MACGILLIVRAY FREEMAN'S
DREAM BIG
ENGINEERING OUR WORLD

GRADE 4:

WIND-POWERED LED

Grade level: 4

Lesson length: 2.5 hours

> The landscape is changing as we find alternative ways to meet our energy needs and rely less on fossil fuels. Hydropower from dams, wind power, solar power, wave energy, and even methane gas from sewage and anaerobic digestion processes are all examples of renewable, alternative energy sources that engineers are harnessing. Students will learn about one of these renewable energy sources as they design a wind turbine. They will test blade designs on a windmill and see if it can light an LED light bulb.

In the Film

Engineers are leading the way as the world explores alternative energy sources to supplement or replace the fossil fuels humankind has come to rely upon. In the *Dream Big* film, we see engineers harnessing the power of the sun in the Ivanpah Solar Facility. In this facility, engineers have developed a system that converts the radiant energy from the sun into thermal, mechanical, and ultimately electrical energy. In this activity, students investigate another form of renewable energy, wind energy, and discover how engineers harness the power of our atmosphere to create energy for tomorrow.

NGSS Disciplinary Core Ideas

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electrical currents.

4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

NGSS Engineering Practices

4-ETS1.C Optimizing the Design Solution

Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.

Key Words/Vocabulary

Electrical energy: Energy of the movement of electrons through a circuit.

Mechanical energy: Energy of motion.

Materials

Per class:

- ☐ Box fan
- ☐ Pencil sharpener
- ☐ One KidWind Mini Turbine Kit (can be sourced from online vendors like Amazon; see Teacher Prep Notes for alternative)
- ☐ Windmill Blade Testing Device Instructions

Per team:

- ☐ Fan template
- ☐ Paper for taking notes
- ☐ Pencil or pen
- ☐ 2 corks
- ☐ Hot glue or thumbtacks
- ☐ Windmill Blade Testing Device preassembled:
  - ☐ Half-gallon milk carton
  - ☐ Water or other weight
  - ☐ ¼-inch by 1-foot dowel
  - ☐ Small paper cup
  - ☐ 1-foot length of string
  - ☐ Scissors
  - ☐ 2 metal washers
- ☐ Materials that may be used for making turbines:
  - ☐ 1 empty water bottle
  - ☐ Other scrap materials (e.g., soda bottles) for making turbine blades
  - ☐ 4 notecards, or cardstock
  - ☐ 1 foot of tape
  - ☐ 8 paper clips

Teacher Prep Notes

Though KidWind makes an excellent DC turbine that requires little to no assembly, it is not the only option. You can also buy a small DC motor, alligator clips, and an LED light. Attach the LED light to the DC motor using the alligator clips. When you spin the motor shaft, the LED light will illuminate. Similar to the KidWind motor, students' wind propellers are affixed to a cork, and the cork is pushed onto the motor shaft so that the spinning blades spin the shaft and generate light.

Before class starts, preassemble the testing devices for each team (see Research and Gather Information), according to the Windmill Blade Testing Device Instructions.

Be prepared to discuss the kinds of energy often used in society (radiant, electrical, thermal, mechanical, and so on) and have examples ready. Talk about how energy transfers convert energy to usable forms for humans. Have an explanation ready to explain how wind turbines convert mechanical energy (in the form of wind) to mechanical energy in the spinning of a turbine, to the electrical energy in the generator, to the radiant energy in a light bulb.

To Do

Determine the Problem or Question to Solve: 15 minutes

1. Before watching the IMAX movie *Dream Big*, give students an overview of what they are about to experience. This film is about engineering and the ways that engineering can inspire, challenge, and enrich our lives. Give students the following questions to think about as they are watching the film:
   - ☐ What forms of alternative energy did you see in the film?
   - ☐ What are the benefits of having multiple sources of energy?
   - ☐ What role are engineers playing in the future of energy?
2. Debrief as a whole class after viewing the film. Allow students to reflect on the guiding questions you gave them. If necessary, remind students of some of the current challenges we face regarding the consumption of energy: dependency on nonrenewable fossil fuels, the by-products of nuclear waste, greenhouse gas emissions, and so on.
3. Introduce the design challenge. Explain that in keeping with a worldwide initiative, many countries are exploring how they can reduce their dependency on fossil fuels such as coal, oil, and gas. Our planet provides many opportunities to harness energy with minimal impact on the planet, but so far the technology to harness energy from these sources on a massive scale has not been perfected. Out of the identified alternative sources, a few have risen to the top as showing the most promise: wind, solar, and tidal. Today students will use the provided materials—a KidWind Turbine with LED light (or similar materials as described in Teacher Prep Notes), a cork, and a turbine blade design of their choice—to design and build a wind turbine capable of generating energy.

Research and Gather Information: 60 minutes

1. Divide the class into teams of three.
2. To each group, distribute fan templates that students can use to create pinwheels. Have students cut along the solid lines and fold along the dotted ones. Instruct them to attach each pinwheel to the end of a cork with a spot of hot glue or a thumbtack.
3. Explain that the next step is to experiment with how air pressure can interact with the different predesigned wind turbine/pinwheel blades. Instruct each group to attach its pinwheels to their preassembled Windmill Blade Testing Device by poking the unused end of the cork onto the pointed end of the dowel rod. Place the windmills, with pinwheels attached, one foot away from a box fan. Turn the box fan on and let it blow on the pinwheels.

Students should record the amount of time it takes for each pinwheel design to raise the washers. Discuss with students the idea that the faster the pinwheel is moving, the more energy it is creating, and the faster it can raise the washers. For each of their three designs, students should note what worked well and what did not.

Review the kinds of energy often used in society (radiant, electrical, thermal, mechanical, and so on) and brainstorm examples of each. Talk about how energy transfers convert energy to usable forms for humans. Connect back to the wind turbines being built in class. They convert mechanical energy (in the form of wind) to mechanical energy in the spinning of a turbine, to the electrical energy in the generator, to the radiant energy in a light bulb.

Plan a Solution: 15 minutes

If students are unfamiliar with the concepts of criteria and constraints in engineering, take the time now to introduce these two fundamental ideas. Engineers look at challenges through the lens of criteria (what does my device have to do?) and constraints (what are the limitations I face in making, testing, and using the device?). Spend some time as a whole class brainstorming the criteria and constraints of this particular engineering challenge.

Guide groups to identify one factor from each pinwheel design to use as inspiration for designing the blades of their turbine. Their goal will be to develop a design that will harness the most energy by spinning the fastest when air pressure is applied. Students should draw a diagram of what they plan to build, labeling the materials they will use and describing how energy is transferred to the light bulb in the device.

Make It: 30 minutes

Give each group a baggie of materials and one cork with which to build the turbine blades. Blades can be made of paper, plastic, or another material. Allow students to build their designs, visiting each group and pushing them to fluently talk about their design, how it transfers energy, and how they will know if it is generating a lot of energy (more motion = more energy). The final blades should be attached to a cork for easy attachment to the turbine generator in the next step.

Test: 30 minutes

Attach each cork/turbine blade, one at a time, to the motor shaft of the turbine generator. Place a dot of hot glue on the cork before sticking it onto the turbine. This will ensure full contact so that it is spinning the motor as it spins from the wind. When you are switching groups, simply pull off the cork and the hot glue will easily peel off. Place the turbine at set lengths (e.g., 1 foot, 2 feet, 3 feet) from a box fan on low speed. Compare the input and output of energy from each stage.

Evaluate: 10 minutes

Ask students to reflect on the following questions and share their thoughts with the class:

1. Does your turbine spin effectively under airflow?
2. Does it hold up to the air pressure without breaking?
3. Does it produce enough electricity to light the bulb?

Taking It Further

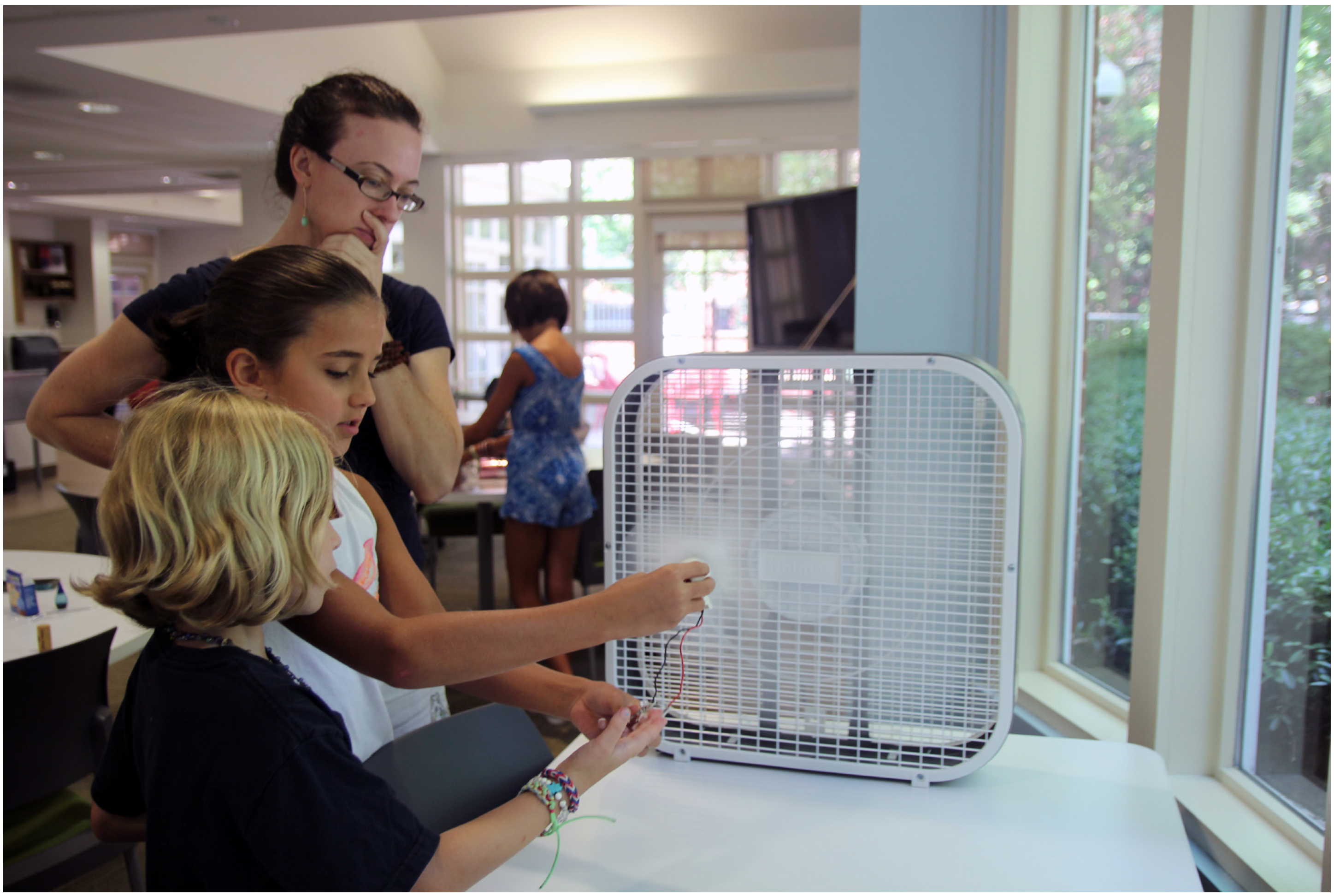
Retest turbines at different fan speeds for each of the suggested stages.

Students can attempt to light multiple LEDs or use a voltmeter/ammeter to measure with greater accuracy.

Search the web for other pinwheel blade designs and templates.

Explore more ways that engineers are protecting our planet through innovations in alternative energies and in designing recycling solutions and strategies for cleaning up our planet.

Document your students' work through our social media outlet: #dreambigfilm



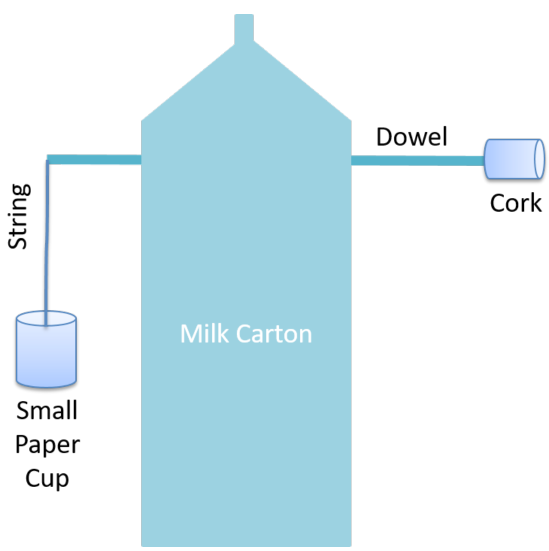
WINDMILL BLADE TESTING DEVICE

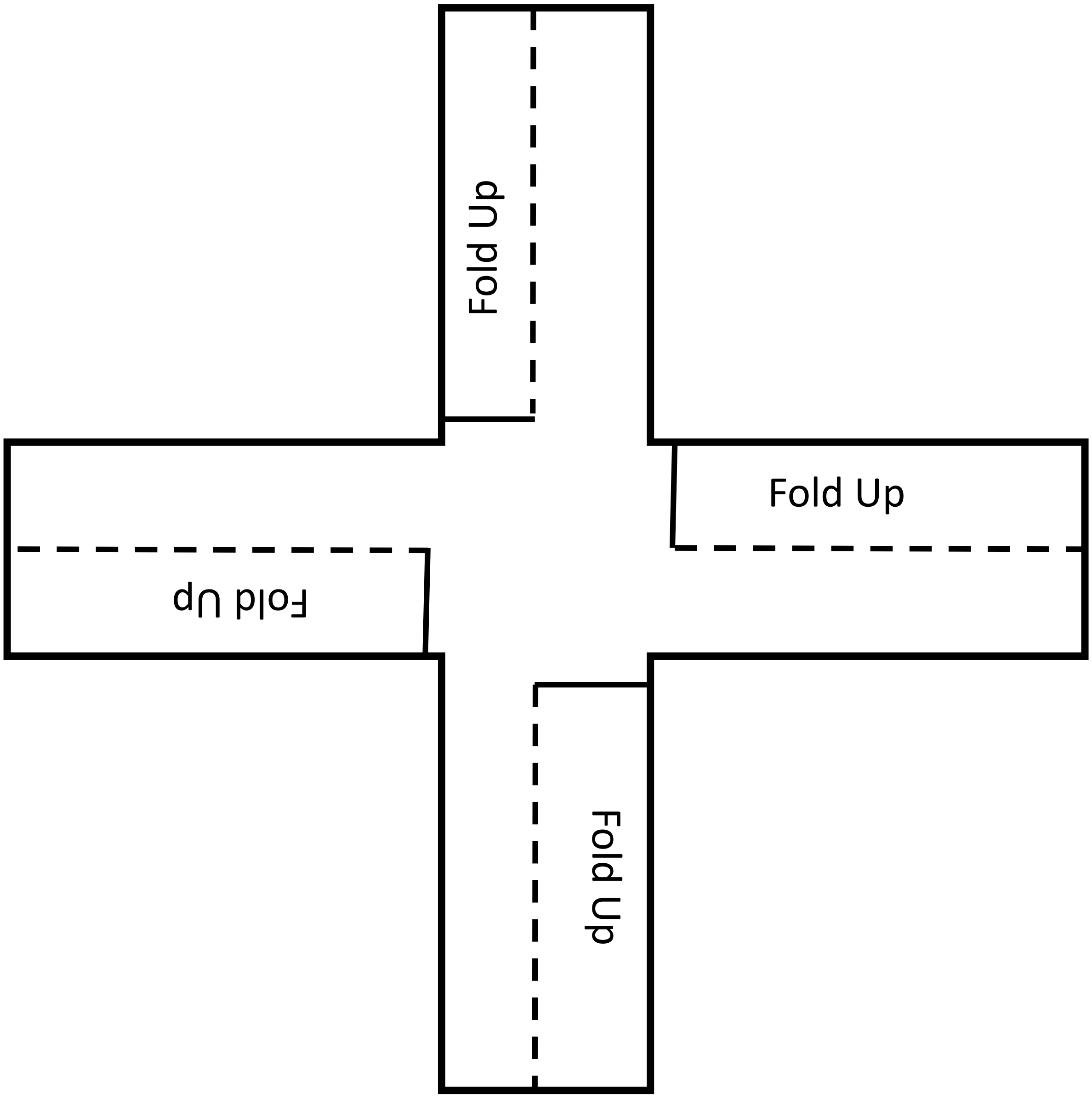
Assembly Directions:

1. Add water/weight to the milk carton (if using water, fill halfway).
2. Pierce the milk carton 2 inches beneath the top edge. Pierce the milk carton on the opposite side at the same relative location.
3. Sharpen a 1/4 inch by 1 foot wooden dowel rod by placing one end into a pencil sharpener. Place the dowel rod through the holes you made in the milk carton so that both ends are protruding on either side.
4. Tie 1 foot of string around the unsharpened end of the dowel rod.
5. At the loose end of the string, tie it to a small paper cup. This is most easily done by piercing the small paper cup with scissors near the top on either side, looping the string through, and closing with a knot.

Directions for Use:

1. Each group of students should have attached a pinwheel to one end of a cork before testing with this device.
2. Attach the blank end of the cork to the sharp end of the dowel by simply pushing the cork onto the sharp point until it is firmly stuck.
3. Place 2 metal washers in the paper cup.
4. Place the device 1 foot away from a box fan.
5. Turn the fan on and allow students to observe the turbine spinning and doing the work of raising the cup and washers!

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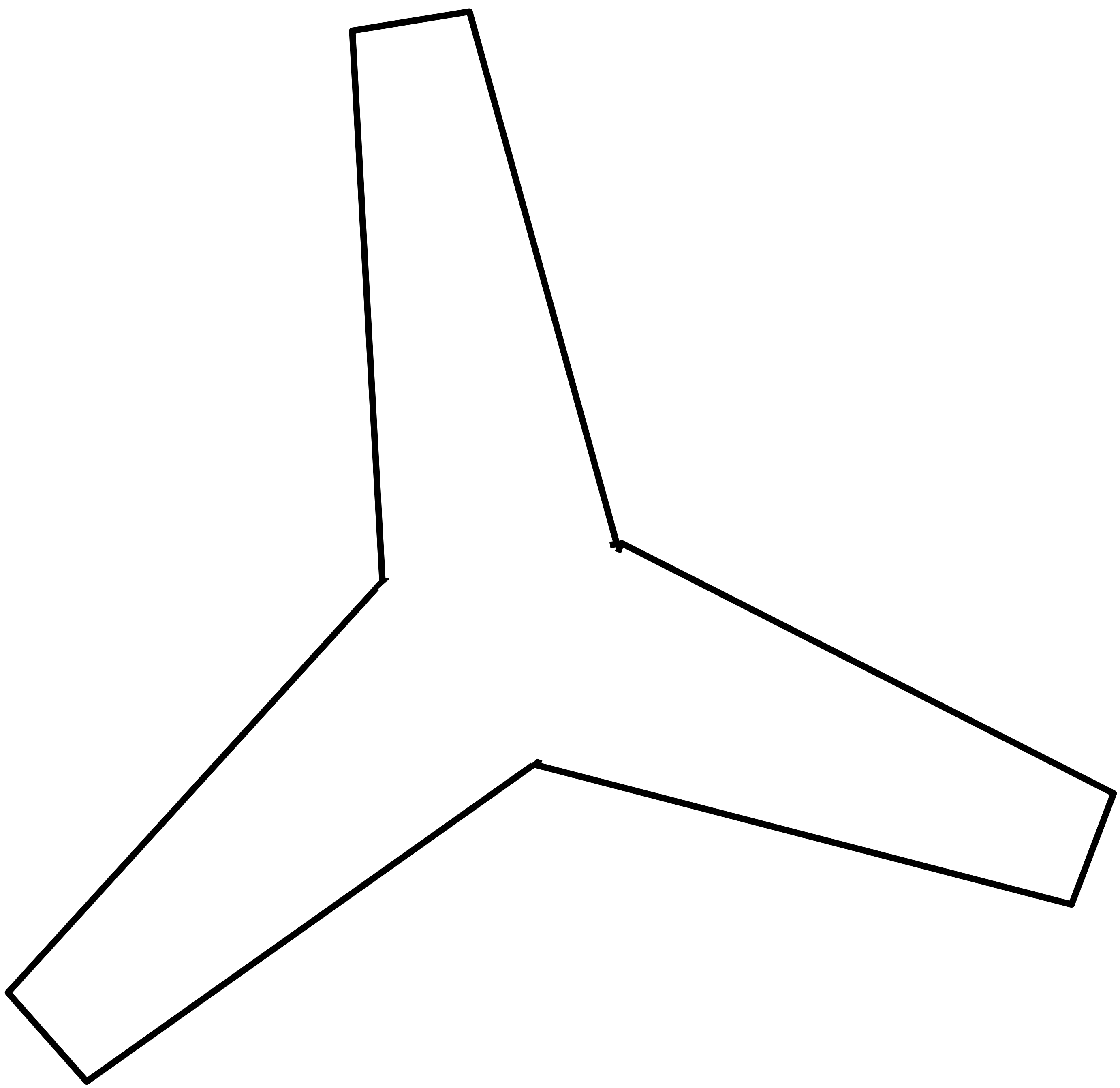

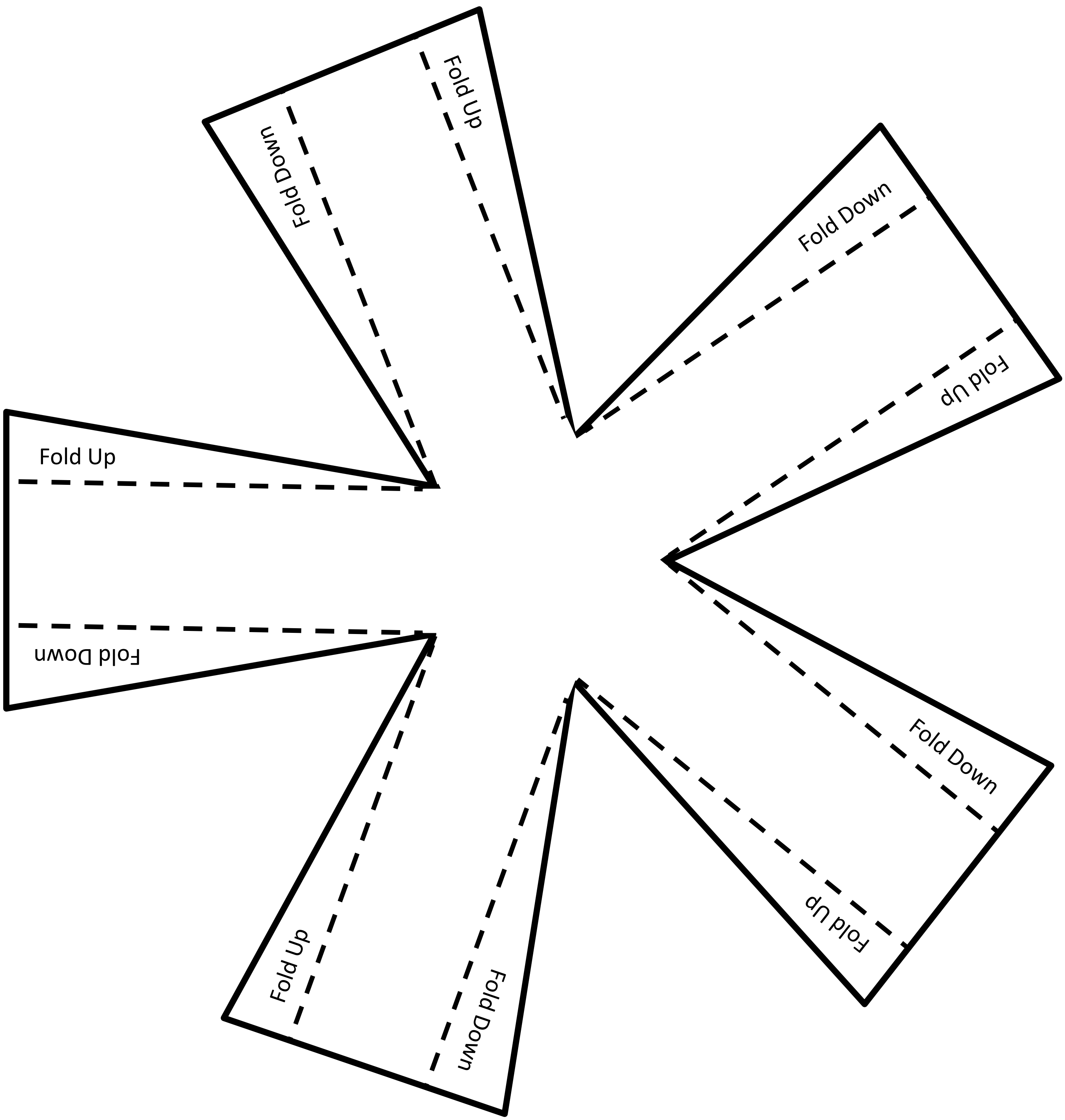
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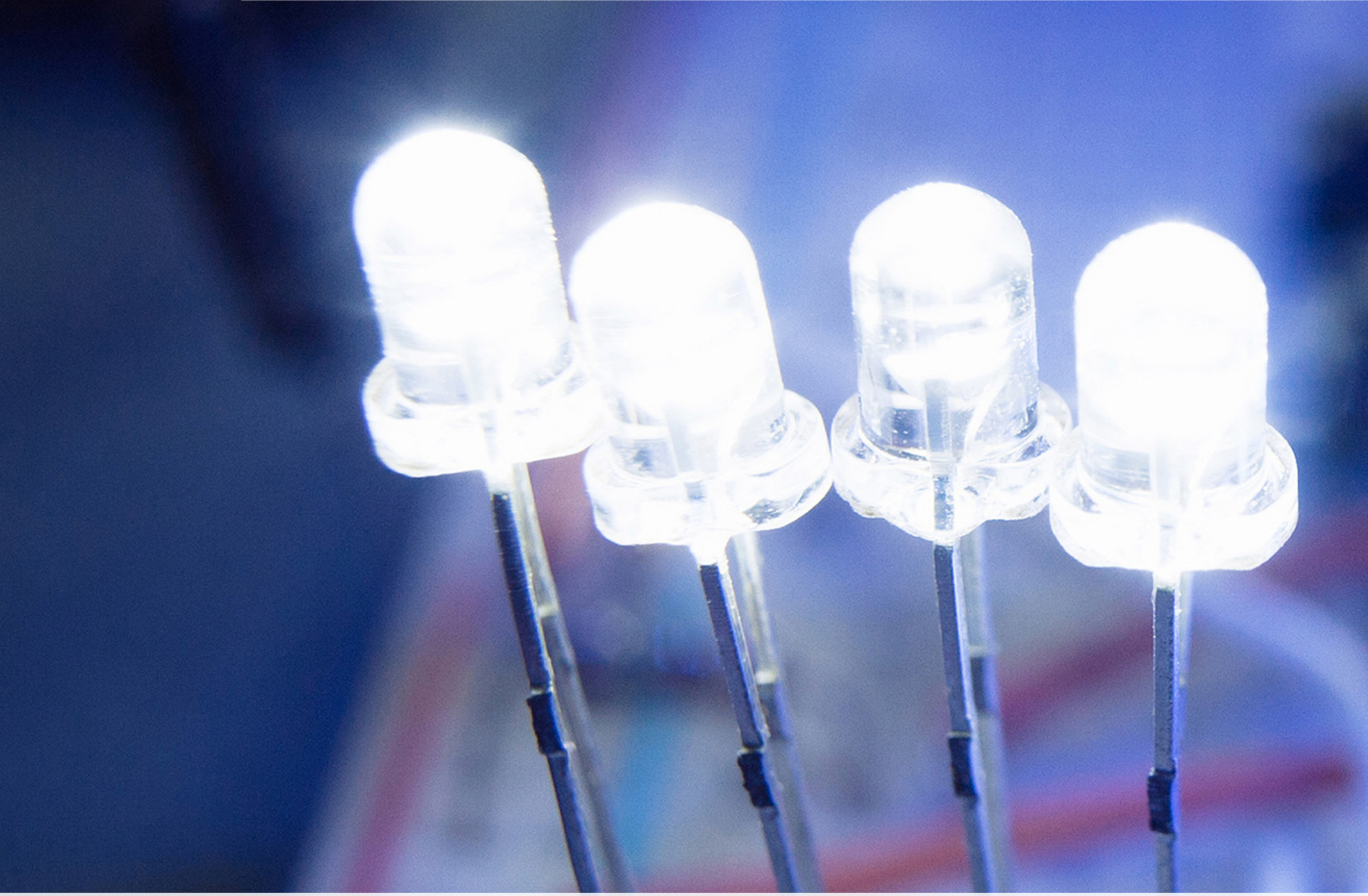
DREAM BIG VIDEO SERIES

WATCH *INCREDIBLE STRUCTURES: EXTREME ENGINEERING*

If we can dream it, we can build it. Take a tour of some amazing structures designed by engineers, like a 1,000-foot glass elevator built on a cliff in China and a fire-breathing dragon that serves as a bridge in Vietnam. Visit the engineers who work from ropes suspended high above the Colorado River near Hoover Dam. Go to discovere.org/dreambig/media-assets and visit Educational Webisodes.



MACGILLIVRAY FREEMAN'S
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GRADE 4:
CROSS-CURRICULAR SUPPLEMENT

In the *Dream Big* Wind-powered LED activity, students experiment with designing wind turbine blades that can generate enough energy to light an LED light bulb. The activity gives students a chance to find out how wind turbines can be a valuable source of alternative energy.

The general topics covered in this lesson include energy transfer, renewable energy, and alternative energy sources.

This cross-curricular supplement contains a math activity, an English language arts activity, and some additional ideas in both subject areas for exploring the topics and concepts introduced in the Wind-powered LED lesson.

Grade 4 Math: Interpreting Graphs

Estimated class time: 30 minutes

Summary

In the *Dream Big* Wind-powered LED activity, students used their observations of spinning pinwheel blades to design an improved version of a pinwheel that harnesses enough wind energy to light an LED light bulb. In this lesson, students interpret a graph that displays scientists' predictions of the impact different forms of alternative energy will have in the United States by the year 2040. Students explore answers to these questions:

- Which forms of alternative energy are expected to make more electricity than they do now?
- Why might some forms of energy be expected to generate less electricity in the future?

Learning Objectives

- Interpret data in a graph
- Explain which forms of alternative energy are likely to supply the most electricity in the future
- Demonstrate the ability to summarize information displayed in graphical form

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Materials

Per class:

- ☐ PDF of Alternative Energy Prediction Graph, projected on a screen

Per student:

- ☐ Student Math handout
- ☐ pencils

Preparation

Before displaying the graph, review how generating electricity requires converting one kind of energy into other forms that people can use. Remind students about their experiments with wind energy. See if students can summarize how wind energy is used to light an LED (the mechanical energy of wind becomes the mechanical energy of a spinning turbine, which converts to electrical energy, which in turn converts to the radiant energy in a light bulb).

Explain that we use the term **watt** to describe a unit of electrical energy—or energy that is used up in order to light a light bulb. This unit measure makes it possible to measure and compare energy from different sources. A watt is such a small amount of energy that we talk about **kilowatts** instead. A kilowatt is 1,000 watts of electrical energy, or power. A **kilowatt hour** means that in one hour, one kilowatt of energy will be used.

Tell students that in this activity, students will see which forms of alternative energy scientists think will create the most kilowatts in the future.

Instruction

1. Display the PDF of the Alternative Energy Prediction Graph. Show students the y-axis of a billion kilowatt hours. Note that it's challenging to imagine these amounts of energy! And yet we need more and more electricity all the time to serve the billions of people on the planet.
2. Point out the other features of this graph, such as the years along the x-axis and the dividing line between history and projections. Ask students to turn to a neighbor and speculate about what the terms hydroelectric, biomass, and geothermal might mean.
3. Distribute the Student Math handout and pencils. Simple definitions of the terms on the graph are provided. Hold a brief discussion of each term to make sure students understand them.
4. Give students a few minutes to answer the questions on the handout before convening as a class to discuss them and come to consensus on the best answers.

Closure

- Lead a discussion to have students share what their ideas are to explain these projections. What do they think will happen in order to create so much more wind and solar energy? What might be limiting the growth of hydroelectric, biomass, and geothermal sources of energy?
- Ask students how old they will be in the year 2040. If the projections for renewable electricity generation are correct, do they think the world will be less polluted by then? Why or why not?

Activity Extensions

- Bring in the boxes for a range of different kinds of light bulbs and distribute them to small groups. Ask students to note the number of watts of electricity the bulbs in the box generate, as well as the lumens. What do they think the difference is between a watt and a lumen? (A watt is a unit of energy, and a lumen is the degree of brightness.)
- Have small groups of students research how much of the energy in your state is generated by alternative forms of energy.
- Have students do a web search for other graphs that show predicted electricity generation for the next few decades. They will find graphs that include nonrenewable sources of energy. Have them draw further conclusions about the future of energy generation and explain those conclusions.

Other Ideas for Math

Here are a few more ways to connect the Wind-powered LED lesson with your math curriculum.

- Have each student group note the length of time that their turbine was able to keep the LED light bulb lit and create a classroom graph of the results.
- Have students watch a film clip showing a set of turbines turning, such as the one through the link below. How would they find the speed of the turbine? Allow students to use a stopwatch to time how long it takes for the turbines to turn 20 times. Then have students use that information to determine the length of one turn. How many turns would a turbine make in one full minute? Have students calculate their answer and then have them watch and count to see how close they are. (youtu.be/92BR9oGS8VQ)

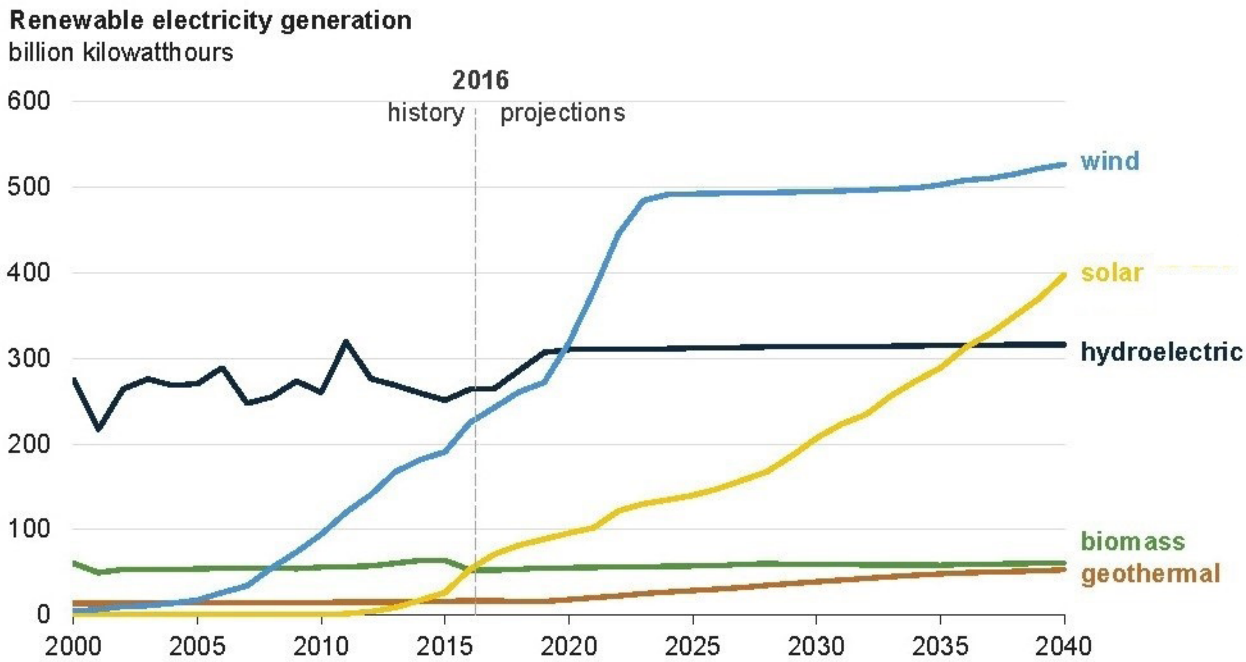
GRADE 4 MATH: STUDENT HANDOUT

Directions: Find the answers to the following questions by using the graph below.

Hydroelectric: electricity generated from water

Biomass: energy generated from wood, crops, animal material, and garbage

Geothermal: energy from heat, hot water, or steam coming from below the Earth's surface



Adapted from the U.S. Energy Information Administration eia.gov/aeo

1. Which source had the greatest generation in 2000?

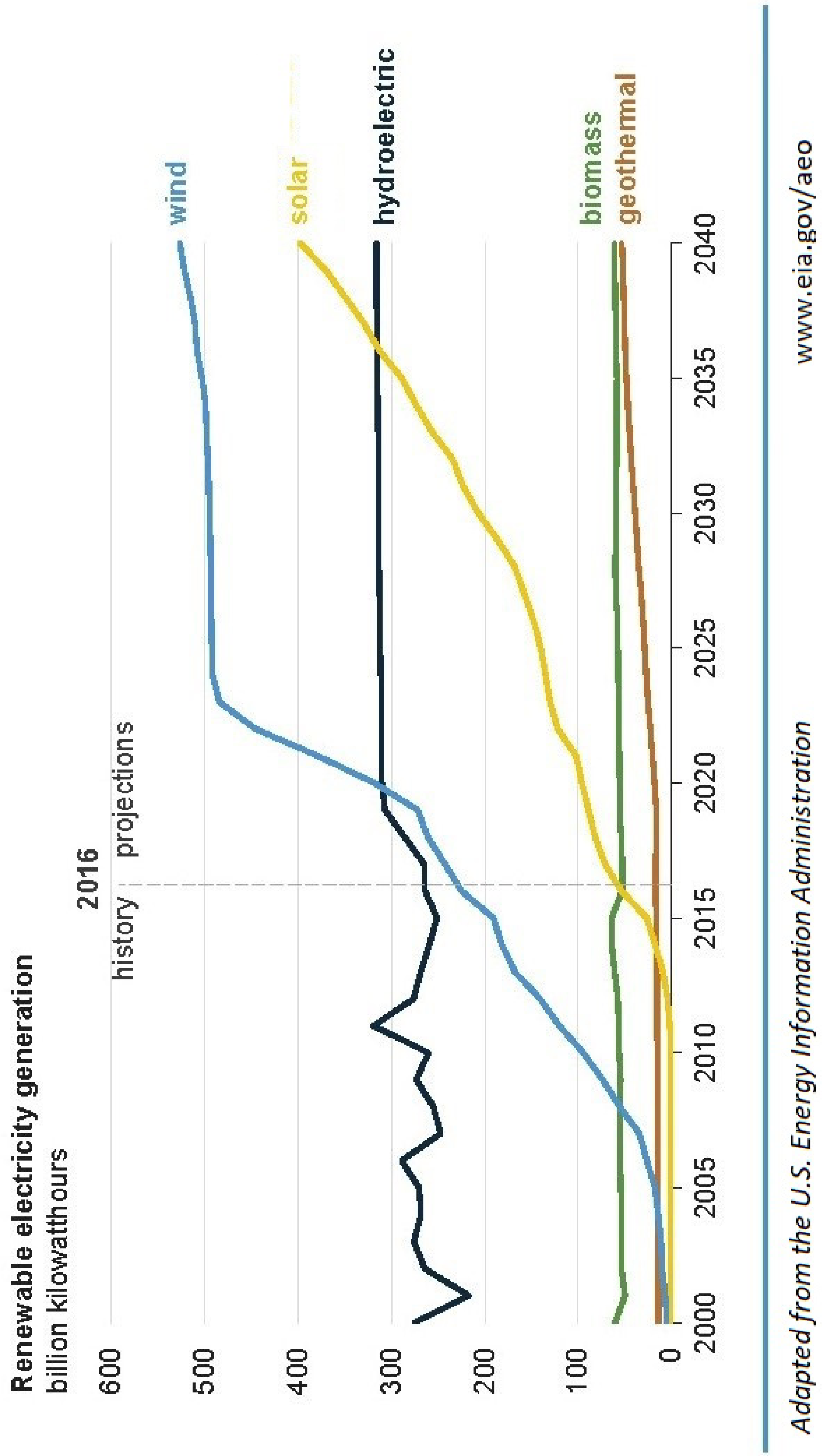
2. Which source had the greatest increase from 2000 to 2016?

3. Which source is expected to grow the most from 2016 to 2025?

4. Which source is expected to grow the most from 2025 to 2040?

5. Which sources have little growth or little expected growth?

Graph for projecting on a screen



Grade 4 English Language Arts: Alternative Energy Research

Estimated class time: 90 minutes

Materials

Per group:

- ☐ Grade-appropriate research materials (books, magazines, websites, printouts) on renewable energy: wind, hydroelectric, solar, geothermal, or tidal. See sources to get started with.*
- ☐ Poster-making supplies: poster board, art materials

Per student:

- ☐ Student Research handout
- ☐ Pencil

*Sources to get started with:

National Geographic, Renewables Roundup (video) nationalgeographic.org/media/renewables-roundup

Energy Kids, U.S. Energy Information Administration eia.gov/kids/energy.cfm?page=renewable_home-basics

Union of Concerned Scientists, Renewable Energy: ucsusa.org/clean-energy/renewable-energy#.Wuo4YaIrLSc

National Geographic, Tidal Energy nationalgeographic.org/encyclopedia/tidal-energy/

National Geographic, Wind Energy (video) nationalgeographic.org/media/yes-in-my-backyard

Ted Ed, short video describing the problems to be solved with solar energy youtube.com/watch?v=RnvCbquYeIM

Burlington Vermont runs entirely on different sources of renewable energy youtube.com/watch?v=zKhzVcHrWH4

Summary

In the *Dream Big* Wind-powered LED activity, students used their observations of spinning pinwheel blades to design an improved version of a pinwheel that harnesses enough wind energy to light an LED light bulb. This activity widens the scope of students' investigations into renewable energy sources as they work with a small group to compile information and create a poster of their findings. Students think about these questions:

- Which kinds of alternative energy work best for different places in the United States?
- How does this renewable source of energy work?
- What problems do engineers face as they make this alternative energy available?

Learning Objectives

- Summarize information about a type of alternative energy
- Integrate information from different sources in order to write knowledgeably about a type of alternative energy
- Decide how best to present information about a type of alternative energy in a poster format

Preparation

Generate a list of types of alternative energy as students call them out. The list should include wind, water (hydroelectric), solar, geothermal, tidal, and biomass. Ask volunteers to explain something about each type and fill in any major gaps in understanding.

Tell students that they are about to learn more about one of these types of energy, and their task is to present what they have learned in a poster so that they can share information with their classmates.

Instruction

1. Organize students into groups of three or four students, ideally according to the type of energy they are most interested in learning about. Distribute the Student Research Handout and discuss how to fill it in.
2. Show students where the research materials are located. Suggest that each member of the group find information from one source, either a book, magazine, printout, or website. Instruct them to take notes from this source by filling in their research handout. Remind them to look for interesting visuals as well as text that will make their poster both informative and interesting.
3. Once students have gathered information independently, tell them to share what they found with their group. Students can pick at least one piece of information from each of their research to include in their poster by circling it on their handouts.
4. Instruct students to make a rough draft of their poster on a separate sheet of paper. At this point they can pick visuals and decide how to organize their information. Artists should start making artwork.
5. Distribute poster board to each group and check in with groups. Show the class where the art materials are.
6. Ask each group to present their poster to the class. Then choose a place to display them.

Closure

Ask students to spend a few minutes reflecting on what they learned in this activity. Tell them to write a paragraph in which they answer one or more of these questions:

- One thing I learned about renewable energy from our project is...
- One thing I learned about renewable energy from a different group's project is...
- I think the hardest part about getting people to use more renewable energy is...

Activity Extensions

- Assemble materials about how your community is making use of renewable energy.
- Ask an engineer to come to class and talk about the successes and challenges of renewable energy in your area.
- Complete relevant activities from the Discover Engineering website at discovere.org/our-activities. Activities include creating a working water mill, designing a folding solar panel, and designing a solar water heater.

Book Connections for English Language Arts

The following books relate to the Wind-powered LED activity. They can be incorporated in your ELA curriculum or used as a warmup for the activity provided in this supplement.

Drummond, Allan, *Energy Island: How One Community Harnessed the Wind and Changed Their World*, Square Fish, 2015. This is the true story of how the residents of a Danish island have used wind power to become energy independent.

Kamkwamba, William, *The Boy Who Harnessed the Wind*, Young Reader's Edition, Puffin Books, reprinted 2016. This true story describes how the 14-year-old author made a windmill with nothing but machine parts and metal scraps to bring electricity and water to his small, destitute African village.

Caduto, Michael, *Catch the Wind, Harness the Sun: 22 Super-Charged Projects for Kids*, Storey Publishing, 2011. The award-winning author has compiled projects with step-by-step instructions that have students learning about, making, and using renewable energy.

GRADE 4 STUDENT RESEARCH HANDOUT

Name:

The kind of renewable energy I am researching:

The book, website, magazine, or handout where I found my information:

Information that we could put on our poster:

1.

2.

3.

Descriptions of pictures that would be helpful to include on our poster: