How Power Plants Work

Last Updated: August 18, 2013

Background

There are many different types of power plant technologies, each with positive and negative aspects. Here we explore some conventional power plant types: coal (where CO_2 is released), coal (where CO_2 is captured), coal-to-gas (where CO_2 is released), coal-to-gas (where CO_2 is captured), wind, natural gas, nuclear, solar cell, energy efficiency, and biomass-and-coal.

In coal power plants where CO_2 is released, the coal is burned to create steam. The steam powers a turbine, which in turn runs a generator, producing electricity. As the coal is burned, it releases CO_2 into the air. While coal plants are steady and reliable, they release a lot of CO_2 into the atmosphere and produce a lot of solid waste in the form of ash. Coal mining also negatively impacts the environment by disturbing the land and potentially polluting streams. In addition, while coal plants are safe for operation, the coal mining is still dangerous today.

In coal power plants where CO_2 is captured, the plant produces electricity the same way as a coal power plant where CO_2 is released. However, there is additional equipment to convert the CO_2 into a liquid and transport it to rock formations, where the liquid CO_2 will be trapped. While this decreases the release of CO_2 into the atmosphere, there is a small chance that CO_2 can contaminate underground drinking water. In addition, there are also very small risks of CO_2 leaks and very small risks of earthquakes occurring as a result of the increase in pressure.

Coal-to-gas power plants (where CO_2 is released) use the heat from the burning of coal into gas to power a turbine. The turbine then runs a generator to produce electricity. The burning of coal to gas also provides heat to make steam, which is used to power a second turbine. Because coal-to-gas power plants have two turbines, they are more efficient than the previously mentioned coal power plants. While coal-to-gas power plants release less CO_2 than coal power plants, they release similar amounts of solid waste and also require coal mining.

Coal-to-gas power plants can also have capture equipment to reduce air pollution from the release of CO_2. This capture equipment is a little better than coal power plants with CO_2 capture, but work in the same way. CO_2 is converted to liquid and stored over 2500 feet underground. The risks are the same as those for coal-to-gas power plants where CO_2 is released, and for coal power plants where CO_2 is captured.

Natural gas power plants work similarly to coal-to-gas power plants. The gas is burned, and the heat from the gas is used to power a turbine. The turbine runs a generator, producing electricity. The hot gas also makes steam, which is used to power a second turbine and a second generator. Natural gas can either be found in conventional sources or unconventional sources. Conventional natural gas is found in sandstone and other sponge-like layers of rock, while unconventional natural gas can be found trapped in shale deep underground. Unconventional natural gas can be extracted with methods such as horizontal drilling, where a vertical well is drilled, followed by a hole drilled sideways. A salty water solution is then pushed through the well, causing the rock to break up as the result of high pressure and releasing the gas to the surface. While natural gas still releases CO_2 into the atmosphere, it is about half that of a coal power plant, and doesn't release any solid waste. However, drilling for unconventional natural gas is controversial, and may disturb local plants, animals, and water supplies.

Nuclear power plants require enriched uranium atoms. These atoms are split to release heat, which powers a turbine that runs a generator, creating electricity. Many people worry about

the safety of nuclear power plants. However, the chance of a nuclear accident is very small, and the plants release almost no radiation into the ground, air, and water. The waste from nuclear plants will emit radiation, but storage technology should keep the waste safe for up to thousands of years. Nuclear technology built in the future will be even safer than the already safe design as well.

Two well-known equations govern power. Ohm's Law states the voltage (V) is equal to the product of the current (I) and resistance (R), or:

$$V = I * R$$

and the power (P) is equal to the product of the voltage and the current, or:

$$P = V * I = R * I^2$$

Additionally, Kirchoff's Current Law states that all currents into a node sum to zero, and Kirchoff's Voltage Law states that all voltages in a loop sum to zero.

Objectives

Students will be able to:

- Describe what the most common fuels used in conventional power plants are
- Understand how power plants generate electricity through boiling water and spinning a turbine. They should also understand the concept that spinning an object can produce electricity (even if they don't know the physics behind it).
- Burning fuel to produce electricity is inefficient.
- The relative greenhouse gas emissions from coal and natural gas power plants.

Materials Needed

- Pinwheels
- Hot pot burner
- Stand
- Hand-cranked flashlight
- "How Power Plants Work Lesson 3.pptx"

Safety Concerns

None.

Vocabulary

- Power: describes how much energy can be produced in a given time. Also to supply a device with electricity; the product of voltage and current. A common unit of measurement is a *watt* (W); also measured in watts, kilowatts, megawatts, etc.
- Energy (general): Energy that the plants and animals originally obtained from the sun is stored in the form of carbon in natural gas. Also the capacity of something to do work; an

amount. Measured in watt-hours, kilowatt-hours, megawatt-hours. A typical American household used 940 kWh per month in 2011.

- Voltage: the difference in the electric charge of two places. A common unit of measurement is a *volts* (V).
- Current: flow of electric charge, or the flow of electrons. A common unit of measurement is an ampere, or amp (A).
- Resistance: a material's opposition to electric current. A common unit of measurement is an ohm (Ω).
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Procedure

Time	Activity	Description	Supplies
15	Introduction	Group discussion: 1. Where does electricity come from? Describe conventional power plants, what fuels are used (pass around coal and can of natural gas).	
25	Pinwheel Experiment	Have students break into groups. 1. Let students play around with pinwheels, finding right angle to blow in order to get them spinning fast. 2. Have students hold two pinwheels in line and blow such that they both spin. Observe speed of second (downwind) pinwheel. Remove first pinwheel and observe change in speed in second. a. Why does this occur? b. Is all of the energy in your breath converted into rotational energy of pinwheel? c. How could you increase the fraction of breath energy converted into rotational energy? d. What is efficiency and how does it relate to what we have just done?	Pinwheels
5	Teacher Demonstration	Boil water and spin a pinwheel. Describe that this is what happens inside a power plant. Promote group discussion.	Hot pot burner, pinwheel, stand
5	Teacher Demonstration	Spin hand crank and generate power. Promote group discussion.	Hand-cranked flashlight
15	Lecture	1. Describe how turbines operate in real turbines: both Brayton and Rankine cycles. 2. Display efficiency numbers, relate to earlier experiment with multiple turbines. 3. Display emissions with tie-in to common graphic.	"How Power Plants Work Lesson 3.pptx"

Additional Resources

Reputable

Emirates Nuclear Energy Corporation. "ENEC: How Does Nuclear Energy Work?" Emirates Nuclear Energy Corporation. Web. 19 Jul 2013. <http://www.enec.gov.ae/learn-about-nuclear-energy/how-does-nuclear-energy-work/>

The Emirates Nuclear Energy Corporation gives a succinct summary of how nuclear power works with an accompanying video to demonstrate the process. Teachers looking for a reputable source to explain the basics behind nuclear power could look here.

Electric Power | Georgia State University. URL: [Last accessed August 25, 2013]. http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elepow.html

Energy | US Energy Information Administration (EIA). URL: [Last accessed August 25, 2013]. http://www.eia.gov/

Office of Nuclear Energy | Department of Energy (DOE). URL: [Last accessed August 25, 2013]. http://energy.gov/ne/office-nuclear-energy

United States Environmental Protection Agency,"Natural Gas." *US Environmental Protection Agency*. 30 Apr 2013. Web. 13 Jun 2013. <http://www.epa.gov/cleanenergy/energy-and-you/affect/natural-gas.html>.

This EPA page gives a summary on what natural gas is, what natural gas is used for, and how it's used to generate power. If a teacher wanted to get a better background on natural gas, this would be a good place to start looking.

Opinion / Newspaper

Base concepts of methane and other hydrocarbons | Youtube. URL: [Last accessed August 25, 2013]. http://www.youtube.com/watch?v=UY8DAlHkkw8

Coal Can Do That. "Coal-To-Liquids & Coal-To-Gas." Coal Can Do That. Web. 21 Jul 2013. <http://www.coalcandothat.com/coal-to-gas.php?view=section2>

The Coal Can Do That page talks about the benefits and process of converting coal into either a liquid or a gas. Though it is clearly biased, teachers looking to introduce the process of gasification could look here.

International Risk Governance Council. "Power plant CO2 capture technologies." International Risk Governance Council. 2009. Web. 21 Jul 2013. <http://www.irgc.org/issues/carbon-capture-and-storage/power-plant-co2-capture-technologies/>

The International Risk Governance Council primarily links to a research paper from Edward Rubin that discusses Carbon Capture and Sequestration technology. However, it also gives a brief summary of what it is, and how the IRGC approached the research. Teachers ultimately looking for an incredibly detailed summary of CCS – from the research paper – could look here.

Pittsburgh Tribune Review. "NRG Energy to burn natural gas at coal-fired generating plant." Pittsburgh Tribune Review. 25 June 2013. Web. 21 Jul 2013. <http://triblive.com/business/headlines/4249970-74/coal-gas-plant#axzz2Zi1t4eXg>

Because of increasingly strict emissions standards, NRG Energy plans to convert their coal power plant to natural gas. The article gives some statistics on how many power plants NRG Energy has, what the estimated cost of the switch may be, and how power generation will differ. Teachers looking for a current event on why the topic is relevant could look here.

World Coal Association. "Coal electricity, coal power plants – World Coal Association." World Coal Association. Web. 21 Jul 2013. <http://www.worldcoal.org/coal/uses-of-coal/coal-electricity/>

The World Coal Association page on coal power plants – while biased in favor of coal – provides statistics on coal usage globally, provides a helpful diagram of what a power plant consists of, and talks about recent improvements in efficiency. Teachers looking to highlight some of the positive aspects of coal power plants could look here.

Author(s)

Lesson idea from David Luke Oates, Alan Jenn, and Julian Lamy; final product compiled by Kelly Klima on behalf of the Leonard Gelfand Center for Service Learning and Outreach.

Funding Sources

Portions of this work were supported by a) the Leonard Gelfand Center for Service Learning and Outreach, and b) the Center for Climate and Energy Decision Making (SES-0949710) through a cooperative agreement between the National Science Foundation and Carnegie Mellon University.

Next Generation Science Standards Alignment

HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Crosscutting Concept: Influence of Science, Engineering and Technology on Society and the Natural World

PS3.A: Definitions of Energy

PS3.B Conservation of Energy and Energy Transfer