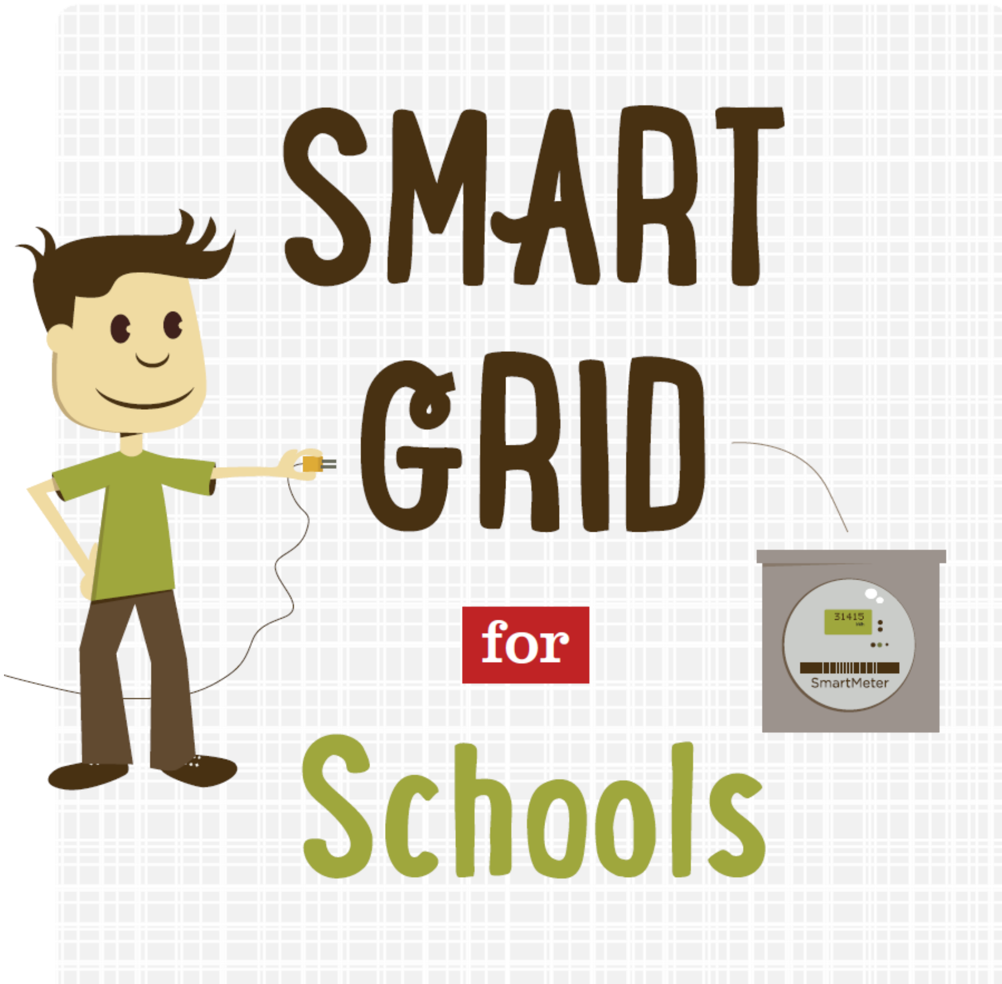


Construction Set Curriculum

Grades K-4

Teacher Edition

Center for Mathematics Science and Technology

Center for Renewable Energy

Illinois State University

Introduction:

The Smart Grid Construction Set allows your students to build a model of the electrical grid system in the same manner in which the actual grid was built. They start with early forms of energy and trace how electricity changed the landscape of energy production and use. Your students will learn about early inventors and see their discoveries in action as they convert muscle power into electricity. They will then see a demonstration of a steam engine and learn how it was connected to a generator to produce power. They will hook up two houses to their power plant and then expand it to serve many customers. Your students will experience the need for monitoring as their grid grows and determine where monitors should be inserted.

Use:

Each black plastic tote of the SGFS Set contains enough materials for up to sixteen students simultaneously. There are four different power plants that plug into one Headquarters Office. It is recommended that up to four students are assigned to each power plant. From these power plants, each group will create their electrical grid model. The curriculum is divided into time periods so that the students build their grid in the same manner that the actual grid was developed.

Initially, you and your students may feel that cutting, stripping, and hooking up wires is too complex for young children. Several years of experience with thousands of children has proven they can do it with minimal instruction/demonstration. How far they go with this, however, is dependent upon the amount of time available and student interest. The curriculum may be adapted to a variety of skill levels at your discretion.

Safety:

The entire system operates on 5 volts of direct current (DC). This power comes from the Headquarters Office, not the individual power plants. This way voltages can be controlled easily regardless of the number of power plants. The low voltage poses extremely little risk of injury to students.

Do not allow students to connect the hand-crank generator to the grid system. It can produce far too much voltage and will destroy the LED lights. Be certain all generators are put away before work begins on the grid.

Since the electricity is DC and all of the lights are diodes (LED) polarity is important. Use red, black, or blue wires on the springs and white wires on the alligator clips.

A direct short will result anytime a colored wire comes into contact with a white wire. Since the voltage is so low, a spark probably will not be noticeable, nor will anything immediately become hot or start to burn. The green light on the power supply will begin to blink and power will automatically shut off. **Since all four grids operate from the same power supply, a problem on one will affect them all.** There is a 2 amp fuse on each power plant, and it may “blow,” with a direct short. To restore power, simply remove the direct short and replace the fuse if necessary. Be certain to inspect student work to avoid direct shorts and fix the problem immediately if a short inadvertently occurs.

Standards:

The Smart Grid for Schools program can be used to address several educational standards in Science (NGSS), Mathematics (CCSS.Math), Social Studies (SS), and English Language Arts (CCSS.ELA). Many of these standards are addressed within the curriculum while others can be addressed by implementing optional enhancements.

Grade Level	Discipline and Standard	Where and how the standard is addressed
Kindergarten	NGSS.K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.	Students turn the crank on the generator fast and slow, noting the speed of the motor and/or brightness of the bulb. They compare the speed to how quickly they get tired or out of breath. They see the correlation between input and output.
Kindergarten	CCSS.Math.K.MD.3. Classify objects and count the number of objects in each category. Classify objects into given categories; count the numbers of objects in each category and short the categories by count. (Limit category counts to be less than or equal to 10.)	Classify and count various models in the grid system. Count LED lights. Count springs. Count number of customers on each grid line, etc. Classify them by building type, pole type (single or double), etc.
Kindergarten	CCSS.Math.K.CC.1-7. Know number names and the count sequence, Count to tell the number of objects, and Compare numbers.	Make a list of items in the set and allow students to write in the number of each. Compare their list to the inventory list in the box.
First	NGSS.1-PS4-2. Make observations to construct an evidence-based account that objects can be seen only when illuminated.	Students will get excited when the light on the front porch of the house lights up. Use this opportunity to ask them about how lights make it possible to see things. Also, on page 15 (TE) the invention of the light bulb is addressed. Discuss how this changed society.
First	SS.H.1.3. Create and use a chronological sequence of events.	This activity is presented in chronological order. As a class draw a timeline of the development of the electrical grid. You may wish to insert other significant and age-appropriate events such as the invention of
First	CCSS.ELA.RL.1.1. Ask and answer questions about key details in a text.	There are several opportunities throughout the experience where students are asked questions about key details in the text. Their responses can be written and submitted to the teacher.
First	1.OA.1 and 2 Represent and solve problems involving addition and subtraction.	Students can count houses or other components and add or subtract to determine the number of household with or without power in the event of a broken wire or damaged transformer.
K-1	CC.ELA.RI.K.1. With prompting and support, ask and answer questions about key details in a text.	The text provides specific details on the historical development of the electrical grid. Students are asked to address these facts in the discussion sections throughout the experience.
Second	2.MD 1-4 Measure and estimate lengths in standard units.	Measure the length of the grid line from power plant to furthest customer (house). Measure the distance between poles. Calculate how many more poles would be needed to go further distances.

Grade Level	Discipline and Standard	Where and how the standard is addressed
Second	NGSS.2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.	When students are learning to strip the wires on page 18 (TE) they can be asked about materials. The coating on the outside is a plastic insulator whereas the inner core of the wire is a metal conductor. Ask them what other materials are probably conductors or insulators used in the construction of this set of models.
K-2	SS.IS.2.K-2. Explore facts from various sources that can be used to answer the developed questions.	Throughout the experience students are required to stop and reflect on their work, addressing questions about what they are learning. Answers will come from their reading and experiences.
K-2	SS.IS.1.K-2. Create questions to help guide inquiry about a topic with guidance from adults and/or peers.	Students will be very interested in this activity. Encourage their questions about energy and why it is important to modern society. Also, students may wish to discuss environmental impacts.
K-2	SS.IS.5.K-2. Ask and answer questions about arguments and explanations.	Throughout this experience students are asked to do unusual and unfamiliar tasks. They will discuss within their groups what to do and how best to do it. Encourage their discussions.
Third	NGSS.3-ESS3-1. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.	On page 35 (TE) the Smart Grid Monitor is used to locate a problem caused by a storm. This is a good opportunity to discuss with students the wild fires started in California by downed power lines. How will the Smart Grid reduce the chance of fires?
Third	CCSS.ELA.W.3.7. Conduct short research projects that build knowledge about a topic.	This experience can be used as an introduction to a number of research topics including history, technology, society, environment, economics, etc.
Third	CCSS.ELA.SL.3.2. Determine the main ideas and supporting details of a text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.	Students are required to read these instructions and follow them to successfully complete the tasks. They can be asked to read aloud to their team-mates. They will naturally find the main ideas as they seek to build their grid.
Third	SS.H.3.5. Explain probable causes and effects of events and developments in U.S. history.	This activity is presented in chronological order. Draw a timeline of the development of the electrical grid, inserting significant events and developments in U.S. history. Discuss cause and effect.
Third	3.OA 1-4 Represent and solve problems involving multiplication and division.	Calculate how many poles will be needed to extend the grid a given distance given the spacing between them. Measure in rather large units so that the numbers stay relatively small.
Third	3.NF.1 Understand a fraction 1/b as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction a/b as the quantity formed by a parts of size 1/b.	Count lights and determine the fraction of lights in the entire grid that go out when any given wire is disconnected, fuse is blown, or switch turned off.

Grade Level	Discipline and Standard	Where and how the standard is addressed
Fourth	CCSS.ELA.W.4.2. Write informative/ explanatory texts to examine a topic and convey ideas and information clearly.	The discussion questions could be assigned as written responses in complete sentences. They could also be assigned reports on an energy-related topic requiring research. Another option is for them to write and illustrate instructions for how they made their grid.
Fourth	CCSS.ELA.RI.4.5. Describe the overall structure (e.g., chronology, comparison, cause/effect, problem/solution) of events, ideas, concepts, or information in a text or part of a text.	These instructions are written in a Learning Cycle format. Students could be assigned to review and critique these instructions.
Fourth	CCSS.ELA.W.4.7. Conduct short research projects that build knowledge through investigation of different aspects of a topic.	Many students will be very interested in this project and will want to learn more. Some may even consider a career in the electrical energy field because of this exposure. Facilitate independent research.
Fourth	CCSS.ELA.W.4.8. Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources.	Require entries into a journal concerning the students experience with the Smart Grid for Schools system. Encourage them to organize this information into a digital slide show to be presented to parents and/or school board members.
Fourth	4. OA 2 Multiply or divide to solve word problems involving multiplicative comparison, e.g., by using drawings and equations with a symbol for the unknown number to represent the problem, distinguishing multiplicative comparison from additive comparison.1	Work fluidly with watts, volts, and amps. Watts is a measure of power. Volts is a measure of pressure, and Amps is a measure of volume. Watts= Volts x Amps Most outlets in a house are 120 volts. Watts or Amps are often printed on tags on electrical devices. Most fuses in a home are set to turn off at either 10 amps or 15 amps, depending on the size of the wire.
Fourth	NGSS.4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	Ask students how the electrical energy is getting from the power plant to the customers. What do customers use electricity to do? Most of these models change electricity into light. The factory changes it to motion. What changes occur in their homes?
Fourth	NGSS.4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.	On page 25 (TE) students are asked to select the best power plant. This provides the opportunity to discuss energy sources and their impact on the environment and economy.

Grade Level	Discipline and Standard	Where and how the standard is addressed
G3-5	NGSS.3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	When completed with this activity, propose that students design and build a model of the electrical grid of the future using all renewable energy sources. Provide them criteria and constraints such as power requirements and location restrictions.

Career Connections:

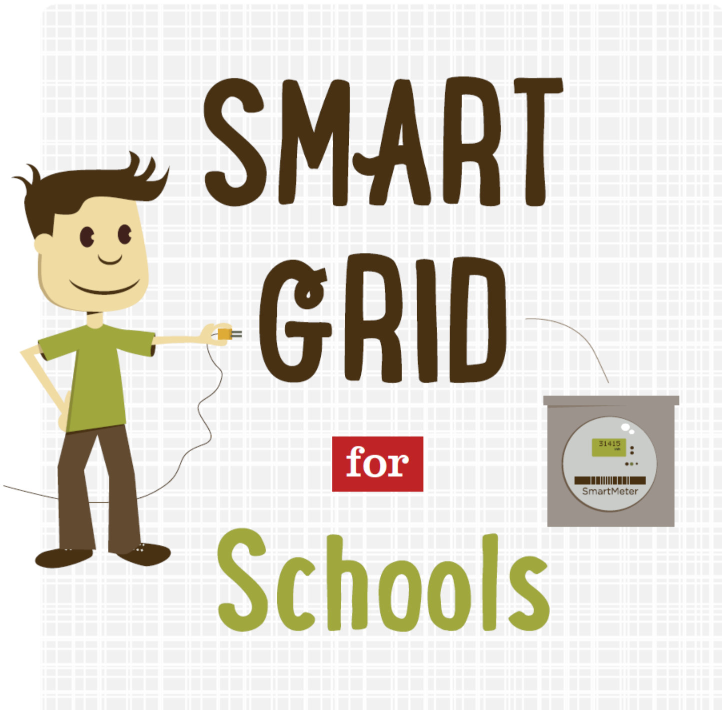
While it is true that most children in elementary school are not seriously considering their career choice, many of them can tell you what they want to be when they grow up. It is important that they are exposed to a wide variety of career options so that as they move toward high school and college, they can make well-informed choices.

In this activity, students will be working with electricity, making an electrical grid, and using some of the tools of an electrician. Look for opportunities to discuss some of the following information with students showing exceptional aptitude and interest.

Electricians	install, maintain, and repair electrical power, communications, lighting, and control systems.
2018 Median Pay	\$26.53 per hour \$55,190 per year
Typical Entry-Level Education	High school diploma or equivalent, apprenticeships or technical college
Job Outlook, 2018-28	10% (Faster than average)

Power line installers	install or repair electrical power systems and telecommunications cables, including fiber optics.
2018 Median Pay	\$31.67 per hour \$65,880 per year
Typical Entry-Level Education	High school diploma or equivalent, apprenticeships or technical college
Job Outlook, 2018-28	4% (Faster than average)

Information on careers can be found in the Occupational Outlook Handbook published by the U.S. Bureau of Labor Statistics, www.bls.gov



Construction Set Curriculum

Grades K-4

Look around your classroom for things that run on electricity.

How do we make electricity?

How does it get to your school?

Lets find out.

Almost all work used to be done with muscle power. They did not have machines or power tools. Animals helped to make work easier but both humans and animals get tired quickly.

About 2300 years ago inventors started making water wheels to crush grain, saw wood, pump water, and do many other jobs. About 1000 years ago the Dutch started making windmills to do many of the same tasks and to pump water.

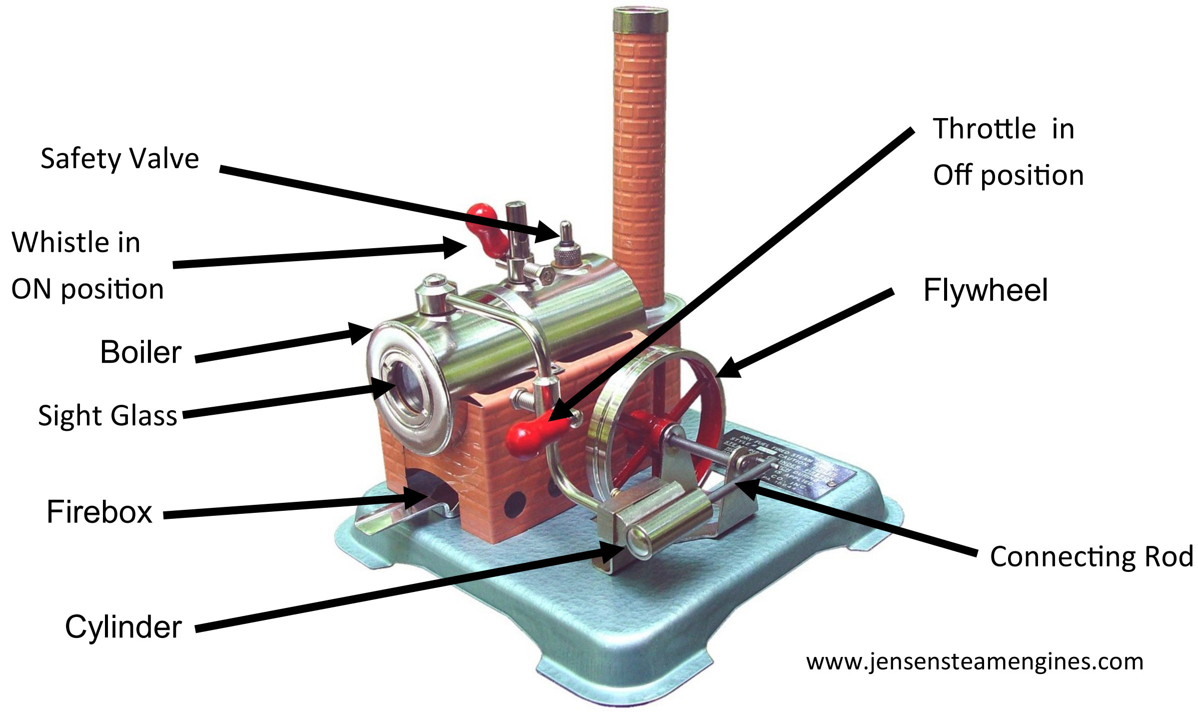
CCSS.ELA.SL.3.2. Determine the main ideas and supporting details of a text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.

Students are required to read these instructions and follow them to successfully complete the tasks. They can be asked to read aloud to their team-mates. They will naturally find the main ideas as they seek to build their grid.

https://web.uml.edu/gallery/var/albums/Tsongas-Industrial-History-Center/Re-Inventing-America/Old-Sturbridge-Village/DSCN0899OSV%20waterwheel.JPG?m=1397825962

Steam Power (1769-1820): Exploration

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



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

Can you explain how it works?

Teacher Note:

The steam engine is used only as a teacher demonstration. 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.

Operation of the Steam Engine: (included as teacher background information only, use as appropriate)

The chemical energy stored in the fuel tablet is converted to heat energy through burning (combining with oxygen). The heat is transferred to the water in the boiler. Since water expands 1600% when converted from a liquid to gaseous form (steam) pressure builds in the closed container. It would eventually burst the boiler if this pressure was not released through a valve or safety mechanism.

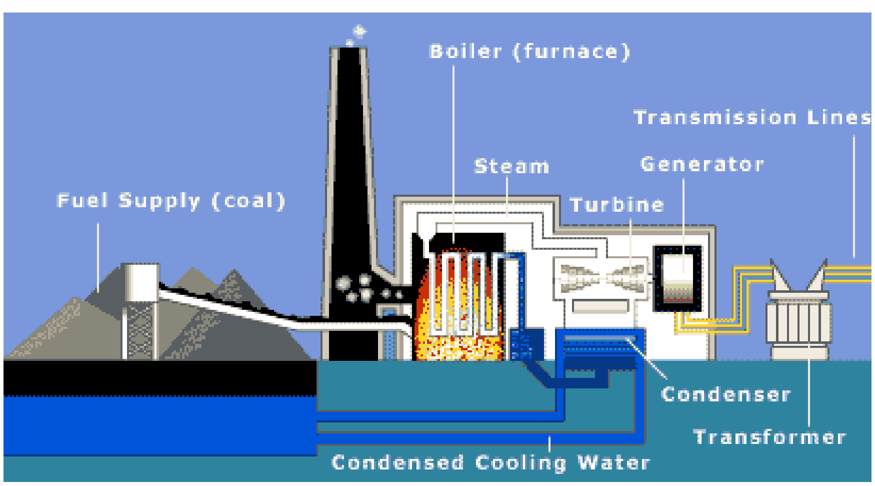
As the throttle valve is opened, steam pressure moves through the pipe to the valve mechanism. Notice how the cylinder rocks back and forth on a pivot point as the flywheel spins. When the top end of the cylinder rocks up, a hole in the side of the cylinder aligns with the steam pressure hole. Steam pressure is directed into one side of the cylinder where it pushes on the top of the piston. As a result, the piston slides to the other end of the cylinder. This motion is captured by the connecting rod and finally to an offset pin on the side of the flywheel. The reciprocating motion of the piston and connecting rod is converted to rotary motion at the flywheel.

As soon as the piston reaches the end of the cylinder, the energy stored in the spinning flywheel pushes the piston back into the cylinder. The cylinder rocks down, aligning the hole in the side of the cylinder with another hole that is just below the steam inlet hole. Steam can escape from this exhaust hole. Since the steam only pushes the piston one direction, this engine has a single-acting piston.

Steam locomotives use a side valve that first directs steam pressure to the top of the piston (pushing it down) and then sends steam pressure to the bottom of the piston (pushing it up). This is called a "double acting" engine since the piston is pushed both directions. A double acting engine runs much smoother and provides much more power than a single acting engine. As the slide valve is directing steam pressure to one side of the piston, it is also opening a hole on the other side of the piston so that the steam that had been on that side can escape. On a steam locomotive, this exhaust steam is directed up through the smoke stack resulting in "puffing" of the smoke and the characteristic "chug, chug, chug" sound.

An internal combustion engine in an automobile is not double acting. The piston is only pushed down, never up. Double acting is not practical with a gasoline or diesel engine due to the burning of the fuel inside the combustion chamber.

The modern reciprocating steam engine was designed by James Watt in the mid-1700s and was still in operation in locomotives 200 years later. Most power plants and many large ships use steam power, but with a turbine rather than a reciprocating engine. The steam turbine consists of a series of fan blades mounted on a single shaft. As steam pressure enters one end, it causes the fan blades to spin at a very high rate of speed. A series of gears slows the speed of the turbine shaft to spin a generator or the shaft of a propeller in a boat.



https://lakeinfo.tva.gov/web/sites/images/coalfired.gif

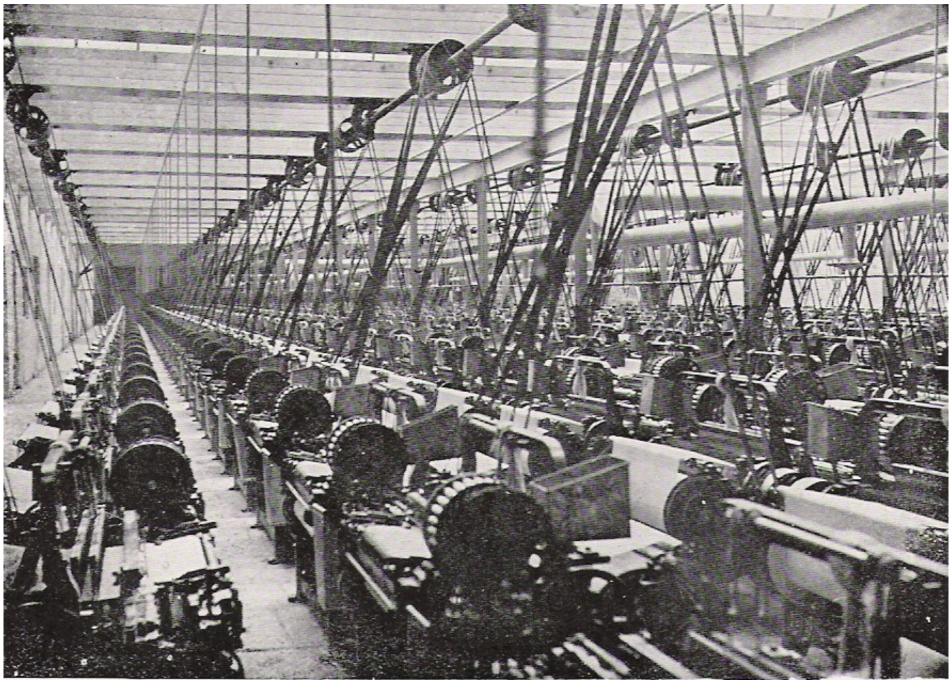
SS.IS.1.K-2. Create questions to help guide inquiry about a topic with guidance from adults and/or peers.

Students will be very interested in this activity. Encourage their questions about energy and why it is important enough to risk damage to the environment.

Steam Power (1769-1820): Discussion

1. What happens to the water as the fuel burns?

The water gets hot and changes from a liquid to a gaseous (steam) state at 100^0 C. During this phase change, it expands by 16 times, producing pressure within the closed boiler.



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SS.H.3.5. Explain probable causes and effects of events and developments in U.S. history.

This activity is presented in chronological order. Draw a timeline of the development of the electrical grid, inserting significant events and developments in U.S. history. Discuss cause and effect.

2. This is an old factory powered by a steam engine. Would you want to work in this factory?

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.

3. Why were steam engines better than wind or water power?

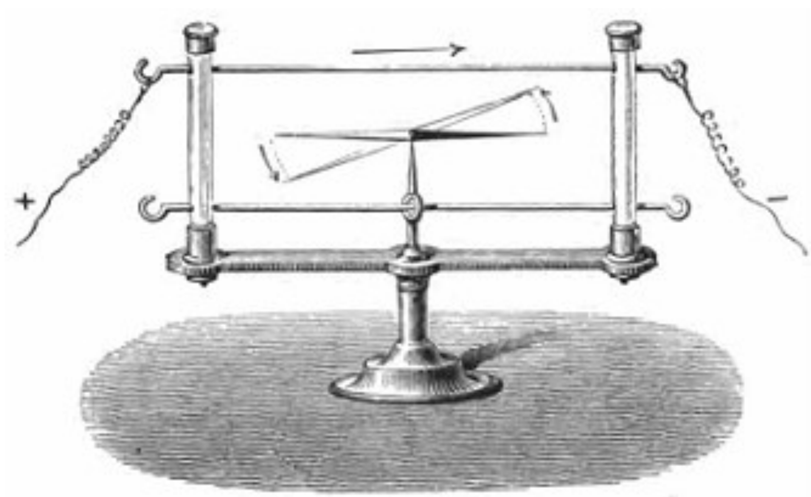
Steam engines were not dependent on wind or water conditions and could be placed anywhere, not limited to being near rivers or in windy areas.

SS.IS.2.K-2. Explore facts from various sources that can be used to answer the developed questions.

Throughout the experience students are required to stop and reflect on their work, addressing questions about what they are learning. Answers will come from their reading and experiences.

Linking Magnetism & Electricity (1820-1831): Exploration

About 200 years ago Andre-Marie Ampere figured out how to make magnets using electricity. In 1831 Michael Faraday discovered you could make electricity by moving some wires past a magnet. He wrote "Faraday's Law" that describes how electricity and magnetism work together.

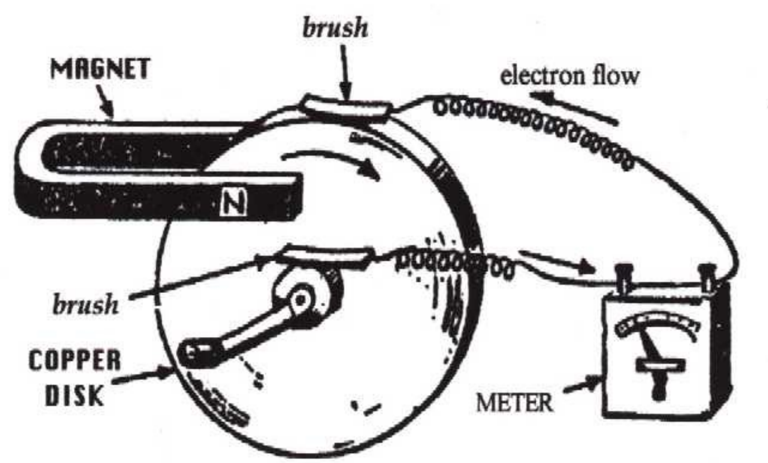


Electricity can make a magnet….

https://c8.alamy.com/comp/MR6HPR/reconstruction-of-oersteds-experiment-of-1819-when-he-discovered-that-a-magnetised-needle-could-be-deflected-by-an-electric-current-dated-19th-century-MR6HPR.jpg

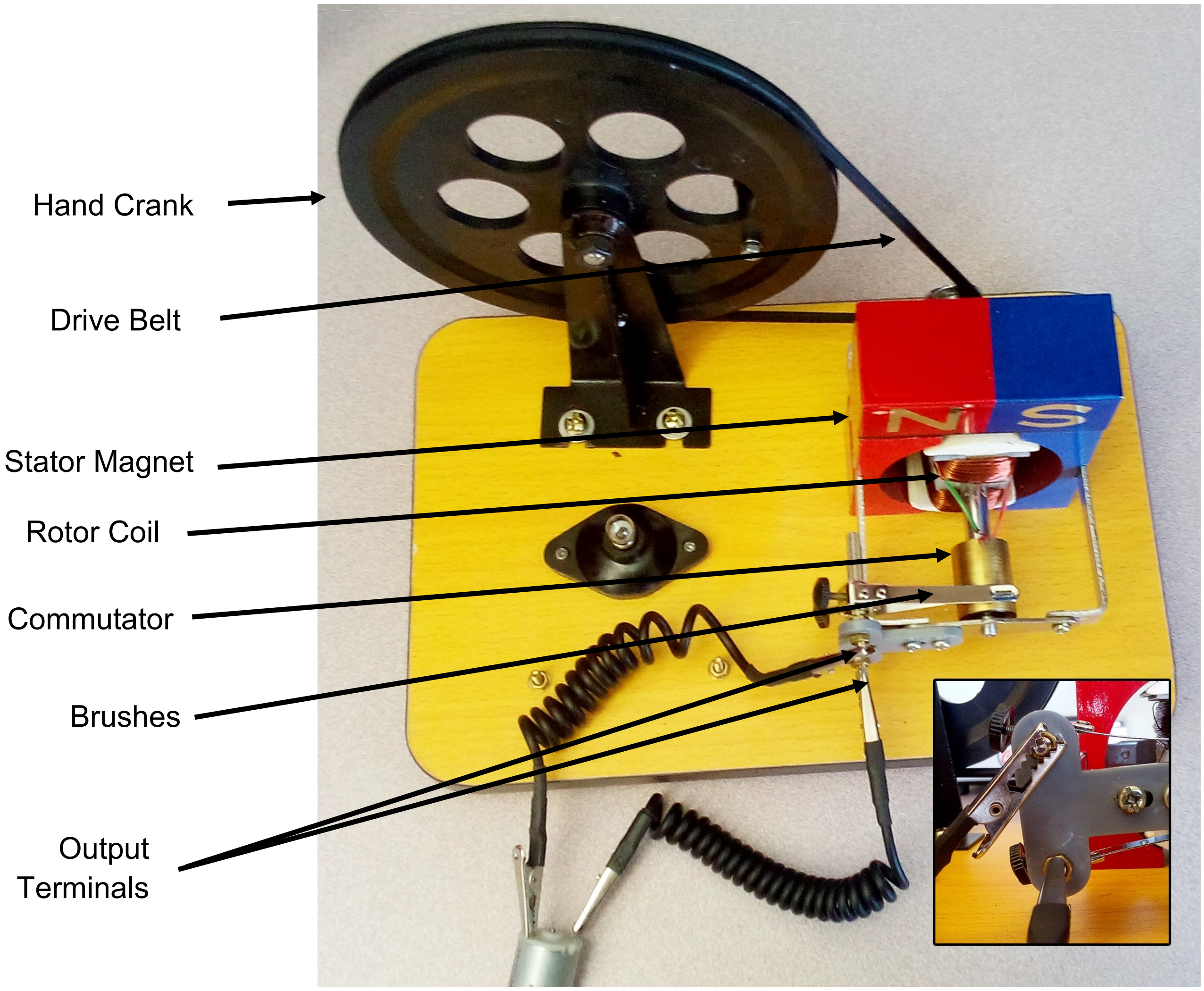
CCSS.ELA.RL.1.1. Ask and answer questions about key details in a text.

There are several opportunities throughout the experience where students are asked questions about key details in the text. Their responses can be written and submitted as an assignment.



https://emediapress.com/wp-content/uploads/2017/05/faradisk1.gif

...and a magnet can make electricity.

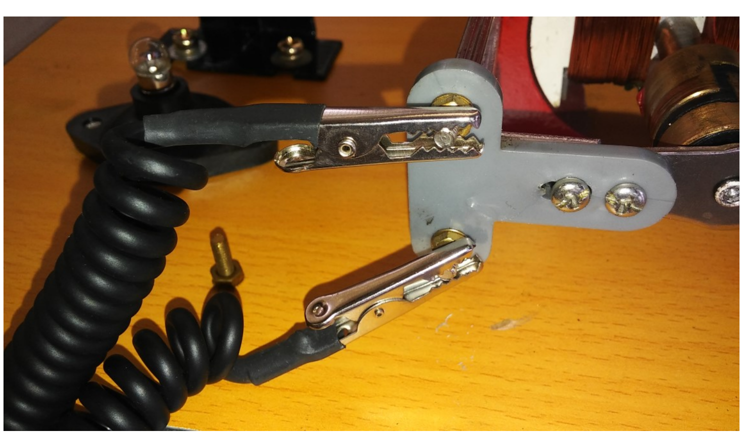


1. Turn the crank on the generator. What part spins and what part does not move?

   The rotor rotates and the stator stays stationary.

2. Connect two wires from the generator to the motor.

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



2. 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.

3. 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.

4. Turn the crank faster. 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.

NGSS.K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

Students turn the crank on the generator fast and slow, noting the speed of the motor and/or brightness of the bulb. They compare the speed to how quickly they get tired or out of breath. They see the correlation between input and output.

Linking Magnetism & Electricity (1820-1831): Discussion

1. How do you think the generator is making electricity?

A wire spins inside a magnet.

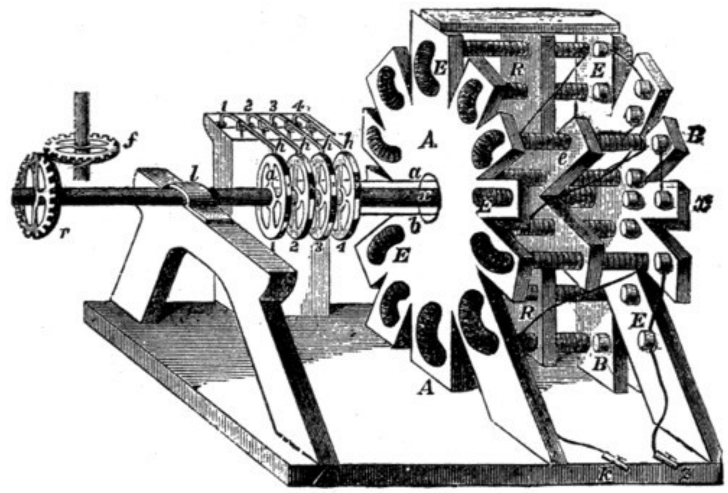
2. How does electricity get from the generator to the motor?

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

Inventors soon hooked up generators to their steam engines to make electricity. Jacobi invented the electric motor in 1835.

En.wikipedia.org

Moritz von Jacobi



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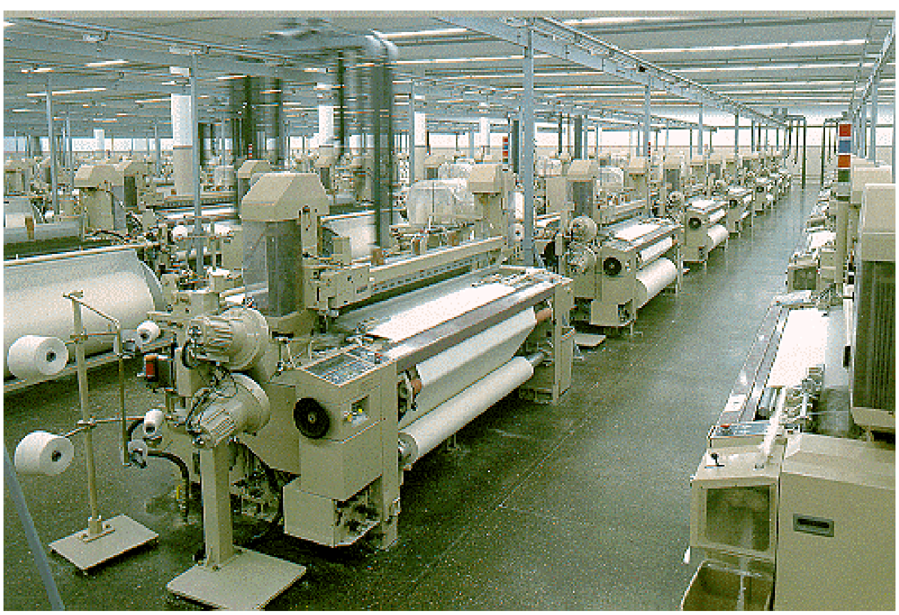
The Jacobi Motor in 1834



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<u>CCSS.ELA.W.4.7.</u> Conduct short research projects that build knowledge through investigation of different aspects of a topic.

Many students will be very interested in this project and will want to learn more. Some may even consider a career in the electrical energy field because of this exposure. Facilitate independent research.

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.

https://image.pbs.org/poster_images/assets/amex27_img_edlamp.jpeg.resize.710x399.png

<u>NGSS.1-PS4-2.</u> Make observations to construct an evidence-based account that objects can be seen only when illuminated.

Students will get excited when the light on the front porch of the house lights up. Use this opportunity to ask them about how lights make it possible to see things. Also, on page 14 the invention of the light bulb is addressed. Discuss how this changed society.

1. Hook the 2 wires to the screws by the light bulb.

2. 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

1. How did the speed that you turned the crank affect the motor and the light bulb?

   More mechanical energy was put into the system (turning faster) so more electrical energy is produced and bulb gets brighter. Also, since the students are putting more energy into the gen erator, they will get tired and start breathing faster. If it turns too slowly, the motor will not spin and 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 did change the direction of the mo tor. This is because of which wire it positive and which one is negative. The bulb works the same either way.

2. How did the electric lightbulb change the way people lived?

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

3. 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 a spark, a hot wire (maybe a starting a fire) and, at the very least, a dead battery.

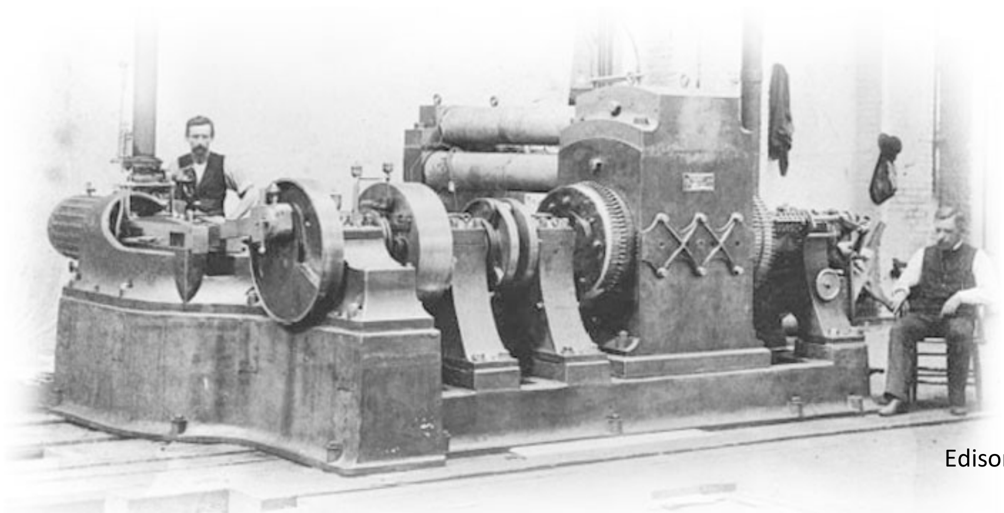
IMPORTANT !!!!

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. The lights on the grid system are designed for 5 volts only.

NGSS.4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. Ask students how the electrical energy is getting from the power plant to the customers. What do customers use electricity to do? Most of these models change electricity into light. The factory changes it to motion. What changes occur in their homes?

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.



Edison National Historic Site

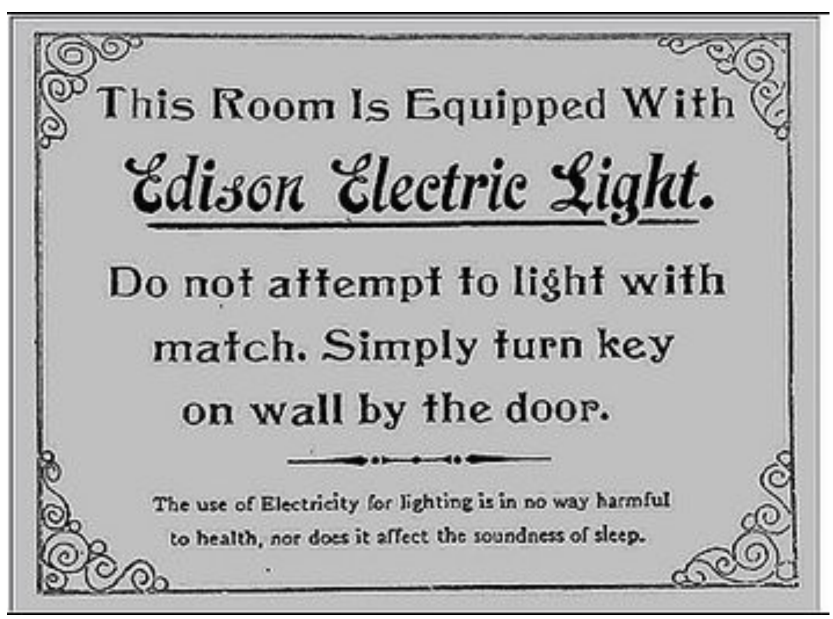
CC.ELA.RI.K.1. With prompting and support, ask and answer questions about key details in a text.

The text provides specific details on the historical development of the electrical grid. Students are asked to address these facts in the discussion sections throughout the experience.

SS.H.1.3. Create and use a chronological sequence of events. This activity is presented in chronological order. As a class draw a timeline of the development of the electrical grid. You may wish to insert other significant and age-appropriate events such as the invention of the car, computer, etc.

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

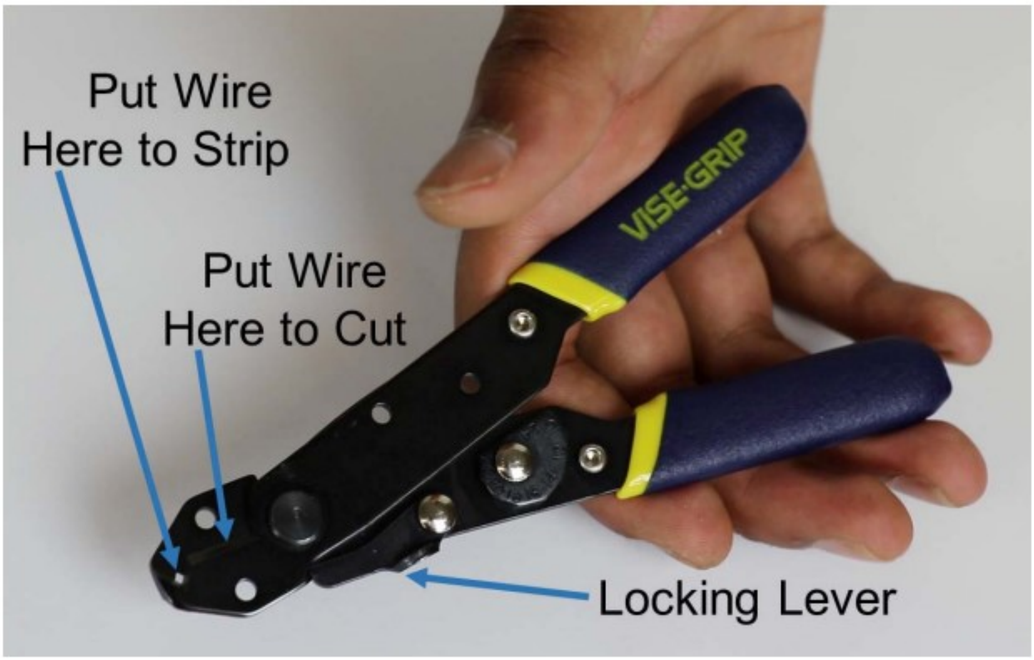
http://news.bbc.co.uk/local/dorset/hi/people_and_places/history/newsid_8155000/8155528.stm



New Skills for Electricity: Exploration

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

Your students will want to start hooking up wires immediately. Spend a few minutes to show them how to cut and strip wires and how to connect them to the springs and alligator clips. Actual grid assemble begins on page 21 (TE).

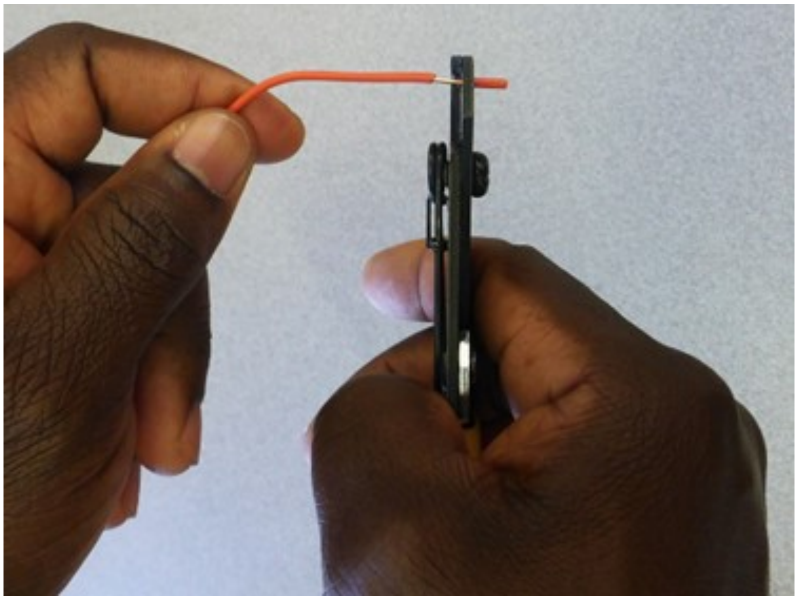


1. Your teacher will show you how to cut and strip wires.

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. It works well to hold it in place with a small piece of tape.

NGSS.2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose. When students are learning to strip the wires on page 17 they can be asked about materials. The coating on the outside is a plastic insulator whereas the inner core of the wire is a metal conductor. Ask them what other materials are probably conductors or insulators used in the construction of this set of models.



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

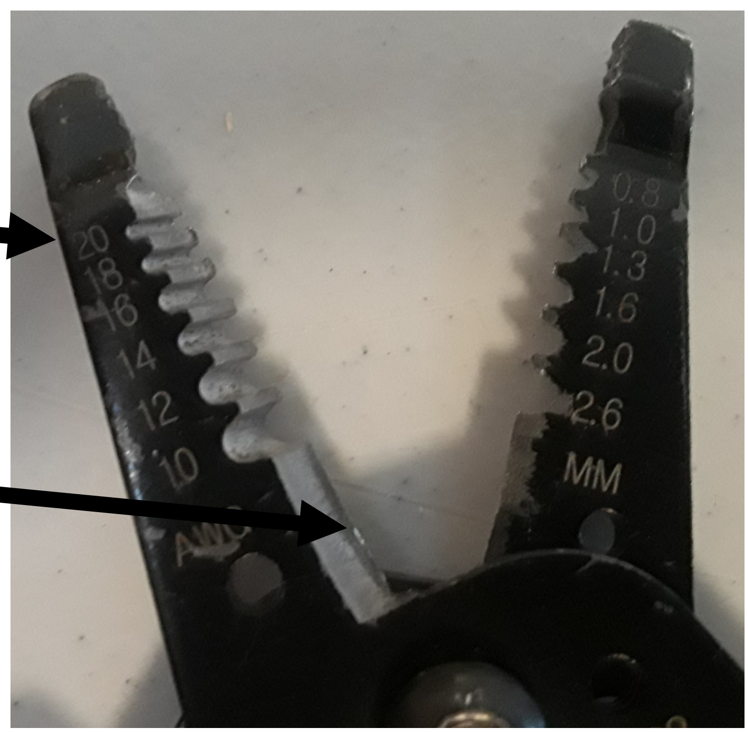
This is a good opportunity to discuss careers. Ask your students if they ever seen one of these tools or if they know somebody who uses one. It is likely that several of your students know an electrician. You may wish to invite an electrician to visit your classroom. She/he will be impressed with what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

Your wire tool might look like this:

Put the wire in the first notch labeled “20.”

Use this notch to strip the wire.

Cut here



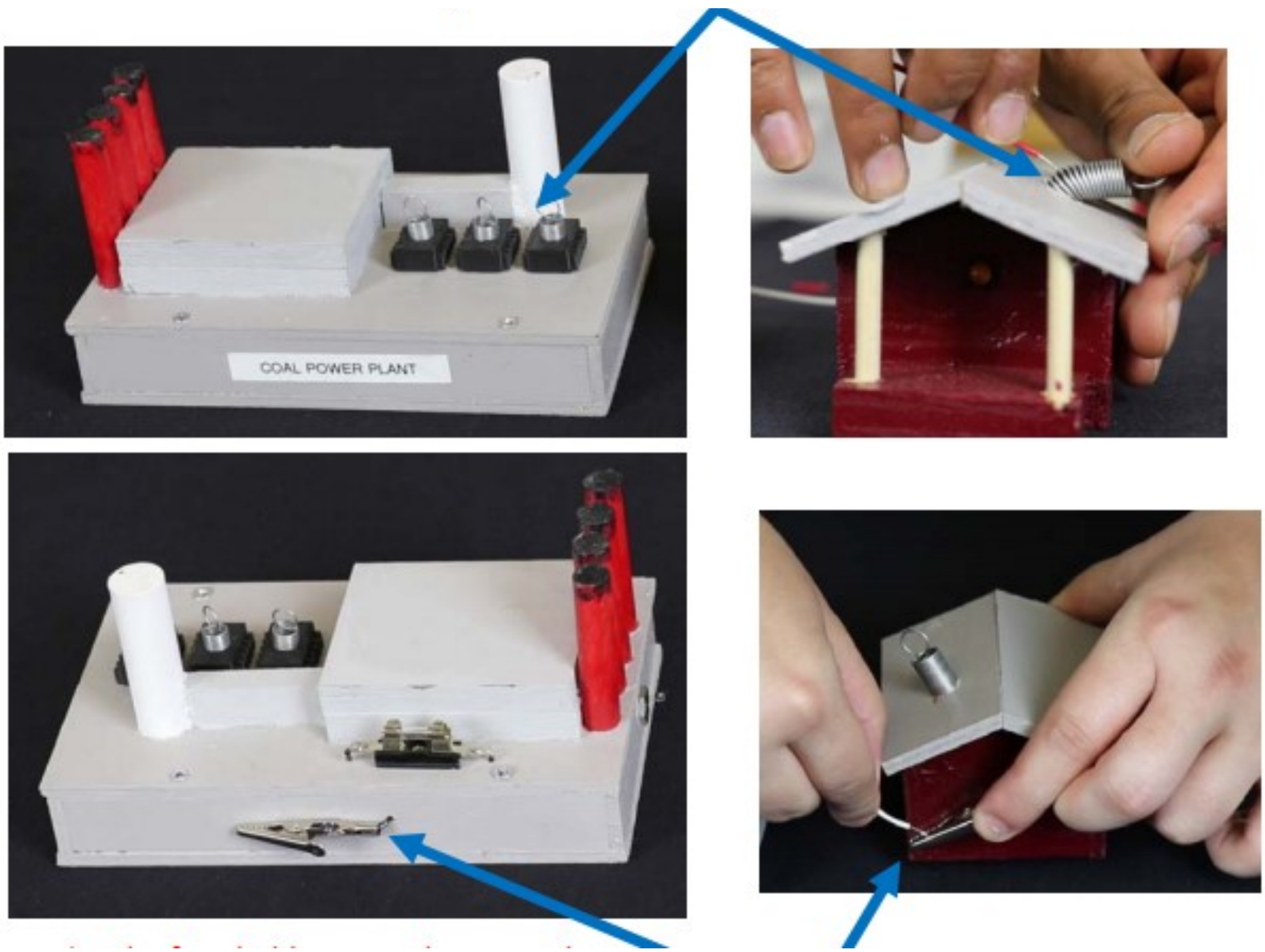
2. The color of the wire is very important. Red, black, and blue wires connect to springs. White wires connect to alligator clips.

Using the wrong colors makes it easy to connect a positive spring directly to a negative alligator clip. This will burn out the fuse.

3. 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. It is unnecessary to twist the wire around the spring. If multiple wires are to be inserted in the same spring, bend it different directions (left for one, right for the next, etc.).

ONLY **RED, BLACK, or BLUE wires connect to springs**



ONLY **WHITE wires connect to alligator clips**

New Skills for Electricity: Discussion

1. Show your teacher how to cut a wire.

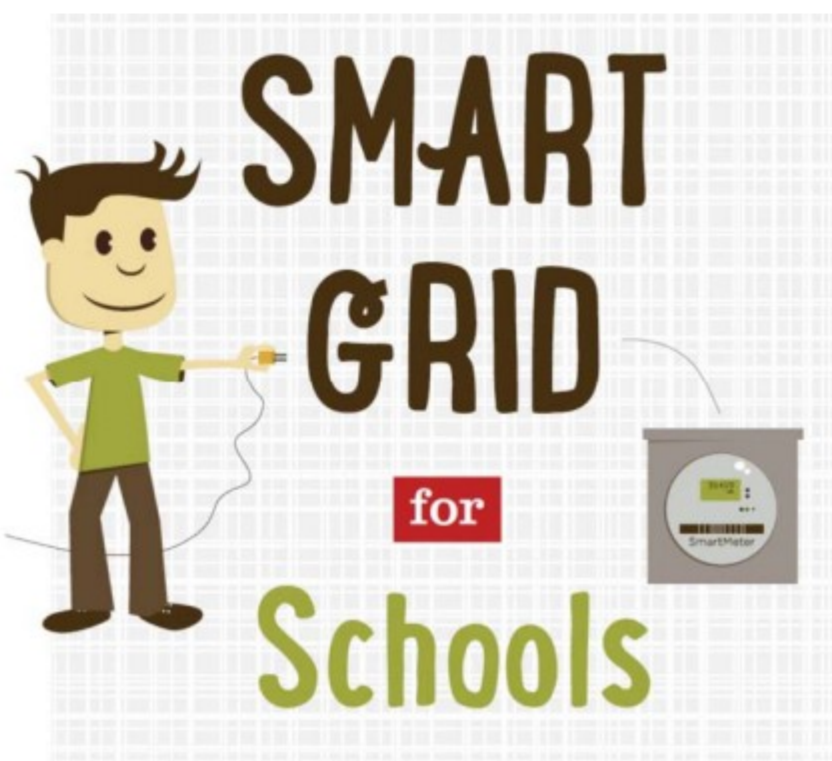
Young students have little trouble cutting a wire, but they might not get it to the right length. They usually cut them too short.

2. 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 will either cut all the way through the wire or not cut through the plastic insulation. For these wires, it must be set on 20. Also, inexperienced electricians tend to twist the cutter when they pull the wire. This binds it in the cutter making it difficult to pull off. With some practice, your students will get it figured out.

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

People working with electricity know that 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. For example, in your home outlets, a black wire always connects to the gold screw, the white wire to the silver screw, and the bare wire to the green screw.



SS.IS.5.K-2. Ask and answer questions about arguments and explanations.

Throughout this experience students are asked to do unusual and unfamiliar tasks. They will discuss within their groups what to do and how best to do it. Encourage their discussions.

Electricity to Your House (1900-1920): Exploration

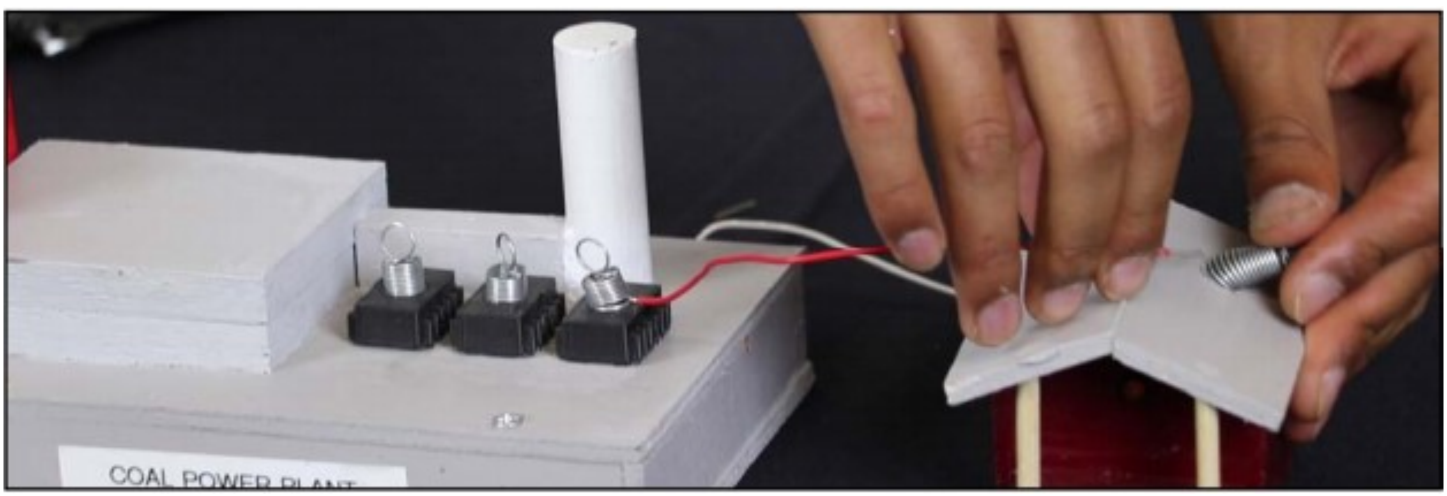
1. Pick a power plant and put a red, black, or blue wire on one of the springs.

CCSS.Math.K.CC.1-7. Know number names and the count sequence, count to tell the number of objects, and compare numbers.

Make a list of items in the set and allow students to write in the number of each. Compare their list to the inventory list in the box.

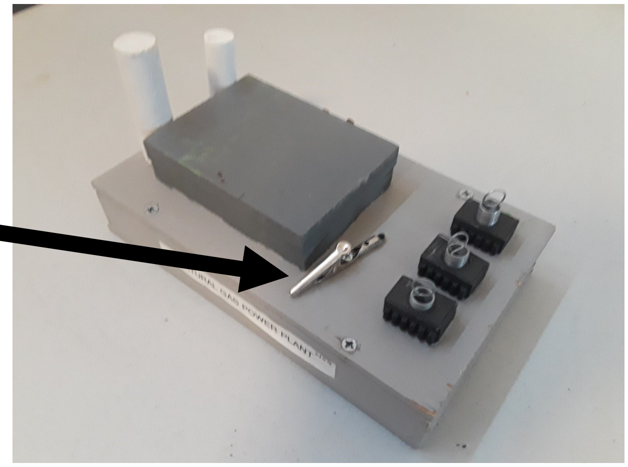
Notice the fuse holder on each power plant. There are several replacement fuses packed with your kit, although it is unlikely they will be needed. Also note there are three spring terminals. In upper grades students use all three. It does not matter which ones are used by your students. Inspect the wiring before allowing students to connect to the Headquarters Office.

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

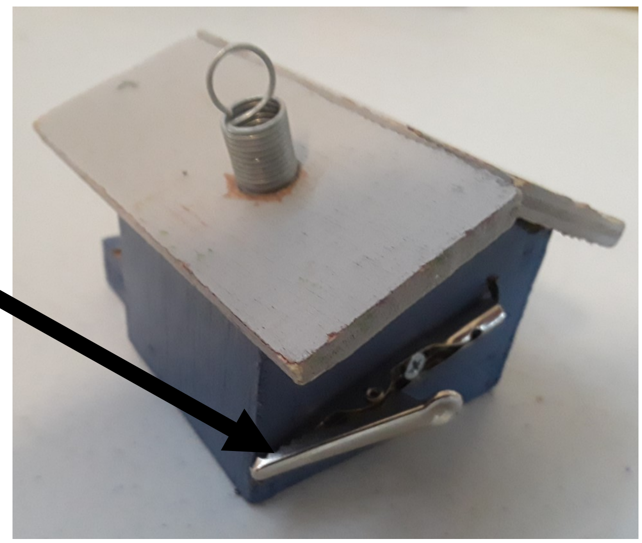


There are several different buildings, most of which will work fine for you students. It is easiest and probably most appropriate to use the houses. They may wish to use one of the businesses or other buildings. Do not allow your students to use the factories or any of the other larger commercial buildings.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

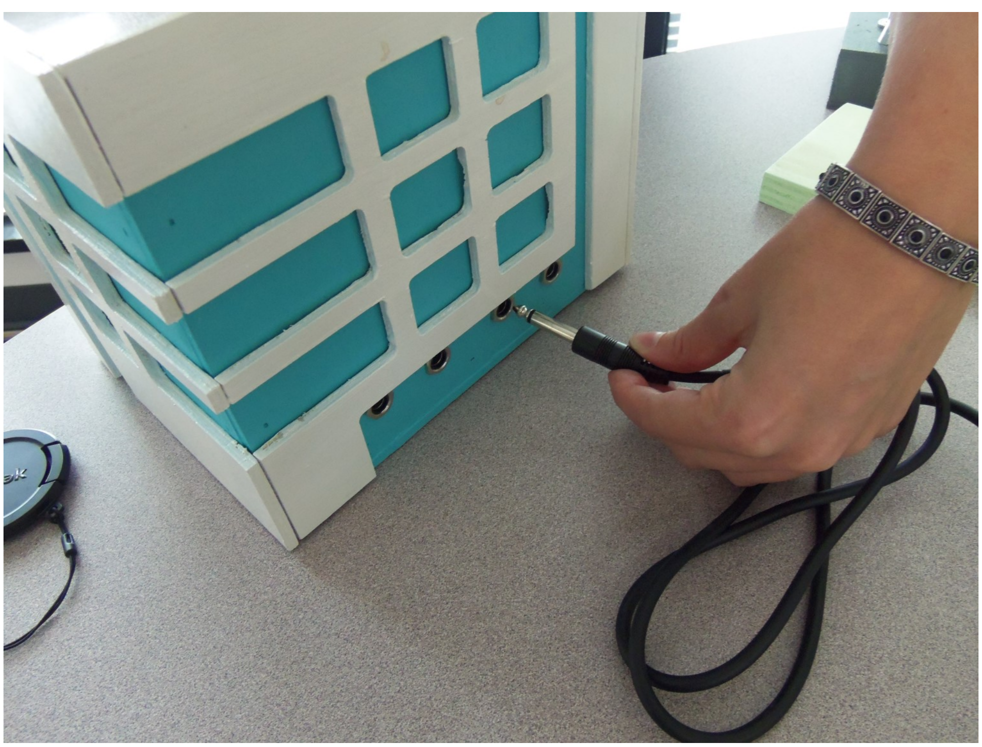
3. Put a white wire here.



4. Connect the other end of the white wire here.



5. Your teacher will check it and turn on the power.



Thick, 1/4" cable connecting the Headquarters Office to the power plants

The 5-volt electrical power for the grid comes from the adapter that plugs into a wall outlet and is inserted into the side of the Headquarters Office. The 1/4" jacks are power outputs that supply power to the power plant.

6. Did your home get power? How do you know?

There is an LED on each house that will illuminate when powered.

CCSS.Math.K.MD.3. Classify objects and count the number of objects in each category. Classify objects into given categories; count the numbers of objects in each category and short the categories by count. (Limit category counts to be less than or equal to 10.)

Classify and count various models in the grid system. Count LED lights. Count springs. Count number of customers on each grid line, etc.

Electricity to Your House (1900-1920): Discussion

1. What type of power plant did you use?
   - ◊ Natural Gas
   - ◊ Coal
   - ◊ Nuclear
   - ◊ Renewable

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 hard (nearly impossible) to discard. Renewable energy (solar and wind) is not as harmful to the environment as other sources, but can be unreliable since wind speeds vary and it is always dark at night.

www.energy.gov/eere/wind/how-do-wind-turbines-work

2. Have you seen a wind farm?

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

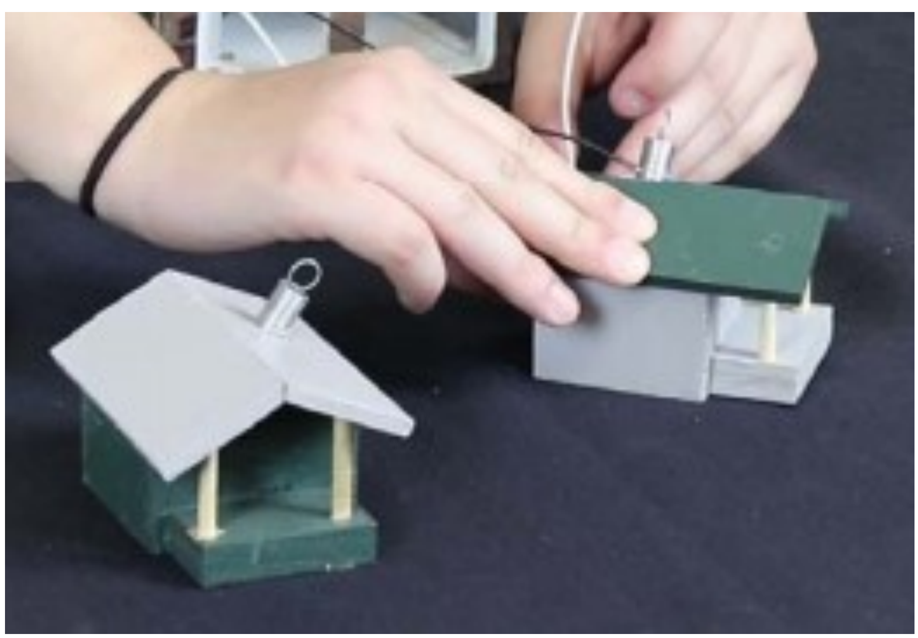
3. What is the best kind of power plant?

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. .

<u>NGSS.4-ESS3-1.</u> Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment. Students are asked to select the best power plant. This provides the opportunity to discuss energy sources and their impact on the environment and economy.

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

1. Unplug the power.
2. Connect a colored wire from the spring on the house to the spring on another house.
3. Connect a white wire from on alligator clip to the other.



4. Call your teacher to check your wires.

Look for any place where the white wire and red wire connect. Help students resolve problems but avoid fixing it for them.

Did both homes light up? If not, what was wrong?

All connections in this system are in parallel, so both houses should receive the same power.

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

1. Has your electricity ever shut off at your house? Did the whole neighborhood go dark? Why?

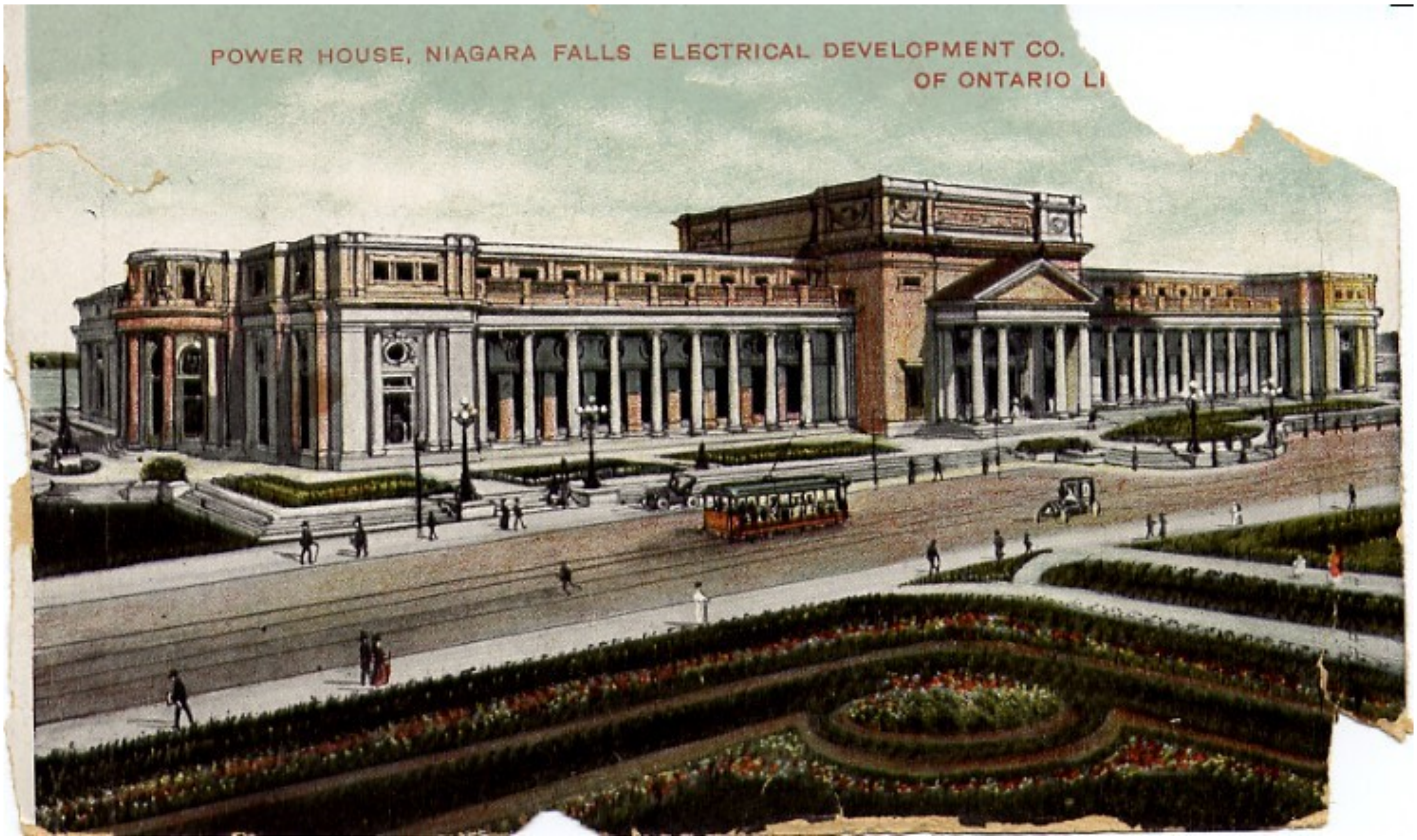
   Usually several houses in the neighborhood share the same main power line. If there is a problem the entire neighborhood looses power.

2. 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 multipli cation, check out wind turbines for sale on the internet. Larger ones are obviously more ex pensive, but produce much more power than smaller models. That is why wind turbines are so large and power plants are huge.

Lowes.com

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



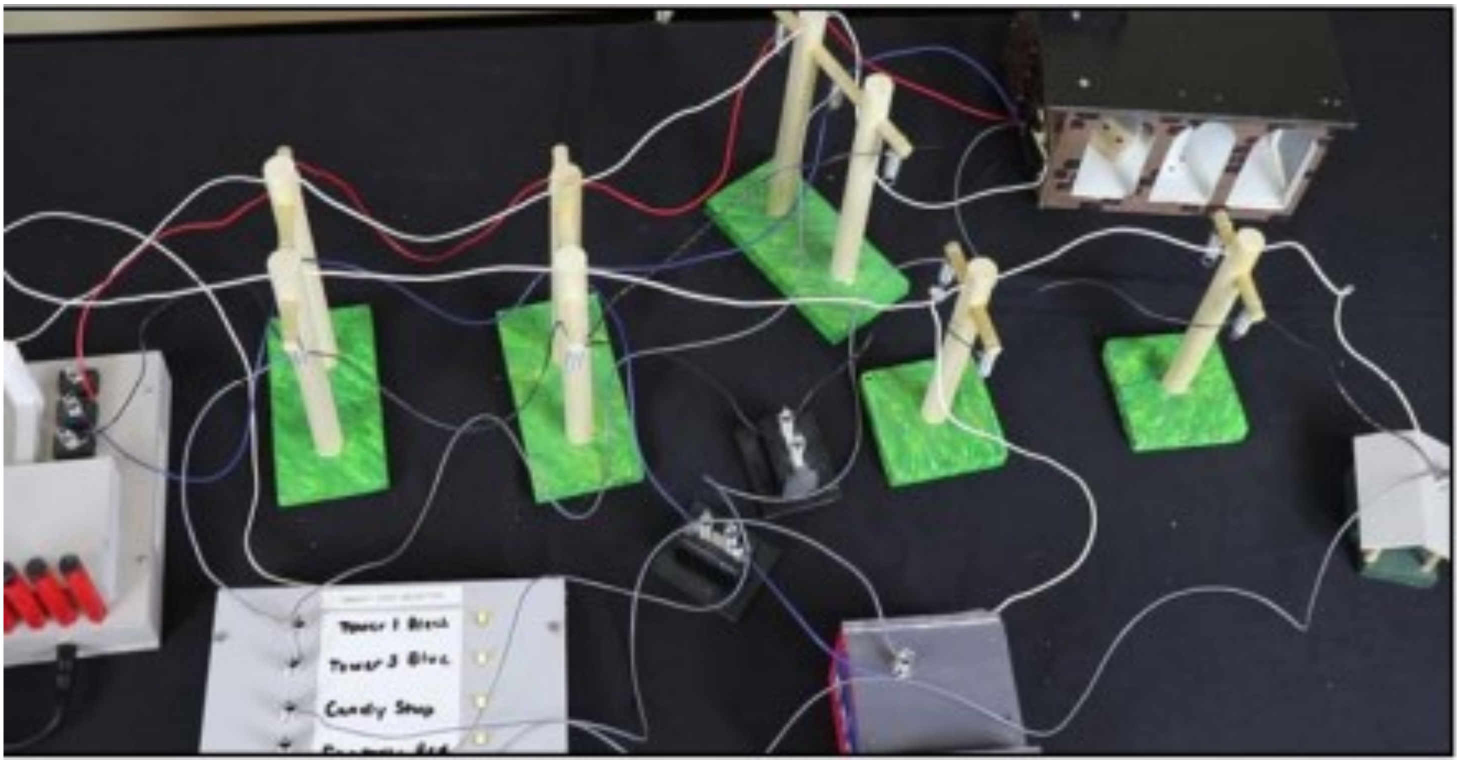
https://www.niagarafallsmarriott.com/niagara-seasons/toronto-power-generating-station/

High Voltage (1886-1917): Exploration

1. Unhook all of your wires.

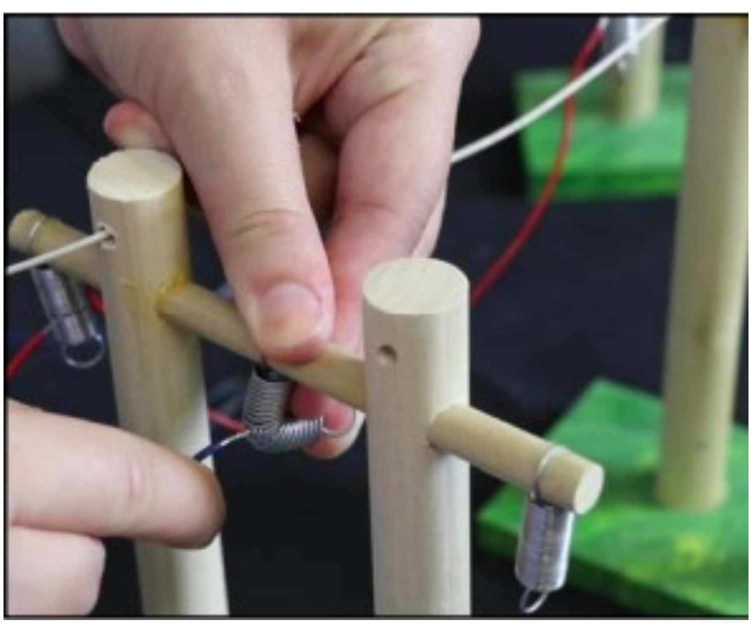
2. Put the power plant at one end of your table.

3. Put your homes at the other end of the table.



4. 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. The white wire is the “ground” or “common” wire. It goes through the holes in the top of the poles.

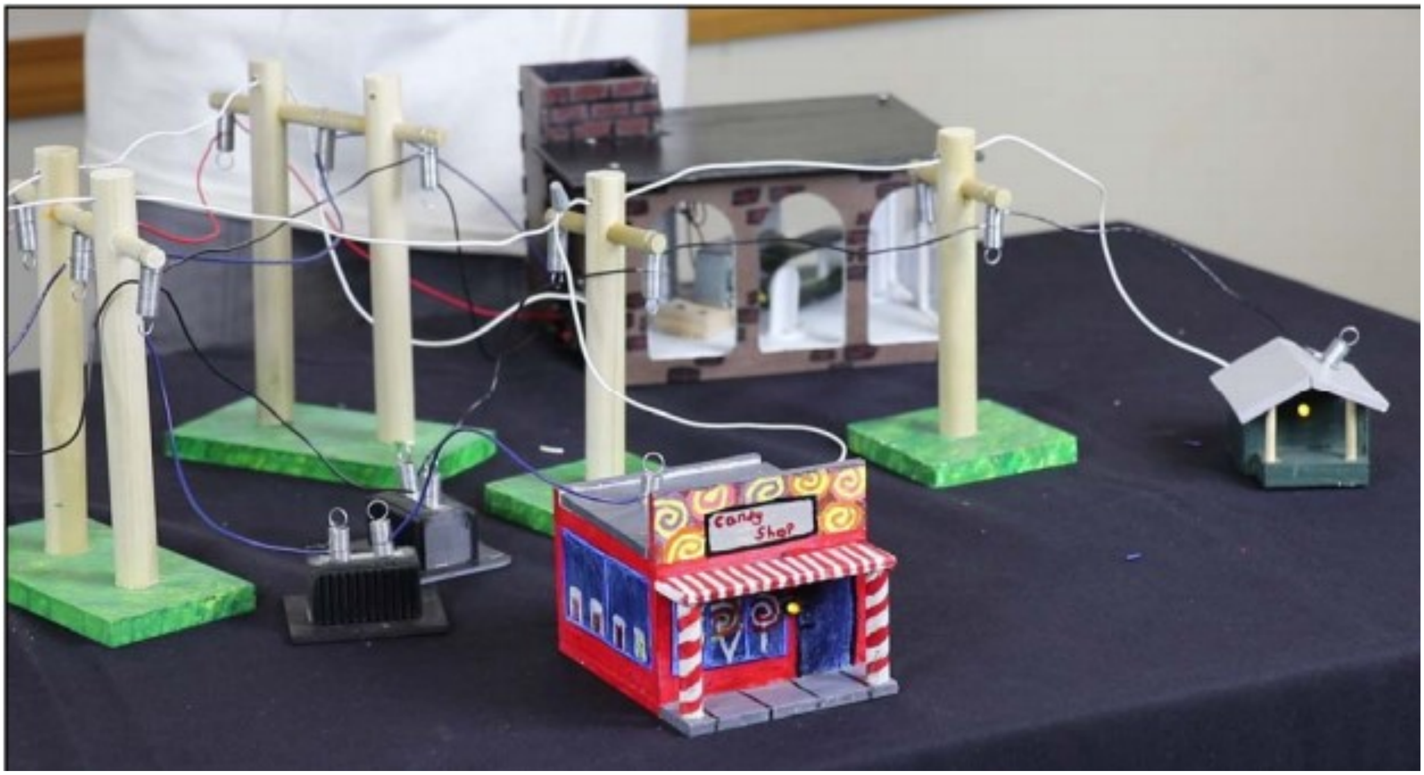


5. Put in a transformer.

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 you 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. Two lines of 120 volts each enter a home.

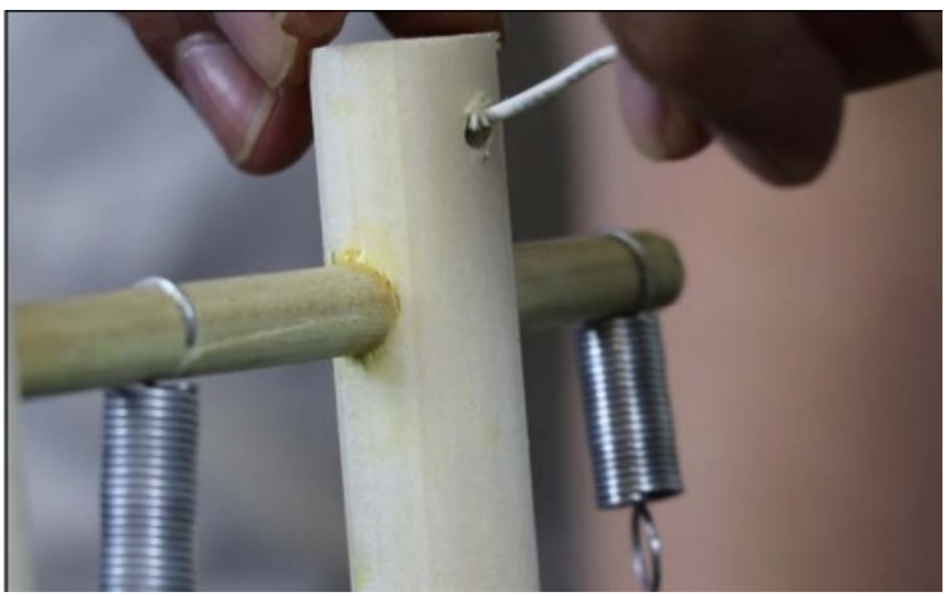
6. Hook up shorter poles.



7. Hook a colored wire from the last pole to your house. The pole closest to the house should have a 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. The red, black or blue wire should be on the poles.

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



9. Call your teacher to check it.

Did your homes light up? If not, what was wrong?

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

High Voltage (1886-1917): Discussion

1. Did you put in transformers?

Transformers in substations change the voltage of the electrical power.

https://energyeducation.ca/encyclopedia/Electrical_substation

4. OA 2 Multiply or divide to solve word problems involving multiplicative comparison, e.g., by using drawings and equations with a symbol for the unknown number to represent the problem, distinguishing multiplicative comparison from additive comparison.

Work fluidly with watts, volts, and amps. Watts is a measure of power. Volts is a measure of pressure, and Amps is a measure of volume.

Watts= Volts x Amps

Voltages in cities and neighborhoods vary from 4000 to 34,000 volts.

2. Is there a transformer by your house?

electrical-engineering-portal.com

Most outlets in a house are 120 volts. Most houses can draw up to 100 amps at any given time. The maximum power an average house could ever use is 120 volts x 100 amps = 12,000 watts. Houses seldom use that much power but the grid must provide for it. Three houses in the same neighborhood could draw 36,000 watts. At 120 volts, that would be 300 amps.   watts=volts x amps   amps=watts/volts

36,000 watts / 120 volts = 300 amps

300 amps is a lot of current which requires large, expensive wire. To reduce the current, electric companies increase the voltage coming to the neighborhood to 7200 volts. Now 12,000 watts / 7200 volts = 1.6 amps. A smaller, cheaper wire can be used. A bucket transformer reduces the voltage to 120 volts right before it goes into the house.

Research electrical use of your school, local businesses, and industries and calculate watts, volts, and amps.

https://internationalelectricalsuppliers.weebly.com/

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

https://woodpoles.org/

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.

2.MD 1-4 Measure and estimate lengths in standard units.

Measure the length of the grid line from power plant to furthest customer (house). Measure the distance between poles. Calculate how many more poles would be needed to go further distances.

3.OA 1-4 Represent and solve problems involving multiplication and division.

Calculate how many poles will be needed to extend the grid a given distance given the spacing between them. Measure in rather large units so that the numbers stay relatively small.

PHOTOGRAPH BY STATE ARCHIVES OF NORTH CAROLINA

Monitors (1950-2000): Exploration

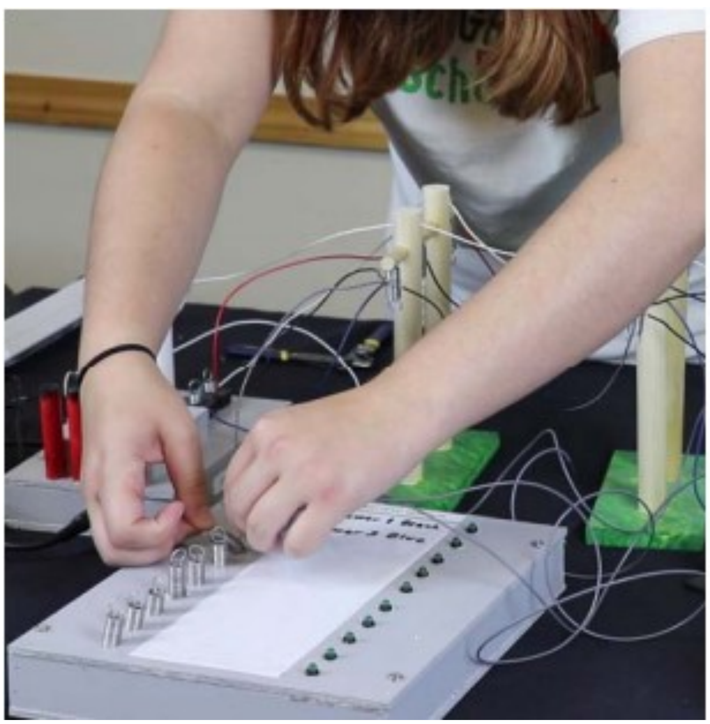
1. Connect a white wire from the alligator clip on the power plant to the alligator clip on the monitor.

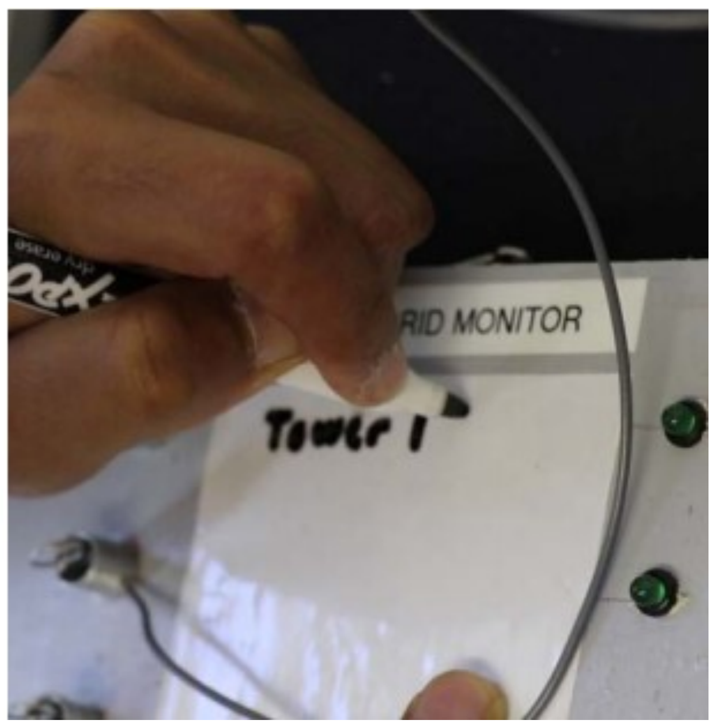
Some of the Smart Grid monitors connect to the Headquarters office with an audio cable. They do not have an alligator clip and do not need it. They have an on/off switch and a red indicator light.

2. Connect a gray wire to any spring on your grid.

Well, any spring that has a red, black, or blue wire attached.

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





4. Write the location of where the gray wire it attached. Use the dry erase marker.

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

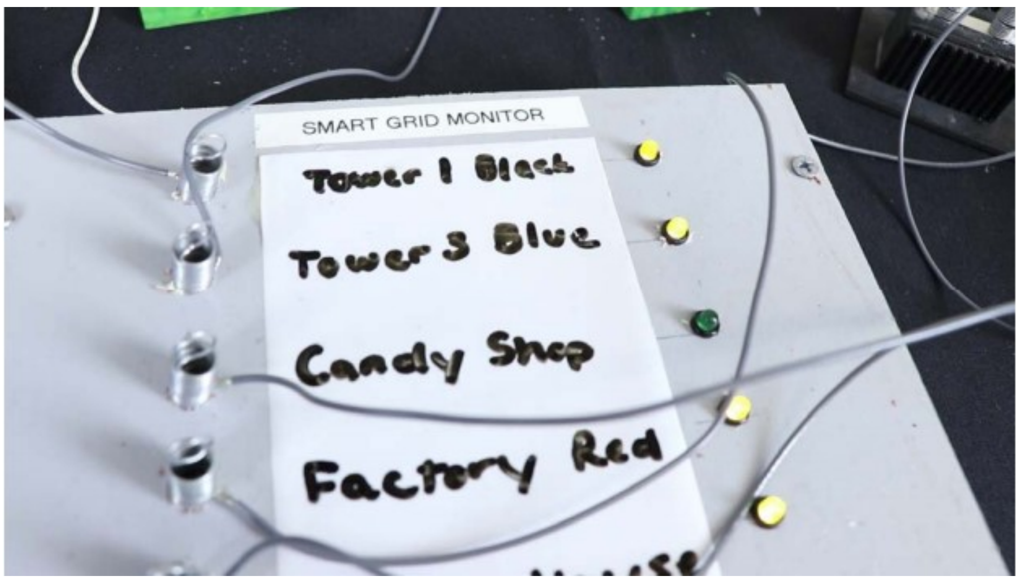
Monitors (1950-2000): Discussion

1. What happens when you connect the gray wire to the moni tor?

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

2. What does the Smart Grid Monitor tell you?

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



1.OA.1 and 2 Represent and solve problems involving addition and subtraction.

Students can count houses or other components and add or subtract to determine the number of household with or without power in the event of a broken wire or damaged transformer.

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

3.NF.1 Understand a fraction 1/b as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction a/b as the quantity formed by a parts of size 1/b.

Count lights and determine the fraction of lights in the entire grid that go out when any given wire is disconnected, fuse is blown, or switch turned off.

Smart Grid (2000-2020): Exploration

1. Hook up more gray wires on your Monitor and grid.

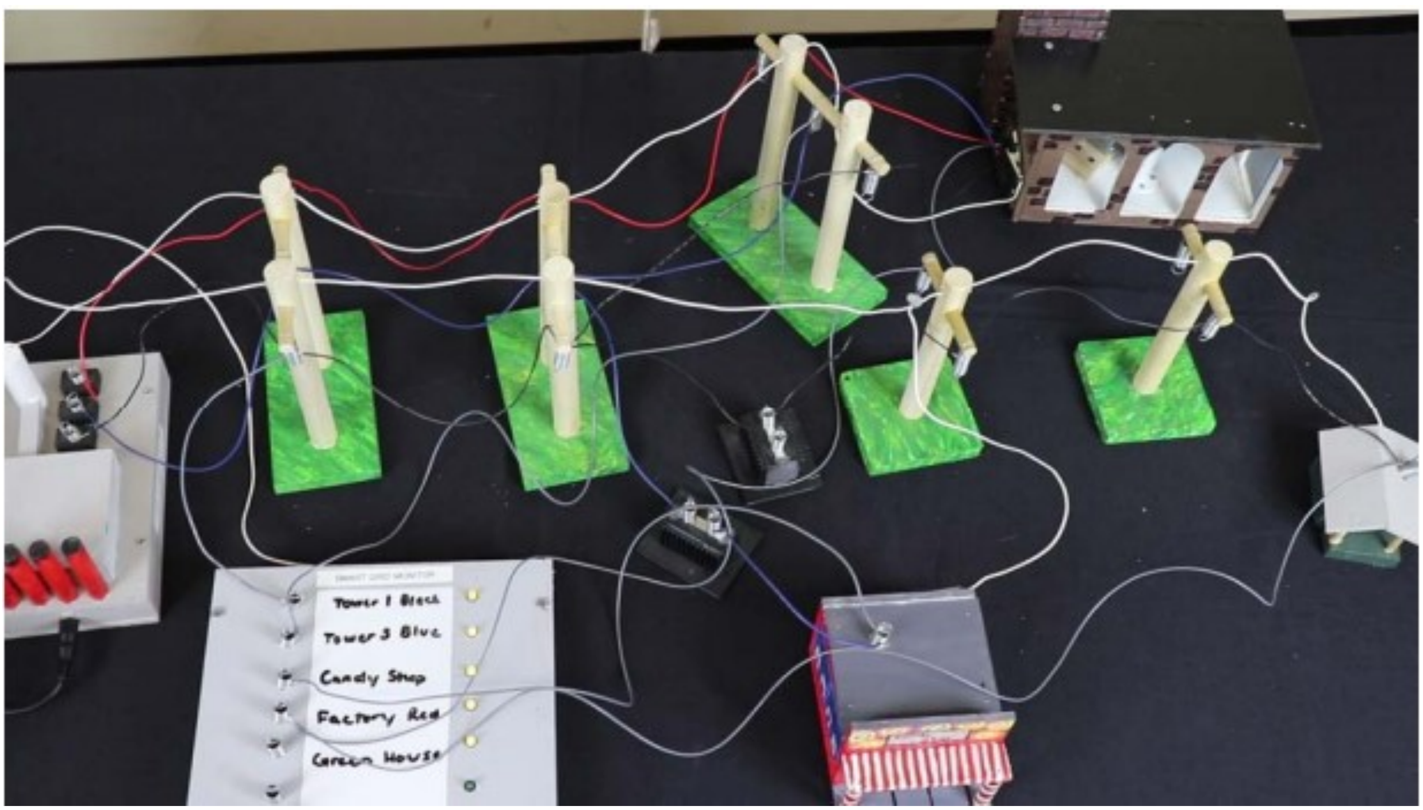
Students can select any locations, but will probably discuss what information will be most helpful. For example, they may want to know if power is actually leaving the power plant and if it is getting to the home. They can then install more sensors at other key locations in between.

2. Your teacher is going 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.

3. Find the problem using your Smart Grid Monitor.

The green light will tell them where there is power and where the line is “dead.”



<u>NGSS.3-ESS3-1.</u> Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard. The Smart Grid Monitor is used to locate a problem caused by a storm. This is a good opportunity to discuss with students the wild fires started in California by downed power lines. How will the Smart Grid reduce the chance of fires?

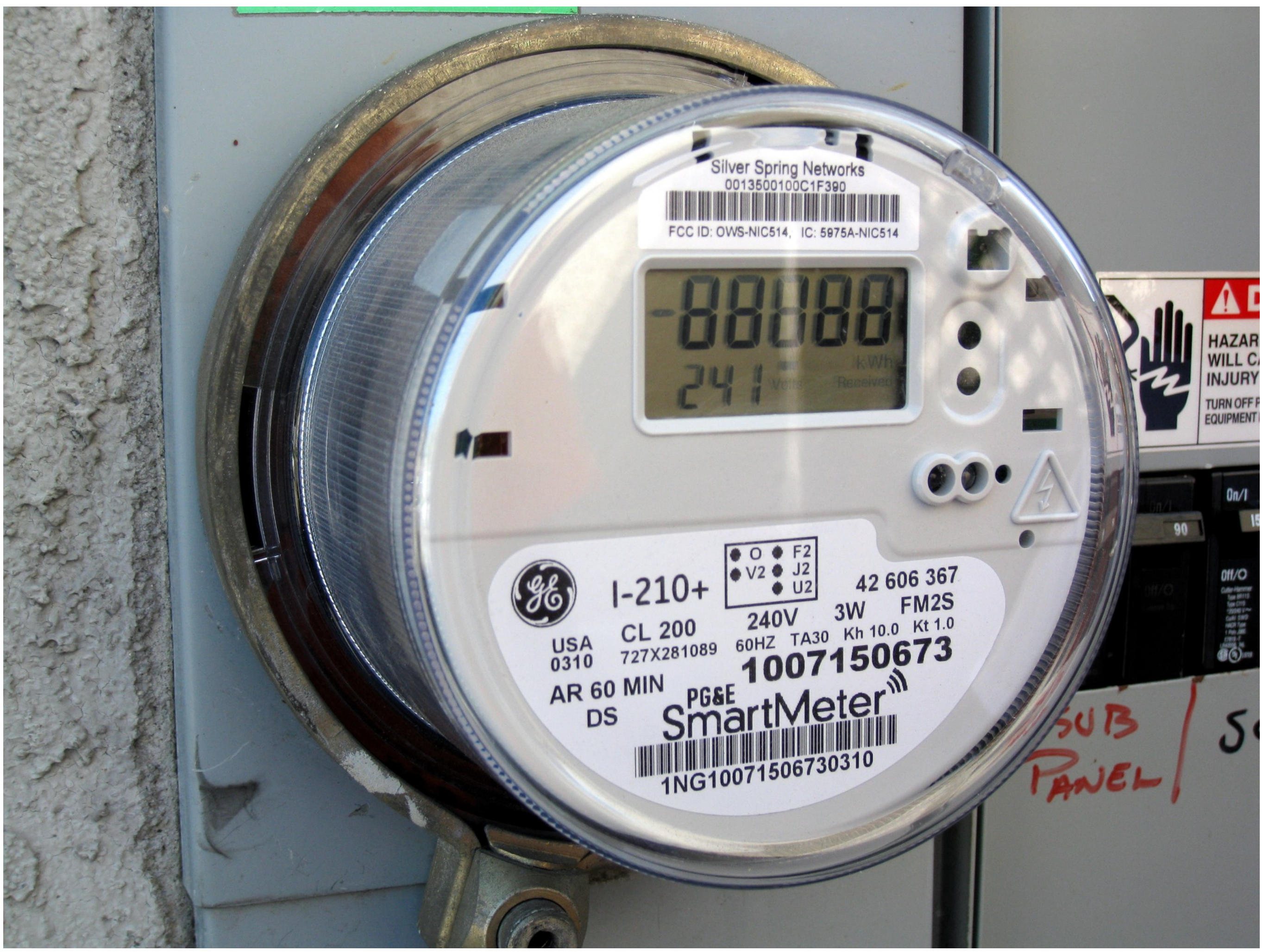
Smart Grid (2000-2020): Discussion

1. How does a power company know if a customer's power goes off?

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

2. With Smart Meters how does the power company know if a customer's power goes off?

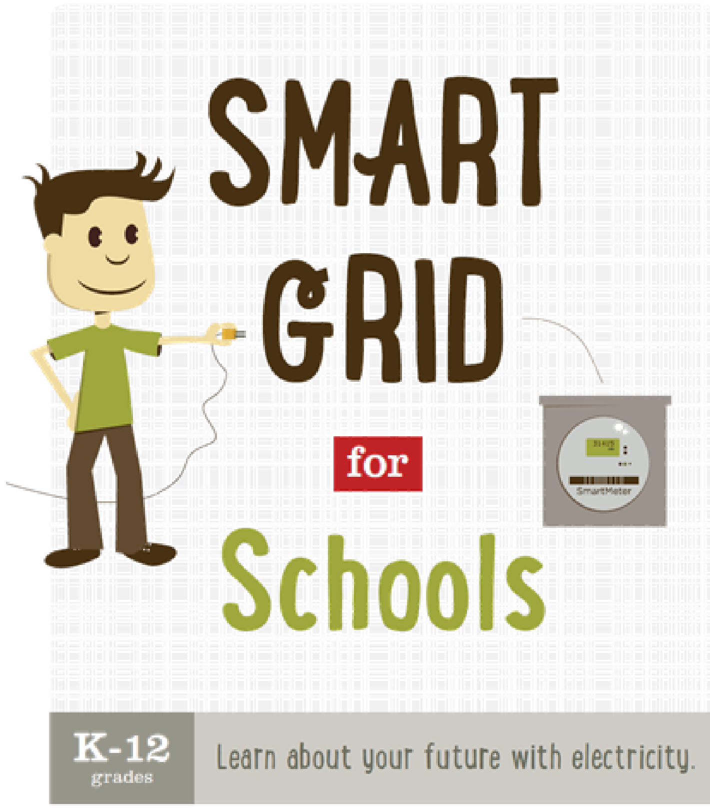
   With Smart meters installed, the power company will know instantly when a customer loses power. They will be able to pin-point the problem quickly and accurately, making repair and restoration of



Follow Up Discussion Questions

Use these questions as appropriate.

- What did the students like about making their electrical grid?
- Tell your students about the power plants in your area.
- Take your class outdoors and point out the wires and transformers near your school.
- Remind your students to NEVER play around wires.
- Draw a picture of your school with a wind turbine or solar panels. Would it work?
- Your students may have heard about climate change being caused by the burning of fossil fuels. Discuss coal and gas power plants, why they are needed, what other sources of energy can be used to produce electricity.



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CCSS.ELA.W.4.2. Write informative/explanatory texts to examine a topic and convey ideas and information clearly. The discussion questions could be assigned as written responses in complete sentences. They could also be assigned reports on an energy-related topic requiring research. Another option is for them to write (and illustrate) instructions for how they made their grid.

CCSS.ELA.W.3.7. Conduct short research projects that build knowledge about a topic. This experience can be used as an introduction to a number of research topics including history, technology, society, environment, economics, etc.

NGSS.3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. Propose that students design and build a model of the electrical grid of the future using all renewable energy sources. Provide them criteria and constraints such as power requirements and location restrictions.

CCSS.ELA.RI.4.5. Describe the overall structure (e.g., chronology, comparison, cause/effect, problem/solution) of events, ideas, concepts, or information in a text or part of a text. These instructions are written in a Learning Cycle format. Students could be assigned to review and critique these instructions.

CCSS.ELA.W.4.8. Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. Require entries into a journal concerning the students experience with the Smart Grid for Schools system. Encourage them to organize this information into a digital slide show to be presented to parents and/or school board members.

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