

# Power the Grid: Empowering Our Communities

## Key Concepts

Students identify forms of energy present in the model system and the power grid system it represents. By analyzing energy systems, students will get acquainted with the concept of carbon emissions, carbon footprints, and energy flows.

## Time Required

45–85 minutes in one or two class periods.

## Standards

### Disciplinary Core Ideas

- [MS-PS2.B](#)  
Types of Interactions
- [MS-PS3.A](#)  
Definitions of Energy
- [MS-PS3.B](#)  
Conservation of Energy and Energy Transfer

### Cross Cutting Concepts

- Systems and System Models
- Energy and Matter
- Stability and Change

### Science and Engineering Practices

- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence

## OVERVIEW

This activity first introduces students to the basics of the power grid as a system made up of subsystems. They will watch and discuss a video showing how energy is converted into power that is then transmitted and distributed throughout the community. They then identify different sources of energy for producing electricity, learn the difference between nonrenewable and renewable energy sources, and learn what energy sources have a high carbon footprint. Finally, students construct parallel circuits and use them to model the power grid and talk about energy. They discuss aspects of the model, including energy flows within the system, how different subsystems of the power grid are represented, and limitations of the model.

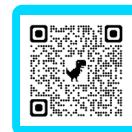
## LEARNING OBJECTIVES

At the end of the lesson, students will be able to:

- Identify and discuss the main subsystems of a power grid system
- Describe the difference between renewable and nonrenewable energy sources, and identify energy sources as one or the other.
- Discuss how the class model of a power grid represents the parts of its system and its limitations (the parts of the system not about to be represented in the model).
- Track inputs, outputs, and energy flows through their power grid models.

## ADDITIONAL RESOURCES

Additional resources for this lesson can be found at <https://kidwind.org/activity/MSPowerGrid>



## BACKGROUND

*Power grids* get electricity to where it is needed. Power grids include *power plants* that are used to generate electricity. The electricity is “pushed” (*transmitted*) through the grid over long distances through high-voltage *transmission lines*, and stepped down at local *transformers* to lower-voltage *distribution lines* that handle *distribution* of electricity to homes and businesses.

Power plants *transform energy* from some form (heat, wind, solar, or nuclear are the most common) into electrical energy. Electricity can be generated from *renewable or nonrenewable* sources of energy. Some nonrenewable sources of energy have high *carbon footprints* because they involve burning fuels, which releases carbon dioxide as *carbon emissions* into the atmosphere, contributing to global warming and climate change.

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Click [here](#) to check out the NGSS Website, Full NGSS Standards, or Science and Engineering Practices in the NGSS.

## MATERIALS

Each group will need a set of these items.

You may want to package them together in a kit:

- Student Guide (5 pages)
- 10 LED lightbulbs (8 red, 2 green)
- 1 manila folder, cut into pieces
- Maker Tape (2- to 3-foot strip per student)
- Jumper leads with alligator clips (2 per student group)
- Narrow (1/2-inch) transparent tape
- 1 hand crank motor with handle (3D and Laser files available for printing handle)
- 1 solar panel
- 1 coin cell battery
- 1-2 pair(s) of scissors
- Ruler
- Pencil

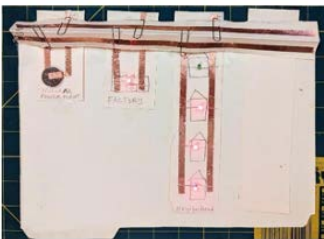
## GETTING READY (30-60 MINUTES)

The following should be done prior to the start of the class. You should plan for at least 30 minutes to complete the set-up.

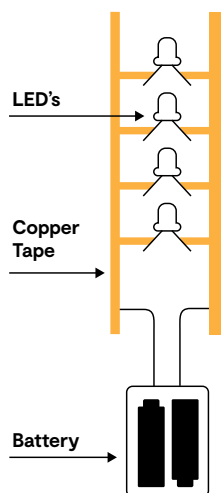
Work through the activity yourself. This will allow you to understand what students are likely to have trouble with, and brush up on your circuitry knowledge, as students will have questions.

Cut the Maker Tape. You may want to cut the maker tape into 2-3 foot strips so that each student has their own piece. This will save the students work time.

Prepare the base of the power grid [optional].



Parallel Circuit



You may want to save class time and make construction easier for students by preparing the manila folders:

- Cut along the folding mark farthest from the fold on the front flap.
- Mark along the cut edge onto the folder back with a ruler, making four lines from (a) 0.5 to 2.75 inches; (b) 3.25 to 5.5 inches; (c) 6 to 8.25 inches; (d) 8.75 to 11 inches.
- Cut slits along the four lines with a utility knife. Use a cutting board or mat.
- Fold the manila along the line with slits, creating a “tent” on top.

OR (no utility knife required)

- Cut through both layers of the folder along the folding mark farthest from the fold.
- Tape the folded strip to the edge of one of the folder sides in five places, leaving four 2-inch slits.

Prepare cards to hold loads, power plants, and distribution lines. Cut 2-inch-wide strips from the cut-away sections of the manila folder. These will be used to hold “distribution” subsystems of the power grid model.

Post the Essential Question(s) on the board, or have them ready to post. You will find these in Step 1 of the activity below.

Decide how to distribute materials. Either create student “kits” ahead of time or have the students gather materials from a common “store” during class.

## ACTIVITY

### PART 1: INTRODUCE THE LESSON (~10 MINUTES)

Students activate and record existing understanding so they are ready to make connections to new information.

#### Step 1: Introduce the Essential Questions.

Post them on the board or in some other prominent place.

- Where does the electricity for our school come from?
- Why does it matter where our electricity comes from?

#### Step 2: Have Students Consider the Essential Questions.

For example, you could have students write down or talk about everything they can think of about the questions:

- In a notebook or on a handout for later reference
- On sticky notes for later placement and organization on the board
- In a joint file, again to make it possible to organize and possibly save them
- Have students turn-and-talk in pairs

#### Step 3: Engage Students in Sharing and Recording Their Prior Knowledge.

Ask students to share what they know or believe about the essential questions and record the contributions in the “K – What I Know” section of a KWL chart. For example, you could:

- Lead a class discussion about the essential questions, while you or students record the major points in the KWL chart.
- Ask students (with your help) to organize the class responses on sticky notes or in a joint file into categories, to be summarized for the KWL chart.

### PART 2: BUILD BACKGROUND KNOWLEDGE (10-20 MINUTES)

#### Step 1: Watch a Video About the Power Grid.

With students now thinking about the power grid, energy sources, and electricity, pause and watch the following video: [Overview of the Electricity Grid by PJM Interconnection](#) (video timing: 0:35–3:58).

#### Step 2: Review and Record.

Record what students learned from the video about the power grid. Write student contributions into the “L” section of the KWL chart.

#### Step 3: Introduce Energy Sources.

The following are some facts you can share, as well as some questions we suggest you ask your students to get them thinking:

- Tell students or post: Most states use a variety of energy sources to power the grid. This energy mix typically includes: natural gas, nuclear power, coal, oil, & renewable energy.

Ask: Where do each of these types of energy come from?

- Answer: Coal, oil, natural gas, and nuclear fuel (uranium) are all mined from the ground, while renewable energy comes from sources such as the sun, wind, moving water, or heat in the ground.

#### Step 4: Introduce Energy Impacts.

Scientists measure the impact of an energy source on the climate in terms of [how much carbon dioxide \(g CO<sub>2</sub>\) it produces per kilowatt-hour \(kWh\)](#) of energy it produces for people to use.

- Wind energy produces 11 g CO<sub>2</sub>/kWh
- Coal produces 980 g CO<sub>2</sub>/kWh
- Natural gas produces 465 g CO<sub>2</sub>/kWh

Ask: How much more carbon dioxide per kilowatt hour does coal produce than wind energy?

- Answer: The carbon footprint of coal is almost 90 times larger than that of wind energy.

Ask: How much more g CO<sub>2</sub>/kWh does natural gas produce than wind energy?

- Answer: The carbon footprint of coal is more than 40 times larger.

Ask: Why might some regions want to use more energy from renewable sources and less from non-renewable sources?

- Answer: Make sure students mention the impact of carbon emissions on global climate change as one of the reasons.

Ask students for new “K” and “L” entries based on the new information. Add student contributions to the KWL chart.

Record what students “Wonder.” Ask students what they don’t yet understand and want to know more about.

Record their contributions in the “W – Wonder” section of the KWL chart.

### **Part 3: Introduce the Modeling Activity (5-10 minutes)**

#### **Step 1: Introduce the Modeling Activity.**

Pass out the student guidebooks.

Explain that they will be building circuits to model the power grid in some states. Each student team will create circuits using the Maker Tape.

Show students the materials. Make sure all students understand what the parts of the kit are, particularly parts they may not have seen before, such as Maker Tape and LEDs.

#### **Step 2: Explain How to Use Maker Tape.**

You may need to explain that Maker Tape works best if it is not cut between circuit elements. There are three videos in the “Resources” section of this activity that demonstrate techniques for using the tape for creating circuitry.

- How to unroll the tape as you go and fold it around corners: <https://www.youtube.com/watch?v=e5HoBxfFb3U> (2:41)
- How to tape on LEDs: <https://www.youtube.com/watch?v=NS2RcreuLww> (0:42)
- How to add a coin battery: <https://www.youtube.com/watch?v=8XFwtzHNFYIY> (0:53)

#### **Step 3: Review Safety Considerations.**

Ask students to recall what a “short circuit” is. Make sure everyone understands that they should not link up the positive and negative sides of a battery or generator without a load in between.

#### **Step 4: Check for Questions and Distribute Materials.**

Answer any questions students may be left with. Additionally, either pass out the kits you prepared or allow teams to come to the “materials store” you set up to pick out the materials listed in their Student Guide.

### **PART 4: BUILD TIME! (15-20 MINUTES)**

#### **Step 1: Expectations Reminder and Beginning Activity.**

You might remind students to ask each other when they feel stuck before coming to talk to you. Students should begin the activity using the handout to guide them.

Remember to circulate to check in with teams, provide suggestions, answer questions, and make sure students understand what the different materials represent.

#### **Step 2: Worksheet Time.**

Have teams complete the “Modeling a Power Grid / Energy Forms and Flows” pages in the Student Guide. When finished, ask them to complete the “Getting Energy to a Power Grid” page in the Guide.

#### **Step 3: Have Teams Link Up Their Models [Optional].**

Students can combine their circuits into one extended power grid using the remaining jumper leads with alligator clips.

#### **Step 4: Discussion.**

Conduct a class discussion of what students see in their models. Help students to focus on the ways that the model represents a real power grid. Be sure to bring up difficulties with getting enough power or consistent power to the LEDs, leading to them flickering or not lighting. This problem is representative of problems with generating enough or consistent enough electricity in real power grids, which can lead to brownouts or blackouts.

**PART 5: REVIEW & CLOSING (10-15 MINUTES)****Step 1: Wrapping Up.**

Have students clean up their spaces. You may want to collect the extra supplies.

Lead a class discussion about what students observed in their models. What was challenging? What was interesting? How hard was it to get all the lights working? Were there times when the lights flickered? Were there times when only some lights were working and others were not? What seemed to cause those changes?

**Step 2: Reflect on Learning Objectives.**

Consider asking the following questions if you feel they haven't yet been addressed by the class. Write student contributions into the KWL chart.

- What transformations of energy are there in our models? How well do they represent what happens in a real power grid?
- What are the inputs and outputs in this system? How does the energy flow through the system?
- What is the difference between renewable and nonrenewable sources of energy?
- What sources of energy have the highest carbon footprint? Which have the lowest?

Revisit the essential questions

- Ask: What have we learned about where the electricity for our school comes from?
- Ask: What do we now know about why it matters where our electricity comes from?

Revisit what students "Wonder."

- Review the questions on the KWL chart and update those that have been answered.
- Decide which ones students still want to answer and make a plan with students for how they will answer them [optional].

**EXTENSIONS & INTEGRATIONS****Student Readings:**

- [Electrical Grid | CK-12 Foundation](#) - Reviews the various components of a power grid and how they work together.

**Research**

The questions and statements below are topics for which students could conduct research to find evidence. Some of the statements are false. Challenge students to figure out which ones.

- In a power grid system, is it necessary to balance demand and supply of electricity?
- What causes grids to break down? What causes brownouts and blackouts?
- Wind energy has the ability to be used or not based on power grid needs. This is referred to as *dispatchability* with little impact to cost. Compared to what is possible with nonrenewable energies, curtailing production increases costs, sometimes dramatically.
- Wind energy is predictable and sustainable.
- Wind speed does not just suddenly stop, it only decreases slowly and smoothly.
- The angle of the blades of a power turbine to the wind can be adjusted to increase or decrease how much power the wind turbine can generate.
- Wind energy is not like other energy sources of energy (for example: nuclear, solar, fossil fuel burning) that are used to generate electricity for the power grid.
- Generating electricity from wind energy does not produce carbon dioxide.
- There is no mining or transportation of raw materials with the use of wind energy unlike coal, oil, or natural gas.

## VOCABULARY

**Carbon Footprint** – The total amount of greenhouse gases generated by a technology when it is used, often measured over a single use or over a year.

**Circuit** – A closed loop of conductive materials where electricity can flow from the power source through the path to the load back to the power source.

**Distribution** – The delivery of electricity from substations to consumers.

**Distribution Lines** – Cables used to distribute electricity to consumers such as homes and businesses.

**Electricity** – Electricity is the flow of charged particles, called electrons, through a circuit.

**Electrons** – Negatively charged subatomic particles that move freely through a conductor.

**Generation** – The process of transforming a primary energy source (heat or kinetic energy) into electrical energy.

**Load** – Something using electrical power in a circuit: for example, a light bulb, motor, computer, or appliance.

**Nonrenewable Electricity** – Electricity that is generated from a nonrenewable energy source that will run out, such as coal, oil, natural gas, or nuclear power.

**Power Stations** – Place where physical energy is converted into electrical energy.

**Power Source** – The source of electrical energy in a circuit, for example: a battery, solar panel, or wind turbine.

**Renewable Electricity** – Electricity that is generated from a renewable energy source that will never run out, such as wind, solar, water, or biomass.

**Substation** – A hub where electricity from power plants or bigger lines is controlled and distributed to different neighborhoods and buildings.

**Transformer** – A device that transfers electricity from one circuit to another, often at a different voltage.

**Transmission** – The movement of large amounts of electrical energy from a generating site to electrical substations and community grids for consumer use.

**Transmission Lines** – Cables used to transmit large amounts of electricity at high voltages.

**Voltage** – The amount of pressure from a power source that pushes electricity through a circuit.

## ADDITIONAL RESOURCES

→ [Energy 101: Electricity Generation, EnergyNowNews YouTube Channel](#)

### Maker Tape Video Resources:

→ [How to unroll the tape](#) (2:41). From Mr. T the STEM Guy.

→ [How to tape on LEDs](#) (0:42). From Mr. T the STEM Guy.

Name(s) \_\_\_\_\_ Date \_\_\_\_\_

## Power the Grid

Offshore wind is a key component of New Jersey's Plan to transition to clean energy by 2035.

### ESSENTIAL QUESTIONS TO KEEP IN MIND:

- Where does the electricity for our school come from?
- Why does it matter where our electricity comes from?

### WHAT IS A POWER GRID?

#### Transporting Electricity

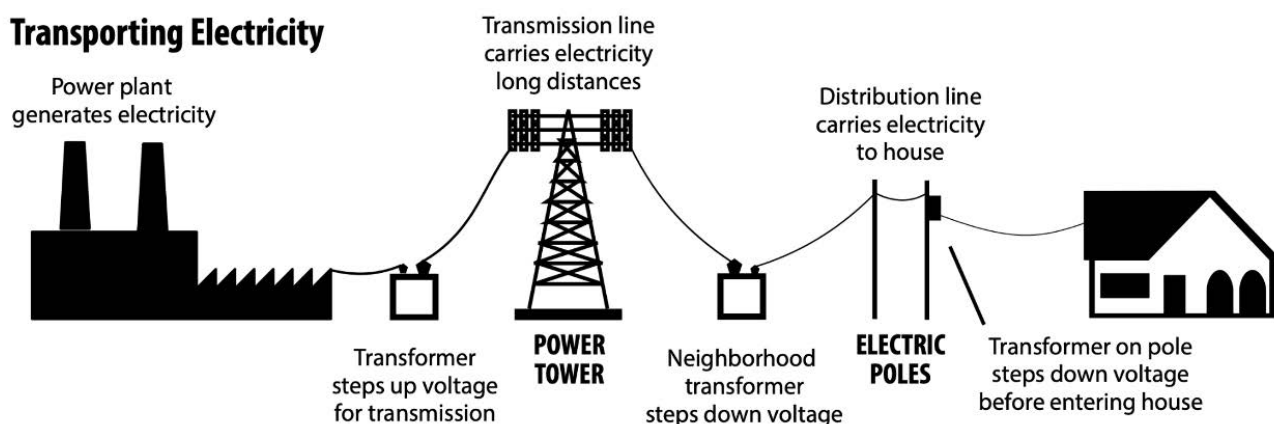


Image from NEED Project: [Elementary Energy Infobook- Electricity Travels Through Wires](#)

Power grids get electricity to where it is needed! They include power plants to transform heat, wind, solar, and nuclear energy into electricity. They also include transmission lines that carry lots of electricity at high voltage, and distribution lines that carry smaller amounts of lower-voltage electricity to your home where it will be consumed. Electricity is the movement of charged particles called electrons in a circuit.

In this activity you will build a circuit to model the power grid. Our model will include representations of transmission lines, distribution lines, and consumers. It also includes representations of three kinds of power plants that generate electricity from different kinds of energy: nuclear, solar, and wind energy. Solar and wind energy are *renewable*, but nuclear is *non-renewable*.

Before beginning the project steps below, review the “Expert Tips for Using Maker Tape” and “Safety” sections at the end of this document.

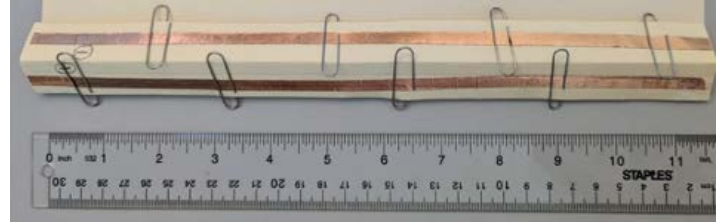
### MATERIALS

- 10 LEDs (8 red, 2 green)
- 1 hand crank motor with handle
- 1 manila folder, cut into pieces
- 1 solar panel
- Maker Tape (2- to 3-foot strip per student)
- 1 coin cell battery
- 2 jumper leads with alligator clips
- Scissors
- Narrow (1/2-inch) transparent tape
- Ruler and pencil

## PROJECT STEPS

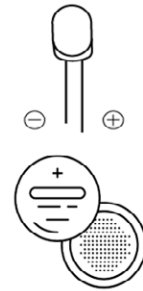
### Build Transmission Lines

1. If it's not yet done, add an 11-inch strip of Maker Tape to each outside of the folded strip cut from the manila folder.
2. Mark the side closest to the bottom fold (+) and the other (-).
3. Add 2 paper clips, one on each transmission line, to each of the four slits beneath the transmission lines.

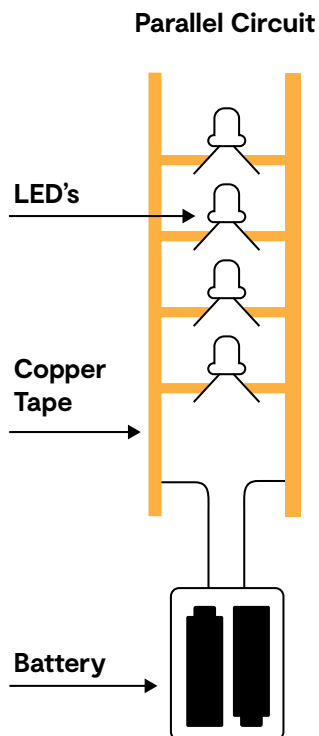


### IMPORTANT

- The longer leg of an LED is positive (+)The shorter leg is negative (-).
- Coin batteries also have a (+) side marked on them (the back is (-)).
- The solar panel and hand crank each have a red wire which is positive (+) and a black wire that is negative (-).
- Be sure to always match (+) parts to (+) lines and (-) parts to (-) lines.



### Create Distribution Areas



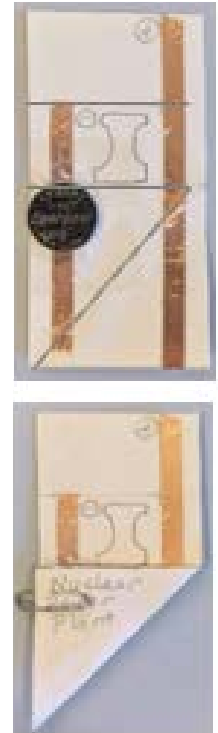
4. Take a 2-inch wide card of manila. Use your ruler to draw a horizontal line one inch from the end of the card. Draw 2 vertical lines one inch apart along the length (long side) of the card. The left line should start at the line one inch from the end of the card. The right line should go from the top to the bottom of the card.
5. Mark the shorter line as negative (-) and the longer line as positive (+).
6. Cover the two drawn lines with Maker Tape so that you have two parallel lines of Maker Tape on the card as shown in the image. Cut one piece of Maker Tape to be the exact length of the left line, then place the tape directly over the line. Do the same for the right line - cut a piece of Maker Tape exactly the length of the right line and place the tape directly over the line.
7. Between the two strips of Maker Tape, draw the "buildings" you want to model, for example, a factory or some houses.
8. Bend the legs of an LED out flat, one leg to each side, so that you can lay it down across your building with the LED in the center. The right leg of the LED should touch the right line of Maker Tape and the left leg of the LED should touch the left line of Maker tap.
9. Use transparent tape to secure the LED leg on each side.
10. Repeat steps #4-9 two more times to make a total of 3 distributions areas (1 per card).

### Create the Nuclear Power Plant (Nonrenewable Power Source)

11. Take a 2-inch wide by 4-inch tall manila card.
12. Repeat steps #4-5 on this new card.
13. Draw a fourth line across the middle of the card, dividing the card into an upper half and lower half, and creating a square in the middle.
14. Draw a fifth diagonal line from the bottom left corner of the card up to the right end point of the middle line drawn in step 13.



15. Repeat step #6, adding two strips of Maker Tape to cover the two long parallel lines on the card.
16. Place a coin battery on top of the left (-) strip of Maker Tape, just below the centerline.
17. Secure the coin battery to the card using transparent tape. Do not cover the center of the battery with tape – be sure to leave the center of the battery clear.
  - 17a. Cut 2 pieces of transparent tape 1.5 inches long.
  - 17b. Secure the top edge of the coin battery to the card. Take one of the 1.5 inch strip of tape and place it horizontally across the top of the coin battery.
  - 17c. Secure the bottom edge of the coin battery to the card. Take the second 1.5 inch strips of tape and place it horizontally across the bottom of the coin battery.
18. Fold the bottom right corner of the card up to the left, along the diagonal line, as is shown in the image. This should connect the (+) strip of Maker Tape (the bottom of the right line) to the center of the coin battery, where there is no tape.
19. Secure the folded flap to the manila card using a paperclip.



### Test Your Model

20. Slide a model distribution area into one of the slots under the model transmission lines. Adjust the paper clips so the clip on the close (-) **transmission line** touches the short (-) **distribution line** on the card, and the paper clip on the far (+) line touches the long (+) line on the card. *Make sure that that the metal paperclip touches the copper Maker Tape directly and that there is no transparent tape between them. We want the two metal components to connect to create the circuit.*
21. Slide your model nuclear power plant into another slot and adjust the paper clips as in step #17.
22. Ensure that your red LEDs light up (your green LEDs may be dim). Adjust the paper clips to have a solid connection to the copper of the Maker Tape as needed, and tape down the cards and the transmission line fold to make sure everything is secure.
23. Connect the remaining two model distribution areas the same way you did in step 20.
24. Adjust the cards and paper clips to ensure you have solid connections, just like you did in step 22.

### Attach the Wind Turbine and Solar Panel (Renewable Sources)

25. Tape the metal tip of the red wire from the hand crank to one end of the positive (+) transmission line where the copper is showing.
26. Similarly, tape the black wire onto the same end of the negative (-) transmission line. *A hand crank represents wind turbines. The handle will need your energy to light the LED, just like a wind turbine needs blowing wind.*
27. Tape the metal tip of the red wire from the solar panel to the other end of the positive (+) transmission line.
28. Similarly, tape the black wire onto the same end of the negative (-) transmission line. *The solar panel relies on light from the sun. Put your solar panel close to the window or use a flashlight to add solar power to your model power grid.*
29. Before you test your hand crank and solar panel, you need to break the connection to the coin battery so that your model power grid is no longer battery-operated. Do this by removing the paper clip and unfolding the triangular card flap on your nuclear power plant model.

**MODELING A POWER GRID / ENERGY FORMS AND FLOWS**

*Draw your model power grid in this space. Label all of the power grid subsystems that are represented in your model. On your drawing of your model, draw arrows to show the flow of energy through the system.*

**MODELING A POWER GRID / ENERGY FORMS AND FLOWS**

In what ways does this model do a good job of representing a power grid system?

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In what ways does this model NOT represent a power grid well?

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What transformations of energy do you identify?

*Form of Energy*

*Transforms Into*

_____	→	_____
_____	→	_____
_____	→	_____
_____	→	_____
_____	→	_____

What are the inputs to the power grid system you modeled?

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What are the outputs from the model power grid system?

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## GETTING ENERGY TO A POWER GRID

As you are running your model with the power sources on, what do you notice about the lights? Are there times when the lights stay on steadily? Are there times when they flicker? What seems to cause those changes?

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Were there any times when some of the LEDs failed to light? What happened? Why do you think the LEDs failed to light?

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In what ways do the LED lighting problems you see in your model represent problems with real power grids well or poorly?

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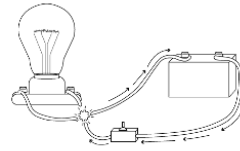
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## EXPERT TIPS FOR USING MAKER TAPE

- Fold the maker tape in half the long way. The crease that you create down the middle will help it peel more easily.
- Maker Tape can easily stick to itself. Do not remove all the backing paper at once. Instead, slowly peel the paper backing while you are securing it to the project.
- Avoid cutting the Maker Tape between circuit elements. Instead, fold it to go around corners.

## SAFETY

Do not stack coin cell batteries. Do not store them in a way that they could accidentally pile onto each other. Piled coin cell batteries could cause a short circuit.



Short circuits are very dangerous. They happen when electricity flows without passing through a load such as an LED or fan. The battery can become very hot.

Coin cell batteries are amazing, but if eaten by humans or animals can become lethal. Never put any type of battery in your mouth.



## VOCABULARY

**Carbon Footprint** – The total amount of greenhouse gasses generated by a technology when it is used, often measured over a single use or over a year.

**Circuit** – A closed loop of conductive materials where electricity can flow from the power source along the path to the load and back to the power source.

**Distribution** – The delivery of electricity from substations to consumers.

**Electricity** – Electricity is the flow of charged particles, called electrons, through a circuit.

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**Generation** – The process of transforming a primary energy source (such as heat or kinetic energy) into electrical energy.

**Load** – Something using electrical power in a circuit: for example, a light bulb, motor, computer, or appliance.

**Nonrenewable Electricity** – Electricity that is generated from a nonrenewable energy source that will run out, such as coal, oil, natural gas, or nuclear power.

**Power Plant** – A place where physical energy is converted into electrical energy.

**Power Source** – The source of electrical energy in a circuit, for example: a battery, solar panel, or wind turbine.

**Renewable Electricity** – Electricity that is generated from a renewable energy source that will never run out, such as wind, solar, water, or biomass.

**Substation** – A hub where electricity from power plants or bigger transmission lines is controlled and distributed to different neighborhoods and buildings.

**Transmission** – The bulk movement of electrical energy from a generating site to electrical substations and community grids for consumer use.

**Voltage** – The amount of pressure from a power source that pushes electricity through a circuit.