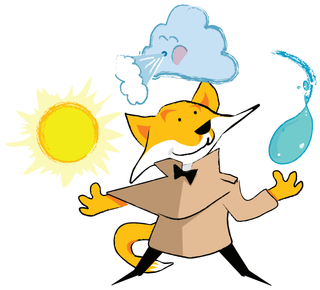

Lesson 6: Energy Transfers and Efficiency in Large-Scale Energy Generation

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 1
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.

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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

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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

4

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

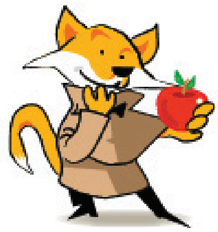
Session 3-4: investigate electrical generation methods; consider power plant efficiencies

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.

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
12 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

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