INSIDE ENERGY Bringing Energy Reporting Down to Earth™

Turning Wasted Heat into Power

LESSON OVERVIEW

In this lesson students learn about energy loss to heat at power plants. Students are introduced to the concepts and real life relevance by listening to a four and a half minute Inside Energy audio clip (*IE Questions: Can We Turn Power Plants' Wasted Heat Into Power?*). Students then research for themselves and discuss the details of how power plants work. Finally, students are challenged to apply their new knowledge by designing and building an energy efficient steam-powered turbine. 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 heat, electricity, and kinetic energy.
- 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 and build a project with specific goals and constraints.

GRADE LEVELS: 6-8

KEY VOCABULARY/CONCEPTS

- Power
- Force
- Energy
- Transformation
- Transfer
- Fossil fuels
- Combustion
- Heat energy
- Kinetic energy
- Electric energy
- Electromagnetic
- Power Plant
- Turbine
- Generator
- Particle motion
- States of Matter

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

MULTIMEDIA RESOURCES

IE Questions: *Can We Turn Power Plants' Wasted Heat Into Power?* [Audio]

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

SUGGESTED TIME: 4 days

- Day 1: Engagement
- Day 2: Exploration
- Day 3: Explanation and begin Elaboration
- Day 4: Elaboration

MATERIALS

- Library or computers with internet for online research (Day 2)
- Variety of turbine-making materials (Day 3 and 4)
  - Heavy duty aluminum foil
  - Index cards
  - File folders
  - Wax paper
  - Plastic bags
  - Plastic straws
  - Unsharpened pencils
  - Pushpins
  - Washers
  - Variety of tapes
  - Scissors
  - String
  - Other building materials?
- Steam testing device (see diagram in ***Elaboration*** section) Day 3 and 4
  - Hot plate
  - Pot or beaker with water
  - Pie tin or lid with hole (~3cm in diameter) to use as lid on top of pot/beaker
  - Safety goggles
  - Oven mitt

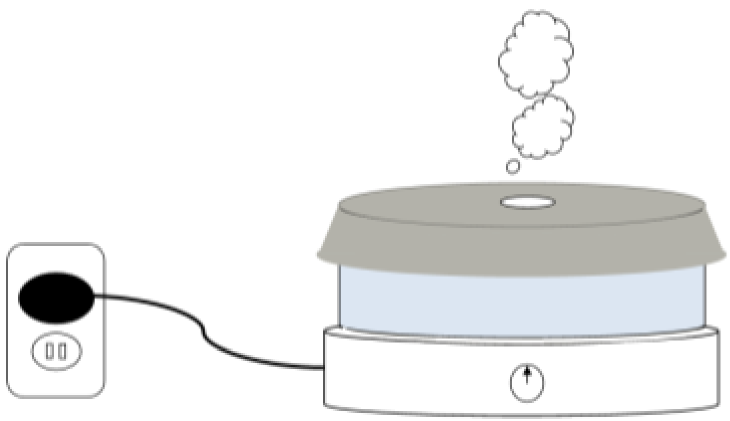
LESSON PREP

Collect and organize materials for design and build challenge in Elaboration phase (Days 3 and 4). Prepare the steam testing device ahead of time and turn on the heat ahead of time so that steam is ready when needed during the class.

THE LESSON

Engagement	Listen to the audio sound clip, *IE Questions: Can We Turn Power Plants' Wasted Heat Into Power?* You may also choose to have students read the text that accompanies the sound audio clip, but **do not provide the visual diagrams from the webpage**. Discuss the following: • What are the different types of energy discussed in the audio clip? • How is energy transferred and/or transformed in the cases discussed in the audio clip? • If coal power is only about 30% efficient, what happens to the rest of the energy? Where does it go? • Why do we care if power plants are efficient or wasteful? • Why is CHP (combined heat and power) mostly only found in large settings such as

	universities or hospitals? Ask students to create a diagram to show how fuel is converted into power in a typical power plant, in a combined cycle system, and in a combined heat and power (CHP) system. Diagrams should be based on prior knowledge and their understanding of the audio clip. Diagrams may resemble the diagrams included with the text on the Inside Energy webpage, but students should not see these diagrams prior to creating their own. **Evaluate** the discussion and diagrams for current understanding as well as misconceptions. In particular, evaluate for understanding of concepts such as conservation of energy, energy transfer vs. energy transformation, heat, and force. Use these points to focus and redirect during the Exploration and Explanation phases.
Exploration	Ask students to research how power plants and steam turbines work to produce electrical energy. Potential resources may include text books, the library, and the internet. At a minimum, students should find answers to the following questions: • What is a turbine? • What forms of energy can be utilized to create steam in a power plant? (*coal combustion, petroleum combustion, nuclear combustion, geothermal heat*) • How does steam turn the turbine? (*the force of the steam molecules hitting the blades of the turbine causes movement of the blades*) • How is the mechanical energy of the spinning turbine transformed into electrical energy? (*magnetic conduction - a wire coil spins around a magnetic field causing electrons to move – the flow of electrons is electricity*) If students conduct research during class time, the teacher can converse with students one on one and in small groups to **evaluate** their understanding of power plants and energy transformation within the plants.
Explanation	In a class discussion and/or diagram, students should explain how electricity is created in steam-powered power plants. During the discussion or within the diagram, students should address the following questions and concepts: • What causes the turbine(s) to turn? Is energy transferred or transformed in this step? • How is the mechanical energy of the spinning turbine transformed into electrical energy? (*response details may vary depending upon student familiarity with electromagnetism*) • Identify points in the system where energy can be "lost". Where does it go? • Natural gas power plants do not normally produce steam. How do these power plants turn the turbine? Can energy also be lost in these power plants? How so? • If students completed the Inside Energy lesson, "A Watched Pot", have them compare the energy loss in heating a tea kettle to the energy loss in a power plant. How is this energy loss similar? How is it different? • Consider the audio clip, *IE Questions: Can We Turn Power Plants' Wasted Heat Into Power?* What are some different ways that the "lost" energy can be recaptured and used? Teacher and students should **evaluate** student understanding of the concepts with a specific focus on energy, energy transfer, energy transformation, and conservation of energy.
Elaboration	As the video pointed out, energy loss in power plants can be minimized and fossil fuel use can be made more efficient.

	Challenge student groups to design, build, and test their own high-efficiency steam-powered turbine using materials provided (*see materials list*). Provide students with the following guidelines: 1. Students may only use the materials provided. 2. Turbines must be testable by placing them over a stream of steam exiting a hole in a lid/pie tin on top of a pot/beaker of boiling water (*see diagram*). 3. Efficiency will be determined by the rate of rotation of the turbine (rotations/minute). The rotational rate is not the actual efficiency. Student groups will be able to compare different designs and should understand that a higher rotational rate indicates more kinetic energy transfer from the steam molecules to the turbine as compared to turbines with lower rotational rate. In this case, greater energy transfer means a higher efficiency. 4. The challenge is to design and build the most efficient (fastest turning) turbine with the understanding that the faster the turbine turns, the more energy it has and the more energy it could transform into electricity. 5. After the first build, students will be able to test their turbine, observe other student groups' turbines, and rebuild for greater efficiency. 6. Retest the second-round designs. Steam tester diagram:  Possible extensions and alternatives: 1. In place of steam, a blow dryer could be used. Discuss how the air flow is similar to the air forced through a turbine in power plants that use natural gas combustion as the fuel/energy source. 2. Expand the challenge to include the design and build of a turbine connected to an electromagnetic generator (add magnets, copper wire, and cardboard tubes to the materials list). Connect the generator to an electric meter and test by measuring energy output. 3. Combine this lesson with [the Inside Energy lesson, "Power Grid Reliability."] For the elaboration section of the second lesson, have students redesign their turbines to be both efficient *and* to maximize the effect of inertia.

	Evaluate student understanding of concepts as they apply what they have learned and consider what they still do not know. As they work, talk to students about the challenges that they face. What makes this project difficult? What do they feel confident about?
Evaluation	Teacher and students should evaluate student learning throughout the lesson. At end of lesson, have students reflect on what they learned, what challenges they faced, and what they would do to improve their turbine's efficiency and why. Make sure that they can connect their engineering project back to the initial Inside Energy audio clip. How could they improve their overall efficiency by considering options such as combined power cycles or combined heat and power? Assess for understanding of key vocabulary including energy, conservation of energy, energy transfer and energy transformation.

TEACHER RESOURCES

BSCS 5E Instructional Model[1]
The BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications[2]
How Power Plants Work[3]

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-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-PS1.A: Structure and Properties of Matter

- Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)
- In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

[1] https://bscs.org/bscs-5e-instructional-model
[2] http://static.nsta.org/files/sc1408_10.pdf
[3] http://www.entergy.com/energy_education/power_plants.aspx

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

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)
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3)

MS-PS3.C: Relationship Between Energy and Forces

- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2)

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

<u>National Standards – Benchmarks for Science Literacy</u>

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.