Lost in Transmission

LESSON OVERVIEW

In this lesson students learn about energy loss to heat during transmission over power lines. Students are introduced to the concepts by watching a four minute Inside Energy video (*Lost in Transmission: How Much Electricity Disappears between a Power Plant and Your Plug?*). Students then investigate for themselves in a hands-on circuit lab and connect their learning to the video and the real world through a class discussion and/or lab write-up. Finally, students are challenged to apply their new knowledge by designing a project to determine the amount of energy lost within an individual home. The lesson is organized using the 5E Instructional Model. While each section builds upon the previous, educators may find that they only need to use one or two sections to meet their teaching goals.

LEARNING OBJECTIVES

Students will:

- Explore the concept of energy in terms of electricity, kinetic energy, and heat.
- Understand that energy can change forms (transform) and move location (transfer) but that energy is ultimately conserved.
- Connect the physics concept of energy to real world cases and problems.
- Apply an understanding of energy concepts to design a project that answers questions about energy use/loss in their own lives.

GRADE LEVELS: 6-8

KEY VOCABULARY/CONCEPTS

- Transmission
- Distribution
- Voltage
- Current
- Power
- Resistance
- Energy transformation
- Electric energy
- Heat energy
- Kinetic energy

CREDITS: Lesson developed by Tiffany Kapler. Multimedia developed by Inside Energy.

MULTIMEDIA RESOURCES

Lost in Transmission: How Much Electricity Disappears between a Power Plant and Your Plug [Video]
Optional: *IE Questions: How Much Do Energy "Vampires" Cost Us?* [Web post]

Inside Energy is a collaborative journalism initiative of partners across the US and supported by the Corporation for Public Broadcasting

SUGGESTED TIME: 3 days

- Day 1: Engagement and Exploration
- Day 2: Explanation
- Day 3: Elaboration

MATERIALS

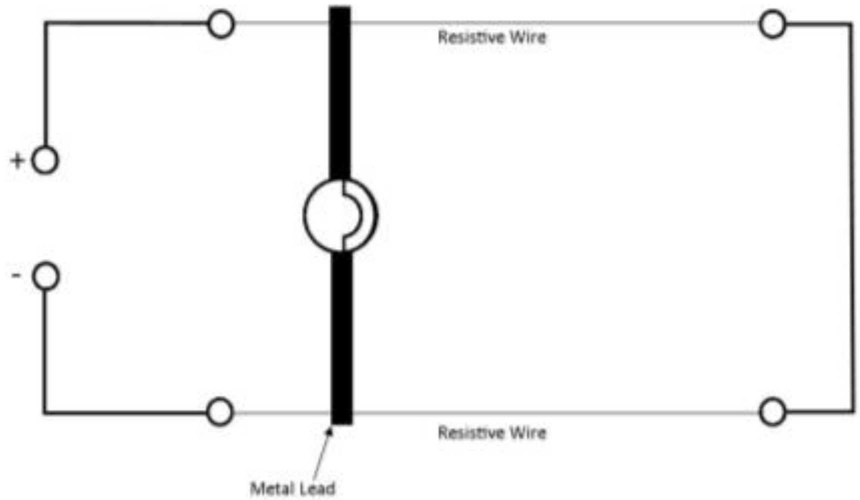
- 2 AA Batteries
- Battery holder (for 2 AA batteries)
- Resistive wires (total resistance ~15Ω)
- Small lightbulb (2.5 V, 0.3 A) in a holder with metal leads
- Connecting wires
- Board with pegs or other apparatus for circuit set up
- Thermometer
- Multimeter (optional)

LESSON PREP

To save classroom time, the teacher may choose to set up the circuits ahead of time or to organize the materials to make circuit set up by students more efficient.

THE LESSON

Engagement	View the video *Lost in Transmission: How Much Electricity Disappears Between a Power Plant and Your Plug?* Also have students read the text that accompanies the video. Discuss the following: • What are the different types of energy described in the video? • How is energy transformed from one type of energy to another? • What role does kinetic energy (motion energy) play in energy loss during transmission and distribution? **Evaluate** the discussion for current understanding as well as misconceptions. Use these points to focus and redirect during the Exploration and Explanation phases.
Exploration	Allow students to explore how the distance electricity travels along a wire affects the energy output. 1. Set up a circuit (or have students set up the circuit) using 2 AA batteries as the electricity source and two parallel resistive wires. The wires should be close enough that a small lightbulb in a holder connected to metal leads could set across both wires to close the circuit. See diagram.

	 2. Have students investigate the available energy at various distances along the wires by using the lightbulb to close the circuit at three or more locations along the wires. They should predict what they think will happen before actually conducting the investigation. At each location record observations and leave the lightbulb in place for a minute. Students should then use a thermometer to measure the temperature at different locations along the resistive wire and record their results. 3. *Optional:* Have students use a multimeter to close the circuit much like they did with the lightbulb and metal leads. Measure the voltage (V) and current (amps) at various (at least 3) places along the resistive wires. Test leads from the meter should be placed on opposite wires but at the same distance in the circuit from the power source (batteries). Students should record their measurements and use a ruler to measure the distances along the wire where voltage and current measurements are taken. Power available can be determined using the equation P=IV (power=current*voltage). They can then create a graph to look for a relationship between distance and current, voltage, and power. Teacher can use lab time to observe and converse with students to **evaluate** their understanding of circuits, as well as their understanding of their results.
Explanation	In a class discussion and/or lab write-up students should be able to explain their results. Guiding questions and discussion prompts might include: • Compare the circuit set-up to the energy grid that provides energy for our homes, schools, and lives. What do the batteries represent? What do the resistive wires represent? What does the lightbulb represent? • Describe how the position of the lightbulb along the wire affected its brightness. • Describe how the position of the meter leads affected the voltage (V), the current (amps), and the power (watts). • Did the resistive wires give off any heat? Where? How? In other words, how is electric energy transformed into heat energy? Are there any other forms of energy involved? (*kinetic*) • Explain the lightbulb/voltage and temperature results. Does all of the battery power reach the lightbulb? Where does the "lost" energy go?

	• The wire used had a relatively high level of resistance*. How would the results change if the wire was made of a superconducting (very low resistance) material? Explain. • How does this experiment relate to the video, "*Lost in Transmission*"?** • Why is it important to understand energy, energy transfer, and energy transformation when considering powering our homes, towns, and cities? • Can you think of examples of products that depend upon the heat/energy given off due to high resistance wires? (*the filaments in incandescent light bulbs; the heat element in hair dryers*) Teacher and students should **evaluate** student understanding of the concepts with a specific focus on energy, energy transfer, energy transformation, and transmission. *It may be helpful to compare resistance to friction. It slows down electrical current much like friction slows down moving objects. In both cases energy (electrical and kinetic) is transformed into heat energy. **Reiterate the point from that video that high voltage transmission wires are *not* made of high resistance materials, but that at great distances, the resistance adds up and is noticeable on a large scale. Resistant wires were used in the lab in order to scale down the size and still observe a measurable effect.
Elaboration	As the video pointed out, energy loss can be estimated relatively easily from energy production at the power plant to where it enters into the home at the meter. What is harder to know is the amount of energy lost *after* it enters the home. Challenge student groups to design a project that could estimate or measure the amount of energy loss within a home as electricity travels from the meter to all of the appliances, electronics, and other electrical items. Students do not need to actually carry out the project. The project is simply to apply the concepts learned in previous phases and to consider what additional information they may need to research and/or data they may need to collect. Designs should include details such as: • What tools they may need (Multimeter? Power meter?). • What information they may need to research and where they will find that information (example: How much electricity travels through the meter in a day/month? Call the utilities company or use a utility bill to find this information). • Data they may need to collect. • Calculations they may need to make. • How their results will be measured or estimated. • How their results will be presented (Watts? Amps? Percentage lost? Cost?) • What energy loss will be calculated? From meter to outlet? Energy lost to energy "vampires" (see *IE Questions: How much do energy "vampires" cost us?*) • All steps required to determine power loss **Evaluate** student understanding of concepts as they apply what they have learned and consider what they still do not know.
Evaluation	Teacher and students should evaluate student learning throughout the lesson.

TEACHER RESOURCES
BSCS 5E Instructional Model[1]
The BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications[2]

STANDARDS ALIGNMENT

Colorado State Science Standards

SC09-GR.8-S.1-GLE.2 There are different forms of energy, and those forms of energy can be changed from one form to another – but total energy is conserved.

Next Generation Science Standards

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

MS-PS3.A: Definitions of Energy

- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

MS-PS3.B: Conservation of Energy and Energy Transfer

- When the motion energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5)
- The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)

National Standards – Benchmarks for Science Literacy

4E/M2 (Grades 6-8): Energy can be transferred from one system to another (or from a system to its environment) in different ways: 1) thermally, when a warmer object is in contact with a cooler one; 2) mechanically, when two objects push or pull on each other over a distance; 3) electrically, when an electrical source such as a battery or generator is connected in a complete circuit to an electrical device; or 4) by electromagnetic waves.

4E/M4 (Grades 6-8): Energy appears in different forms and can be transformed within a system. Motion energy is associated with the speed of an object. Thermal energy is associated with the temperature of an object. Gravitational energy is associated with the height of an object above a reference point. Elastic energy is associated with the stretching or compressing of an elastic object. Chemical energy is associated with the composition of a substance. Electrical energy is associated with an electric current in a circuit. Light energy is associated with the frequency of electromagnetic waves.

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1 https://bscs.org/bscs-5e-instructional-model
2 http://static.nsta.org/files/sc1408_10.pdf