Look around the room for things that run on electricity.

How do we make electricity?

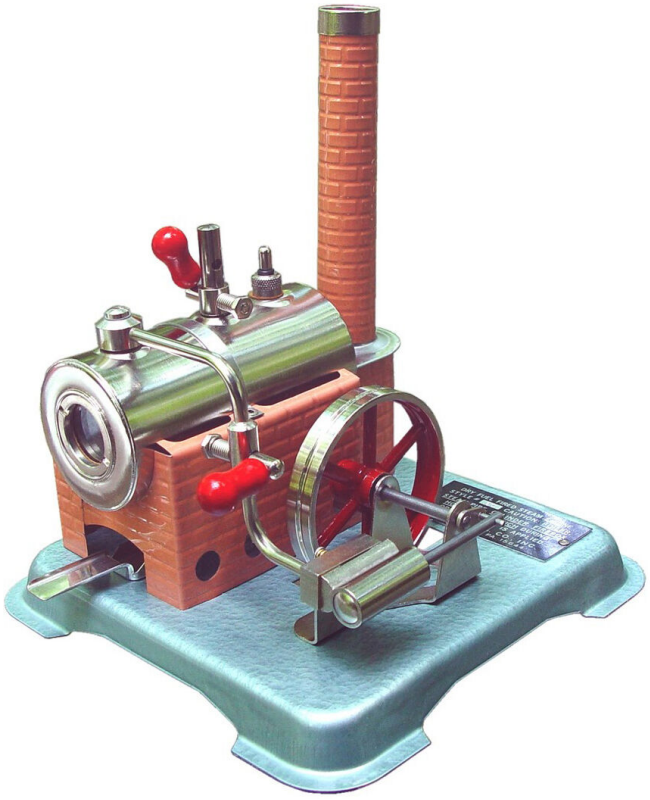
How does it get to your school?

Let's find out!

Steam Power (1769-1820): Exploration

About 250 years ago James Watt invented the steam engine. How do you think a steam engine works?

(Answers will vary.)



Your teacher will run the steam engine. Watch what happens.

Can you explain how it works?

The steam engine is used only as a teacher demonstration.

Instructions:

Unscrew the safety valve and use the small funnel to fill the boiler with water to about halfway up the sight glass on the end.

Place 2 fuel tablets on the firebox tray. They light easily with a match.

Within about 5 minutes steam pressure will build to the point that the engine will run. Usually this requires adjustment of the throttle and a quick flip of the flywheel. The whistle will be very effective in getting the students attention.

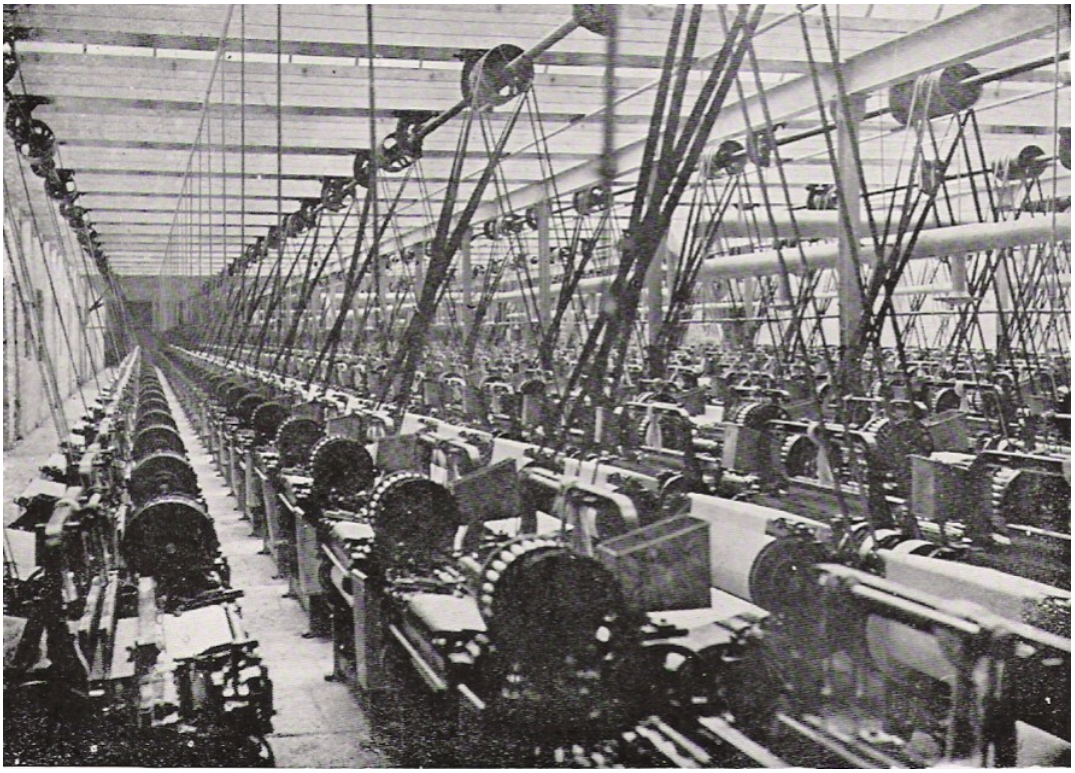
Spend as little or as much time on the engine as your pacing allows. The main idea of including the steam engine is to provide a historical perspective on the transfer of energy. You may wish to use a rubber band as a drive belt to spin the shaft of a small motor. This will generate about 2 volts of electricity that can be measured with the multimeter (set on DC voltage) or possibly illuminate a small bulb.

The fuel tablets can be extinguished by blowing them out. The engine will get hot so be careful when handling it and be sure it has cooled before packing it away.

Steam Power (1769-1820): Discussion

What happens to the water as the fuel burns?

The water gets hot and changes from a liquid to a gaseous (steam) state at 100 °C or 212 °F. During this phase change, it expands by 16 times, producing pressure within the closed boiler.



This is an old factory powered by a steam engine. Would you want to work in this factory? Why or why not?

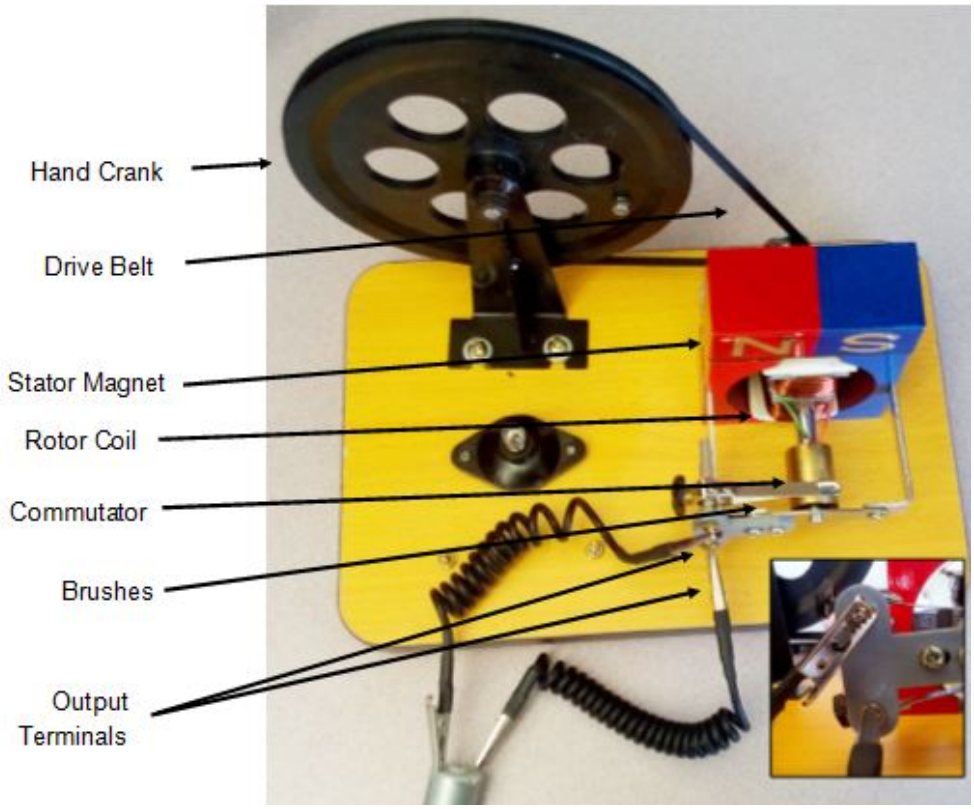
Although it was a big improvement over previous work conditions, steam powered factories were full of belts, pulleys, and open gears. They were not safe. This picture is of a textile mill where fabric was woven and garments sewn together.

Why were steam engines better than wind or water power?

Steam engines were not dependent on wind or water conditions and could be placed anywhere, they were not limited to being near rivers or in windy areas.

Linking Magnetism to Electricity (1820-1831): Exploration

Mr. Ampere used electricity to make magnets in 1827. In 1831 Michael Faraday used magnets to make electricity.



Turn the crank on the generator. What part spins most and what parts do not move at all?

The most important observation is that the rotor rotates and the stator stays stationary.

Connect two wires from the generator to the motor.

Note: The alligator clips cannot touch the metal case of the motor and cannot touch each other. A small piece of tape on the motor shaft will make it easier to see that it is turning.

Turn the crank. What happens?

The crank spins the rotor with a belt. The rotor is a coil of wire that spins inside the magnetic field. The stationary magnets are called the "stator." Electricity is generated and flows through the wires to make the motor spin. The generator uses magnets to make electricity. The motor uses electricity to make magnets, causing the shaft to spin.

Turn the crank slowly. What happens?

The motor will turn very slowly, if at all. Help students realize that they are putting very little energy into turning the crank and very little energy is coming out.

Turn the crank fast. What happens?

The motor will spin very fast indicating that it is receiving a lot of energy. The students will also get tired quickly, indicating that they are putting a great deal of energy into the generator. Help them to see the correlation between their input and the generator output.

Linking Magnetism to Electricity (1820-1831): Discussion

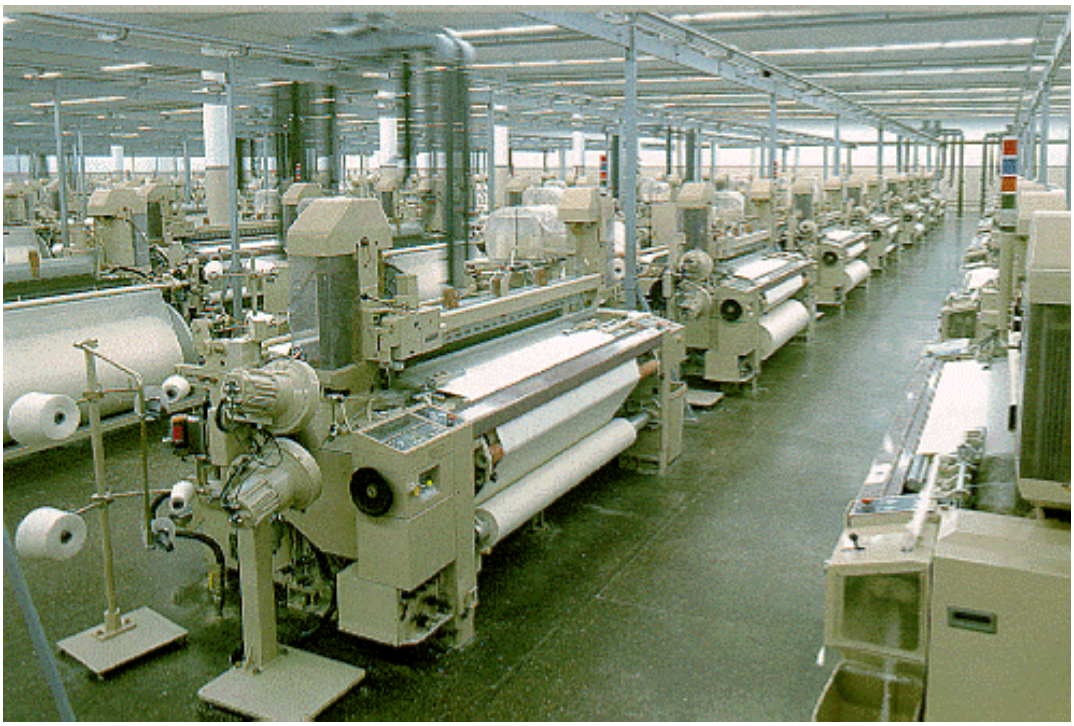
How do you think the generator is making electricity?

A wire spins inside a magnet.

How does electricity get from the generator to the motor?

Electricity goes from the shiny metal brushes to the wires then to the motor.

Inventors soon used steam engines to turn generators. The generators made electricity. Jacobi invented the electric motor in 1834.



Modern factories with electric machines are much safer for the workers than the old machines powered by steam engines and belts.

Electric Lights (1860-1900): Exploration

For about 50 years electricity was only used in factories.

Nobody thought they needed electricity in their houses until the invention of the light bulb.

Clip the 2 wires to the screws by the light bulb.

What happens as you turn the crank?

The electricity being generated is not of uniform power. It fluctuates widely with the spinning of the rotor. The bulb will flicker at slow speeds and glow bright at higher speeds.

Electric Lights (1860-1900): Discussion

What happens when you turn the crank fast?

More mechanical energy was put into the system (turning faster) so more electrical energy is produced and bulb gets brighter.

What happens when you turn the crank slowly?

If it turns too slowly, the light will not light up.
Your students may have also noticed that the direction they spun the generator did not matter with the light bulb, but it did change the direction of the motor. This is because positive and negative affect direction of motor movement while the bulb works the same either way.

How did the electric light bulb change the way people lived?

With the electric light bulb, it was much more likely that people would be out and about after dark. This allowed employers to schedule a "night shift" so factories could continue working around the clock.

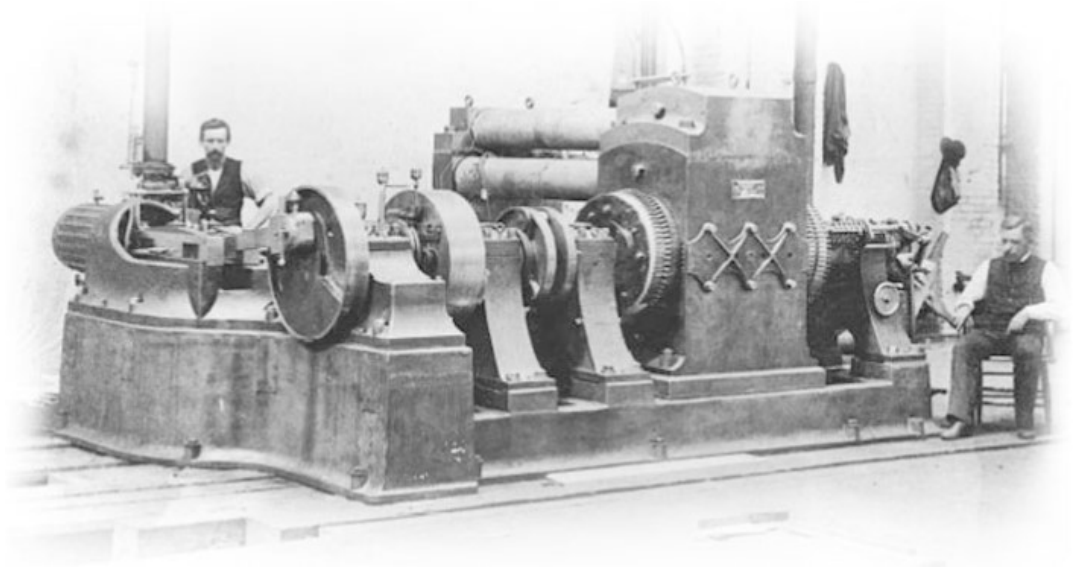
Why must you never allow the two bare ends of the wires to touch each other?

One wire is "positive" and the other is "negative." If they touch, a "short circuit" occurs, allowing electricity to flow with little resistance. A short circuit often results in ahot wire, a spark (maybe starting a fire) or a drained battery.

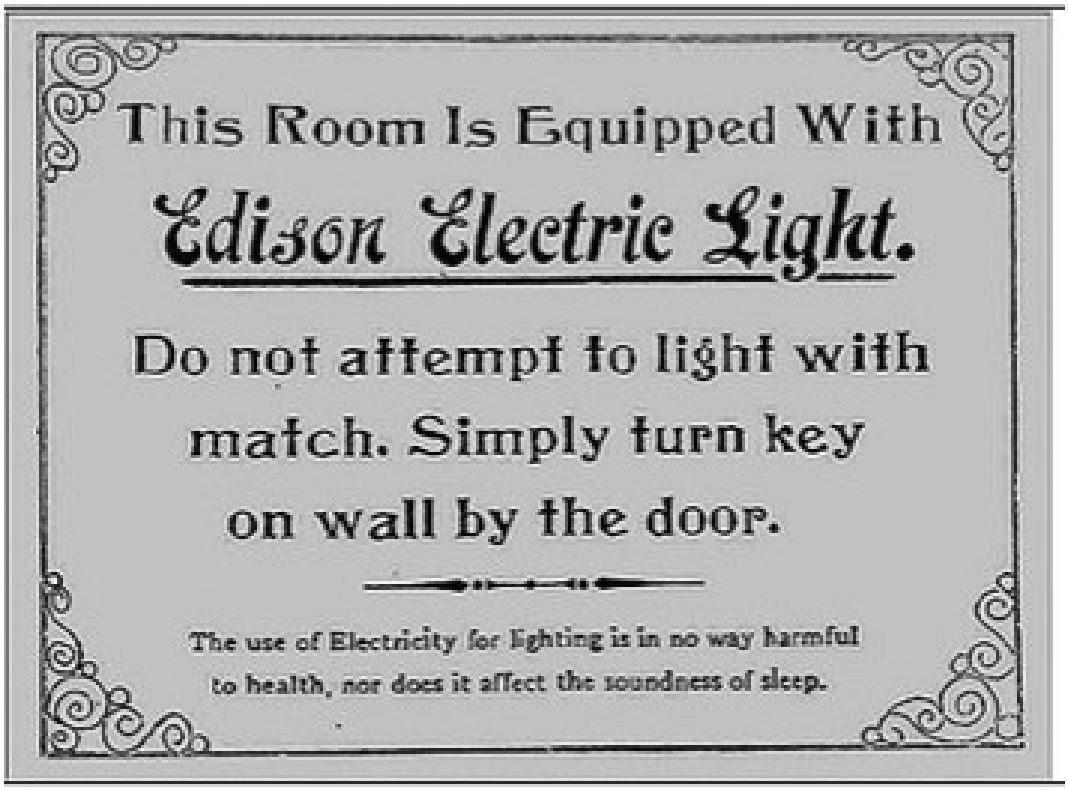
You will not need the generator any more. Put it away.

Be absolutely certain that a hand-crank generator is NEVER attached to the grid system. It can generate over 20 volts of electricity, which is 4 times the voltage the grid set is designed to handle.

In 1841 Frederik de Moleyns made the first light bulb. Thomas Edison improved the bulb and made a generator and "power grid." He put electric light bulbs at Pearl Street Station in New York City in 1882. This was one of his huge generators.



This sign helped people learn how to use the new light bulbs.



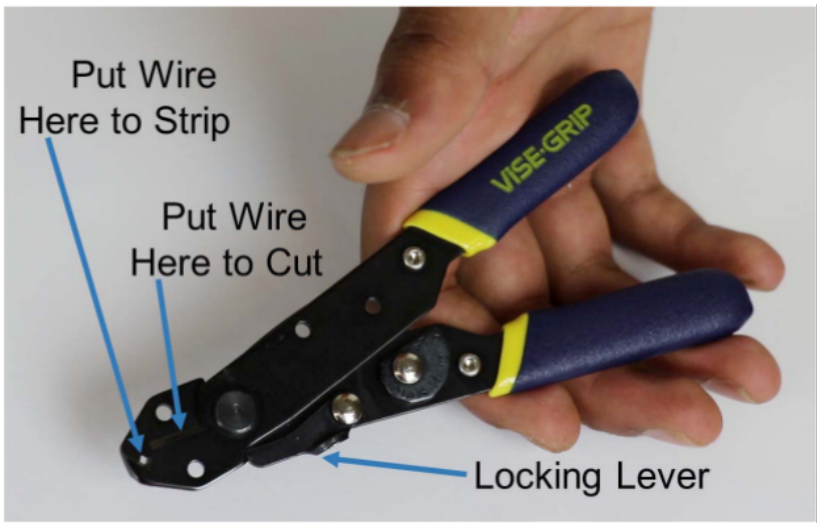
New Skills for Electricity (1865-today): Exploration

There are a few things you need to know before you can get started hooking up your grid.

Note: Your students will want to start hooking up wires immediately. Spend a few minutes showing them how to cut and strip wires and how to connect them to the springs and alligator clips.

Your teacher will show you how to cut and strip wires.

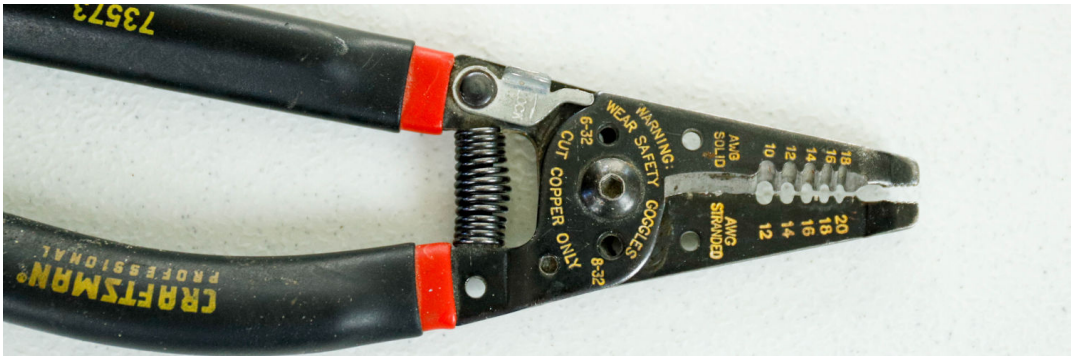
There are two different types of wire cutter/stripper tools.
Adjust the cutter to strip the wire by turning the little dial on the side. It should be set on 20. You can hold it in place with a small piece of tape.



Your wire tool might look like this:

Pull the wire to remove the insulation. Students tend to twist the tool, making it difficult to pull out the wire.

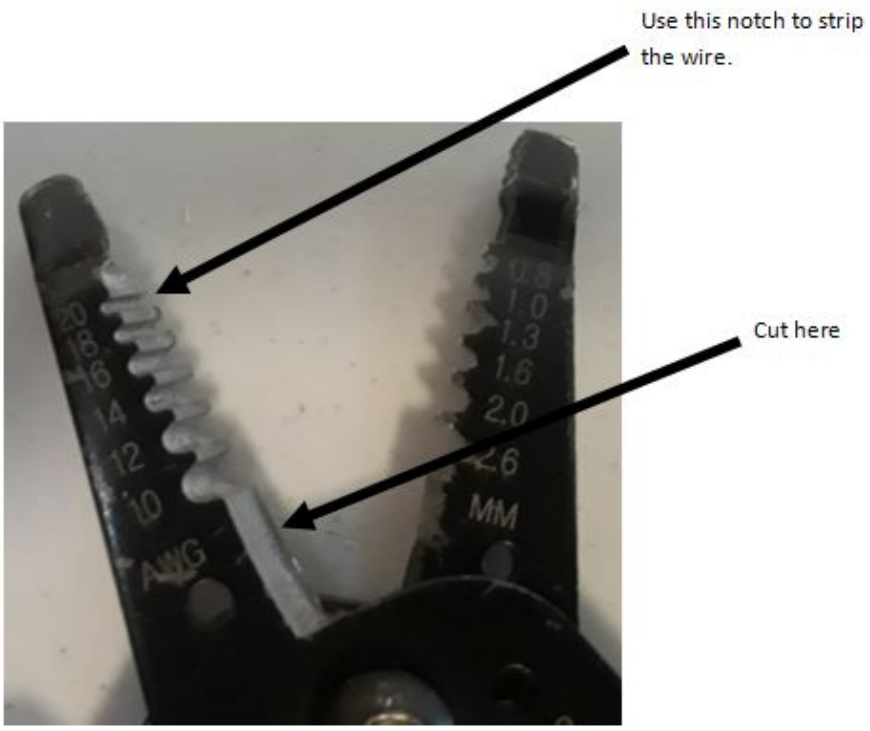
This is a good opportunity to discuss careers. Ask your students if they have ever seen one of these tools or if they know somebody who uses one. It is likely that several of your students know an electrician. You may wish to invite an electrician to visit your classroom. She/he may be impressed with what your students are doing.



Use this notch to strip the wire.

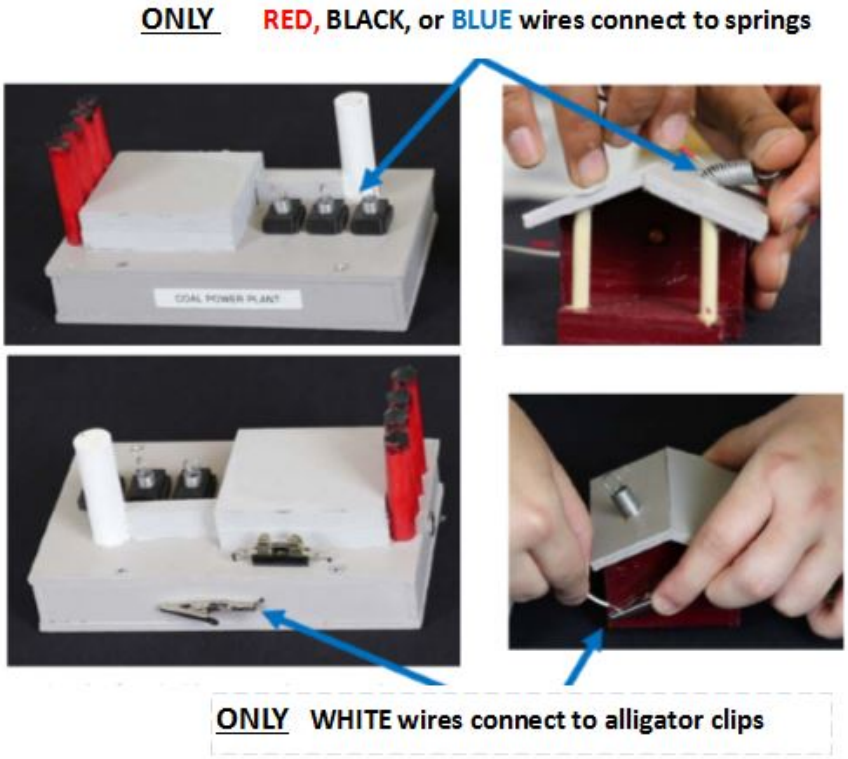
Cut here.

Put the wire in the first notch labeled 20.



The color of the wire is important. Red, black, and blue wires connect to springs. White wires connect to alligator clips.

If the wrong-colored wires are used, it is more likely a positive spring will connect directly to a negative alligator clip, which will burn a fuse in order to protect the system. If this happens, correct the problem and replace the fuse in the power plant using one of the extras packed in your kit. Throw the ruined fuse away.



To connect wires, push the spring to the side or pull it down. Stick the bare end of the wire into the spring.

Releasing the spring allows the coils to tighten on the wire, holding it securely. You may need to demonstrate this technique to your students. Do not twist the wire around the spring—this can cause the lights to flicker and the system to be unreliable. If multiple wires are to be inserted in the same spring, bend it different directions (left for one, right for the next, etc.).

New Skills for Electricity (1865-today): Discussion

Show your teacher how to cut a wire.

Young students have a little trouble cutting a wire, but they might not get it to the right length. They usuallycut them too short.

Show your teacher that you can strip the plastic insulation off a wire.

It seems everyone has trouble figuring out how to strip a wire. If the dial is set incorrectly, the cutter willeither cut all the way through the wire or not cut through the plastic insulation. For these wires, it mustbe set on 20. Also, inexperienced electricians tend to twist the cutter when they pull the wire. This bindsit in the cutter making it difficult to pull off. With some practice, your students will get it figured out.

Why is it so important to use the right color of wire?

People working with electricity know certain things cannot be connected to other things. A positive cannot connect directly to a negative. By using different colors of wires, it is less likely that the wrong connections will be made.

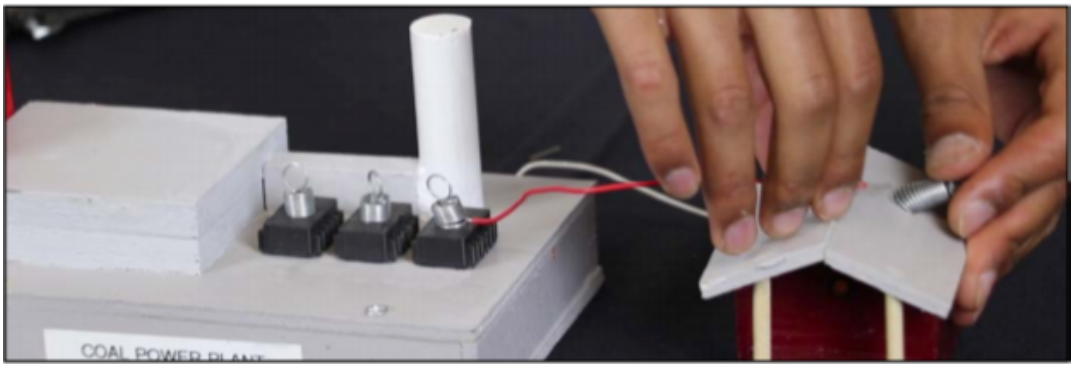
Electricity to Your House (1900-1920): Exploration

Pick a power plant and put a red, black, or blue wire on one of the springs.

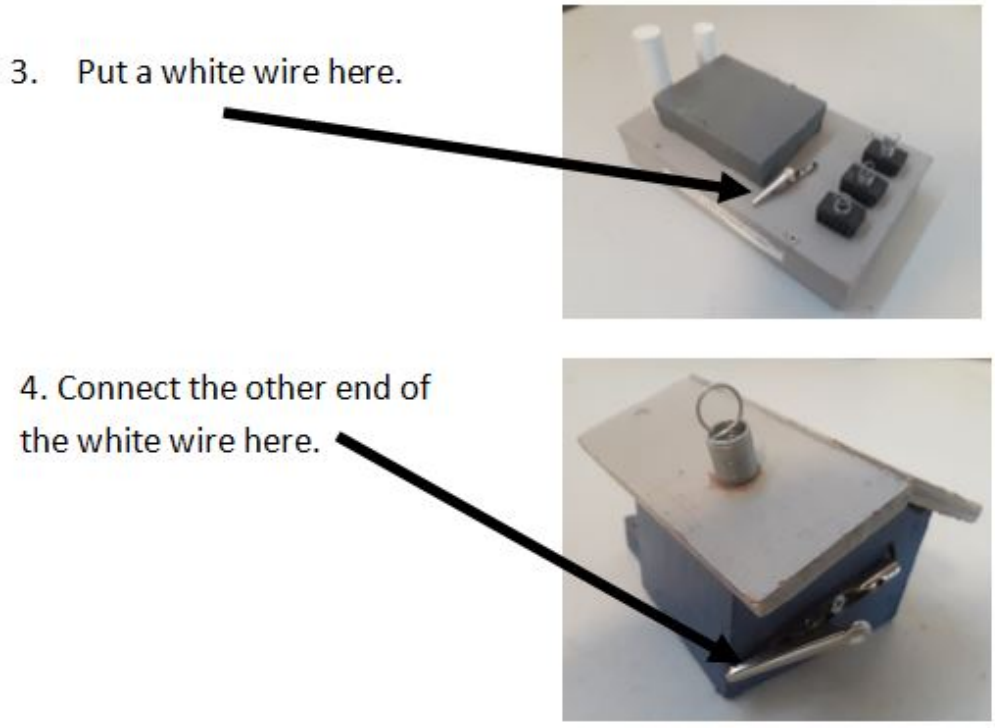
There are three spring terminals on each power plant. In upper grades students use all three, but for lower grades it does not matter which ones are used by your students. Inspect the wiring before allowing students to connect to the headquarters office.

Pick a house. Put the other end of the colored wire in the spring.

There are several different buildings, most of which will work fine for your students. It is easiest and probably most appropriate to use the houses. They may wish to use one of the businesses or other buildings.
Do not allow your students to use the factories or any of the other larger commercial buildings. They have 3 springs instead of one and they operate on 3-phase electricity only, a concept introduced in upper grades.



Pinch a white wire in the alligator clip on the power plant. Pinch the other end of the wire in the alligator clip of the house.



Your teacher will check it and turn on the power.

There is an LED on each house that will illuminate when powered.
Note: The 5-volt electrical power for the grid comes from the adapter that plugs into a wall outlet and is inserted intothe side of the headquarters office. The 1/4" audio cables supply power to the power plant.

Did your home get power?

Electricity to Your House (1900-1920): Discussion

What type of power plant did you use?

• Natural Gas

• Coal

• Nuclear

• Renewable (Wind or Solar)

You may wish to discuss environmental impacts of different types of power plants. Simply stated, coal and natural gas plants produce pollution, but these fuel sources are abundant and relatively inexpensive. Nuclear energy does not pollute, but produces waste products that are nearly impossible to discard. Renewable energy (solar and wind) may not be as harmful to the environment as other sources, but they can be unreliable since wind speeds vary and it is always dark at night.

Have you seen a wind farm? If so, where have you seen it?

There are several wind farms in Illinois producing about 5% of the total electrical use in the state. Nuclear power is the largest producer of electricity in Illinois at about 52% of the total.

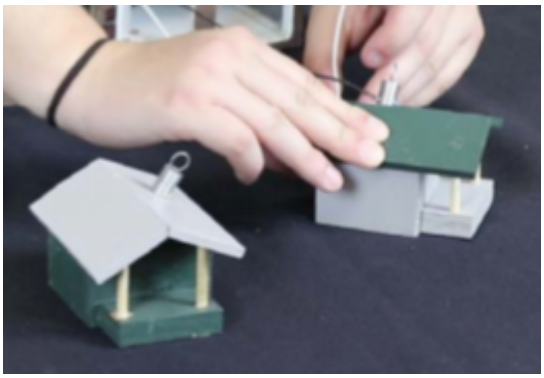
What is the best kind of power plant?

There is no "best" kind of power plant. All have positive and negative aspects. The purpose of this question is to start a discussion. Your students will all have opinions. Help them base their opinions on facts as much as possible.

One Power Plant, Many Houses (1920-1940): Exploration

Unplug the cable from the headquarters office.

Connect a colored wire from the spring on the house to the spring on another house.



Connect a white wire from one alligator clip to the other.

Call your teacher to check your wires.

Did both homes light up? Why or why not?

Look for any place where the white wire and red wire connect. Help students resolve problems but avoid fixing it for them. When they are ready, plug the 1/4" audio cable back into the power plant. All connections in this system are in parallel, so both houses should receive the same power.

Unplug the cable from the headquarters office.

Unplug the colored cable from the power plant spring.

Move the homes away from the power plant and place a low voltage pole between them.

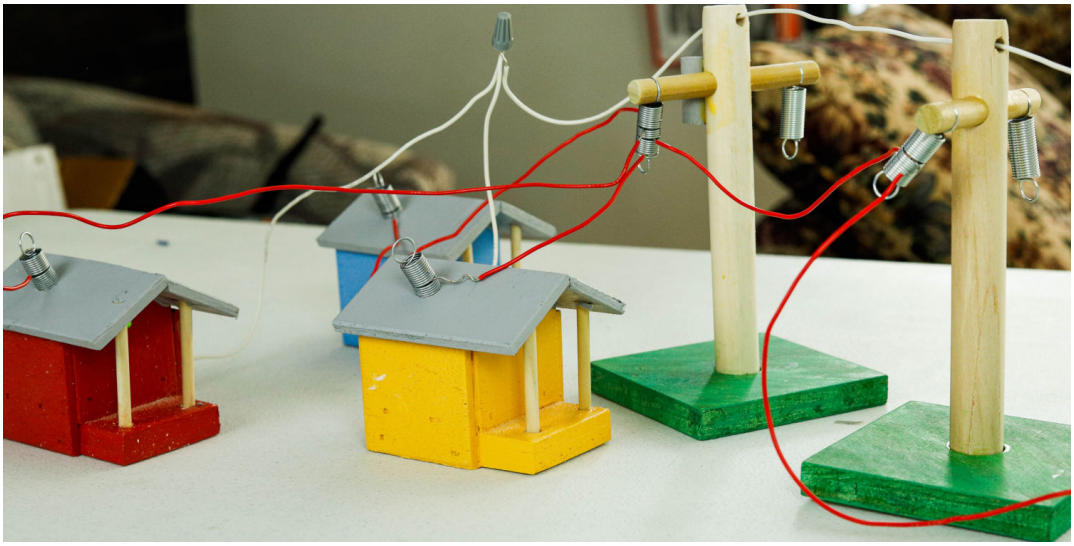
Connect all the wires you need to—colored wires from spring-to-spring and white wires from alligator clip to alligator clip.

Students may struggle to use the springs on the distribution poles. While it is easiest to bend springs on buildings to the left or right, it is sometimes easiest to pull springs down on distribution poles before sliding the wire inside.

White wires can be run through the hole at the top of the distribution poles, or they can run along the ground—whichever is easiest.

Call your teacher to check your wires.

Did both homes still light up? Why or why not?



One Power Plant, Many Houses (1920-1940): Discussion

Have you ever lost electricity at your house? Did the whole neighborhood go dark? Why?

Usually several houses in the neighborhood share the same main power line. If there is a problem, the entire neighborhood loses power.

Why does every house not have their own generator?

Some houses have their own stand-by generators. Big generators, however, are much less expensive to build and operate than thousands of small ones. For example, on a small scale a 2000 watt generator costs about $500 and an 8000 watt generator is about $1000. It is four times bigger but only twice as expensive. If you wish to do some research and multiplication, check out wind turbines for sale on the internet. Larger ones are obviously more expensive, but produce much more power than smaller models. That is why wind turbines are so large and power plants are huge.

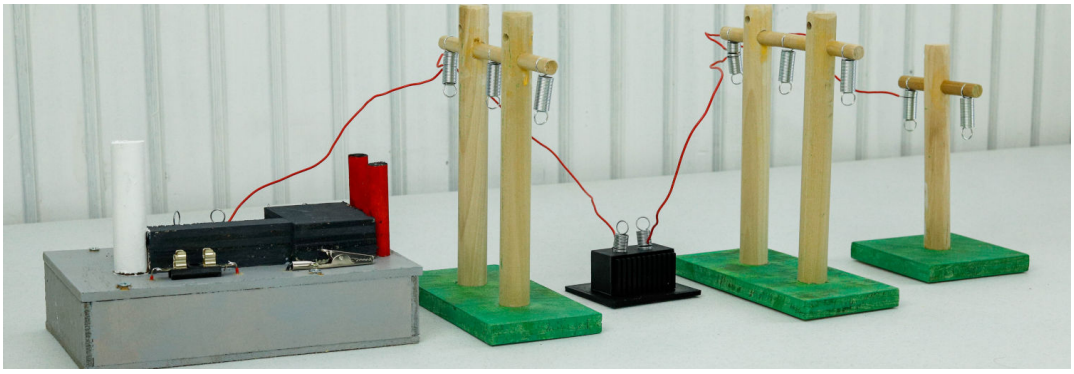
Thomas Edison, Frank Sprague, George Westinghouse and Nicola Tesla were all inventors. They figured out how to get electricity to your house.

High Voltage (1886-today): Exploration

Unhook all of your wires.

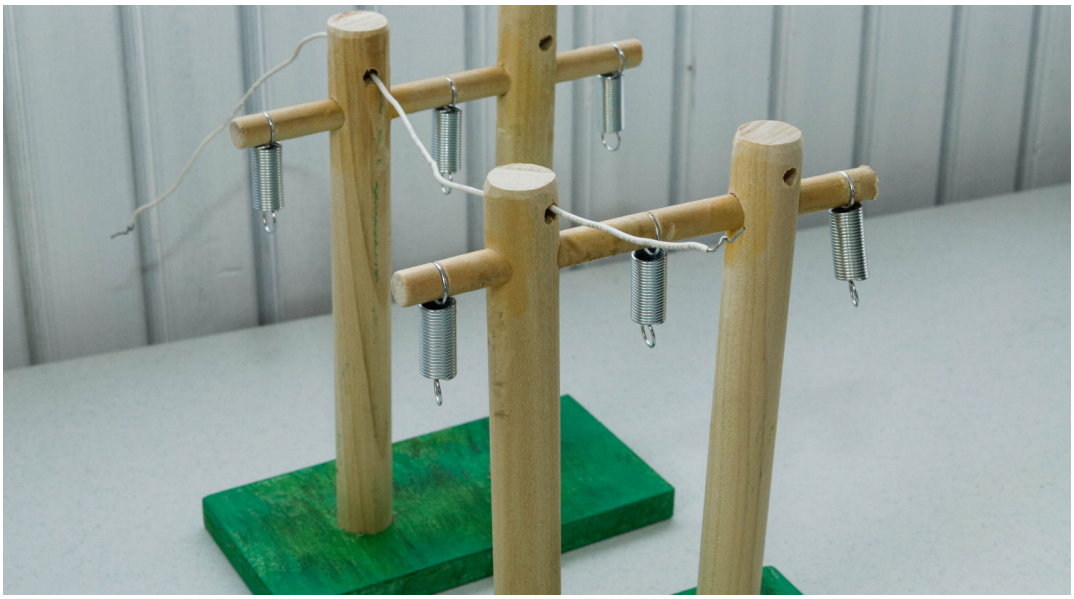
Put the power plant at one end of your table.

Put your homes at the other end of the table.



Hook up a colored wire on the tall poles.

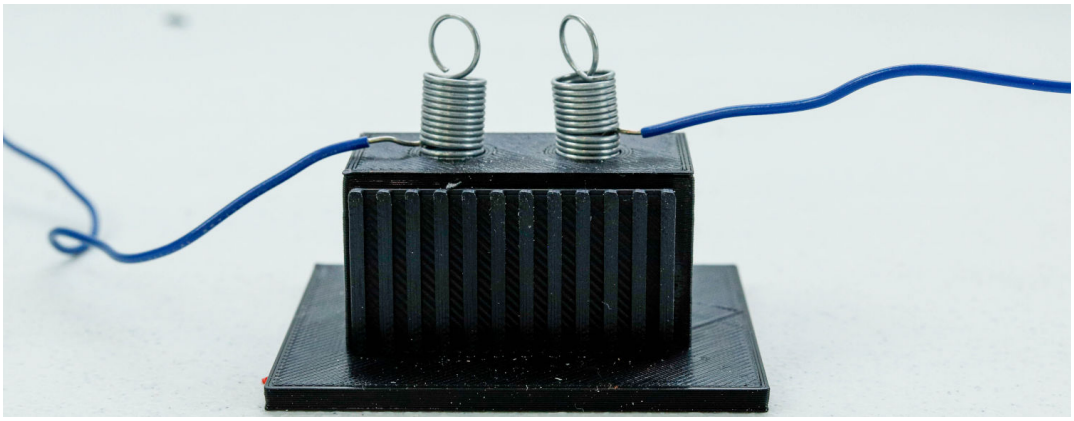
Students can use a red, black, or blue wire on the poles. Older students will use all three. It does not matter which springs they use, but the springs on the poles are not connected to each other, so two wires must be put in each spring. The white wire is the "ground" or "common" wire. It goes through the holes in the top of the poles, not through a spring.



Put in a transformer.

Basically, the taller the pole or the higher the wire is off the ground, the higher the voltage that the line carries. Transformers (the black rectangles in your model) must be placed between any change of voltage in your system. Transformers are needed between the high voltage transmission towers and the low voltage distribution poles. A "step up" transformer increases voltage and a "step down" transformer reduces voltage.

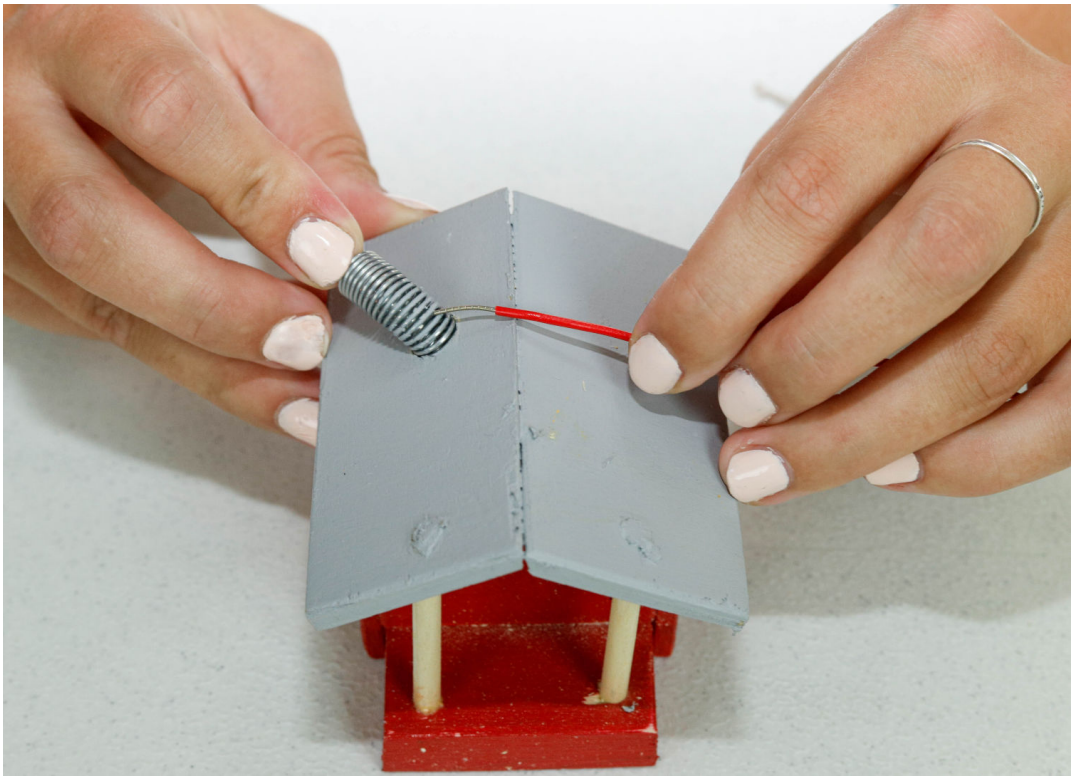
The transformers in this kit simply connect one spring to the other. They are representative of a transformer but do not "work." A transformer is built into each power plant to step up the voltage for transmission. The voltage in transmission lines usually exceeds 115,000 volts. Transformers in substations "step down" this voltage to safer levels as it is distributed throughout a city. Lines are 120 volts where they enter a home.



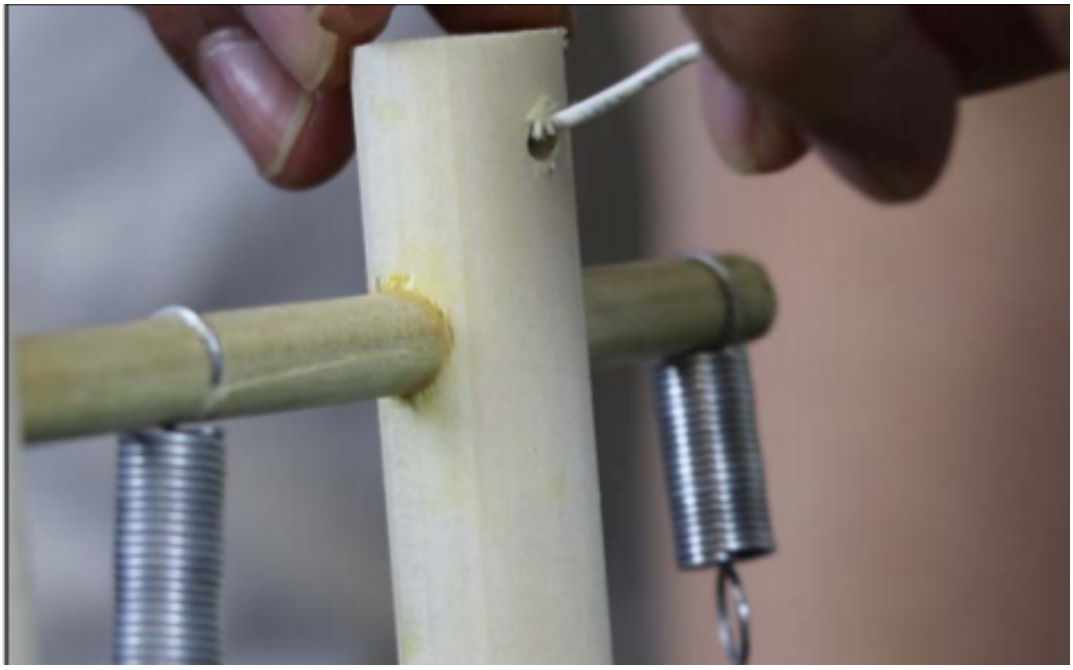
Hook up short poles.

Connect a colored wire from the last pole to your house. The pole closest to the house should have a grey bucket transformer on it.

A typical grid layout would consist of a power plant, a step-up transformer to tall transmission towers, a step down to shorter poles, another step down to distribution poles, and finally, connections to a home. Only red, black or blue wire should attached to springs on the poles.



Connect a white wire from your house to the power plant. It goes through the holes in the top of the poles.



Call your teacher to check it.

Did your homes light up? Why or why not?

A poor wire connection is usually the culprit when the system does not work.

High Voltage (1886-today): Discussion

Why did you put in transformers?

Transformers in substations change the voltage of the electrical power. Voltages in cities and neighborhoods vary from 4,000 to 34,000 volts.

Is there a transformer by your house?

(There is a transformer near every customer, but students may not have noticed it.)

Electric companies made long power lines to connect lots of customers. But, long power lines make it hard to find problems.

Work on the early electrical grid was particularly dangerous. Safety procedures for working with high voltages were not yet established. Wages were relatively high, but so was the injury and death rate.

Monitors (1950-2000): Exploration

Connect a 1/4" audio cable from the headquarters office to your smart grid monitor.

Turn on the switch. A red light should come on.

Connect a gray wire to any spring on your grid.

The spring should already have a colored wire attached to it.

Connect the other end of the gray wire to the top spring on your monitor.

Write the place where the gray wire is attached. Use the dry erase marker.

Do not allow students to write on the wood, only on the erasable surface and only with a dry erase marker.

Monitors (1950-2000): Discussion

What happens when you connect the gray wire to the monitor?

The green light will illuminate when power is available at that particular location on the grid.

What does the smart grid monitor tell you?

It tells the operator where there is power, and where there is not. This information helps locate problems.

In 1953 American Electric Power built a grid system that connected seven states. This grid allowed companies to share power plants and cover demand if one of them went offline.

Smart Grid (2000-2020): Exploration

Hook up more gray wires to your monitor and grid.

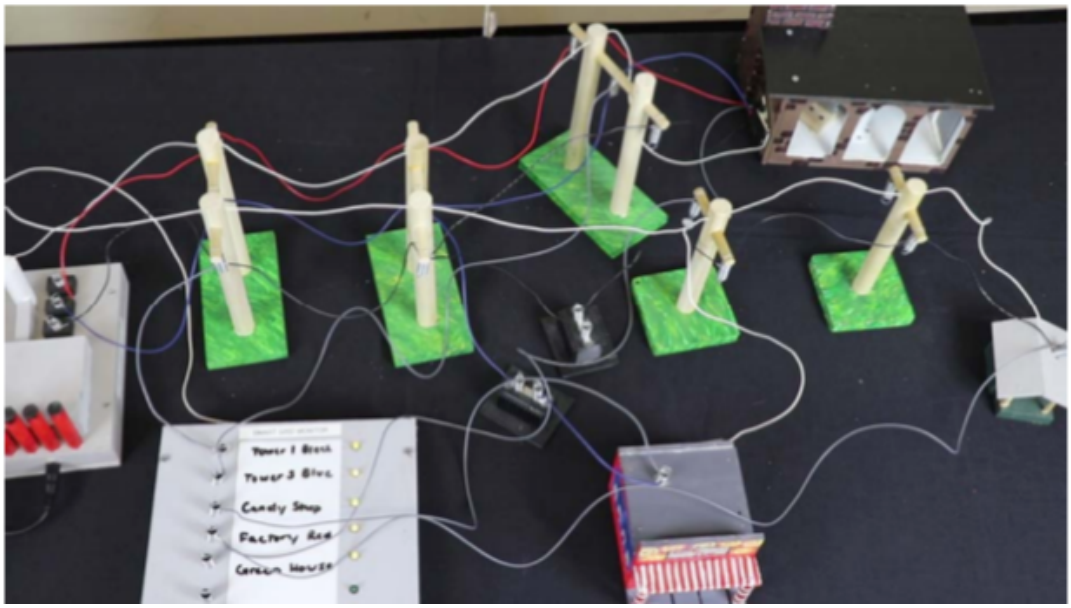
Students can select any locations, but will probably discuss what information will be most helpful. For example, they may want to know if power is actually leaving the power plant and if it is getting to the home. They can then install more sensors at other key locations in between.

Ask your teacher to take off a wire.

You are playing the role of a storm. A wire is broken and customers lose power. The smart grid monitor will allow technicians to pin-point the problem.

Find the problem using your smart grid monitor.

The green light will tell them where there is power and where the line is disconnected.



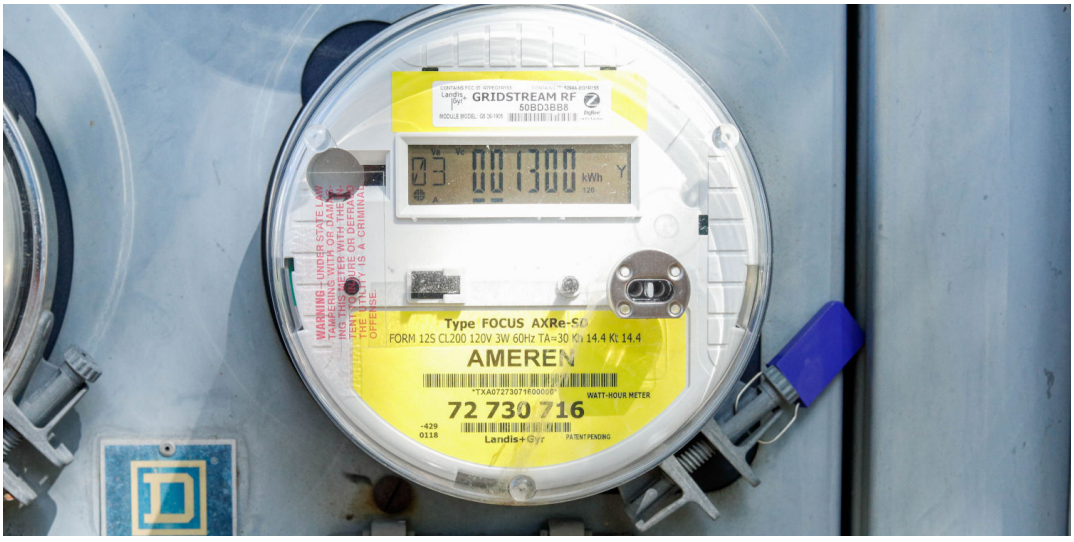
Smart Grid (2000-2020): Discussion

How does a power company know if a customer's home loses power?

In the traditional grid system, electrical technicians only know of the power outage and its approximate location by mapping phone calls reporting a problem. If nobody calls in, the power company does not know there is a problem.

With smart meters, how does the power company know if a customer's power goes off?

With smart meters installed, the power company will know instantly when a customer loses power. They will be able to pin-point the problem quickly and accurately, making repair and restoration of



Follow-Up Discussion Questions

What did you like about making the electrical grid?

Remember, power is important but it can be unsafe. NEVER play around electrical wires inside or outside your home.

Draw a picture of your school with a wind turbine or solar panels. What would it take for it to work?

This might be an opportunity to talk about the limitations of technology. How much of the playground would need to be covered with solar panels to power the school? How big of a battery would you need to store that power?

How could you save electricity at your home or school?

If everyone were driving electric cars in 10 years, how does the grid have to change?