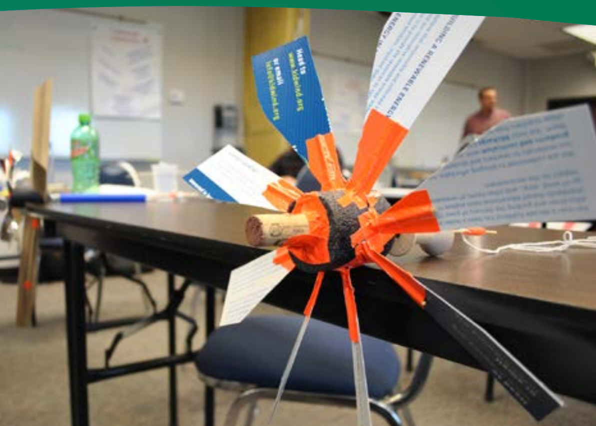
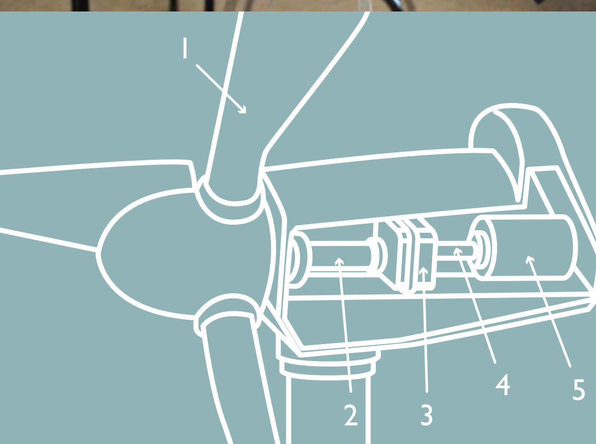
WindWise Education

Wind Energy Activities for Students





Grades 6–12

3rd Edition

KidWind PROJECT®

www.KidWind.org

WindWise Education Curriculum

From the KidWind Project & Normandeau Associates

■

Third Edition

■

Saint Paul Gainesville

WindWise Education Curriculum

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Contents

Forward

WindWise Education is a comprehensive curriculum that explores the dynamic field of wind energy. WindWise Education gives teachers the tools to teach 6th–12th grade students about this timely and critical energy resource. It is an advanced, interdisciplinary wind energy curriculum that can be incorporated into a wide range of subjects. The lessons use scientific data and real-world scenarios to help students learn to think critically so they can make informed decisions about wind energy in the future.

As interest in green, renewable energy has increased, the demand for and investment in wind energy has risen. At the end of 2013 China had the most installed generating capacity of wind power (91,142MW), with the United States in second and the European Union third. Yet despite having fewer turbines, the United States generated the most energy from wind (167 billion kWh) in 2013. This is enough energy to power close to 15 million US homes for an entire year. As wind energy becomes more widespread, many communities are learning about wind energy for the first time in their own backyards. WindWise Education provides students with the opportunity to ask key questions such as: Where are the best locations for wind farms? How is wildlife impacted by wind turbines? And how can I build a better turbine? Through hands-on lessons, students learn and discuss the role that wind energy plays in their communities and the country.

Each lesson includes an inquiry-based introduction to encourage creative thinking and a hands-on activity to develop analytical skills. WindWise Education features case studies and profiles of professionals are featured to provide students with real-world examples from the wind energy sector. Through these lessons, students become engaged in thoughtful, real-world dialogue about the future of wind energy.

The core curriculum includes 19 lessons with three appendices, each framed around a key question related to wind energy. The curriculum package includes:

- Inquiry-based approach to encourage critical thinking skills
- Standards-based lessons for middle and high school students in areas of physics, biology, technology, earth science, environmental science, math, geography, language arts, economics, and social studies
- Data and maps
- Case studies
- Profiles of professionals
- Reading passages
- Answer worksheets for teachers
- Assessment tools that measure comprehension for each activity

Each lesson is laid out in an easy-to-use format, including pages for teachers (in color) and students (in black and white). Teacher pages provide background information, lists of materials, standards, assessment questions, and tips. Student pages include reading passages, case studies, professional profiles, and worksheets.

Support & Materials

A wide variety of support materials for each lesson are available on the KidWind website. These include:

- Powerpoints you can use in the classroom
- Links to reading materials, citations and videos
- Websites where you can purchase materials to complete the lessons

Head to http://learn.kidwind.org/windwise to access these support materials.

Teacher Training

WindWise Education is most effective when it is paired with teacher training. Expert instructors from KidWind can provide provide one-day hands-on trainings about the WindWise curriculum nationwide.

Workshop participants get to:

- explore the basic principles behind wind energy
- learn how to implement WindWise lessons with students
- experience WindWise through interactive activities

For more information on wind energy workshops contact the KidWind Project.

KidWind Project
www.KidWind.org
877-917-0079

Lesson	Lesson Title	Grade	Subject	Key Concept
Unit 1: Energy Creation and Choices				
1	Understanding Forms and Sources of Energy	6–8 9–12	Environmental Science Physical Science	Students learn the difference between forms and sources of energy and that energy is useful to us because of its ability to change form.
2	Understanding Electric Power Generation	6–8 9–12	Environmental Science Physical Science Technology	Students learn about the environmental, economic, and social trade-offs of electrical power generation technologies.
3	What Is the Cost of Inefficiency?	6–8 9–12	Environmental Science Physical Science Technology	Students learn about work, energy, and power and that using electrical appliances and devices has economic and environmental costs.
Unit 2: Where is the Wind and How Does it Work?				
4	What Causes Wind?	6–8	Physical Science Social Studies Earth Science	Students learn about the forces that cause wind and the ways in which these forces are measured.
5	Where Is It Windy?	6–8 9–12	Earth Science Social Studies	Students learn how topography and elevation affect wind speeds, and identify optimal locations for wind farms based on wind speed.
6	What Are Wind Shear and Turbulence?	6–8 9–12	Mathematics Earth Science	This activity helps students understand the concepts of wind turbulence and wind shear—or the smoothness and speed of the wind at different altitudes above the ground.
7	Can Wind Power Your Classroom?	6–8 9–12	Physical Science Technology/ Engineering Mathematics	Students conduct a simple energy audit for the classroom and estimate what size wind turbine could power their classroom under local wind conditions.
Appendix: Collecting Wind Speed Data at Your School		9–12		

Lesson	Lesson Title	Grade	Subject	Key Concept
Unit 3: Experiments With Turbines				
8	How Does a Windmill Work?	6–8 9–12	Physical Science Technology/ Engineering	Students learn the fundamental parts of a windmill, how different rotor designs affect performance, and how energy is transferred from wind into usable mechanical energy.
9	How Does a Generator Work?	6–8 9–12	Technology/ Engineering Physical Science	Students learn how electricity is generated and how design variables affect electricity production.
10	Which Blades Are Best?	6–8 9–12	Physics Technology/ Engineering Mathematics	Students learn through experimentation how different blade designs are more efficient at harnessing the energy of the wind.
11	How Can I Design Better Blades?	6–8 9–12	Physical Science Technology/ Engineering Mathematics	Students learn how to design and construct different turbine blades to maximize the power output of a wind turbine.
Appendix: Advanced Wind Turbine Blade Design and Airfoils		6–8 9–12		
Appendix: Using WindWise to prepare for a KidWind Challenge		6–8 9–12		
Unit 4: Wind Energy and Wildlife				
12	How Does Energy Affect Wildlife	9–12	Living Environments Earth Science Environmental Science	Students learn that different electricity generation sources have very different effects and risks to wildlife.
13	What Is Wind Power's Risk to Birds?	6–8 9–12	Technology Mathematics Living Environments	Students learn how bird behavior and ecology are related to avian impacts from wind turbines and how scientists study these impacts.
14	Can We Reduce Risk to Bats?	6–8 9–12	Living Environments Technology	Students analyze bat behaviors and propose a wind farm operational plan that could reduce the risk of bat mortality.
15	Are Birds Impacted by Small Wind Turbines?	6–8 9–12	Science Living Environments Technology	Students will conduct field studies to learn how biologists study wind turbine impacts on birds. Data collected will be shared as part of a citizen science project.
Unit 5: Siting Wind Energy Facilities				
16	How do People Feel About Wind Energy?	6–8 9–12	Language Arts Social Studies	Students explore what effects media can have on people's perception of wind energy.
17	What Locations Are Best for Offshore Wind?	6–8 9–12	Mathematics Physical Science	Students explore offshore wind development—comparing maps illustrating different siting considerations and using scale models to understand the visual impact of an offshore wind farm.
18	Where Do You Put a Wind Farm?	6–8 9–12	Social Studies Environmental Studies Earth Science Mathematics	Students learn how to analyze data (maps, tables, and written information) to compare and contrast two potential sites for a wind farm.
19	When Is a Wind Farm a Good Investment?	6–8 9–12	Economics Social Studies Earth Science Mathematics	Students learn what factors impact the economics of a wind farm and compare and contrast two potential sites.

ACKNOWLEDGMENTS

KidWind and Normandeau have been dreaming up ideas for a more advanced wind energy education program for a couple of years. We felt there was a need for a comprehensive curriculum that touched on all aspects of wind—from science and technology to economics and biology. Our companies met at a wind conference in 2008 and quickly realized we were the perfect match. KidWind is the original wind energy K–12 education and turbine kit company. Normandeau Associates designs curriculum and teacher training programs, in addition to conducting wildlife studies for wind energy. It was meant to be.

We were thrilled when the New York Energy Research and Development Authority (NYSERDA) gave us the opportunity to design WindWise Education for New York State teachers. Thanks to NYSERDA, we have put our ideas into action and created an innovative curriculum along with supporting materials such as a Website and other teaching tools. We are truly grateful for NYSERDA's support.

In early 2009 we launched WindWise with an online survey about wind energy education. More than 400 educators told us what they did and did not want in a curriculum. They also gave us good ideas on how we could make this curriculum as useful as possible. We have drawn from the expertise of a fantastic team of teachers and wind energy professionals we call the CAB (Curriculum Advisory Board). The CAB has tested these activities and given us their guidance throughout the development of WindWise. We are hugely grateful for their assistance and input.

The 2nd and 3rd edition of WindWise add several new lessons, improves and updates original lessons, and nationalizes the lessons for the entire US.

Thank you for taking the time to explore the curriculum. We hope you enjoy using it in your classroom. If you have feedback, ideas, suggestions, or just want to talk more about wind, feel free to contact us. We always enjoy hearing from you.

—KidWind and Normandeau WindWise Education Team

WindWise is a production of KidWind Project and Normandeau Associates

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For more information on the program, visit our website:
www.KidWind.org

You are also welcome to contact us

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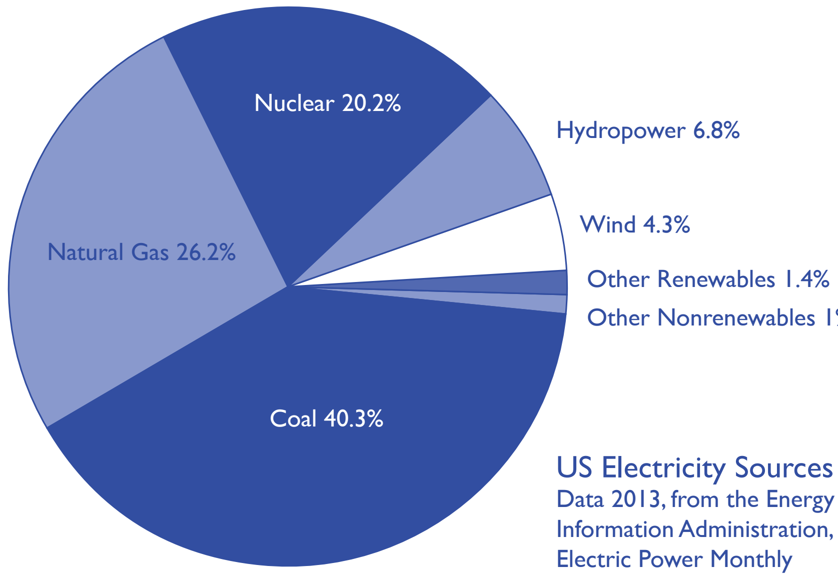
Introduction

WHY WIND?

We tend to take for granted where our electricity comes from. We expect that when we flick the switch, the lights will come on. Behind that switch are billions of dollars of investment and thousands of people making sure that it is just as simple as that—flicking the switch.

Between 2009 and 2013, wind power comprised 31 percent of all new energy installations in the US (AWEA). As investors and power producers look to build new power infrastructure, they are looking to build wind farms at an increasing rate.



US Electricity Sources
Data 2013, from the Energy Information Administration, Electric Power Monthly

Of our current generation mix, over 4 percent of our energy is generated by the wind.

The US wind industry now totals 62,300 megawatts (MW = 1,000,000 watts) of cumulative wind capacity through the end of the third quarter of 2014. Some industry leaders believe that by the year 2030 we will get 15–20 percent of our energy from the wind. Reaching this goal will take great effort and lots of scientists, engineers, and technicians.

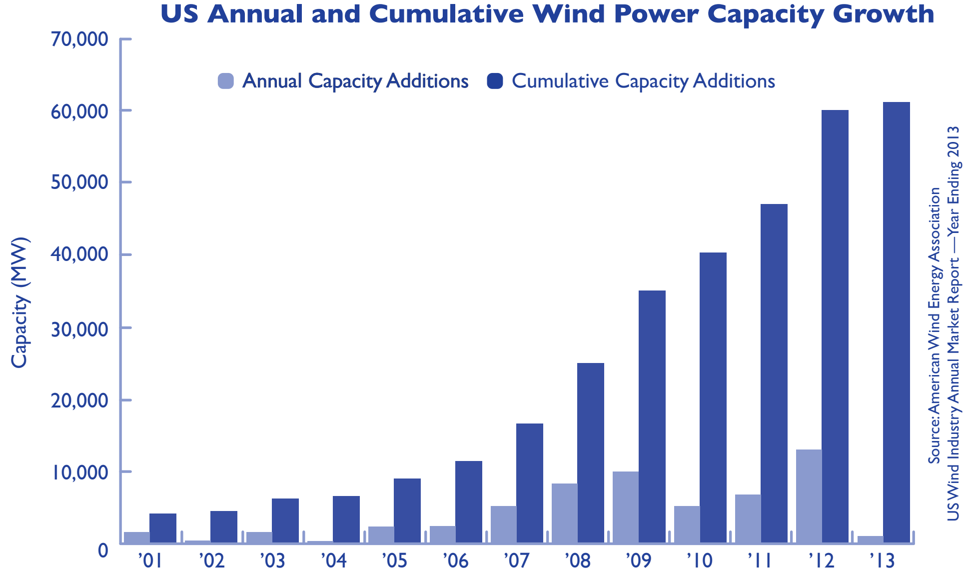
Why are we seeing more wind?

Per capita average consumption of electricity in 2013 was approximately 12,000 kWh. This is seven times higher than in 1949. Predictions are that US consumption will increase 1–2% a year for the next 20 years due to population and consumption changes (Department of Energy).

In many states, there is a drive to meet this increasing consumption by reducing overall demand (efficiency and conservation) and by generating electricity using cleaner technologies like wind, solar, and biomass.

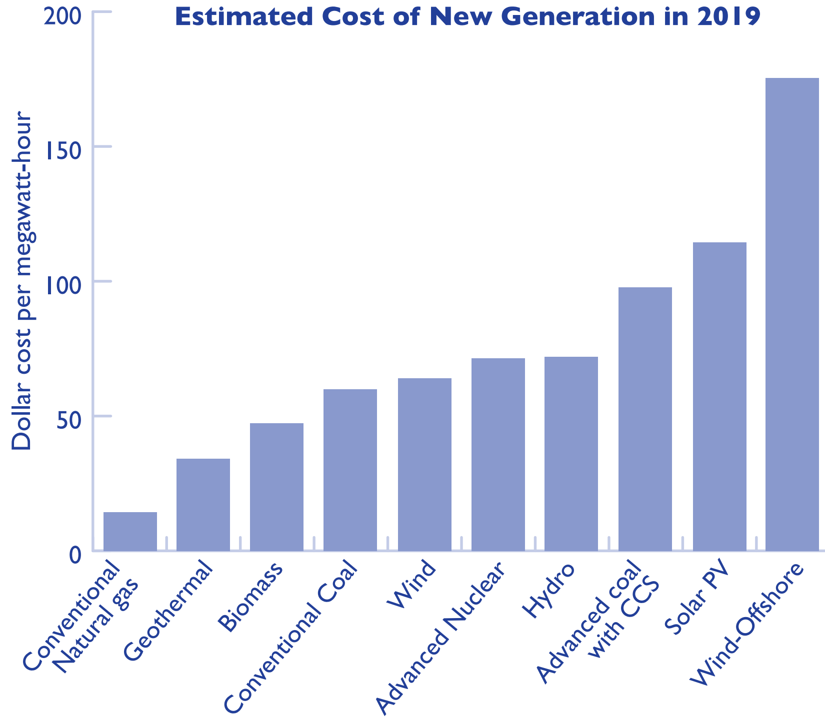
Why this push for renewable sources of electricity? States and local governments are reacting to public pressure to reduce negative environmental impacts to air, water, and wildlife from coal, nuclear, and large hydropower generation. Based on data from the Intergovernmental Panel on Climate Change (IPCC), many state and regional governments are convinced that they need to significantly reduce the amount of carbon that is being pumped into the atmosphere. If they do not make radical changes, they

US Annual and Cumulative Wind Power Capacity Growth



feel that their constituents will be adversely impacted by climatic change.

To convince power producers to build renewable energy facilities, over 30 states have enacted Renewable Portfolio Standard (RPS) legislation. These laws mandate that a specific percentage of electricity must come from renewable resources by a specific date. For example, in New York, the RPS mandates that 29 percent must come from renewable sources by 2015. These mandates are creating a huge market for renewable clean energy in the states where they have been enacted. Currently there is no national level RPS legislation, but there is a push to make that a reality.



Data: US EIA, *Levelized Cost of New Generation Resources in the Annual Energy Outlook 2014*

Decreasing wind energy costs

As investors seek to build new renewable energy infrastructure, they look for the cheapest option. As of right now the cheapest, most mature utility scale option is wind energy. As you can see from the graph, in 2014 wind energy is one of the most affordable renewable energy options with a low carbon footprint.

The reduction in the cost of wind energy production is significant and has been realized through investment advances in wind energy technology. Investment returns in large wind farms have also been helped by significant government financial incentives to help offset the high initial capital cost of a wind farms.

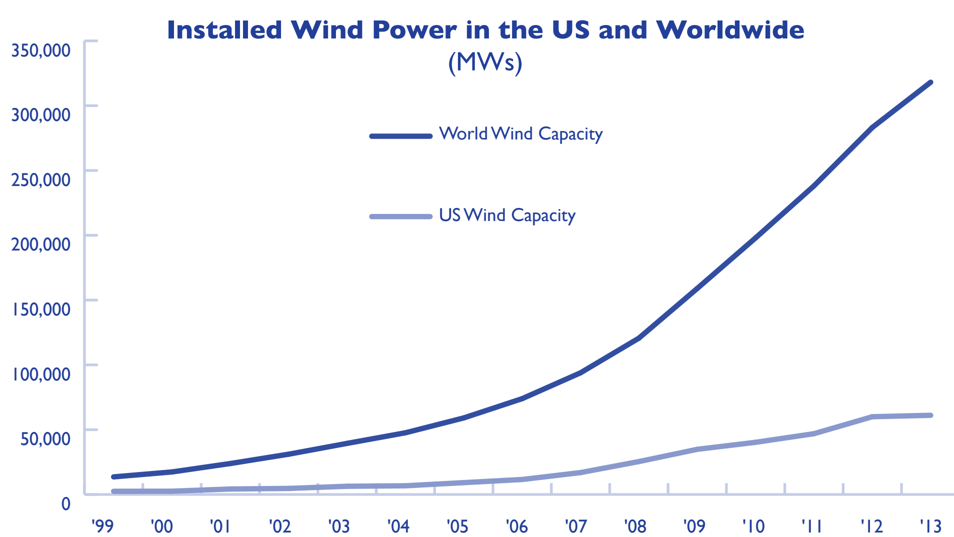
Wind energy is not free; a large wind farm may cost $200 million to build, but the fuel is free. In a world where fuel prices have only one direction to go, wind is pretty interesting to investors and consumers.

Over the next 5–10 years, we are going to see many more wind turbines on the landscape. How dramatically this impacts the reliability and cost of electricity will depend on a variety of factors. The next few sections will help you understand the promise and challenges that face wind energy today.

Wind in the US and worldwide

Wind power has seen rapid growth over the past 20 years. In 1990, wind energy had the capacity to produce 1,930 MW worldwide. About 76% of this installed capacity was located in the United States (1,484 MW). The vast majority of these wind turbines were located in California. By the beginning of 2014, installed wind capacity world wide had increased to 318,105 MW or 318 GigaWatts. (A gigawatt is 1,000,000,000 watts.)

In addition to the US, other countries at the forefront of wind energy installations include: China, Germany, UK, Brazil and India. At certain times of the day, Denmark can get more than 50% of its electrical energy from wind power.



Data: GWEC, US DOE WindExchange

For many years, Europe led the development of wind farms and manufacturing of wind turbine components. More recently, the wind industry has spread globally, especially to China. Many of the top 10 wind turbine manufacturers are still based in Europe: Vestas (Denmark), Enercon (Germany), Gamesa (Spain), GE Energy (United States), Siemens (Denmark/Germany), Suzlon (India), Nordex (Germany), Acciona (Spain), Repower (Germany), and Goldwind (China). Of these ten manufacturers, seven have now opened manufacturing facilities in the US.

Today there are hundreds of companies producing components for wind turbines: gearboxes, turbine blades, braking systems, bearings, towers, and more. These companies are based all over the world. It has been estimated that the global wind industry employs approximately 834,000 workers today.

Turbines are also getting much larger and more efficient. The average turbine in 1990 stood only 54 meters tall and produced a maximum of 500 kilowatt (kW, 1000 watts). In 2014 most new turbines stand 100 meters tall and produce 2 MW of power at rated speed. The largest turbines produced in 2014 can produce 8MW. These turbines are designed for offshore applications.

HARNESSING WIND POWER

Basic concepts of wind power
Windmills have been used for centuries to pump water or to move heavy rocks to grind seeds into grain. A wind turbine is the modern advancement of the windmill, instead using the wind to turn an electrical generator.

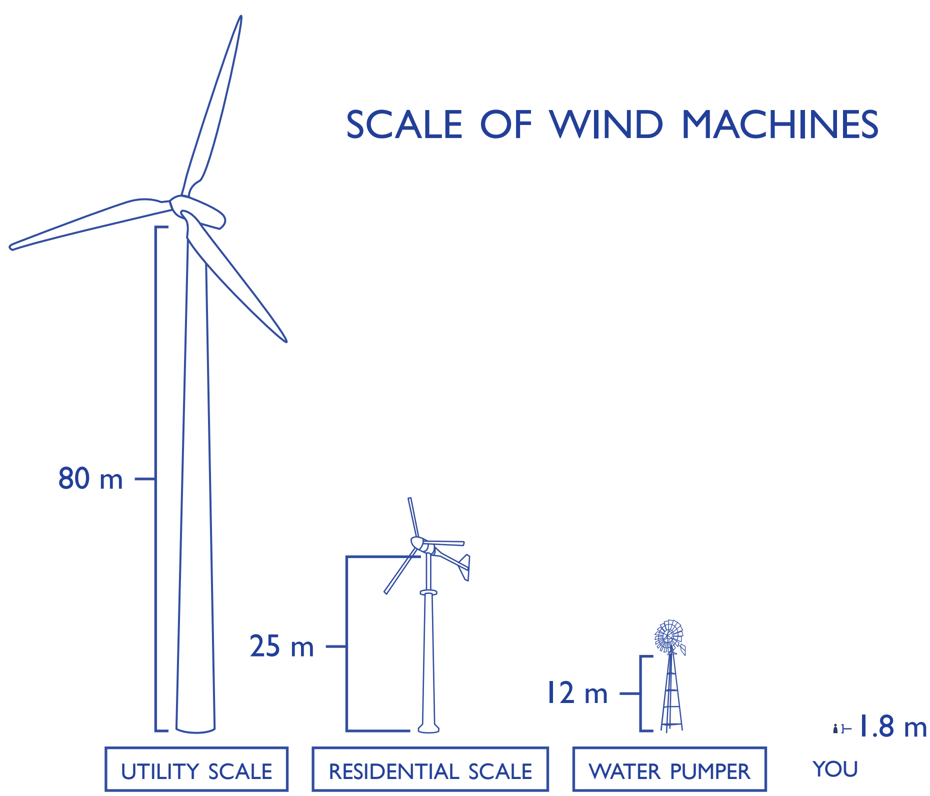
The force of the wind on the blades causes them to move. As the rotor turns, it spins a driveshaft which is connected to a generator. The spinning generator converts mechanical (rotational) energy into the electrical energy we use every day. Large wind turbines often have a gearbox between the rotor and the generator so that the generator can spin much faster than the blades are spinning. (See the large wind turbine image on page page 16).

The amount of electricity a wind turbine is able to produce depends on several variables: wind speed, the diameter (size) of the rotor, the density of the air, and the efficiency of the turbine. Wind speed, or velocity, dramatically affects how much power is available in the wind. As wind speed doubles, the power available in that wind is multiplied eight times!

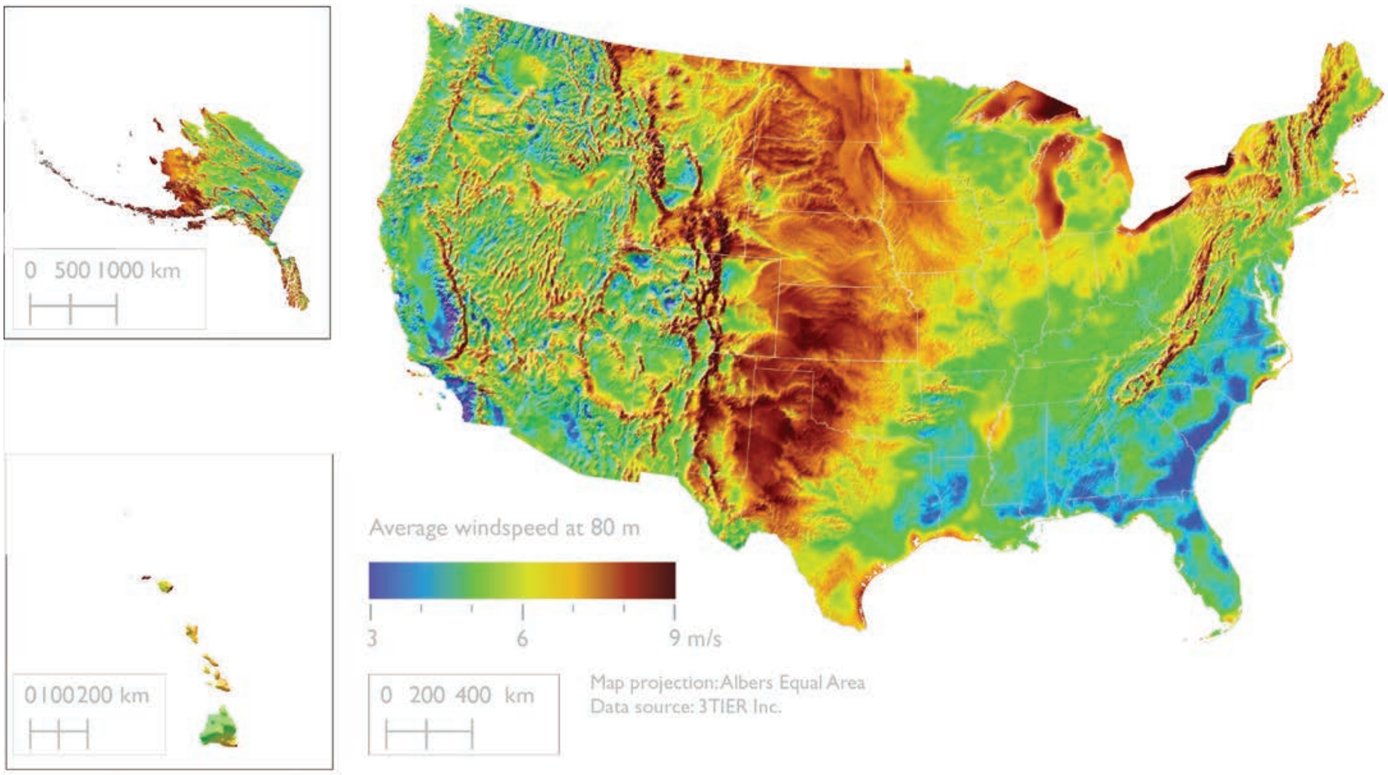
Large wind turbines are often built in clusters called wind farms. A wind farm may have just a few turbines or several hundred. Wind farms act just like other power plants—feeding electricity directly into the power grid.

Small vs. large wind turbines
Wind turbines come in all shapes and sizes. The smallest wind turbines produced have a rotor diameter of 1 meter and only produce enough power to charge a few 12 volt batteries—or about 100 watts. A wind turbine that could power your whole house is still considered "small." This wind turbine might have a rotor diameter of 7 meters and could produce 10 kW (10,000 watts).

A typical "large" or utility scale wind turbine has a rotor diameter of 100 meters and stands on a tower 100 meters tall. This wind turbine could produce 2 MW (2,000,000 watts)—enough electricity for about 400 American homes. Utility-scale turbines are getting bigger and bigger. The largest turbine produced in 2014 can produce 8MW of power and has a rotor diameter of 160 meters.



US WIND RESOURCE



Where Are Wind Farms?

Since wind velocity greatly affects the power in the wind, it makes sense to build wind farms in places that are very windy. Look at the wind speed map of the United States. Where would you put a wind farm? The windiest places in the US are the Great Plains (the “wind belt”), mountainous areas, and coastal areas. Currently, the majority of wind turbines installed in the US are in the Great Plains, from Texas to North Dakota.

In Europe, many wind farms have been built out in the sea—miles from land. Consistent, fast, and smooth offshore wind means that these wind farms can make a lot of power. It is safe to assume that there will be many offshore wind farms built around the US in coming years.

WIND ENERGY CHALLENGES

Humans have harnessed wind power for thousands of years using windmills, sailboats, and other mechanisms. The current versions of residential—and utility—sized turbines are young, with designs less than 20 years old. How long have we been burning coal or other fuels—thousands of years? Will there be problems? Yes, but with continued investment wind turbine technology is going to become more efficient, longer lasting, and more economical. The question is will we make those investments and have some patience?

Technological Hurdles

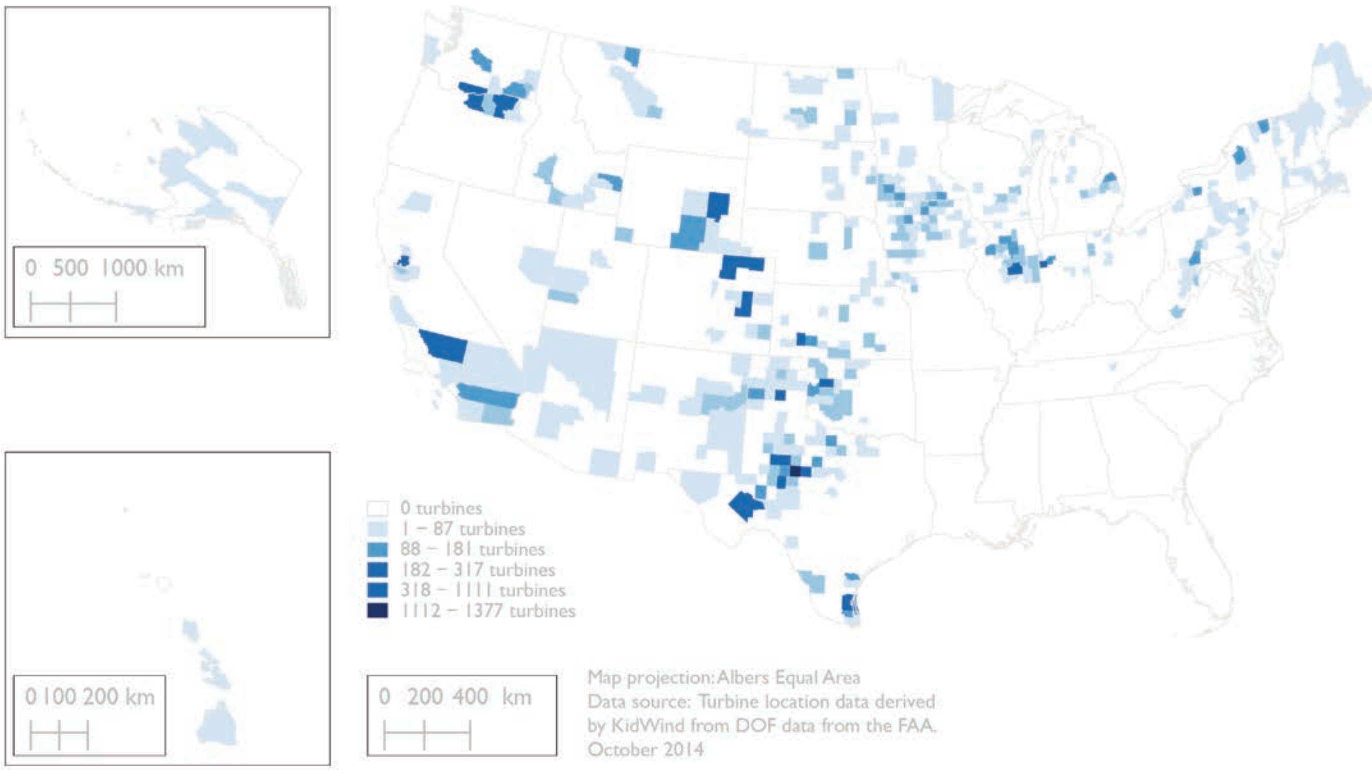
The industry continues to learn how to make wind turbines larger, cheaper, longer lasting, and more reliably connected to the grid. This process is accelerating as the market grows and more companies try to make money in a rapidly growing industry.

Major research is currently taking place on improving, or removing gearboxes from large turbines, squeezing more electricity from generators, enhancing blade performance, and programming control systems that automate wind turbine response and performance.

Variable Production

One major complaint is that wind energy is not reliable since we cannot predict when the wind will blow. This is not exactly true: there is a huge amount of research taking place to more accurately predict when the wind will blow, how fast it will blow, and for how long. The better the wind industry gets at predicting the wind resource, the more like

NUMBER OF TURBINES PER COUNTY



other power plants wind farms will become; it is all about prediction. As they say in the industry "the wind is always blowing somewhere." We just need to quantify and predict.

Do we need resources when the wind does not blow? Yes. Do we need a 100 percent backup for wind farms? No! Some studies have shown that the amount of reserve power to cover variable wind production could be in the 8–10 percent range; others put it higher at 20–40 percent. The actual ratio depends heavily on proximity of wind generation to load, other generators on the system, overall system load (both forecasted and real time), planned outages of generators and transmission lines, and other reliability criteria.

Currently we do not store wind energy; as it is produced it goes right onto the grid. This may change in the future; storage options are being explored in compressed air, pumped water, and hydrogen technology systems.

Transmission

Some consider transmission to be the single biggest hurdle facing wind energy development. Moving wind-generated power from rural locations to urban centers is going to require a great deal of infrastructure. This will be costly and not without controversy; people do not like high voltage power lines in their neighborhood. Some claim we should distribute the turbines more evenly and generate power closer to the cities and urban locales. The problem with this is that often the wind resource is not as good in those locations and some of the economies of scale of having a large farm are lost.

Cost is a huge issue. Who pays the billions in upgrade costs to get the power where it needs to go? Is it a cost that is shared by everyone who uses the grid? Is it a cost that generators will pay? Is it a cost that companies that own transmission will pay? These questions are still being played out.

Offshore wind power is very promising as 48 percent of our population lives within 50 miles of the ocean. The concept would be to build large wind farms in the ocean or the Great Lakes and run cables many miles back to shore. In 2010, Cape Wind received approval to build the first offshore wind farm in the US.

Ecological Factors

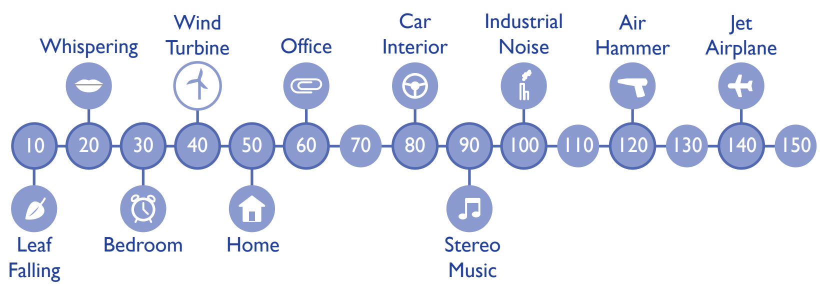
Compared to other energy-generation sources, wind energy has very low impacts on the environment and on wildlife. A wind farm requires many studies before construction begins to determine whether ecosystems or wildlife will be impacted during construction and operation. These studies look at the location and type of natural areas at the site, the wildlife species present, the potential placement of turbines, the placement of power lines, and the location of maintenance roads and structures. Wind energy has a small physical "footprint," meaning that the space the turbines, roads, and buildings take up is small. Wind farm infrastructure generally takes up only about 2–5 percent of a wind farm's land. Wind farm developers must consider the potential impacts to wildlife, especially birds and bats, when they are deciding where to place their turbines.

Birds and bats can be impacted by wind turbines in three main ways: they can be killed by the blades when they are flying, they can be displaced from their normal habitat by the presence of the turbines, and their habitat can be impacted by the construction of turbines and wind farm infrastructure. Although birds do collide with turbines, turbine collisions are a very small risk to birds in general and are only a minor contributor (less than 1 percent) to human-caused bird fatalities nationwide. Nevertheless, bird impacts from turbines are continually monitored and studied by scientists and regulators. Bats have recently become a major concern for developers and scientists. Bats can be killed by collisions with turbines or by "barotrauma" when they suffer a sudden drop in pressure if they fly too close to a spinning turbine blade. There is uncertainty about the amount of impact turbines have on bat populations. Scientists, developers, and regulators are working together to learn more about and minimize the impact that wind farms have on bats.

Sound

There have been complaints about adverse impacts related to the sound that turbines produce. A number of individuals living near wind farms have made the claim that their health has been negatively impacted by the sound and infrasound produced by turbines. The industry has produced studies that declare this is not supported by medical fact. Nevertheless this problem will definitely be explored more deeply in the next few years to determine appropriate setbacks for wind turbines from peoples' homes and businesses.

Wind Power and Sound (Decibels)



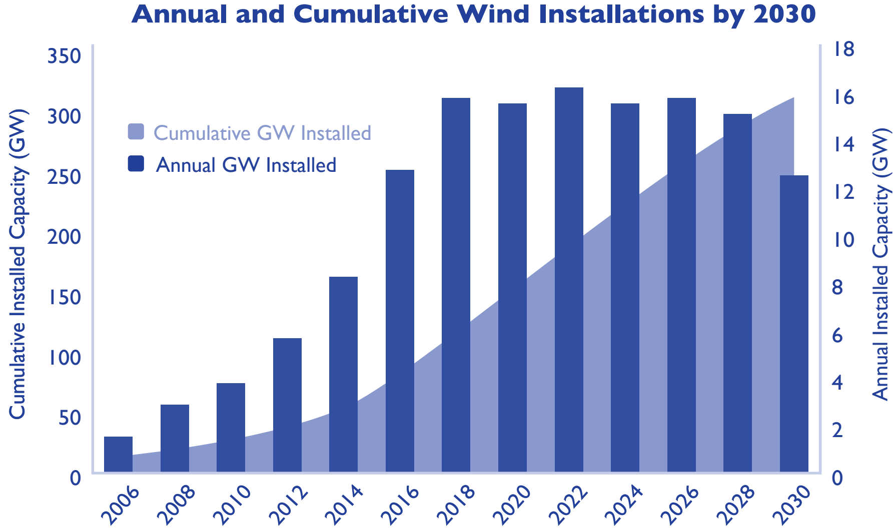
Landscape Impact and Public Perceptions of Wind Energy

While a large majority of Americans support the production of wind energy as a concept, there can be resistance to the siting of wind turbines in rural communities. While local concerns often relate to sound, health, and wildlife issues, residents are also very concerned about how these new technologies will impact landscape values and local economies.

In some locations around the US, wind projects are creating bitter local politics where neighbors are being pitted against one another. Active oppositional campaigns are politically challenging new projects. While some landowners are benefiting from lease payments, their neighbors often claim that viewshed impacts are significantly affecting entire communities and this may result in lower property values and erode the historic qualities of small towns. (A viewshed is an area of land, water, or other environmental elements that is visible to the human eye from a fixed vantage point). Local planners and elected officials often have to balance these concerns with the new jobs and tax base the wind farm may provide.

Many communities feel the solution to these conflicts is more transparency and democracy in the process of building a wind farm. The industry counters that it has the most open process of any energy generation source currently being constructed.

Annual and Cumulative Wind Installations by 2030



20% Wind Energy by 2030 DOE Report (2007)

Cheap Fossil Fuel Prices
If natural gas and coal remain very cheap, that makes it harder for wind energy to compete for capital and makes the cost of wind energy more expensive compared to those sources. One thing that may change is that in the next 5–10 years, we could see a tax on carbon. This would add an additional cost to coal and natural gas generation and make wind a more attractive option. At this point a "carbon tax" is a very controversial proposition in US politics.

Future of Wind
It is clear that we are going to see more electricity from wind energy in the future. How much will depend on the variety of factors that we have discussed. A recent Department of Energy report predicts we will get about 5 percent of our electricity from wind in 2020.

Another report released in 2008 indicated that with aggressive public policy and private investment, the US could produce 20 percent of its electricity from wind by 2030. That would be a colossal program. There are currently 35 GW (1GW=1000 MW) of wind power capacity installed in the US. To get to 20 percent we need 305 GW! That's a lot of turbines.

Would this be challenging? Definitely! Is it possible? Based on this study, we have the technology, materials and skills to do this. What we need is the will.

The benefits of this kind of widespread clean energy development would be monumental. By 2030, in this scenario we would reduce the cumulative amount of CO_2 being put in the atmosphere by 7600 metric tons. Close to 200,000 jobs would be created to manufacture, install, and maintain these devices. Additionally, we would see huge reductions in water use for power and reductions in negative health impacts from pollutants from other energy sources. If wind energy is introduced properly, we would see little or no increase in the cost of electricity and no decrease in reliability.

One of the major findings of the "20% by 2030" report was that a major hurdle in reaching this goal was that in the US there is a predicted decrease in the number of trained engineers and scientists who could do the research required to improve the turbine technology. What this means is that we would be importing much of this new technology, not inventing or designing it ourselves. That is a problem that WindWise seeks to address.

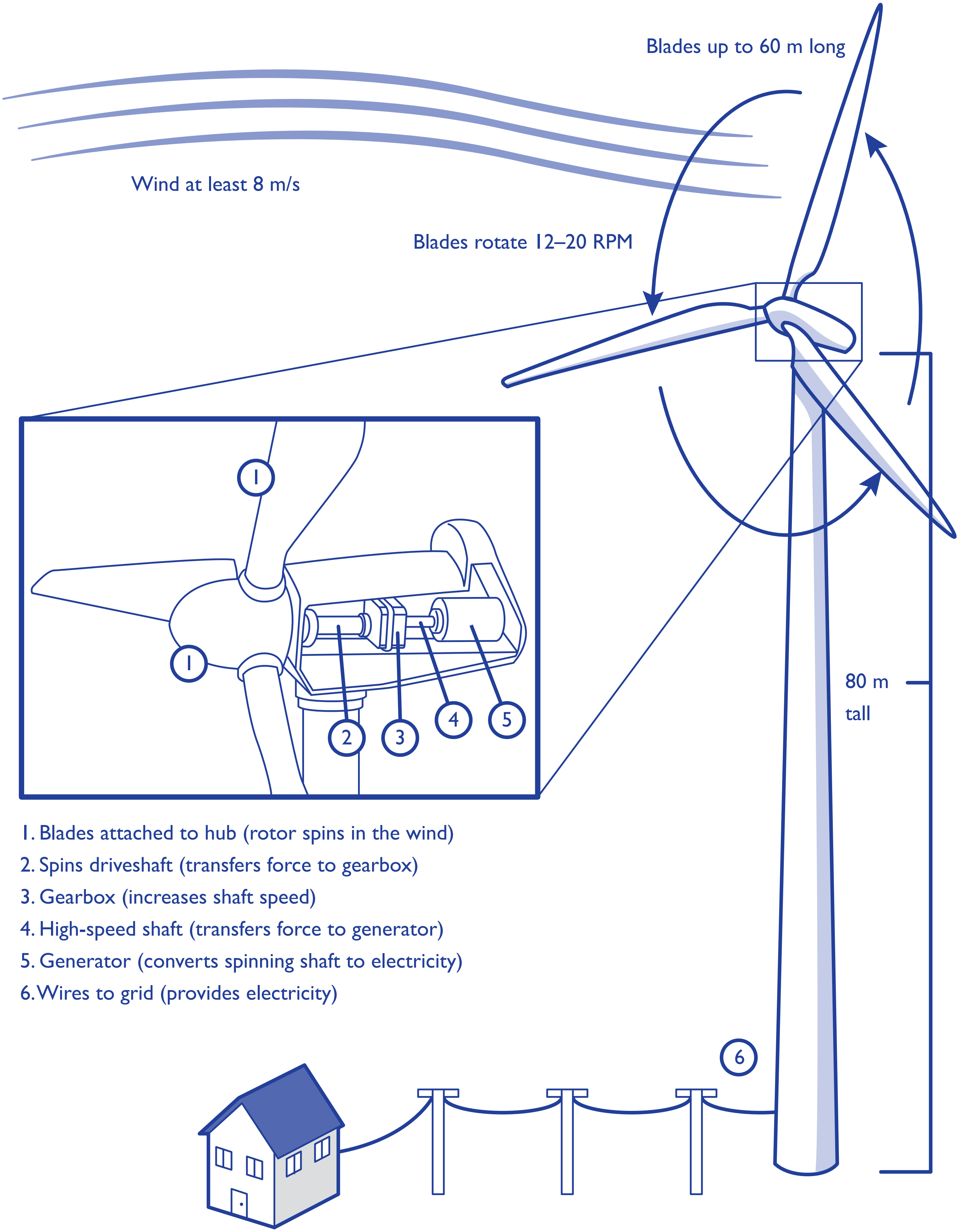
There is a great deal of work to be done and this is a beginning. WindWise is designed to start students down a road towards where they understanding the limits and promise of wind energy and seeing it as a career choice in the future.

Off we go!

A QUICK HISTORY OF WIND ENERGY TECHNOLOGY

3,500 BC	Egyptians made the earliest known sailboats, using the wind to propel boats.
200 BC	Windmills were used to pump water in China.
600 AD	In Persia (present-day Iran), windmills were used to grind grain into flour.
1100 AD	Wind power appeared in Europe during the medieval period. Windmills were used to grind grain.
1300 AD	The first horizontal-axis windmills appeared in Western Europe and were used to drain fields in the Netherlands and to move water for irrigation in France.
1800s	American settlers used windmills to pump water along the western frontier. By the late 1880's, six million windmills had sprung up across America. Steel blades for windmills improved efficiency.
1887	The first windmill for electricity production was built by Professor James Blyth in Glasgow, Scotland.
Early 1900s	Electric wind turbines appeared all over Europe and were used to power rural homes and farms in America.
1920's	French inventor G.J.M. Darrieus developed a vertical axis turbine shaped like an eggbeater.
1931	A 100 kW wind turbine was built in the USSR (present-day Russia). This is a precursor to the modern wind turbine.
1941	A large wind turbine (1,250 kW) was constructed in Vermont in response to fuel shortages. This supplied power for several years during World War II.
1956	A 200 kW, three-bladed turbine was invented by Johannes Juul in Denmark. This turbine inspired many later turbine designs.
1973	The OPEC oil embargo caused oil prices to rise dramatically. High oil prices increased interest and research in alternative energy sources.
1977–1981	The US designed several two-bladed turbine prototypes. One prototype, called the MOD-1, had a 2 megawatt capacity.
1985	California wind capacity exceeded 1,000 megawatts, enough to power 250,000 homes. Wind turbines were still very inefficient at this time.
1990's	Growing public concerns about environmental issues such as air pollution and global warming encouraged interest in renewable energy.
1991	The world's first offshore wind farm began operating off the coast of Denmark.
1999	The US Department of Energy began the Wind Powering America (WPA) Program
2001	Wind energy capacity reached 24,800 megawatts. The global wind power industry generated about $7 billion in business.
2004	The cost of electricity from wind generation became competitive with fossil fuel generation.
2014	Global wind power exceeded 318,105 megawatts installed, employing 834,000 people with an economic impact of over $81 billion annually.

ENERGY TRANSFERS AND CONVERSIONS IN A TURBINE



1. Blades attached to hub (rotor spins in the wind)
2. Spins driveshaft (transfers force to gearbox)
3. Gearbox (increases shaft speed)
4. High-speed shaft (transfers force to generator)
5. Generator (converts spinning shaft to electricity)
6. Wires to grid (provides electricity)

UNIT 1: ENERGY

UNDERSTANDING FORMS AND SOURCES OF ENERGY

LESSON 1

KEY CONCEPT

Students learn the difference between forms and sources of energy and that energy is useful to us because of its ability to change form.

TIME REQUIRED

2 class periods

GRADES

6–8
9–12

SUBJECTS

Environmental Science
Physical Science

BACKGROUND

You need to understand the differences between forms and sources energy to talk about and make informed decisions about energy choices.

Forms of energy are terms scientists use to classify the main types of energy—kinetic and potential. Radiant (light), thermal (heat), and mechanical (motion) energy are examples of forms of energy.

Sources of energy are resources that supply the energy needed to heat our homes, run our appliances, and move our automobiles. Petroleum, coal, and wind are examples of natural energy sources.

OBJECTIVES

At the end of the lesson, students will:

- describe the main forms of energy and give examples
- explain what an energy transformation is and diagram the transformations that take place in an energy system, highlighting waste heat at each step
- state the major sources of energy and identify them as either renewable or nonrenewable
- differentiate between forms and sources of energy
- identify the form of energy stored or delivered in each of the major energy sources

METHOD

Students explore forms of energy, sources of energy, and energy transformations through a demonstration, PowerPoint presentation, class discussion, reading passage and worksheets.

MATERIALS

- ❑ Lamp
- ❑ 40-watt incandescent light bulb
- ❑ Battery-operated flashlight
- ❑ Hand-generator flashlight
- ❑ Student reading passages and student worksheets*

  * included in with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

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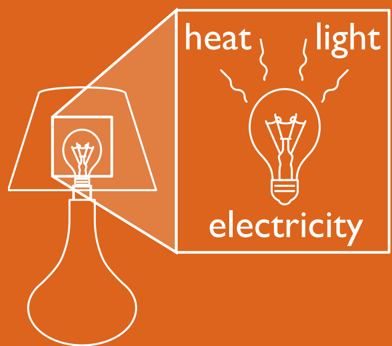
LIGHT BULB DEMONSTRATION



Tell students that all of the thermal energy generated was "lost" because it cannot be captured to do useful work and that the "lost" energy is called waste heat

GETTING READY

- Make copies of the Student Sheets
- Review the Student Reading Passage and the "Sources of Energy" PowerPoint presentation to become familiar with these concepts.
- Try out the Light Bulb Energy Transformation demonstration

PART 1: FORMS OF ENERGY

Step 1: Introduce the concept–forms of energy

Tell students that scientists classify energy into categories called forms of energy. Ask students if they can name some of the forms of energy that they've already learned about in school. Write all of their ideas on the board without comment. Students will probably include some energy sources (solar, wind, etc.) in their answers. If students do list some sources of energy, note these for use in Part 3 in this lesson. Next, tell students to read Passage 1: Forms of Energy. After they complete the Reading Passage, ask students to identify additional examples of each form. Have the class try to categorize the list on the board based upon the forms of energy in the table in the Reading Passage. Suggested categories include Forms of Energy, Examples of Forms of Energy (visible light, food, etc.), and Other (sources of energy, energy carriers, etc.). Tell students to complete the Part 1 questions on Student Worksheet 2.

PART 2: ENERGY TRANSFER, ENERGY TRANSFORMATION DIAGRAMS, AND WASTE HEAT

Step 1: Light bulb energy transformation demonstration

Tell students that energy's ability to change form is what makes it useful and that when energy changes from one form to another, it is called an energy transformation. Ask students to provide examples of energy changing from one form to another. Tell them to use the Forms of Energy Table in the Reading Passage to help them.

Plug in the lamp with the 40-watt incandescent light bulb.

Ask students why this demonstration is an example of an energy transformation.

Answer: The electrical energy going into the bulb is changed into radiant (visible light) and thermal (heat) energy. If students are not able to identify the thermal energy, have some of them come up and put their hand near the bulb. You can also set up a thermometer near the bulb, using a stand, to record the temperature increase.

Caution: Do not allow students to touch the bulb as it might result in a serious burn.

Explain how an incandescent light bulb produces radiant energy (light). Inside the light bulb, there is a thin metal wire called a filament that glows when electricity flows through it. If students have ever shaken a burned out incandescent light bulb, they have heard pieces of the filament hitting the glass.

The electricity flowing through the filament creates a great deal of friction. Eventually the friction causes the filament to become so hot that it glows "white" hot, producing visible light.

Ask students to use their Forms of Energy sheet to identify the energy transformations that take place in a light bulb. Tell students that an energy transformation diagram is a short-hand way of expressing the energy transformations that take place in an energy system. On the board, write the following energy transformation diagram that outlines the energy transformations that take place in an incandescent light bulb.

Electrical Energy $\longrightarrow$ Thermal Energy $\longrightarrow$ Radiant Energy

(Note: all arrows in energy transformation chains should point to the right)

Step 2: Waste heat and the laws of thermodynamics
Explain to students that each time an energy transformation takes place, some of the original form of energy is changed into waste heat. Remind students about how much heat the incandescent light bulb produced. Tell students that all of the thermal energy generated was "lost" because it cannot be captured to do useful work and that the "lost" energy is called waste heat. Waste heat occurs during any energy transformation because of the First and Second Laws of Thermodynamics. You may want to discuss these concepts with your students if you have not done so already.

Ask students to read Passage 2: The Laws of Thermodynamics. They should also take a look at Passage 3: Energy Losses.

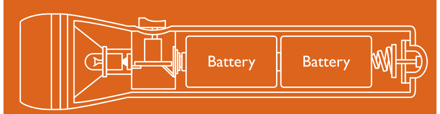
Tell students that the waste heat generated is generated each time an energy transformation takes place. The waste heat can be shown in an energy transformation diagram by writing or drawing waste heat ($\wr \wr \wr$) above each arrow. Show them what this looks like by writing waste heat above the arrows in the energy transformation diagram you wrote on the board in Step 1 (for the incandescent light bulb). It should look like this:

Electrical Energy $\xrightarrow{\wr \wr \wr}$ Thermal Energy $\xrightarrow{\wr \wr \wr}$ Radiant Energy

Step 3: Battery-operated and hand-generator flashlight demonstration
Bring in a battery-operated flashlight with an incandescent bulb rather than light-emitting diodes (LEDs). Turn it on and show it to the students. Tell students to look at their Forms of Energy sheet and ask them what form of energy a battery-operated flashlight produces.

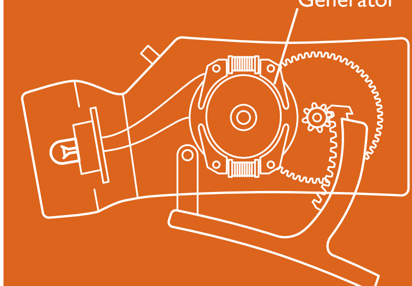
Answer: radiant energy

FLASHLIGHT



Two flashlights use different sources of energy to light a bulb in different ways. One uses the stored energy in a battery to generate light. The other uses the mechanical energy of your hand to generate light.

Some hand powered flashlights have a capacitor that stores short bursts of energy. If your flashlight has a switch it has this type of storage and you may need to add another step on your energy diagram



Ask students what form of energy produced the radiant energy.

Answer: Thermal energy. If students don't identify this transformation and say electrical or chemical energy, tell them that another energy transformation takes place between these two steps. Refer them back to the incandescent light bulb transformation outlined in Step 1. What did they experience when they put a hand near the bulb?

Ask students what form of energy produced thermal energy.
Answer: Electrical Energy

Ask students what is inside the flashlight that produces the electrical energy.
Answer: Batteries

Tell students to look at the Forms of Energy sheet and ask them which form is stored in a battery.
Answer: Chemical Energy

Write the following the following energy transformation diagram on the board.

Chemical Energy ⟶ Electrical Energy ⟶ Thermal Energy ⟶ Radiant Energy

Note: Students may not be able to feel the thermal energy produced by the small light bulb in a flashlight, but if it is an incandescent bulb and not a LED, it is generating some thermal energy that students could feel if they could touch the bulb.

Show students the hand-generator flashlight. Depending on the kind you have, your explanation may be different. Tell them that this flashlight does not use batteries to produce radiant energy and that there is a small generator inside the flashlight that is operated by pumping the handle. Explain that this is the same type of generator that produces electricity in power plants (only it is much, much smaller). Point out the magnet and coils of wire inside. Show them that the handle is connected to a gear and when it is pumped, the circular magnet spins inside two coils of wire. The spinning magnet inside the coils of wire generates an electric current. Tell students that they're going to trace the energy flow in this flashlight all the way back to the original source (the Sun). As students trace the energy transformations back to the Sun, write each answer on the board until you have a complete energy transformation diagram. Note: it may be easier for students to start with the radiant energy produced by the flashlight and work backwards.

What form of energy is produced in a hand-generator flashlight?
Answer: Radiant Energy

What form of energy produced the radiant energy?
Answer: Thermal Energy

What form of energy produced thermal energy in a light bulb?
Answer: Electrical Energy

What form of energy produced the electrical energy?
Answer: Mechanical Energy (pumping the handle)

What form of energy gives someone the ability to pump the handle?
Answer: Chemical Energy (food)

What form of energy powers the food chain?
Answer: Radiant Energy (light powers the photosynthetic process in green plants)

What form of energy produced the radiant energy plants need to make their own food?
Answer: Nuclear Energy (fusion in the Sun)

The energy transformation chain would look like this:

Nuclear Energy → Radiant Energy → Chemical Energy
→ Mechanical Energy → Electrical Energy →
Thermal Energy → Radiant Energy

Almost all energy transformations can be traced back to the fusion process in the Sun. Note: this is an important concept and should be covered again in the next section when reviewing sources of energy. All but one of the major energy sources we rely on (geothermal) can be traced back to the Sun as the original source (ex. all fossil fuels are believed to be the result of the compression and pressure on the remains of prehistoric plants and animals, wind is the result of uneven heating of the Earth's surface, hydropower is the result of the hydrologic cycle powered by the Sun, etc.)

Additional Practice
There are many other examples you can use with students on the Example Energy Transformation Diagrams Student Sheet (courtesy of www.need.org). After you have completed some transformations, select a few from the sheet and write them on the board. The students can then attempt to complete these on their worksheet (Worksheet 2, question 3). If students have not already answered Worksheet 2, questions 1 & 2, ask them to complete them.

READING PASSAGE 3

The diagram in this passage is designed to help you and your students understand how the electricity generated by the wind would make it to a lamp in your house. It also discusses losses at each transformation step.

PART 3: SOURCES OF ENERGY

Step 1: Introduce the concept of sources of energy
Introduce the idea that there are nine resources called primary sources of energy, so called because they exist in nature and do not come from a refining or generating process. You can begin the conversation by asking students where the energy comes from to meet their everyday needs. Students may offer examples that include primary and secondary sources and it will be important to help them understand the difference.

As an example, coal is a primary source of energy because we can dig it out of the ground and burn it. Gasoline is not a primary source of energy because it needs to be refined from petroleum; current electricity is not a primary source of energy because it must be generated using one of the primary sources such as coal, wind, or natural gas.

Students can further classify these sources into nonrenewable (coal, petroleum, natural gas, and uranium) and renewable (wind, solar, geothermal, hydropower, and biomass). The main difference between these two sources is that renewable sources can be replenished in our lifetime and nonrenewable cannot.

Step 2: Energy overview PowerPoint presentation
Show students the resource page PowerPoint presentation. Suggested talking points for teachers are in the Notes section of the presentation.

Step 3: The difference between forms and sources of energy
Ask students to complete Worksheet 1 and answer the questions in Part 3 on their Student Worksheet 2.

VOCABULARY

energy – The ability to do work or to cause a change.

energy carrier – A secondary energy source that is an efficient and safe way to move energy from one place to another. Energy carriers do not exist in nature but must be refined or generated from a primary source of energy. Gasoline and electricity are examples of energy carriers.

energy transformation – Energy being changed from one form to another. An example is radiant energy from the Sun being transformed into chemical energy of sugar during the process of photosynthesis.

energy transformation diagram – A short-hand method of listing the energy transformations that take place in an energy system.

entropy – The scientific principle that eventually all energy, as it used, becomes so diffused or scattered (random) that it loses its ability to do useful work.

forms of energy – Scientific classification of the different types of energy.

natural resource – Energy resources that can be found within the environment such as wind, petroleum, and uranium.

nonrenewable energy – Energy sources that have a fixed amount of supply on the earth, because they take a long time to form. Petroleum and natural gas are examples.

renewable energy – Energy that can be replenished within our lifetime such as such as energy from the Sun and wind.

sources of energy – Resources found in nature that can be obtained to provide heat, light, and power such as natural gas, coal, wind, and solar energy.

thermodynamics – The study of the transformation of energy into work and its relationship to variables such as temperature, volume and pressure.

waste heat – energy that is transformed to heat and "lost" from the resulting form as energy is transformed from one form to another.

EXAMPLE ENERGY TRANSFORMATION DIAGRAMS

Fuel in a power plant creating moving steam

Chemical Energy (coal) → Thermal Energy (water heating making steam) → Mechanical Energy (steam moving)

Sun heating the ground then heating the air, making wind

Nuclear Energy (fusion) → Radiant Energy (infrared waves) → Thermal (ground getting warm) → Radiant Energy (ground releasing infrared waves to air) → Thermal Energy (air heating) → Mechanical Energy (air rising and moving around the planet)

Wind to electricity in a wind turbine

Mechanical Energy (moving air) → Mechanical Energy (rotating blades, gears, shaft, etc.) → Electrical Energy (generator)

Sun to electricity (photovoltaic)

Nuclear Energy (fusion) → Radiant Energy (visible and UV waves) → Electrical Energy (via solar or photovoltaic panel)

Sun to plants growing

Nuclear Energy (fusion) → Radiant Energy (visible light waves) → Chemical Energy (photosynthesis—light waves to sugar)

Rechargeable battery being charged and then running a portable game system

Electrical Energy (from the wall socket) → Chemical Energy (chemistry of the battery stores electricity) → Electrical Energy (Chemical reaction transformed to electricity)

There are many, many more. Once you get the hang of it, you can envision the energy transfers taking place all around you. See if your students can come up with some of their own.

READING PASSAGE 1: FORMS OF ENERGY

It is important to understand energy because it drives our world and all that is in it. Energy is in everything. We use energy for everything we do, from making a jump shot to baking cookies to sending astronauts into space. To use energy without understanding it is to run the risk of wasting it.

Energy is the ability to do work. For scientists, work involves change (a melting ice cube) or movement (a speeding car). Scientists classify energy in a physical sense as:

- Potential (stored) energy
- Kinetic (moving or working) energy

The different forms of potential and kinetic energy are listed in the table below.

Table 1. Forms of energy (Table courtesy of The NEED Project www.need.org)

POTENTIAL ENERGY	KINETIC ENERGY
Stored Energy or Energy of Position	**Energy of Motion**
Chemical – Energy stored in chemical bonds such as coal, natural gas, and petroleum.	Radiant – Energy that travels in electromagnetic waves such as x-rays, UV waves, visible light waves, radio waves, and infrared (heat) waves.
Nuclear – Energy in the nucleus of an atom. It is extracted through fission (splitting atoms) or through fusion (fusing atoms).	Mechanical – Movement of things or objects from one place to another. Wind is a movement of air molecules.
Stored Mechanical – Energy in a mechanical item such as a spring that is compressed or a rubber band that has been stretched.	Electrical – Movement of electrons such as in lightening or electrons in electrical wires.
Gravitational Energy – Things that have mass and have height above the surface of the Earth have stored energy due to gravity. Water above a dam or a rock held above your head has stored gravitational energy.	Thermal – Internal energy of vibrating molecules. Temperature is a measure of this internal energy. The faster molecules within a substance vibrate, the higher the temperature
	Sound – Movement of energy through objects.

READING PASSAGE 2: LAWS OF THERMODYNAMICS

Energy is the ability to perform work, and it is around us all the time in many forms. Work is a force that can cause an object to move. Work done by animals and machines requires a quantity of energy. For an animal or machine to do something that requires energy, the energy must be changed from one form to another during the process of work.

The First Law of Thermodynamics, loosely interpreted, states that energy can neither be created nor destroyed; it changes from one form to another. During a transformation, some of the available energy is used to cause work to happen, and in the process the energy changes to a different form.

At first glance, this seems like a wonderful arrangement. If energy can't be destroyed, can we continue to use it over and over again?

The answer is "no" because of the Second Law of Thermodynamics which states that it is impossible to make heat flow from something that is hot to something that is cold without using a source of energy. The effect of this law is that, once used, energy loses its ability to do work even if it is not destroyed.

A child on a swing provides an example of this principle. Mechanical energy in the child's body is used to set the swing in motion. When no more energy is put into the swing by pushing or pumping, it will gradually stop. It would seem that all of the energy was gone. If you had a very sensitive thermometer, however, you could measure that some of the mechanical energy had changed (transformed) to a low heat. It would show an increase in the temperature of the swing and the swing supports and in the air around the swing.

The heat is not sufficient to be useful, however. It is passed off to cooler surroundings. In such cases the energy is said to be degraded (weakened) to a point where we are not able to use it.

The child on the swing can demonstrate what entropy means. The swing slowed down and came to a stop. The energy was not all gone, but it was so scattered that it could do no more work. The principle of entropy is this: eventually all energy, as it is used, becomes so random that it loses its ability to do work. Each time an energy transformation takes place, some of the original energy is "lost" to waste heat.

Another example of the principle of entropy was shown during the incandescent light bulb demonstration. The purpose of a light bulb is to produce light (radiant energy); however, all of the electrical energy entering the bulb was not transformed into radiant energy. Most of the electrical energy was transformed to heat (thermal energy). This is experienced this when when people put their hands near a light bulb. The thermal energy generated during this energy transformation cannot be used as it dissipates (is randomly scattered) into the air. It is "lost" because it was not captured and consequently, was not able to perform any useful work. This "lost" thermal energy is also called waste heat. Waste heat is produced every time an energy transformation takes place.

Your body is capable of transforming energy from one form to another. For example, if you eat a hamburger and then exercise (lift weights or participate in an aerobics class), all the movement (mechanical energy) that it takes to exercise requires your body to transform the chemical energy in the hamburger into the mechanical energy to make your muscles move. However, all of the chemical energy in the hamburger is not transformed to mechanical energy. Some of the chemical energy is transformed to thermal energy (waste heat). You can feel your body get hotter the more you exercise.

WORKSHEET 1: FORMS AND SOURCES OF ENERGY

In the United States, we use a variety of resources to meet our energy needs. Use the information below to analyze how each energy source is stored and delivered.

1. Using the table below, determine how energy is stored or delivered in each of the sources of energy. If the source of energy must be burned, the energy is stored as chemical energy.

Nonrenewable
Petroleum ______________________
Coal ______________________
Natural Gas ______________________
Uranium ______________________

Renewable
Biomass ______________________
Hydropower ______________________
Wind ______________________
Geothermal ______________________
Solar ______________________

2. Look at the US Energy Production by Source graphic below and calculate the percentage of the nation's energy use that each form of energy provides.

What percentage of the nation's energy is generated by each form of energy?

Chemical ______________ Nuclear ______________

Motion ______________ Radiant ______________

What percentage of the nation's energy is generated by renewables? ______________

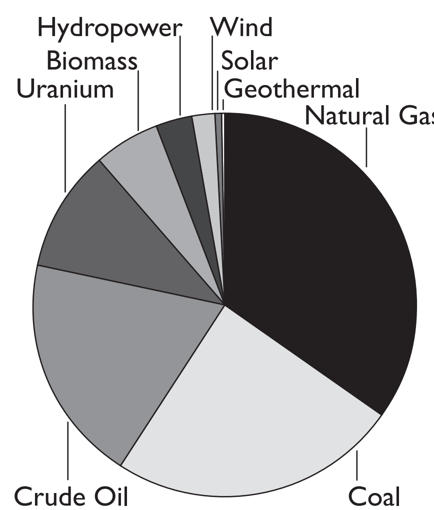
What percentage of the nation's energy is generated by nonrenewables? ______________

This worksheet appears courtesy of The NEED Project

US ENERGY PRODUCTION BY SOURCE, 2013

ENERGY SOURCE	%	USES
Nonrenewable 88.7%		
Natural Gas	34.9%	heating, manufacturing, electricity
Coal	24.4%	electricity, manufacturing
Crude Oil	19.3	transportation, manufacturing
Uranium	10.1%	electricity
Renewable 11.3%		
Biomass	5.6%	heating, electricity, transportation
Hydropower	3.1%	electricity
Wind	2%	electricity
Solar	0.35%	heating, electricity
Geothermal	0.25%	heating, cooling, electricity

Data: US Energy Information Administration



WORKSHEET 2

Part 1: Types of energy

1. List nine forms of energy and provide examples of each of each.

2. Classify the forms of energy you have written down into the two main types of energy discussed in the reading passage. Provide a heading for each group.

Part 2: Energy transfer & energy transformation diagrams

For this part of the lesson, you will need the Forms of Energy table from the reading passage.

1. Write the energy transformation diagram that shows electricity to an incandescent light bulb. (Be sure to label waste heat lost in each transformation).

2. Write the energy transformation diagram that shows the energy in your hand to light produced by a hand-generator flashlight (be sure to label waste heat lost in each transformation).

3. Your teacher has written a few common energy transformations on the board. Complete energy transformation diagrams for at least three of them. If you have more time, you can do more!

Part 3: Sources of energy

1. Explain the difference between a form of energy and a source of energy.

2. List the nine major sources of energy that we rely on in the US.

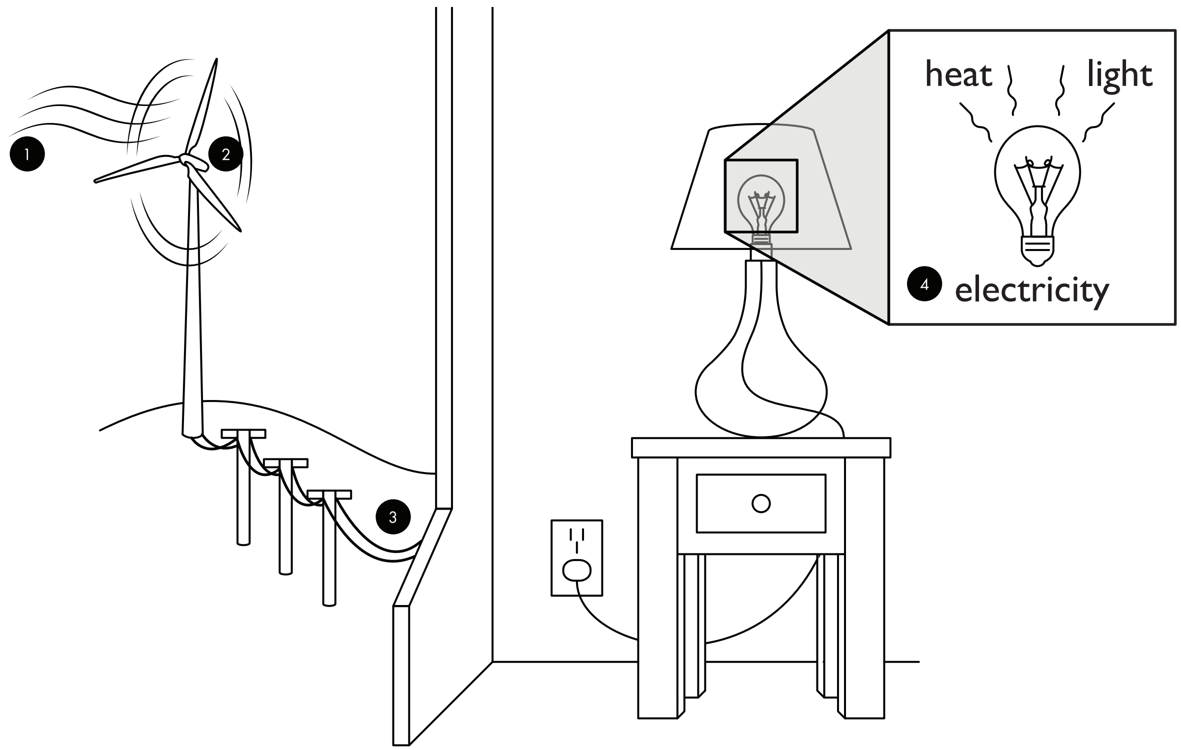
3. List the sources of energy into two categories. Provide a heading for each group.

READING PASSAGE 3: UNDERSTANDING LOSSES

As you can see from this image, to light a bulb in your house using wind power takes many steps.

1 Moving air molecules (wind) cause the wind turbine blades to move. It is impossible to convert 100% of the power in the wind to rotational energy. Typical wind turbines convert 40–50 percent of the moving wind into rotational motion. Maximum theoretical conversion is 59% due to the Betz limit. (Research this to learn more.)

2 Wires moving near magnets generate electricity. Due to friction and design, an electrical generator cannot transform 100 percent of the spinning motion into electricity. Typical efficiency for a wind turbine generator is 90–95 percent.



3 Electricity moves down the wires to your house. "Friction" in the wires, caused by resistance, will not allow 100 percent of the electricity to make it to your house. Typically this transfer of electricity is about 93 percent efficient but depends on a number of factors like distance and wire sizes.

4 Electricity is converted by the lamp and generates heat and light. An incandescent bulb transforms electricity into heat and light. About 97 percent of electricity is transformed into heat and 3 percent into light using an incandescent. If you were using a compact fluorescent bulb (CFL) you would convert 10 percent to light and 90 percent to heat. (See note, lighting efficiency gets very complicated!)

ALONG EACH STEP WE "LOSE" ENERGY.

Start with 100 units of energy

- Wind to generator: lose 50 units of energy in transformation. 50 units remain.
- Generator to electricity: lose 5 units of energy in conversion. 45 units remain.
- Electricity moving down the wires: lose 3 units in transfer. 42 units remain.
- Electricity converted into light: lose 40 units to heat. 2 units are used to light bulb.

In this example if we started with 100 units of power in the wind. We end up with 2 units of power transformed into light.

How do fossil fuels compare to wind in terms of energy transformation? A typical coal fired plant will convert 35–40 percent of the energy in the coal to usable thermal energy to heat water. Natural gas plants perform a bit better converting 50–60 percent of the fuel into usable thermal energy. After that each of these plants will face the same power line and other losses.

Important note on lighting:
Light is measured in "lumens," which correspond to the amount of light produced per watt. For a source of light to be 100 percent efficient, it would need to emit 680 lumens per watt! The luminous efficiency of fluorescent lighting is between 9–11 percent for most CFLs, while conventional incandescent bulbs stand between 2–3 percent. The luminous efficiency of halogen lamps is between the previous two at 3.5 percent efficiency, while newly developed LEDs are between 8–15 percent.

Luminous efficiency is one way to determine which bulb to choose. Another element to look at is the watts it takes to produce the same amount of light. For example: It takes an incandescent bulb 60 watts to produce the same amount of light that would take a CFL bulb only 15 watts to produce. An LED could produce the same light with 8 watts.

WORKSHEET 1: FORMS AND SOURCES OF ENERGY

In the United States, we use a variety of resources to meet our energy needs. Use the information below to analyze how each energy source is stored and delivered.

1. Using the table below, determine how energy is stored or delivered in each of the sources of energy. If the source of energy must be burned, the energy is stored as chemical energy.

Nonrenewable	**Renewable**
Petroleum *Chemical*	Biomass *Chemical*
Coal *Chemical*	Hydropower *Motion*
Natural Gas *Chemical*	Wind *Motion*
Uranium *Nuclear*	Geothermal *Thermal*
	Solar *Radiant*

2. Look at the US Energy Production by Source graphic below and calculate the percentage of the nation's energy use that each form of energy provides.

What percentage of the nation's energy is generated from each form of energy?

Chemical *84.2% (petroleum, coal, natural gas)* Nuclear *10.1% (uranium)*

Motion *5.1% (wind, hydro)* Radiant *0.6% (solar)*

What percentage of the nation's energy is generated by renewables? *11.3%*

What percentage of the nation's energy is generated by nonrenewables? *88.7%*

WORKSHEET 2

Part 1: Types of energy

1. List nine forms of energy and provide examples of each of each.

   Possible answers include chemical (fossil fuels, biofuels, food); nuclear (fission in a nuclear power plant and fusion in the sun); stored mechanical (rubber band, spring) gravitational (holding a book above the ground, an apple on a tree branch); radiant (visible light, x-rays, radio waves); mechanical (car moving down a street, pumping the handle on a hand-generated flashlight); electrical (current moving through a wire); thermal (boiling water, electric blanket); sound (bell, radio, person talking).

2. Classify the forms of energy you have written down into the two main types of energy discussed in the reading passage. Provide a heading for each group.

   Possible answers:
   Kinetic: radiant, mechanical electrical, thermal, sound
   Potential: chemical, nuclear, stored mechanical, gravitational

Part 2: Energy transfer & energy transformation diagrams

For this part of the lesson you will need your Forms of Energy Table in the reading passage.

1. Write the Energy Transformation Diagram that shows the energy transformations in an incandescent light bulb.

   electrical → *thermal* → *radiant*

2. Write the Energy Transformation Diagram that shows the energy transformations in a hand-generator flashlight.

   mechanical → *electrical* → *thermal* → *radiant*

3. Your teacher has written a few common energy transformations on the board. Complete Energy Transformation Diagrams for at least three of them. If you have more time, you can do more!

   Various diagrams depending on the examples chosen.

Part 3: Sources of energy

1. Explain the difference between forms of energy and sources of energy.

   Forms of energy are the types of energy, and sources of energy are the resources we use to supply our energy needs

2. List the nine major sources of energy that we rely on in the US.

   petroleum, natural gas, coal, uranium, biomass, hydropower, wind, geothermal, solar

3. List the sources of energy into two categories. Provide a heading for each group.

   Possible answers include:
   Non-renewable: petroleum, natural gas, coal, uranium,
   Renewable: biomass, hydropower, wind, geothermal, solar

UNDERSTANDING ELECTRIC POWER GENERATION

LESSON 2

KEY CONCEPT

Students learn about the environmental, economic and social trade-offs of electrical power generation technologies.

TIME REQUIRED

2 class periods

GRADES

6–8
9–12

SUBJECTS

Environmental Science
Physical Science
Technology

BACKGROUND

We use nine primary sources of energy to generate our electric power needs in the United States. Electricity is considered an energy carrier because it does not exist in nature in a usable form. Projections are that our electricity demand in the United States will increase 30 percent by 2040. In order to meet this increased demand, additional generation technologies are needed. The question becomes, do we build additional fossil fuel and nuclear power plants or do we use renewable technologies such as wind and solar?

OBJECTIVES

At the end of the lesson, students will:

- understand the concept of energy carriers
- be able to explain why electricity is an energy carrier and not a primary energy source
- be able to explain how electricity is generated and transmitted
- be able to list the primary sources of energy that are used for electric power generation
- be able to compare and contrast advantages and disadvantages of coal vs. wind electric power generation
- understand the advantages and disadvantages of the primary sources of energy used for electric power generation

METHOD

Students explore electric power generation and consider the advantages and disadvantages of different generation technologies through a demonstration, PowerPoint, class discussion, reading passage and worksheets.

MATERIALS

- ❑ Student reading passages and student worksheets*
  *included with this activity

  Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

www.KidWind.org

ENERGY LOSSES

Every conversion or transfer of energy results in a "loss" of energy, but the amount lost varies with the specific conversion or transfer.

GETTING READY

- Make copies of the Student Reading Passages and Student Worksheets
- Review the lesson, student sheets, and PowerPoint to become familiar with the concepts

PART 1: ELECTRIC POWER GENERATION

Step 1: Introduction and energy carriers

Ask students to focus on the important role electricity plays in their everyday lives. Ask them what items they used during the last week that were powered by electricity. Ask them to consider how different their lives would be if they didn't have electricity. How would their lives change? Other questions for students to consider:

- Have any students ever experienced a situation in which their house lost electrical power for a significant amount of time? Ask them to discuss their experiences.
- Where do we get electricity?
- How is electricity produced in a power plant?
- Does all of their electricity come from their local power plant?

Don't worry about whether or not students can answer these questions correctly. The purpose of these questions is to determine students' preconceived ideas. The concepts will be covered in the "Electric Power Generation" PowerPoint presentation that you will show students later in this lesson.

Show students only the first four slides of the presentation. Make sure you go over the talking points in the notes section of the presentation.

Step 2: Electric Connections activity

This activity courtesy of NEED Project. www.need.org

Give each student a copy of Electric Connections instructions.

Ask each student to rank the nine sources of energy in order of their contribution to US electric power generation. Students should use the second column to list their individual rankings in the second column.

Organize students into groups of 3–5. Ask them to review each of their rankings and share with the group the reasons for their ranking. Next, students need to come to consensus on a group ranking and then enter this in the third column.

When they are finished, give each student a copy of the US Electric Power Generation Sources sheet. Tell students to transfer their individual and group rankings to the appropriate columns (columns 4 and 6).

Tell students to read the information next to each source and record the actual ranking of each source in the actual rank column. They will use the percentage of each source's contribution to determine the actual ranking.

Actual ranking
- Coal–1
- Natural Gas–2
- Uranium–3
- Hydropower–4
- Wind–5
- Petroleum–6
- Biomass–7
- Geothermal–8
- Solar–9

Tell students to calculate their individual and group error points and list them in the fifth and seventh columns. Next, have students go over the nine sources of energy and designate each source as nonrenewable or renewable.

Nonrenewable
- Coal (39%)
- Natural Gas (27%)
- Uranium (19%)
- Petroleum (1.75%)

Renewable
- Hydropower (7%)
- Wind (4.1%)
- Biomass (1.5%)
- Geothermal (.4%)
- Solar (.25%)

Ask students to add up the percentages to determine how much of our electricity comes from renewable (13.25 percent) and nonrenewable (86.75 percent) sources.

Hold a class discussion about why students think so much of our electricity is generated by nonrewable sources and so little is generated from renewable sources.

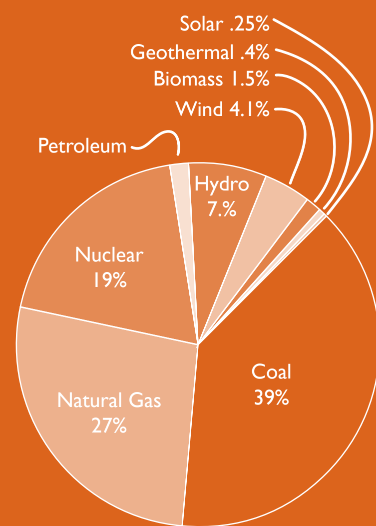
Answer: There is no one answer to this question as many factors are involved. However, one of the major factors is the economics of electric power generation. While some sources are actually cheaper than coal (hydropower, wind, solar, etc.), there are disadvantages with each of these sources (availability, reliability, etc.). This concept is explored in Part 3 of this lesson.

Step 3: Electric power generation and distribution
Show students the remainder of the "Electric Power Generation" PowerPoint presentation (slides 5–23). These slides deal with the generation, transmission, and distribution of electricity. Talking points for each slide are located in the Notes section.

PART 2: CHOOSING FUTURE ELECTRIC POWER GENERATING TECHNOLOGIES

Step 1: Introduction
Ask students if they have any concerns about the US using coal to generate almost 39 percent of our electricity. Possible answers include:
- Coal is not a sustainable energy source. Its quantity is finite.
- Coal-fired power plants are a leading source of toxic mercury in our lakes and streams.

US ELECTRICITY SOURCES



Keep in mind that this chart is showing sources of energy used to generate electricity. It does not contain sources for transportation or heating.

RENEWABLE ENERGY

One common classification system for energy is to label energy either renewable or nonrenewable. These terms relate to how energy is used by human society rather than being fundamental to energy itself. Non-renewable energy is generally extracted from natural resources such as fossil fuels (coal, oil and natural gas), while renewable energy is taken from natural processes as they occur (solar energy, wind energy and hydroelectric power). When energy is released from coal to create electricity, the stock of coal is reduced; hence it is non-renewable. However, energy used from the wind to turn a turbine is not consumed in the same way. Using wind energy does not make the future less windy!

- Coal-fired power plants are a major contributor to acid rain.
- When coal is burned, harmful air pollutants are released into the air, such as sulfur dioxide, nitrogen oxides, and particulates.
- Coal-fired power plants are a major contributor to climate change (global warming) due to carbon dioxide emissions.
- Lives are lost in coal mining.
- Coal extraction has a serious impact on the land, such as destroyed mountain-tops and landscapes.
- This energy source has an impact on public health—24,000 premature deaths per year according to the American Lung Association.

Step 2: The economic, environmental, public heath and safety comparisons of coal and wind
Ask students to read the activity reading passage, "Comparisons of Coal and Wind: Economic, Environmental, Public Health and Safety" (page 48).

Step 3: Exploring the tradeoffs of electric generating technologies
After the students read the passage pose some questions:

- Why do we continue to rely on coal to generate so much of our electricity, considering the environmental and health concerns associated with its use?
- Can students think of any advantages of using coal?
- Are there any disadvantages of the other sources (nuclear, wind, solar, hydropower, etc.)?

The United States Department of Energy projects that our demand for electricity will increase 30 percent by 2040. We will need to increase our generation and must decide on what kind of technologies we want to develop to meet this future demand.

There is no "perfect" energy source for generating electricity. All technologies have economic, environmental, and social advantages and disadvantages.

Renewable technologies such wind and solar rely on "free" resources and don't produce harmful greenhouse gases, but are not always available when needed and sometimes require significant amounts of land.

Technologies such as coal and nuclear reliably produce electricity in large quantities but result in significant greenhouse gasses emissions (in the case of coal or natural gas) or long-term toxic waste considerations (in the case of nuclear).

Recognizing these tradeoffs helps students understand why there is so much debate about which electricity generating technologies we should promote in the future.

Go over the information in the chart on page 51 with students. The data in this chart is provided by the Electric Power Research Institute (EPRI), an independent, non-profit company performing research, development and demonstration in the electricity sector for the benefit of the public.

Spend time with students going over the chart to make sure they understand the rankings. It may help students to understand the rankings if they know how many of each type of electrical power generating technologies would be required to generate an equal amount of electricity. The chart below compares the number of each technology needed to provide the annual electrical energy requirements for a large city such as Chicago (approximately 1 million homes).

TECHNOLOGY	NUMBER
Nuclear	1 plant
Coal	2 plants
Natural Gas	3 plants
Biomass	20 plants
Geothermal	30 plants
Wind	2000 turbines
Solar Photovoltaic	1.6 million PV arrays

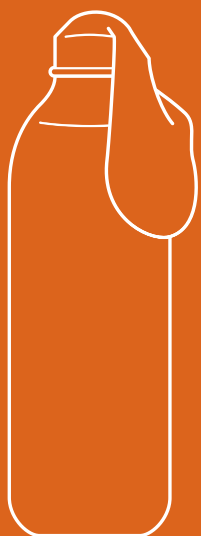
For example, students may not understand why wind receives a "1" (high impact) for land use and nuclear receives a "4" (low impact). However, understanding that it would require much more land to site 2000 wind turbines than it would to construct one nuclear power plant puts the rankings in proper perspective.

Step 4: Choosing future electricity generating technologies activity
After reviewing information in the chart with the students, have them complete the Choosing Future Electricity Generating Technologies worksheet on page 53.

This activity is a values exercise; there are no right or wrong answers for this activity. It is important for students to justify their rankings based on what they think (economics, environment, other, etc.) are the most important considerations in meeting our future electrical power needs. For example, if they rank nuclear as their first choice, they should be able to justify their choice based upon their own values and priorities. A student who thinks that we face major social problems by relying on imported petroleum and environmental issues associated with global warming might rank nuclear power as their first choice because it relies on fuel that is readily available in the US and nuclear power plants don't contribute to climate change due to low CO_2 emissions.

Step 5: Class discussion
Hold a class discussion and have students explain the reasoning behind their rankings. This could be done in small groups or as a whole class discussion.

Stress to students prior to their discussion that there are no right or wrong answers and that the purpose of this activity is to generate discussion and build on each other's knowledge about the advantages and disadvantages of the different electrical power generating technologies.



Place baking soda in the balloon and stretch it over the bottle neck.

Be prepared to have students debate their choices as this chart oversimplifies the considerations that might arise. For example, if the student states that nuclear power plants emit no CO_2, another student may counter with the fact that while this is true, fossil fuels, especially oil in the form of gasoline and diesel, are essential to every stage of the nuclear cycle, and CO_2 is given off whenever these are used. Both facts are correct. The ranking in the chart only deals with CO_2 emissions from the nuclear power plant, not the production of nuclear fuel.

EXTENSION

Carbon dioxide demonstration

The bubbling, fizzing chemical reaction between vinegar and baking soda is a standard science experiment. This variation allows you to collect the gas, carbon dioxide, produced in the reaction, as a demonstration of the greenhouse gas emissions of fossil fuel power plants.

Materials:

- 1 glass or plastic bottle between 8 and 16 ounces in size
- Balloon
- Funnel
- 4–6ounces of vinegar
- 1 teaspoon of baking soda

Directions

- Put vinegar into the bottle.
- Pull the open end of the balloon over the bottom of the funnel.
- Pour the baking soda into the funnel and shake it down into the balloon. If the baking soda gets stuck in the neck of the balloon, use a pencil to push it into the balloon.
- Connect the open end of the balloon to the top of the bottle. Keep the balloon hanging down to one side so no baking soda gets into the bottle. You now have a closed system.
- Lift the balloon straight up and shake to mix the two chemicals.
- When the reaction is done, hold the bottle and twist the balloon several times to seal the base of the balloon.
- Pull on the base of the balloon to remove it from the bottle.
- Tie the end of the balloon to seal the gas in.

Discussion

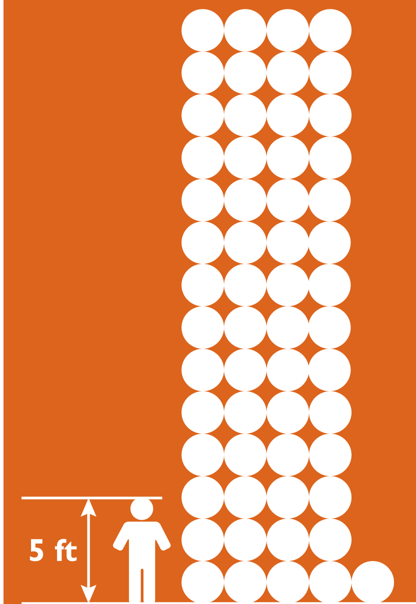
Use this demonstration to help students visualize how much carbon dioxide Americans generate, as explained in the following discussion (Catherine Zandonella).

It's embarrassing to consider how much carbon dioxide (CO_2) we generate. Our cars, homes and lawnmowers spew out this heat-trapping gas on a daily basis. But since carbon dioxide is invisible, we rarely recognize our individual contributions to greenhouse gas emissions.

It would be very helpful if we could inject a dye into CO_2 that made it visible to the human eye. Our cars could be rigged to spew out a putrid brown or a sickly yellow. Just seeing the CO_2 might convince many people to hop on their bikes to do their errands around town. Since coloring CO_2 is not an option at the moment, you have to use your imagination.

The average American's CO_2 emissions are usually tabulated in terms of pounds of CO_2. You are probably familiar with buying your fruits and veggies by the pound. A pound of apples is about three medium-size ones. So how big is a pound of CO_2? It helps to think of CO_2 as gas trapped inside a balloon. Filling a balloon with one pound of CO_2 would swell the balloon to about the size of one of those large rubber exercise balls. The balloon would be about two and a half feet across. Each day the average American fills up about 57 of these balloons through his use of electricity, gasoline, etc.

Now imagine all of those balloons rising up every day from 320,000,000 Americans. You can see how—day after day, year after year—they'd fill up the sky. About half of all electricity in the United States is made from burning coal. Coal-fired power plants emit about 2 billion tons of CO_2 annually. Natural gas power plants, which make about one-fifth of the country's electricity, emit 400 million tons. Only about 10 percent of our electricity is made from hydroelectric and other renewable energy sources such as wind or solar, according to the US Energy Information Agency. Of course, your personal electricity-related carbon emissions depend on where your electricity comes from. But consider that, on average, given the typical sources in this country, even a single 75 watt incandescent bulb burning for two hours a day will generate six pounds of carbon dioxide a month. So be sure to turn off the lights off!



Each day the average American is responsible for the production 57 balloons of CO_2 (large 2 ft wide balloons) through transportation, electricity usage and other lifestyle choices.

VOCABULARY

acid rain – Rainfall made sufficiently acidic by atmospheric pollution that it causes environmental harm, typically to forests and lakes.

carbon dioxide – A naturally occurring gas, a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. It is the principal greenhouse gas that affects the Earth's radiative balance.

climate change – Any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer).

energy carrier – Also referred to as a secondary source of energy. Energy carriers are primary energy sources of energy that are converted in an energy transformation process to more convenient sources of energy (such as electricity) that can be used directly by society. Examples include electricity, refined fuels (gasoline, propane, heating oil, ethanol, etc.) and hydrogen.

global warming – Increase in the temperature of the atmosphere near the Earth's surface and in the troposphere, that can contribute to changes in global climate patterns. Global warming can occur from a variety of causes, both natural and human induced. In common usage, "global warming" often refers to the warming that can occur as a result of increased emissions of greenhouse gases from human activities.

greenhouse gases – Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases are the major contributor to global warming and climate change.

hydrocarbons – Substances containing only hydrogen and carbon. Fossil fuels are made up of hydrocarbons.

ELECTRIC CONNECTIONS

Game instructions

Today, 41 percent of the nation's energy is used to make electricity. Experts predict that this figure will continue to increase. The US is becoming more dependent on electricity to meet its energy needs as we depend on more technology. To meet the growing demand, many energy sources are used to generate electricity. Some energy sources produce a substantial amount of the electricity we consume, while others produce less than one percent.

Individual instructions

Your task is to rank the nine sources of energy in order of their contribution to US electricity production. Place number one by the source that provides the largest amount of electricity, a number two by the source that provides the second largest, down to a number nine by the one that provides the least amount of electricity. Use critical reasoning skills to determine the order.

Group instructions

Starting at the top of the list, ask members to contribute any knowledge they have about each energy source. Brainstorm by asking group members questions such as:

- Is this source limited to a certain area of the country?
- Are there any problems or limitations associated with this source?
- Have you ever seen a power plant that uses this particular source of energy?

One person in the group should take notes. Once the group has gone through the list, it should divide the nine energy sources into three levels of importance: the top three most significant energy sources, the middle four moderately significant energy sources, and the bottom three least significant energy sources. The group should then rank the ten sources of energy in order of their contribution to US electricity production.

Sources used to generate electricity

SOURCE	YOUR RANK	GROUP RANK
Biomass		
Coal		
Geothermal		
Hydropower		
Natural Gas		
Petroleum		
Solar		
Uranium		
Wind		

This worksheet appears courtesy of The NEED Project. www.need.org

US ELECTRIC POWER GENERATION SOURCES

Sources used to generate electricity

SOURCE	STATISTICS	ACTUAL RANK	YOUR RANK	ERROR POINTS	GROUP RANK	ERROR POINTS
Biomass	Biomass electricity is usually the result of burning wood waste, landfill gas, and solid waste. 1.5% of US electricity is produced by biomass.					
Coal	94% of the nation's coal is consumed by electric utility companies to produce electricity. 39% of US electricity is produced by burning coal.					
Geothermal	Most geothermal is from facilities in the western US. Geothermal energy produced 0.4% of the nation's electricity.					
Hydropower	Hydropower is the leading renewable energy source used to provide electricity. 7% of US electricity is produced by hydropower.					
Natural Gas	Approximately one-half of natural gas is used by gas turbines to provide electricity during peak hours of demand. 27% of US electricity is produced by natural gas.					

SOURCE	STATISTICS	RANK	YOUR RANK	ERROR POINTS	GROUP RANK	ERROR POINTS
Petroleum	Petroleum provides 1.75% of US electricity.					
Solar	Solar electricity is generated by solar thermal systems or photovoltaics. Solar provides 0.2% of US electricity.					
Uranium	104 nuclear power plants provided the nation with 19 percent of its electrical energy needs.					
Wind	Most of the wind-generated electricity is produced in Texas, Iowa, and western states. Wind provides 4.1% of the nation's electricity.					
Error points totals						

Error points are the absolute difference between your rankings and those of the EIA's (disregard plus or minus signs).

2013 Data: Energy Information Administration, Annual Energy Report

Scoring:

0–12 Excellent
13–18 Good
19–24 Average
25–30 Fair
31–36 Poor
37–42 Very Poor

This worksheet appears courtesy of The NEED Project. www.need.org

COMPARISONS OF COAL AND WIND: ECONOMIC, ENVIRONMENTAL, PUBLIC HEALTH AND SAFETY

Economics

Comparing the economics of electricity from coal versus from wind can become very complicated since electricity generation has both capital (construction) costs and ongoing (production) costs, and some models may account for other factors as well (fuel, maintenance, transmission, environmental costs, etc.). One of the most cited economic comparisons of different sources of electricity is published by Lazard, an international financial advisory firm.

The Lazard study gives a comparative levelized cost of different sources of electricity in dollars ($) per megawatt-hour (MWh). This study does include existing subsidies and incentives for each source of electricity, but does not factor in environmental costs, potential carbon emission costs, transmission, or other external costs.

According to Lazard, onshore wind energy costs $57–$113 per MWh, while electricity from coal costs $78–$144 per MWh. Without US Federal Tax Incentives, electricity from wind would cost approximately $84–$140 per MWh. Electricity from wind is cost-competitive with coal. Offshore wind energy is not included in the Lazard study, but is more costly.

If environmental costs are considered part of an economic equation, electricity from wind power becomes even more economically preferable compared to coal.

Air quality and public health

Coal—When coal is burned, harmful air pollutants like sulfur dioxide, nitrogen oxides, and particulates are released in to the air. These pollutants cause and aggravate respiratory diseases, damage lung tissue, and can lead to premature death. They can also harm vegetation, trees, crops and water quality. Burning coal is a leading cause of smog, acid rain, climate change, and air toxins such as mercury. In an average year, a typical coal plant generates:

- 10,000 tons of sulfur dioxide (SO_2), which causes acid rain that damages forests, lakes, and buildings, and forms small airborne particles that can penetrate deep into lungs.
- 500 tons of small airborne particles that can cause chronic bronchitis, aggravated asthma, and premature death, as well as haze, obstructing visibility.
- 10,200 tons of nitrogen oxide (NO_x), as much as would be emitted by half a million late-model cars. NO_x leads to formation of ozone (smog) that inflames the lungs, and can damage lung tissue and making people more susceptible to respiratory illness.
- 720 tons of carbon monoxide (CO), which causes headaches and places additional stress on people with heart disease.
- 220 tons of hydrocarbons, volatile organic compounds (VOCs), that form ozone.
- 170 pounds of mercury, a substance of which just .014 teaspoons deposited in a 25-acre lake can make the fish unsafe to eat.
- 225 pounds of arsenic, a substance which will cause cancer in one out of 100 people who drink water containing 50 parts per billion.
- 114 pounds of lead, 4 pounds of cadmium, other toxic heavy metals, and trace amounts of uranium.

Wind: Wind energy does not involve combustion and does not result in the production of carbon dioxide, sulfur dioxide, airborne particles, nitrogen oxide, carbon monoxide, volatile organic compounds, mercury, arsenic, or lead. Consequently, there is no impact on public health.

Climate change (global warming) pollution

Coal: Coal-fired power plants are the primary source of the principal climate change (global warming) pollutant, carbon dioxide.

- Between 1990 and 2003, total US carbon dioxide emissions increased about 18%.
- About 98% of carbon dioxide emissions in the US come from burning fossil fuels.
- There is broad scientific agreement that human activities are causing the temperature of the Earth's atmosphere to rise.
- With only 5% of the world's population, the US emits 22% of the world's greenhouse gases (24 tons per person per year).
- In the last 1,000 years, 20 of the hottest years on record have occurred since 1980. 2005 was the hottest year ever recorded.

Wind: Once again, wind energy does not involve combustion and does not result in the production of carbon dioxide.

Safety

Coal: Underground mining is one of the most hazardous occupations, killing and injuring many in accidents, and causing chronic health problems. The US Department of Labor reports that there were 952 coal-mining fatalities between 1980 and 2010.

Wind: Falling off a roof or wind tower and electrical shock are risks, but they are minimal for properly trained workers. It is difficult to imagine a catastrophic wind accident that would cause 10 or 20 deaths in a single day.

OTHER FACTORS

Solid waste

Coal: Waste created by a typical 500-megawatt coal plant includes more than 125,000 tons of ash and 193,000 tons of sludge from the smokestack scrubber each year. Nationally, more than 75 percent of this waste is disposed of in unlined, unmonitored, onsite landfills and surface impoundments.

Toxic substances in the waste—including arsenic, mercury, chromium, and cadmium—can contaminate drinking water supplies and damage vital human organs and the nervous system. One study found that one out of every 100 children who drink groundwater contaminated with arsenic from coal power plant wastes were at risk of developing cancer. Ecosystems, too, have been damaged—sometimes severely or permanently—by the disposal of coal plant waste.

Wind: No solid waste is generated with wind power.

Water supply and cooling water discharge

Coal: Once the 2.2 billion gallons of water have cycled through the coal-fired power plant, they are released back into the lake, river, or ocean. This water is hotter than the water that receives it. This "thermal pollution" can decrease fertility and increase heart rates in fish. Typically, power plants also add chlorine or other toxic chemicals to their cooling water to decrease algae growth. These chemicals are also discharged back into the environment.

Wind: Water in not involved in the production of wind energy.

Degradation of the landscape

Coal: About 60 percent of US coal is stripped from the Earth in surface mines; the rest comes from underground mines. Surface coal mining may dramatically alter the landscape. Coal companies throughout Appalachia often remove entire mountaintops to expose the coal below. The wastes are generally dumped in valleys and streams.

In West Virginia, more than 300,000 acres of hardwood forests (half the size of Rhode Island) and 1,000 miles of streams have been destroyed by this practice.

Wind: Some people consider the turbines to have an undesirable appearance, especially when there are very tall units and/or large groups of them. The same could be said for coal power plants, but these are concentrated into a smaller number of facilities.

Transportation & storage

Coal: A typical coal plant requires 40 railroad cars to supply 1.4 million tons in a year. That's 14,600 railroad cars a year.

Railroad locomotives, which rely on diesel fuel, emit nearly 1 million tons of nitrogen oxide (NO_x) and 52,000 tons of coarse and small particles in the United States. Coal dust blowing from coal trains contributes particulate matter to the air.

Coal burned by power plants is typically stored onsite in uncovered piles. Dust blown from coal piles irritates the lungs and often settles on nearby houses and yards. Rainfall creates runoff from coal piles. This runoff contains pollutants that can contaminate land and water.

Wind: Wind energy requires no transportation or storage.

ADVANTAGES AND DISADVANTAGES OF ELECTRICITY GENERATING TECHNOLOGIES

Electricity generation technologies all have advantages and disadvantages. Renewable technologies such as wind and solar use “free” resources and don’t produce harmful greenhouse gases, but are not always available when needed and require significant amounts of land. Technologies such as coal and nuclear produce electricity in large quantities reliably, around the clock, but result in significant greenhouse gases (in the case of coal) and long-term waste disposal considerations (in the case of nuclear).

Recognizing these tradeoffs helps everyone understand the considerations that must be taken into account in deciding which energy sources we should be promoting to meet our future electric power needs.

ASSESSMENT OF RELATIVE BENEFIT/ IMPACT	COAL	NATURAL GAS	NUCLEAR	HYDRO	WIND	BIOMASS	GEO-THERMAL	SOLAR PHOTO-VOLTAIC
Construction Cost New plant construction cost for an equivalent amount of generating capacity	**3**	**4**	**0**	**2**	**3**	**2**	**1**	**0**
Electricity cost Projected cost to produce electricity from a new plant over its lifetime	**4**	**4**	**3**	**1**	**2**	**2**	**2**	**0**
Land use Area required to support fuel supply and electricity generation	**2**	**3**	**4**	**2**	**1**	**0**	**3**	**1**
Water requirements Amount of water required to generate equivalent amount of electricity	**0**	**2**	**0**	**2**	**4**	**0**	**2**	**4**

ASSESSMENT OF RELATIVE BENEFIT/ IMPACT	COAL	NATURAL GAS	NUCLEAR	HYDRO	WIND	BIOMASS	GEO-THERMAL	SOLAR PHOTO-VOLTAIC
CO_2 emissions Relative amount of CO_2 emissions per unit of electricity	**0**	**2**	**4**	**4**	**4**	**3**	**3**	**4**
Non-CO_2 emissions Relative amount of harmful air emissions other than CO_2 per unit of electricity	**0**	**2**	**4**	**4**	**4**	**1**	**3**	**4**
Waste Products	**0**	**4**	**2**	**4**	**4**	**1**	**3**	**4**
Availability Ability to generate electricity when needed	**4**	**4**	**4**	**2**	**0**	**4**	**4**	**0**
Flexibility Ability to quickly respond to changes in demand	**2**	**4**	**1**	**4**	**0**	**2**	**3**	**0**

Ranked with 0 meaning highest impact/cost and 4 meaning lowest impact/cost.

CHOOSING FUTURE ELECTRICITY GENERATING TECHNOLOGIES

Based upon your values, rank the energy sources from 1–8, with 1 being your first choice for generating electricity and 8 being your last choice.

ENERGY SOURCE	RANKING	REASON FOR RANKING
Coal		
Natural Gas		
Nuclear		
Hydropower		
Wind		
Biomass		
Geothermal		
Solar		

WHAT IS THE COST OF INEFFICIENCY?

LESSON 3

KEY CONCEPT

Students learn about work, energy and power and that using electrical appliances and devices has economic and environmental costs.

TIME REQUIRED:

2 class periods

GRADE LEVEL:

6–8
9–12

SUBJECTS:

Environmental Science
Physical Science
Technology

KidWind PROJECT®

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BACKGROUND

The US Department of Energy projects that the demand for electricity will increase 30 percent by 2040. Improving the efficiency of homes, businesses, schools, governments, and industries is one of the most constructive, cost-effective ways to address the challenges of high energy prices, energy security and independence, environmental concerns, and global climate change in the near term. Mining this efficiency could help us meet up to 50 percent of the expected growth in US consumption of electricity in the coming decades. This would yield billions of dollars in saved energy bills and avoid significant emissions of greenhouse gases and other air pollutants.

Energy efficiency and energy conservation are necessary first steps toward a sustainable energy future. All energy users need to understand the value of energy efficiency.

OBJECTIVES

At the end of the lesson, students will:

- define the concepts of work, power, and energy, and provide examples of each
- describe the relationship between work, power, and energy
- know how to calculate the economic and CO_2 savings from using energy-efficient appliances
- understand the concepts of energy efficiency and energy conservation and provide examples of each

METHOD

Students apply the concepts of power and energy in order to test three different types of light bulbs with a Kill A Watt Meter.

MATERIALS

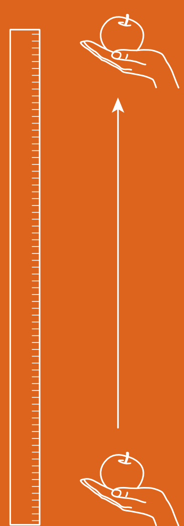
- ❑ 2 lamps
- ❑ 2 light bulbs of equal brightness (measured in lumens); incandescent and compact florescent are included in the activity kit. For additional comparison you can also look for new LED bulbs but they are expensive.
- ❑ Kill A Watt Meters
- ❑ Calculator
- ❑ Student reading passages and student worksheets*

  *included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

POWER

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$



A simple demonstration of work and power can be done using an apple with a mass of 100 grams.

GETTING READY

Make copies of all student sheets. Read over the lesson information and become comfortable with the concepts. Practice using the Kill A Watt Meter and doing the calculations in Part II: Measuring Power and Energy. Set up three stations with a lamp, light bulbs, and Kill A Watt Meter.

ACTIVITY PART I: WORK, POWER AND ENERGY

Step 1: Introduction

Ask students some questions to get them thinking about using electricity, such as:

- What electrical appliances and devices do you use at home?
- Which appliances do you think uses the most electricity in your house? Why?
- What electrical appliances and devices do we use in our classroom?
- Which appliances use the most electricity in our classroom? Why?
- Why is it important to conserve electricity?
- Is there a way to measure how much electricity appliances and devices use? If so, what is it?

Step 2: Discuss the concept of work

Tell students that the scientific definition of work is a force causing a displacement. Write this definition on the board.

Demonstrate this concept to students by lifting an apple one meter. We are using an apple as it represents a mass of 100 grams. The concept of work can be shown by displacing the apple one meter. This can be done quickly or slowly—the amount of work does not change. Power is equal to work/time. 1 watt of power would be equal to lifting this 100 gram apple, 1 meter in 1 second.

Using the definition of work on the board, ask students to tell you why work was done during this demonstration. Answer: You have applied a force to the apple, and displacing it (moved it up one meter).

Ask students to provide other examples of work that can be observed in everyday life such as a tractor pulling a plow through a field, a father pushing a grocery cart down the aisle of a grocery store, a student lifting a backpack full of books upon her shoulder, a weightlifter lifting a barbell above his head, an Olympian launching the shot-put, etc. In each of these examples, a force is exerted on an object that results in the object being displaced.

The amount of time it takes to do work has nothing to do with the amount of work being done. Whether it took you two seconds or four seconds to lift the apple, the same amount of work was done. Whether it took the father one minute or three minutes to move the shopping cart down the aisle does not change the amount of work that was done.

Step 3: Discuss the concept of power

Tell students that the definition of power, on the other hand, is a measure of how quickly a certain amount of work can be done, or the rate at which work is done.

Let's return to the example of lifting the apple. Power depends on the time it takes to raise the apple one meter. Whether the apple is lifted rapidly or slowly, it's the same amount of work. If it is lifted rapidly, the same amount of work is being done in a shorter period of time, and more power needs to be applied.

In order to sell his newly improved steam engines, James Watt was forced to combine the idea of time with the definition of work.

The equation for power is force times distance divided by time: $P = \dfrac{F \times D}{t}$

But F×D=Work, so power is equal to work divided by time or: $P = \dfrac{W}{t}$

The basic unit of work in the metric system is the joule and a joule per second is known as a watt (W).

A watt is roughly the amount of power needed to lift 100 grams (the mass of a average sized apple) one vertical meter of height in one second. Demonstrate one watt by lifting the apple one meter in one second (the amount of time it takes to slowly say one-one thousand).

Ask students if you need to be "powerful" to lift one apple one meter in one second. Explain to the students that because a watt is a small unit of measurement, kilowatts (kW) and megawatts (MW) are sometimes used. A kilowatt is 1,000 watts, or the power needed to raise 1,000 apples one meter in one second. A megawatt is a million watts. Do you have to be "powerful" to lift one thousand or one million apples one meter in one second?

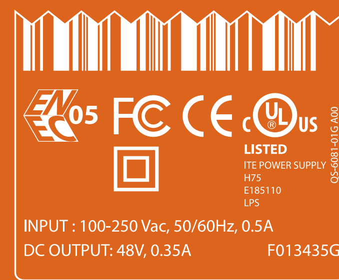
Note: Horsepower is occasionally used to describe the power delivered by an engine. One horsepower is equivalent to 746 watts, or lifting 550 pounds, one foot in one second.

Step 4: Discuss the concept of energy

Tell the students that the amount of energy an appliance or device uses depends on how much power (watts) is needed to operate it and, more importantly, how much time it is consuming that power. A powerful car does not use any energy (gas) if it is parked in the garage all day. The same car consumes a lot of energy during an eight-hour drive to Grandma's house, however.

Energy is the capacity for doing work. It is a quantity, not a rate. Since the joule is a very small quantity of work or energy, explain that electrical energy is measured in larger units known as the watt-hour (3600 J), kilowatt-hour (1000 Wh), or a megawatt-hour (1,000,000 Wh). To determine how much energy an appliance uses in joules, you have to multiply the number of watts needed to operate it by the length of time that it is "on" in seconds. Watts × seconds = wattseconds (Ws), also known as a joules (J).

EXAMPLE POWER LABEL



Almost all electronic devices have a label describing how much power they consume when turned on. These labels vary greatly. To determine how many watts the device will use, multiply the output voltage and the current. Does this match the Kill A Watt meter reading? Why might these be different?

USING KILL A WATT METERS

Kill A Watt Meters are great tools to see power and energy being used by appliances. In a classroom it can be challenging to measure energy due to short lab times. To get around this set up a few meters to measure energy use at the beginning of the day or week.

Another cool thing you can do is let students sign them out for a week and collect data at home. As a class you can aggregate this data for analysis.

During class it is a good idea to have many appliances that students can plug into the Kill A Watt so students can experiment.

PART 2: MEASURING POWER AND ENERGY

Step 1: Demonstrate how to use a Kill A Watt Meter
Distribute the Kill A Watt Meter Student Sheet and the Economic and Environmental Cost of Using Appliances Activity Sheet. Show students the Kill A Watt Meter and explain that it is an instrument that measures the power it takes to run a device and the amount of energy the device consumes.

Demonstrate how to use a Kill A Watt Meter with a device in your classroom or an appliance from home. Go over the directions with the class, plug in your example appliance or device, and demonstrate how the meter can record both power (kilowatts) and energy (kilowatt-hours). See data collection sheet on page 68.

Step 2: Determine the power the appliance uses
The power is measured by pushing the Watt/VA key. With the meter plugged into a wall socket or extension cord and the appliance plugged into the meter, press the Watt/VA key.

Note: The Watt/VA Key is a toggle function key. Press the Watt/VA key once to display watts. Press the key again to display the VA meter. Tell students to record the power of the appliance/device you are demonstrating using the Watt function. The power drawn by an LCD television, for example, is 120 W.

Appliances draw different amounts of power, depending on their use. Make sure students use the appliance to see how it affects power consumption. For example turn the fan on low, medium, and high. Let the computer go into sleep mode. Students may have to choose an average number for this column.

Step 3: Estimate the amount of time the appliance is on in one day
Determine about how long the appliance is using power during the day. If you round this number off to the nearest hour, the next calculation will be easier, but using 15 minute segments will provide more accuracy.

In the LCD television example, the estimated time is 4 hours.

Step 4: Determine the amount of electrical energy the appliance uses in one day
Energy is measured by pushing the KWH/Hour toggle function key. Press the KWH/Hour key once to show the cumulative energy consumption since power was applied to the unit. Then press the key to display the cumulative time since power was applied to the unit.

Energy consumption will be displayed in kilowatt-hours (from 0.01 KWH to 9999 KWH). Time will initially be displayed as hours:minutes (from 00:00) and then will switch to hours (to 9999). To reset, remove the power from the unit momentarily.

It is very challenging to collect enough energy data in one class period to get measurable data that is accurate. If you have time, you can set up a Kill A Watt

Meter early in the morning and leave it on during the day to see how much energy the appliance you are testing has consumed.

We recommend collecting power consumption data with the Kill A Watt and then estimating how much energy your device would consume in a day.

Energy Consumed (Day) = Watts × Hours Device is Used

480 Watt-hours (Wh) = 120 Watts × 4 hours

To make things simple for later calculations, convert watt-hours (Wh) to kilowatt hours (kWh).

$$\text{kWh} = \frac{\text{Wh}}{1000}$$

$$.48\text{kWh} = \frac{480\text{Wh}}{1000}$$

Step 5: Calculate how many kilowatt-hours the appliance uses in one year

To calculate the amount of energy an appliance or device consumes in one year, multiply the amount it uses in one day times 365. Tell students to do this calculation for the demonstration appliance or device and record the amount on their worksheet.

In the television example, 0.48 kWh per day times 365 days equals 175.2 kWh. The television consumes 175.2 kilowatt-hours in one year.

Step 6: Calculate the yearly cost of running the appliance

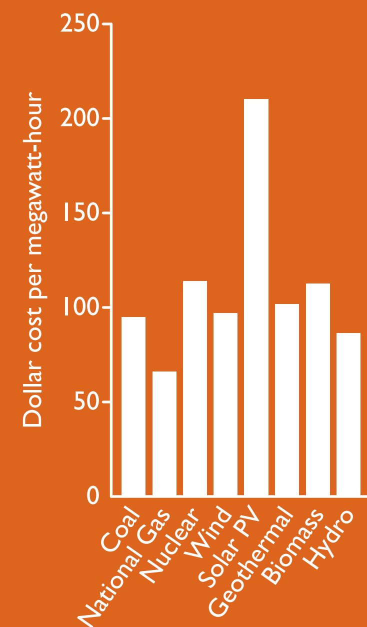
Once you have determined the number of kilowatt-hours the appliance uses in one year, you multiply this number by the amount your power company charges you for each kWh of electricity. In 2010, the national average cost of electricity was $0.10 per kilowatt-hour. Use the map on page 63 to explore energy costs and sources in your state.

The television consumes 175.2 kWh per year; 175.2 times $0.10 equals $17.52. It costs $17.52 to watch four hours of television each day for one year.

Step 7: Determine the amount of carbon dioxide (CO_2) generated in one year by the appliance

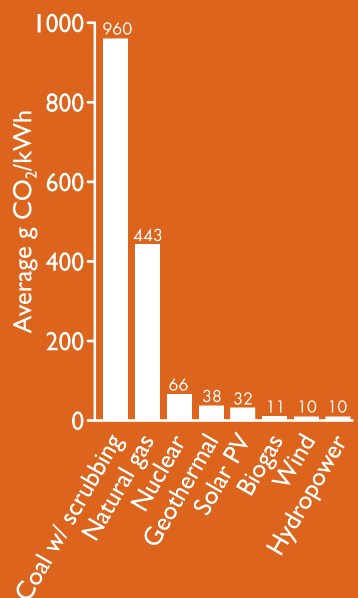
Different sources of energy are used to produce electricity. Each source produces a different amount of CO_2 emissions. Coal produces more CO_2 than any other method of generating electricity. A majority of the electricity generated in the United States comes from coal-fired power plants. The national average for all methods of generating electricity is .62 kilograms of CO_2 per kWh. To calculate the yearly amount of carbon dioxide produced by running an appliance, you multiply the number of kWh of electricity it consumes in one year by .62. Ask students to do this calculation and record the result in the seventh column of the second row. Students can use the map

ESTIMATED COST OF ELECTRICITY, 2016



Data: US EIA, "Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011"

CO_2 EMISSIONS BY SOURCE



Data: Sovacool, Benjamin K. "Valuing the greenhouse gas emissions from nuclear power: a critical survey." *Energy Policy*, Vol. 36, 2008, p. 2950.

on page 63 to determine the amount of CO_2 that each kWh produces in their state.

The television consumes 175.2 kWh per year: 175.2 times .62 equals 108.6 kilograms of carbon dioxide.

Step 8: Calculating the cost and environmental impact of light bulbs
Divide students up into three groups and ask each group to record the type of light bulb they are measuring (incandescent, compact florescent, or LED if you used these bulbs) in the first column of the third row. Tell them to complete the calculations for their bulb. If students are not confident about doing this on their own, you can do this as a classroom demo.

Step 9: Discussion of their findings
Wrap up by discussing what the students discovered. Discuss the economic and environmental costs of each bulb.

- Which type of light bulb consumed the most power? The least power?
- Which type of light bulb used the most energy in a year? The least energy?
- Which type of light bulb costs the most to operate for a year? The least?
- Which type of light bulb produced the most carbon dioxide in a year? The least carbon dioxide in a year?
- Were there any surprises?

Compare your calculations to the data on the box of light bulbs. This is a very good consumer math activity.

PART 3: ENERGY EFFICIENCY

Step 1: Introduction

- What do you think energy efficiency means? What are some examples?
- What do you think energy conservation means? What are some examples?

Step 2: Energy efficiency reading passage
Ask students to read the passage (page 65).

Step 3: Discussion
Ask students which type of light bulb is the most efficient. Ask them to explain their answer.

Remind students that all energy transformations result in waste heat; the amount of "lost" heat is not the same in each transformation. (This concept was covered in Lesson 1.) Energy efficiency is a measure of how well a device transforms or converts one form of energy to another. The less energy that is "lost," the more efficient the transformation and the more efficient the device. In the case of light bulbs, the energy transformation we're looking for is electrical energy into radiant energy (light). The incandescent bulb transforms only 10 percent of the electrical energy into radiant energy. Consequently, we say that it is only 10 percent efficient because 90 percent of the electrical energy is transformed into thermal energy (waste heat). An incandescent light bulb is not a very efficient device.

On the other hand, 65 percent of the electrical energy powering a compact florescent light bulb is transformed into radiant energy, so we say that it is 65 percent efficient because 35 percent is lost to thermal energy (waste heat). This is why many people are switching from incandescent bulbs to compact fluorescents. Compact fluorescents not only save energy; they also save us money because we need to pay a power company for the electricity we use.

LED light bulbs are approximately 80 percent efficient; only 20 percent of the energy is lost to thermal energy.

EXTENSIONS

Measuring other appliances or devices
Ask students to measure the economic and environmental costs of other appliances or devices. On the Economic and Environmental Cost of Using Appliances Activity Sheet, there are additional rows for students to record their findings. You can have some students take a Kill A Watt Meter home to measure electrical devices in their homes.

Energy vampires (phantom loads)
Energy vampires are those electronic devices that we leave in the standby mode. In order to be ready to operate at all times, the electronic device, gadget, or appliance maintains a slow, reduced draw of electricity. The device still sucks energy when turned “off”, hence the vampire reference. Even though the draw of the device is reduced, you are still paying for energy you aren’t using. The bills can add up, particularly now with the rising cost of energy.

This undesired loss of electricity also is known as phantom load and some of the biggest culprits are electronics chargers. iPods, cell phones, and digital chargers have a steady current of energy flowing at all times–even when they say they are fully charged. Additionally, your television and DVD player, computers, auto-coffee maker and cordless phones all consume energy even when they are not in use. Computers can draw 7 watts (W) and microwaves can draw 1.2 W while in standby mode. The reason for standby is convenience, but now this convenience is coming at the cost of higher energy bills!

Consider this scenario: A young, four-person family with two cell phone chargers (1.2 W), two computers plugged in (7 W each), a microwave (1.2 W), a stereo (2.5 W), a DVD player (3 W), and two televisions (3.5 W each): has a total phantom energy load of 30.1 watts. This equates to .7224 kWh of energy per day or 264 kWh a year. In dollars this adds up to approximately $60 annually at the average rate of .10/kWh. And just remember, this is a conservative estimate. Often there are more phantom energy points than just the ones mentioned here.

Even though this is a relatively small portion of your total energy bill (approximately 5 percent of your total home energy consumption), the environmental and financial savings can accumulate, especially if everyone takes action. For the entire United States, this could add up to 65 billion kWh/year, which equals $5.8 billion in savings as well as eliminating 87 billion pounds of carbon dioxide from entering the atmosphere. That's some powerful change.

VOCABULARY

carbon dioxide (CO_2) – A colorless, odorless, non-combustible greenhouse-gas that contributes to climate change.

compact florescent (CFL) – A fluorescent light bulb the size of a standard incandescent light bulb. In a CFL, electricity vaporizes mercury gas, causing it to emit radiant energy which reacts with a coating inside the bulb, transforming UV waves to visible light.

energy – The ability to do work or to cause a change.

energy conservation – Reducing the overall amount of energy used through behavioral changes eg. turning lights off or dialing down the heat.

energy efficiency – Reducing the amount of energy used through improved technology. Examples include changing incandescent light bulbs to CFLs or LEDs and swapping out older appliances with Energy Star appliances.

incandescent – A bulb that makes light by heating a metal filament wire to a high temperature until it glows.

kilowatt (kW) – 1 kW = 1000W.

kilowatt-hour (kWh) – 1 kWh = 1000Wh.

LED (Light Emitting Diode) – A semiconductor device that emits visible light when an electric current passes through it.

megawatt (MW) – 1MW = 1,000kW = 1,000,000W

megawatt-hour (MWh) – 1MWh = 1000kWh

phantom load – The electric current consumed by a device when plugged in but switched to its labeled "off" position.

power – The amount of work done in a given amount of time.

watt – The measure of power consumed by an electrical appliance or device.

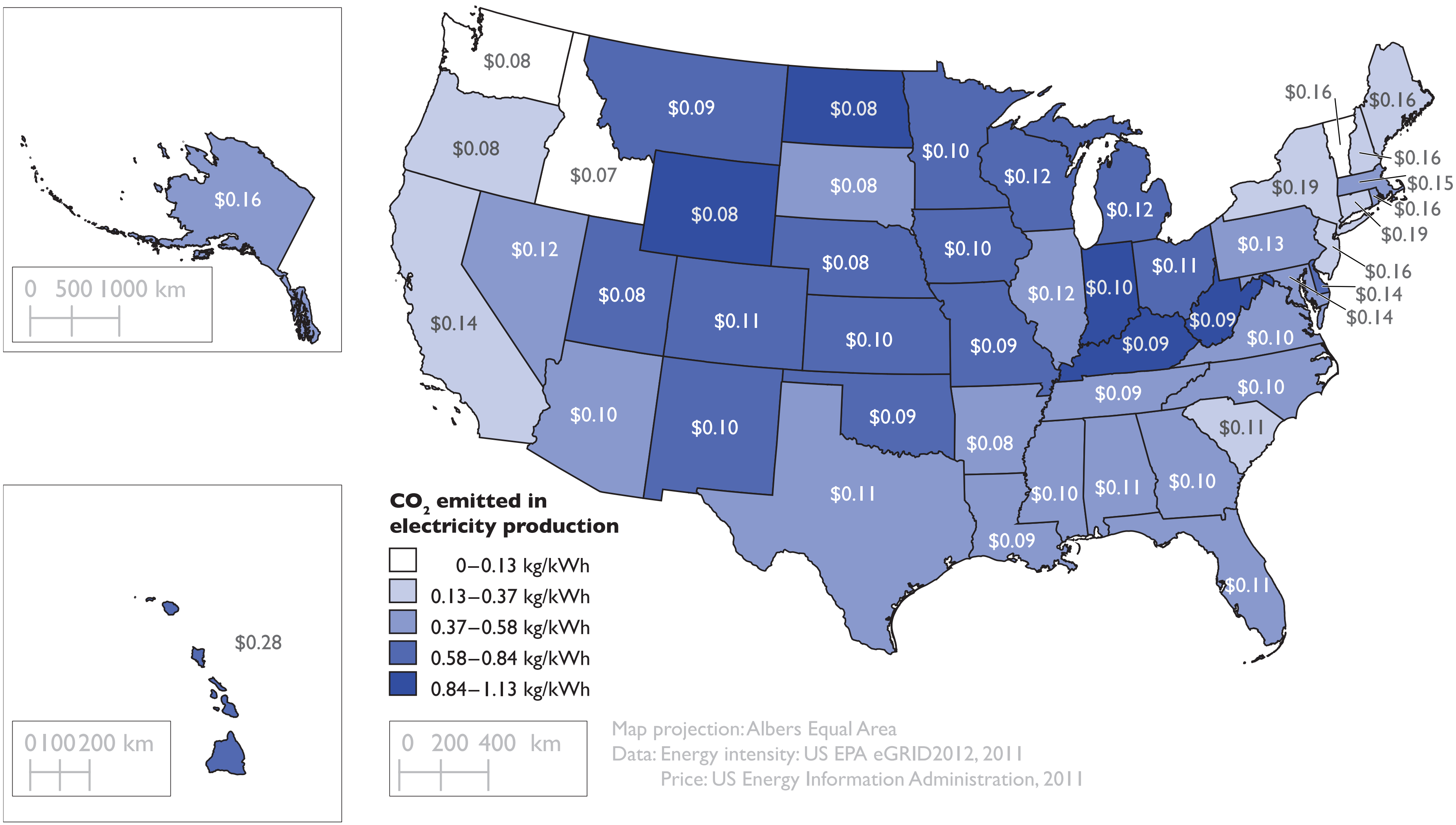
watt-hour – A unit of energy equal to 1 watt of power expended for 1 hour.

work – A measure of force times the distance through which it acts.

RELATED ACTIVITIES

- Previous Lesson 5: Can Wind Power Your Classroom?

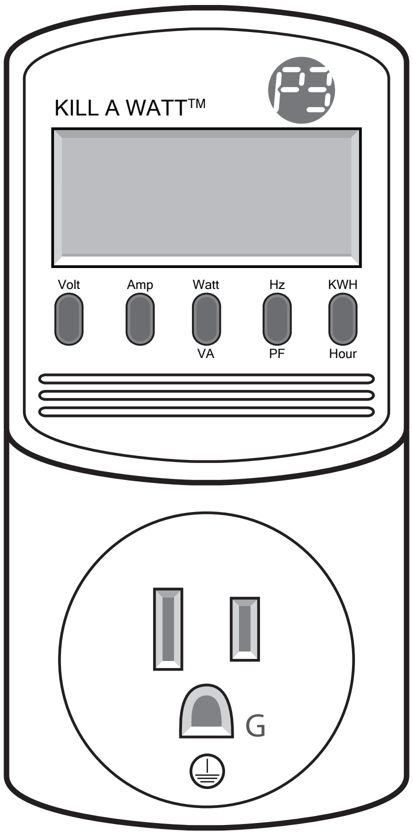
EMISSION INTENSITY AND RETAIL PRICE OF ELECTRICITY (PER KWH)



Map projection: Albers Equal Area
Data: Energy intensity: US EPA eGRID2012, 2011
Price: US Energy Information Administration, 2011

KILL A WATT METER

The Kill A Watt Meter is a device that lets you “see” how much power and/or energy an appliance in your house is using instantaneously or over a period of time. This page will help you understand some of the basic tools on this energy meter.



Directions: Plug the Kill A Watt Meter into a wall socket. Plug the device into the socket on the meter. The Watt button and KWH button are toggle switches. Make sure you have toggled each switch to make sure the readout is for watts (Watt/VA button) and kilowatt-hours (KWH/Hour button).

Volt button

When the Kill A Watt is plugged into the wall, the volt button will probably read somewhere around 120V. When you plug an appliance into the meter, it indicates the output voltage required to run your appliance.

Amp button

The AMP button will measure the flow of electric charge required to run your appliance. This value can vary greatly depending on the appliance you have plugged into the meter. When nothing is plugged in, this should read zero since no charge is flowing.

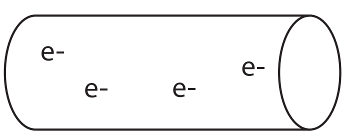
Watt button

The Watt button measures the power required to run your appliance. This is a measure of the movement of electrical energy required to make your device (blender, TV, etc.) function.

KWH

The KWH button measures the amount of energy used by your appliance.

In a water analogy, this would be equivalent to a bucket of water. It is a quantity of energy that can do a certain amount of work. If we had a lot of pressure (voltage) and a lot of water (current) moving through a hose, we could fill up the bucket very fast.

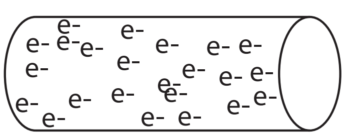


Less Current

What is current?

Current (amperage) is the flow of electric charge in a conductor.

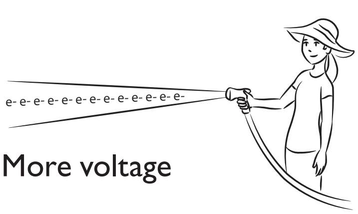
Using water as an analogy, we can think of this as the amount of water flowing through a tube. The higher the current, the more water that is moving in the tube. Low current would be similar to less water flowing in the same size tube.



More Current

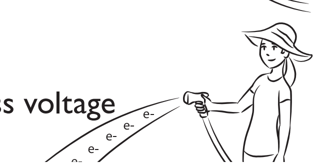
What is voltage?

A negative charge will attract a positive charge, and invisible fields of voltage exist between the charges, kind of like magnetic fields. Voltage causes the attraction between opposite charges; we can quantify this attraction with a simple multimeter.



More voltage

Using water as an analogy, we can also think of voltage like water pressure. Low voltage would resemble water under low pressure. High voltage would resemble water under high pressure. The amount of water is not so important; it is the pressure of the water that matters.



Less voltage

READING PASSAGE: ENERGY EFFICIENCY

Energy efficiency is a very broad term referring to the many different ways we can get the same amount of work (light, heat, motion, etc.) done with less energy. It covers efficient cars, energy saving lighting, improved industrial practices, better building insulation and a host of other technologies. Since saving energy and saving money often amount to the same thing, energy efficiency is highly profitable.

Efficient energy use, sometimes simply called energy efficiency, is the goal of efforts to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing compact fluorescent or LED lights reduces the amount of energy required to attain the same level of illumination compared to using traditional incandescent light bulbs. Compact fluorescent light bulbs use two-thirds less energy and may last 6 to 10 times longer than incandescent lights.

There are various motivations for improving energy efficiency. Reducing energy use reduces energy costs. Reducing energy use is also seen as a key solution to the problem of reducing harmful emissions generated by coal-burning power plants. According to the International Energy Agency, improved energy efficiency in buildings, industrial processes, and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.

Since we currently generate about half of our electricity in the United States from coal-fired power plants, the choices we make about electricity consumption have a significant impact on the amount of carbon dioxide (CO_2) released into the atmosphere. CO_2 is one of the major gases that traps heat in our atmosphere. Every kilowatt-hour (kWh) of electricity that we consume in the US—approximately $0.10 worth of electricity—generates .62 kilograms of CO_2. The amount of CO_2 per kWh changes in different parts of the country, due to the major sources of electrical energy.

STATE	KILOGRAMS CO_2 PER KWH	DOMINANT FUEL SOURCES
Alabama	0.47	coal, nuclear, gas
Alaska	0.47	gas, oil, hydro
Arizona	0.49	coal, gas, nuclear
Arkansas	0.5	coal, nuclear, gas
California	0.25	gas
Colorado	0.79	coal, gas
Connecticut	0.26	nuclear, gas
Delaware	0.81	coal, gas
Washington, DC	1.13	oil
Florida	0.54	gas, coal
Georgia	0.58	coal, nuclear
Hawaii	0.69	oil
Idaho	0.05	hydro
Illinois	0.48	nuclear, coal
Indiana	0.92	coal
Iowa	0.74	coal
Kansas	0.76	coal

Kentucky	0.93	coal
Louisiana	0.51	gas, coal
Maine	0.23	gas, hydro
Maryland	0.56	coal, nuclear
Massachusetts	0.51	gas, coal
Michigan	0.69	coal, nuclear
Minnesota	0.63	coal, nuclear
Mississippi	0.5	gas, coal, nuclear
Missouri	0.82	coal
Montana	0.65	coal, hydro
Nebraska	0.72	coal
Nevada	0.48	gas
New Hampshire	0.27	nuclear, gas
New Jersey	0.25	nuclear, gas
New Mexico	0.83	coal
New York	0.26	nuclear, gas
North Carolina	0.52	coal, nuclear
North Dakota	0.93	coal
Ohio	0.81	coal
Oklahoma	0.68	coal, gas
Oregon	0.16	hydro, gas
Pennsylvania	0.52	coal, nuclear
Rhode Island	0.41	gas
South Carolina	0.37	nuclear, coal
South Dakota	0.41	hydro, coal
Tennessee	0.49	coal, nuclear
Texas	0.56	gas, coal
Utah	0.84	coal
Vermont	0.001	nuclear, hydro
Virginia	0.45	nuclear, coal
Washington	0.13	hydro
West Virginia	0.91	coal
Wisconsin	0.69	coal, nuclear
Wyoming	0.96	coal

Energy efficiency and renewable energy, such as wind power, are said to be the twin pillars of a sustainable energy future. In many countries, energy efficiency is also seen to have a national security benefit because it can reduce the need for energy imports (i.e. petroleum and coal) from foreign countries and may slow down the rate at which domestic energy resources are depleted.

Modern energy-efficient appliances, such as refrigerators, dishwashers, and clothes washers, use significantly less energy than older appliances. Current energy-efficient refrigerators, for example, use 40 percent less energy than conventional models did in 2001.

Energy conservation is broader than energy efficiency and includes active efforts to decrease energy consumption, for example through behavioral change. Examples of conservation without efficiency include lowering the temperature on the thermometer during the winter, turning off the light(s) when leaving a room, and riding a bike or walking instead of driving a car.

CAREER PROFILE: JIM BROWN, ENERGY AUDITOR

I help people save money and protect the environment by showing them ways to save energy in their home or work. As an energy auditor, I examine how energy is being used in a building and then make energy efficiency and conservation recommendations to the people who live or work in the building. I might suggest that they buy new, more energy-efficient appliances and equipment to replace older, less efficient models. There are also lots of different conservation strategies that I tell people about.

One of the most common things that I will do in any building is to switch all of the inefficient, incandescent light bulbs to compact fluorescents or other highly efficient lighting technologies. Another lighting technology that I really like is the passive solar technology that allows the use of daylight, which means letting sunlight into the building instead of turning on electric lights. When a building is designed properly, there often is little need for lights during the daytime.

When I perform an energy audit, I use specialized tools, such as Kill A Watt Meters, blower doors, air flow meters, and infrared cameras to evaluate how much energy a building is using. Kill A Watt meters measure how much electricity an appliance uses when it is on. They are also very helpful in finding energy vampires and phantom loads—appliances that use energy even when they are turned off. My favorite tool is a blower door, which is used to depressurize a building. By forcing air out of the building with the blower door, I can then find where air is leaking into or out of a building. Air leaks can account for a large percentage of the energy used for heating and cooling a building. Infrared cameras can help me pinpoint exactly where the leaks are so that I can come up with a plan to fix them.

Energy auditing is a fun job that involves science, technology, and a good deal of problem solving. The most rewarding parts of the job is knowing that I'm doing something good for the environment and helping people save money. Growing concerns about climate change, energy security, and fuel prices mean that there's more and more work for energy auditors. It's a good career to consider.

Name________________________ Date______________ Class________

THE ECONOMIC AND ENVIRONMENTAL COST OF USING APPLIANCES ACTIVITY SHEET

State _____ Electricity cost ($/kWh) ________ State's major sources of energy____________ Emission intensity (kg of CO_2/kWh)__________

US average cost: kWh: 0.1 US average intensity: 0.62 kg of CO_2/kWh

Appliance/Device	Measured power use (W)	Time Appliance on per day (hours)	Energy used in one day (kWh)	Energy Use in a Year (kWh)	Yearly Cost (use your state energy cost)	CO_2 produced to in one year (use your state data)
Example: (20" LCD Television)	120	4 hours	480Wh = .48 kWh	.48 kWh × 365 = 175.2 kWh	175.2 kWh × $0.10 = $17.52	175.2 kWh × 0.62 kg/kWh = 240.02 kWh

Name______________________________ Date____________ Class_______

WINDWISE ENERGY EFFICIENCY ACTIVITY WORKSHEET

1. Define power (use examples):

2. Define energy (use examples):

3. Unit Conversions (Remember, 1 kW=1,000W and 1 MW=1,000,000 W)
   a. 1500 W = _________ kW
   b. 500 kW = _________W
   c. 1000 kW = _________ MW

Using data from the worksheet:

4. Which light bulb uses the most power?

5. Which light bulb uses the most energy?

6. Name one appliance that would be called an energy vampire. Why is it using energy even when it seems to be turned off?

7. How much energy would the following devices use?
   a. 15-watt compact fluorescent that is on for 10 hours: ____________Wh
   b. 60-watt incandescent bulb that is on 5 hours: ____________Wh
   c. 1200-watt oven that is used for 1.5 hours: ____________Wh

8. Which uses more energy in one month (30 days)?
   a. Energy vampire that uses 5 watts for 24 hours a day
   b. 100-watt stereo that is used for 1 hour each day
   c. 1000-watt toaster that is used for 0.1 hour each day

9. What is one way you can save energy at home through conservation?

10. What is one way you can save energy at home through efficiency?

11. Answer the following questions based on the graph at the end of the worksheet.
    a. People in what country use the most electricity per year?

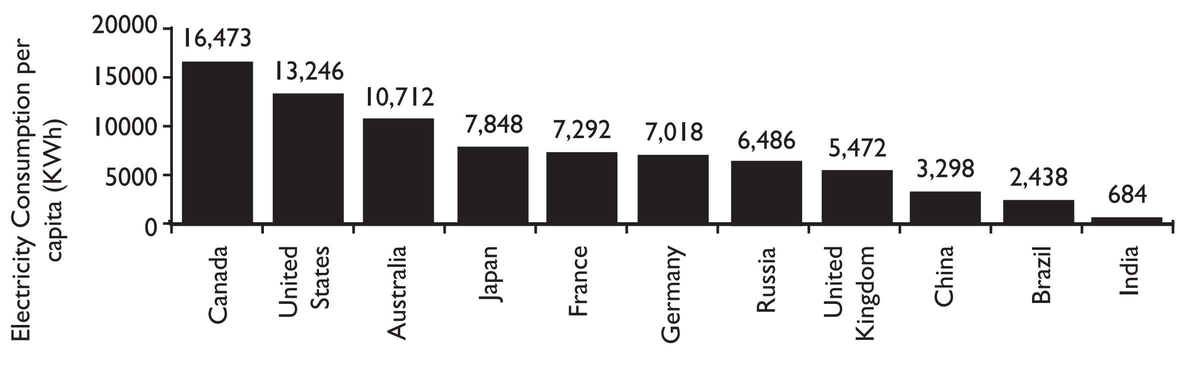
    b. People in what country use the least electricity per year?

    c. Why might there be such great differences in electricity use among different countries?

d. Do you think that people in Europe (such as France, Germany, and the United Kingdom) have a lower standard of living than people in the United States and Canada? Why?

e. How many people in India could live their daily lives using the electricity consumed by one person in the United States?

PER CAPITA ANNUAL ELECTRICITY USE, AROUND THE WORLD



(Data Source: World Bank, 2010-2014)

1. Define power (use examples)
   The amount of work done in a given amount of time. Students may have many examples.

2. Define energy (use examples)
   The ability to do work or to cause a change. Students will have many examples.

3. Unit Conversions (Remember, 1 kW=1,000 W and 1 MW=1,000,000 W)
   a. 1500 W = 1.5 kW
   b. 500 kW = 500,000 W
   c. 1000 kW = 1 MW

Using data from the worksheet:

4. Which light bulb uses the most power?
   Incandescent

5. Which light bulb uses the most energy?
   Incandescent

6. Name one appliance that would be called an energy vampire. Why is it using energy even when it seems to be turned off?
   Student observations. Any device that is consuming power when it is turned "off" can be called an energy vampire. It may be using energy to stay warm so that it can turn on quickly or may not be designed to use electricity efficiently. A few examples include: cell phone chargers, VCRs and DVD players, and TVs.

7. How much energy would the following devices use?
   a. 15-watt compact fluorescent that is on for 10 hours 150 Wh
   b. 60-watt incandescent bulb that is on for 5 hours 300 Wh
   c. 1200-watt oven that is used for 1.5 hours 1800 Wh

8. Which uses more energy in one month (30 days)?
   a. Energy Vampire that uses 5 watts for 24 hours a day 3600 Wh
   b. 100-watt stereo that is used for 1 hour each day 3000 Wh
   c. 1000-watt toaster that is used for 0.1 hour each day 3000 Wh

9. What is one way you can save energy at home through conservation?
   Possible answers include:
   Turning off lights when you are going out of the room
   Take shorter showers
   Energy conservation is changing your behavior in order to save energy.

10. What is one way you can save energy at home through efficiency?
    Possible answers include:
    Using CFL bulbs
    Installing a programable thermostat
    Installing a low-flush toilet
    Using Energy Star appliances

11. Answer the following questions based on the graph at the end of the worksheet.
    a. People in what country use the most energy per year?
    Canada

    b. People in what country use the least energy per year?
    India

c. Why might there be such great differences in energy use among different countries?
People in affluent countries generally have larger houses, more electronic devices, and they tend to waste more energy. Also people from colder climates tend to use more energy for heating and lighting during winter months.

d. Do you think that people in Europe (such as France, Germany, and the United Kingdom) have a lower standard of living than people in the United States and Canada? Why?
Student observations will vary, but generally people in Europe have lights, heat, and all the electricity they need to lead very modern lives. It is all about doing the same with less and improving efficiency. One place to read more about how much energy we could save and still lead very modern lives is at the Rocky Mountain Institute (www.rmi.org/rmi) or American Council for an Energy Efficient Economy (www.aceee.org).

e. How many people in India could live their daily lives using the energy consumed by one person from the United States?
Approximately 26 people. In the US, the average person consumes 13515 kWh of energy each year. In India, the average person consumes 503 kWh of energy per year.

$$\frac{\text{US } 13515 \text{ kWh}}{\text{India } 503 \text{ kWh}} = 26.87$$

UNIT 2: WIND

WHAT CAUSES WIND?

LESSON 4

KEY CONCEPT

Students learn about the forces that cause wind and how to measure these changes in the atmosphere.

TIME REQUIRED

3–4 class periods

GRADES

6–8

SUBJECTS

Physical Science
Social Studies
Earth Science

KidWind PROJECT®

www.KidWind.org

BACKGROUND

The horizontal movement of air, also called wind, is driven by two primary factors: differences in pressure caused by the unequal heating of the Earth's surface and the rotation of the Earth. The factors that cause wind can be measured and are the basic elements of a daily weather forecast. Students also explore how measurements can be made with instruments such as barometers and thermometers.

OBJECTIVES

At the end of the lesson, students will:

- understand the relationship between temperature and pressure in the context of the gases in the atmosphere
- understand the forces that cause wind
- be able to explain how pressure of a fluid changes with speed

METHOD

Through observing a series of demonstrations and participating in hands-on activities, students learn about the relationship between temperature, pressure, and wind speed. On the molecular level, students describe what causes pressure, as well as, changes in pressure. Students then relate these concepts to topography and larger scale weather patterns.

MATERIALS

Hardboiled Egg Pushed into a Bottle

- ❑ Bottle with opening just smaller than the egg. (Iced coffee bottles work well.)
- ❑ Peeled hardboiled egg
- ❑ Matches
- ❑ Small piece of paper

Crushing a Soda Can

- ❑ Soda can
- ❑ Hot plate
- ❑ Tray
- ❑ Tongs

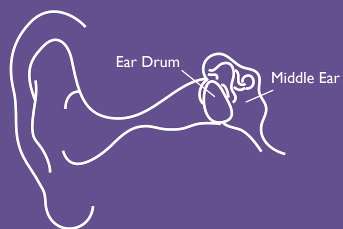
Moving a Table

- ❑ Table
- ❑ Large garbage bag
- ❑ Straws

Unequal Air Pressures

- ❑ 12–18" of clear plastic tubing
- ❑ Balloons that fit tightly over the tubing or over stoppers forced into tubing
- ❑ Clamp

EAR POPPING



Ears "pop" when there is an imbalance between the pressure inside and outside the ear. Airplanes are designed to maintain an air pressure in the cabin that is similar to that of the air on the ground. When the air pressure in the cabin changes, however, an internal blockage such as mucus can prevent equalization of pressure on each side of the ear drum. As a result, the ear drum is pushed in or out, creating a "popping" sensation.

Build a Barometer (1 set for each barometer)
- ❑ Straight sided glass jar (over 6" tall) with screw top lid
- ❑ Narrow plastic 6" ruler
- ❑ Clear tape
- ❑ 9" of clear plastic tubing
- ❑ Water
- ❑ Red food coloring
- ❑ Small clamp

Other Materials
- ❑ Paper
- ❑ Student reading passages and student worksheets*
- ❑ Soda Bottles
- ❑ Barometer (optional)

* included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

GETTING READY

- Study the reading passage to become familiar with the relationship between temperature and pressure and how wind is generated.
- Collect materials for demonstrations.
- Try all demonstrations ahead of time to ensure they are working correctly.
- Make copies of the worksheets for each student.
- Assign the reading passage for homework if desired.

ACTIVITY

What are wind, air, and air pressure?
If students have not read the reading passage, ask them to do so at this time.

Start a discussion to see how much your students already know about these concepts. Here are some questions to get the conversation started:
- What is the fastest wind you have ever experienced?
- Has the wind pushed you around?
- What is air/wind comprised of?
- What do you think causes wind?
- Why does a hot air balloon rise and then drift with the wind?
- Why is it windy sometimes and calm at other times?
- Have you noticed wind is more likely to blow during the day and be calm during the night? Why is that?
- Have you ever had your ears pop? Why do you think this happens?
- What is air pressure?
- How do you measure changes in air pressure?
- Why does air pressure change?

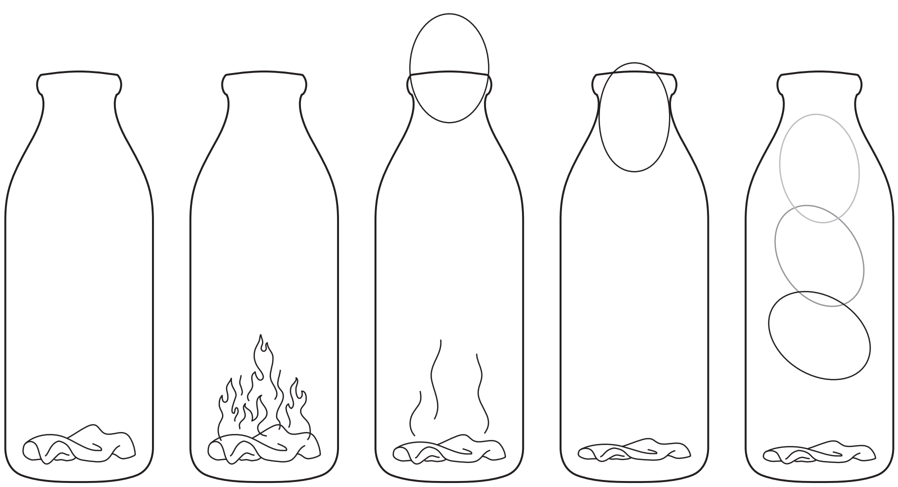
Students will have had a variety of experiences with wind and air pressure. If possible, let them discuss their concepts among themselves for 10 minutes or longer. Once the conversation has concluded, you can begin performing the demonstrations. The demonstrations are designed to be confusing and to force students to think about what may be happening. It can be helpful to ask students to predict what will happen in each experiment before you do them. It is up to you how much you tell the students what is going on in each demonstration. It can help to ask students to draw each demonstration as it is happening and to ask them to explain what they think is occurring. Prompt them to focus on what is going on at the molecular level and what air is comprised of at the molecular level.

For each of the following demonstrations, students should make a drawing to use in answering the questions in Step 1. Each of the demonstrations illustrates one of three important points. Make sure that students think about these as you perform each one:

- When air is heated it expands, causing a drop in air pressure
- Unequal pressures exert forces (Force = Pressure × Area)
- Areas of high pressure push toward areas of low pressure

DEMONSTRATION 1: EGG IN A BOTTLE

Where is this air pressure? I don't see it or feel it!
Light the small piece of paper with a match and drop it into the glass bottle. If the paper stays lit for a few seconds, immediately place the narrow end of a peeled hard-boiled egg over the mouth of the bottle so that it seals the opening.



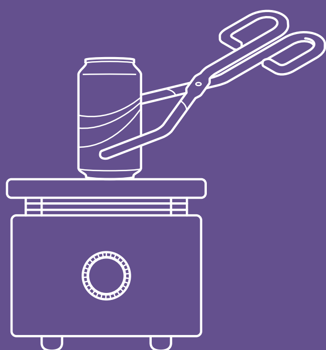
Observe what happens and discuss this with the students.

Discussion: As the air is heated, it begins to "expand," increasing the space between the air molecules. This happens because air molecules become energized when heated and move around faster, taking up more space. This expansion causes some air to escape from the bottle, which may make the egg

ALTERNATIVE EGG DEMO

If you can't use fire for some reason, you can also do the demonstration with the bottle and egg using hot water. Add hot water into the glass bottle and leave for a few seconds to thoroughly warm up the glass, then discard the hot water. Immediately place the narrow end of a peeled hard-boiled egg over the mouth of the bottle so that it seals the opening. Observe what happens and discuss this with the students.

CRUSH A CAN WITH AIR PRESSURE



wobble when it is first put on top of the bottle. As the air inside the bottle cools, the air "contracts" or the space between the air molecules decreases. The egg creates a temporary seal over the top of the bottle. There is less air inside the bottle (remember some of the air escaped when the air expanded), causing unequal pressures to occur between the air in the bottle and the air outside the bottle. The greater air pressure on the outside pushes the egg into the bottle, equalizing air pressure inside and outside the bottle.

Challenge: How can you remove the egg from the bottle without breaking it? Hint: Invert the bottle with the narrow end of the egg in the throat of the bottle, bring the bottle up to your lips, and blow hard. The egg will be forced into your mouth.

DEMONSTRATION 2: CRUSH A CAN WITH AIR PRESSURE

Pour a small amount of water into a soda can and place the soda can on a hot plate. After the water boils for a few minutes, invert the can into a tray of water, using a pair of tongs or some wet paper towels. Instantly, the can will be crushed by the air pressure in the room.

Discussion: As in the egg experiment, when we heat the water in the soda can, the space between the air molecules increases, forcing some of the air molecules out of the container. Newly formed water vapor molecules also push some of the air molecules out. When the heated air and water vapor molecules are quickly cooled, the pressure inside the can is lower than the pressure outside. This pressure difference causes the can to be crushed very quickly. Try to record with a video camera so you can replay and watch in slow motion. You will need a high-speed camera as this happens very quickly.

DEMONSTRATION 3: MOVING A TABLE

You can use a resealable zipper bag, a straw, and a large book to show students that air can move heavy objects. Place a large book on a zipper bag that has been sealed and that has a straw coming out of it. Ask students to move the book with air by blowing into the bag.

For a larger demo, tie off a large trash bag so that is it airtight and place it on a table. Invert a second table and place it on top of the trash bag. Poke a number of small holes in the bag just large enough so a straw can be inserted into each hole. Ask for volunteers to try to move the second table by blowing air into the bag.

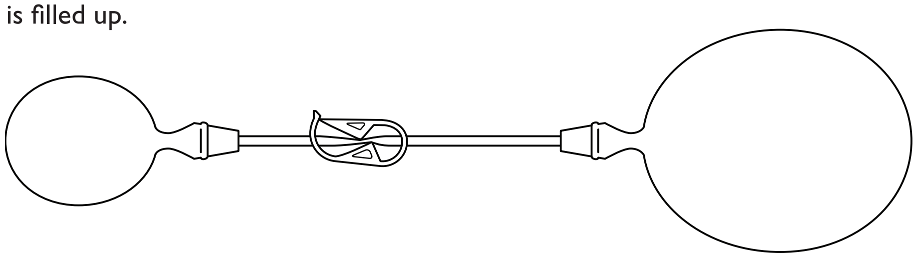
Discussion: The students will be able to force some air molecules into the bags because the air pressure in their lungs is greater than in the classroom and bag. After many puffs, their higher air pressure will exert a force on the bag great enough to lift the book or the table.

UNEQUAL AIR PRESSURE

Step 1. Why does air move?
Attach one balloon to the plastic tubing or rubber stopper. Blow up the balloon to about ¾ of its volume. Clamp the middle of the tubing or fold it over a few times and squeeze hard so the balloon maintains it volume. Blow up the second identical balloon to a very small size and attach it to the other end of the tubing. After asking the students to predict what will happen to the balloons, release the clamp and observe the results.

Discussion: What should happen when you release the clamp is the small balloon inflates the large balloon. Not what you expected, right!? All of us remember that it is much harder to start blowing up a balloon when it is new. We also when know that when we add an extra puff of air to a balloon that is full, many times it pops!

The plastic balloon material is relatively thick when you start to blow it up and becomes thinner as the balloon inflates. This material can eventually become so thin that the inside air pressure eventually pops the membrane. In this demo, the air in a small balloon is under higher pressure than the balloon that is filled up.



Step 2: How does moving air affect pressure?
Quick definition—Bernoulli's principle states that an increase in the speed of the fluid (liquid or gas) occurs simultaneously with a decrease in pressure.

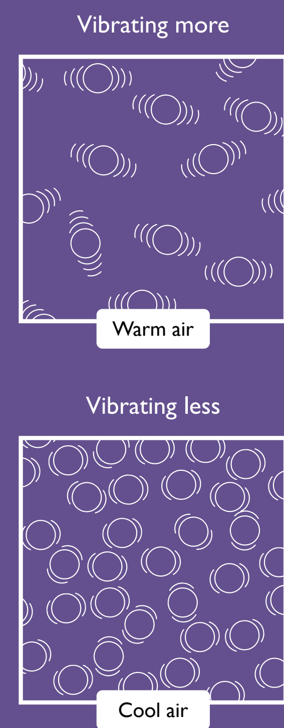
Hold a sheet of 8½ × 11 piece of paper by two corners. Ask the students what will happen when air from your lungs is blown across the bottom of a piece of paper. The usual answer is that the "paper should rise".

Follow up with a similar question, but this time tell the class that the air is blown across the top of the paper. When you do this the paper should also rise. Strange right?

When the air moves faster across the top side of the paper, it exerts less pressure on that side of the page. On the bottom side of the paper, the normal air pressure is still 14.7 pounds per square inch; hence the pressure difference will force the paper up. Again the direction is from high pressure to areas of low pressure.

Place two large plastic soda bottles (2 or 3 liter size) on the lecture table about an inch apart and ask the students to predict what will happen when air is blown through a straw between the two bottles. The bottles should roll together because you have created a low-pressure space in between the bottles i.e., Bernoulli's principle.

AIR MOLECULES



Step 3: Build a barometer (demonstration or hands-on activity)
Now that students understand that air exerts a force caused by differences in pressure, which can be caused by changes in temperature, have them build a simple barometer to show how pressure is measured. Show students a real barometer or download an image from the Internet (see Additional Resources).

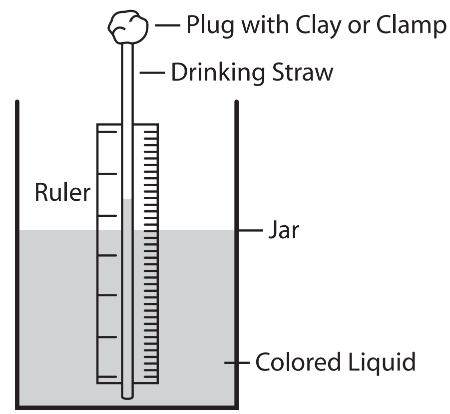


Figure 1: A Simple Barometer

Tape the tube to the ruler and then tape the ruler to the inside of the glass container.

Position the ruler and tube so that the bottom of the tube is clear of the bottom of the container, the top of the tube is above the top of the container, and the top of the ruler is inside the container. Cut the top off the ruler if necessary (see Figure 1).

Fill the container halfway with water and add some food coloring to make observation easier. Draw some water up the tube by inhaling on the straw, seal the top first with your finger, and then quickly seal the top with clay (or a clamp) so that the column of water in the tube is clearly higher than the level in the container.

If air pressure increases, the level of the fluid in the tube will go up. If the air pressure decreases, the level will fall. The change can be measured against the ruler in inches.

Discussion: Inches, centimeters, and millimeters of water or mercury are some of the many units that can be used to measure pressure. A standard barometer is a thin tube over 30 inches long. Normal air pressure, at sea level, is 29.92 inches of mercury or 760 mm of mercury. Normal air pressure can also be expressed as 14.7 pounds per square inch (14.7 psi). For example, a strong hurricane may have pressure as low as 27 inches of mercury.

Tell students to observe their homemade barometer each class period during the next week or two to see what changes take place. Relate the changes to the type of weather outside and see if you can find any patterns. What is the weather or wind speed like when the barometer is "low" or when it is "high"? Typically, low-pressure readings indicate unsettled weather of some kind, while high-pressure readings will be present with nice weather. Tell students to watch the local weather report, or head to the Internet and record barometric pressure for your area and say how it relates to their barometer.

Step 4: Volume, molecules, equilibrium, and pressure
As you do each demonstration, you should make sure that students create a drawing in their notes. Spend a few minutes using these drawings to explore the following concepts:

- Temperature can cause a pressure change at the molecular level.
- Air moves from regions of high pressure to regions of low pressure.
- Pressure differences generate a force which caused the air to move
- Moving air can cause a change in pressure

Step 5: How do these demos apply to wind and weather?
Refocus on the air pressure/air temperature egg demonstration for a minute. An increase in temperature adds kinetic energy to gas molecules in the air, which causes them to move about faster. This action creates more collisions, which cause molecules of gases in the air to move farther apart (expansion). In the confines of a bottle, the only way out is up and out through the mouth of the bottle.

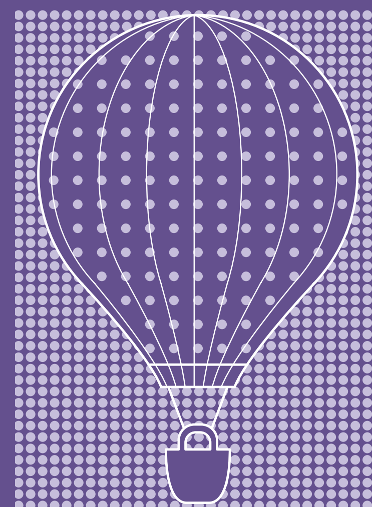
When air warms in the atmosphere, similar principles apply. When the air is heated by the sun, molecules move farther apart, creating a less dense fluid and an area of low pressure. Air from higher-pressure areas will move towards areas of lower pressure to replace the rising air. This is known as wind. Areas with more intense heating will more actively rise, creating stronger winds.

Ask students to study worksheet diagrams 1 and 2 and complete the questions.

EXTENSION: HOW DOES A HOT AIR BALLOON WORK?

A hot air balloon has gas heaters to heat the air inside the balloon. As the air is heated, the air molecules begin to move faster which causes them to move farther apart. As they move farther apart, the overall density of the air in the balloon becomes less than the density of the air outside the balloon. The balloon begins to rise because the less dense hot air lifts the balloon and "floats" on top of the denser, cooler air around it. To bring the balloon down, some of the hot air is let out in openings at the top and cooler air is brought in through the bottom (the heat is turned off). This increases the density of the balloon and causes it to descend.

Make your own hot air balloon
This project can be effective in helping students understand heat, air displacement, buoyancy and causes of wind. It works best indoors, but do this in a room without smoke detectors and with cement or tile floors.



Heating air causes it to expand and become less dense.

⚠ CAUTION!

Students will be using plastic bags and small candles. They must be very careful *not* to let the candle burn the plastic bags they are using as the hot air balloon.

Materials needed (each balloon):

- ❑ 28" long, lightweight garbage bags (the kind custodians place in classroom garbage cans). 24" inch long bags tend to melt too easily.
- ❑ 3 small birthday candles
- ❑ 5" square piece of aluminum foil
- ❑ 4–6 soda straws (straight kind)
- ❑ Lightweight string

Procedure

See student sheet (page 92).

VOCABULARY

barometer – An instrument used to measure atmospheric pressure.

pressure (in the atmosphere) – The weight of air pushing down on each square inch of the Earth's surface.

thermometer – An instrument used to measure temperature.

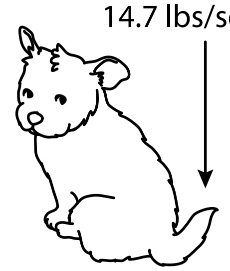
topography – The study and mapping of the shape of surface features of the Earth such as mountains, valleys, rivers and lakes

RELATED ACTIVITIES

- Lesson 5: Where Is It Windy?

READING PASSAGE

The common definition of wind is that it is air flowing from high pressure to low pressure.



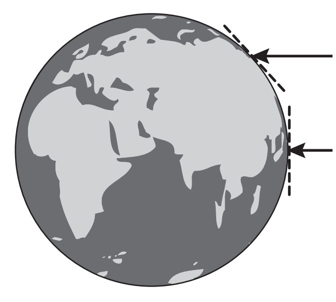
A column of air, one square inch in cross section, measured from sea level to the top of the atmosphere would weigh approximately 14.7 pounds. If you think about how many square inches your body has, that is a lot of weight! Why don't we feel it?

What causes differences in pressure? The closer air is to the ground, the more pressure it is under because air above pushes down on air below. Air is made of gas molecules, which have weight, and it is this weight that causes pressure. A 1 square inch column of atmospheric air pushing down creates approximately 14.7 pounds of pressure at sea level. At higher altitudes, the pressure is less simply due to the fact that there are fewer air molecules above.

Pressure varies in different places and at different times of the day because of the way energy from the sun is distributed. As the Sun's rays hit the Earth, land, water, and vegetation absorb the energy, some of which is given off as heat, which then heats the surrounding air. When air molecules heat up, they vibrate more and move farther apart as they collide with each other more often. This causes them to increase the amount of space (volume) they take up. When air molecules cool down, they come closer together, taking up less space (volume). As the volume of the air molecules increases, the density decreases. Conversely, as the volume of the air molecules decreases, the density increases. This change in the air density causes it to move. Denser, cooled air will fall, and less dense, heated air will rise. As air rises and falls in different places, it creates differences in pressure. Air moves from areas of higher pressure to areas of lower pressure and creates wind.

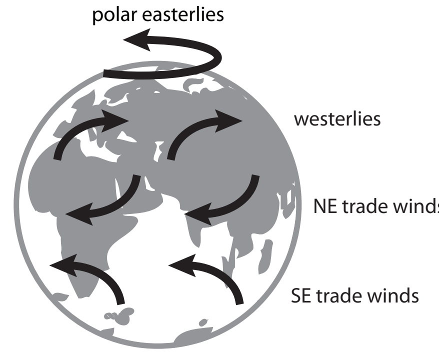
The Earth's spherical shape, topography, vegetation, and water bodies all ensure that every part of the Earth receives different amounts of energy. There will be differences in air pressure due to different temperatures, causing variation in the amount of air rising and falling and therefore variation in wind velocity and direction. For example, sea water heats more slowly than land, creating a major difference in pressure between land masses and oceans. Friction with the ground surface is also a factor, especially where mountain ranges create barriers to wind.

Differences in pressure represent part of the explanation of what causes wind. The second part is related to the Earth's rotation. As the world turns from west to east, the atmosphere turns, too, and in the same general direction. It is for this reason that the prevailing winds in most places blow from a westerly direction generally toward the east. Different levels of air in the atmosphere are affected differently by the Earth's rotation. Air high up in the atmosphere is not affected as much as air below, setting up a situation where air can flow in opposite directions at different altitudes. (You may have seen clouds moving in different directions at different heights.)



The Sun hits the Earth at different angles in different places. This creates uneven heating.

Latitude affects how much solar radiation is received each day. Tropical latitudes receive direct warming from the sun, whereas "high latitudes" (toward either pole) receive solar energy at an oblique angle due to the curvature of the Earth. Tropical latitudes, therefore, warm more easily than high latitudes and so there is a fairly constant rising of air away from the tropics (low pressure), which causes air from surrounding areas to move toward the tropics. Sailors call this constant air flow the "trade winds," which are very reliable.



Trade Winds

Land, water, topography, and the types of vegetation affect how much sunlight is absorbed and reflected. Snow cover plays a major role by reflecting back into space most of the solar radiation it receives. This creates cool air over the extreme northern and southern latitudes as well as over extensive mountain ranges. Cool air is denser than warm air and sinks to the surface, creating large areas of high pressure. This sets up many of the winter storms experienced in northern states such as New York when cold arctic air spreads south due to this high pressure.

Another concept related to wind formation is the Coriolis effect. Large masses of moving air, such as those described above, are pulled into circular rotation due to the Earth's rotation. Instead of air moving in direct lines from high pressure areas to low pressure areas, it is bent into curves. In the northern hemisphere, this causes air to flow clockwise around high pressure areas (anti-cyclones) and counter-clockwise around low pressure areas (cyclones). Severe storms are cyclones with very low pressure. These flows are reversed in the southern hemisphere.


Coriolis Effect

Since differential temperature is the major factor that affects pressure, it is common for large areas of warm air (originating from closer to the equator) to come into close proximity with large areas of cooler air (usually originating closer to the poles). Warm and cold air masses do not readily mix, and where they meet the cold air will push under the warm air, forming a "front." A front can create windy and rainy weather, sometimes with thunderstorms and tornadoes.

This reading passage was adapted from material found on two websites:

- "Exploring What Causes Wind." Robert Leverton. http://learn.kidwind.org/windwise
- "Weather Dudes." http://learn.kidwind.org/windwise

CAREER PROFILE: BILL QUINLAN, METEOROLOGIST

I joined the WCJB TV20 Weather Team in Gainesville, Florida, in 1996. I present the weather at 5:30, 6:00, and 11:00 pm weeknights and oversee the WCJB TV20 weather staff and severe weather coverage for the station. I love weather and am happy that I have a career that allows me to study the weather every day. I love to explain complex weather phenomena to television audiences.

To become a meteorologist, you need to study weather in college. To present weather forecasts on television, it also helps to study mass media. My qualifications include a bachelor's degree in meteorology from the University of Massachusetts and also a Certificate in Broadcast Meteorology from Mississippi State University.

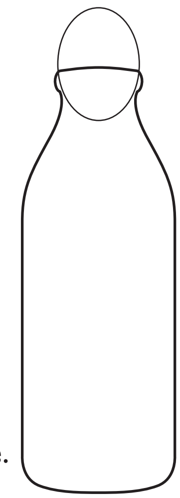
I have been awarded Seals of Approval by both the National Weather Association and the American Meteorological Society. I also present lectures to numerous organizations, including civic groups, schools, and retirement communities in North Florida, where I live with my wife and son.

Name______________________________ Date____________ Class_______

WHAT CAUSES WIND?

Relationship between temperature and pressure

1. What happened to the egg on top of the bottle you were observing?



2. Why did this happen?

3. On the drawing, label pressure areas just before the egg moves into the bottle.

Bag Experiment

4. Could you blow the bag up when it was under the book?

5. Why or why not?

Two Balloon Experiment

6. Why is it hard to blow up a new balloon?

7. When a balloon breaks, do you think the balloon material is very thin or thick?

8. Why does a small balloon always blow up an identical large balloon?

Build a Barometer Experiment

9. In terms of differences in air pressure, explain what happens to the barometer from one day to the next day.

10. A column of air, one square inch in cross section, measured from sea level to the top of the atmosphere would weigh approximately 14.7 pounds. If you think about how many square inches your body has, that is a lot of weight! Why don't we feel it?

Bernoulli's Principle Experiments

11. Why did the paper rise when air was blown across the top of it?

12. State Bernoulli's principle in your own words.

Air Can Exert a Force

13. Land and water heat and cool at different rates. Land heats and cools much faster than water. In coastal areas and areas near large lakes, this phenomenon causes the direction of winds to change at different times of the day and night. Based on what you now know about the relationship between temperature and pressure and how this creates conditions for wind, *circle the correct word in the sentences below and then draw arrows on the diagrams to show which ways the wind will blow.*

    a. On sunny days, in the morning, the Sun heats the land more quickly than it heats the nearby ocean. Because of this, the air over the land will **rise / fall** and the pressure over the land will **increase / decrease**. Because of this, the wind will blow **toward / away from** the ocean and **toward / away from** the land.

On Diagram 1 below, draw in arrows to show where air is rising and falling and in which direction the wind will flow.

INDICATE THE WIND DIRECTION
Label high & low pressure areas

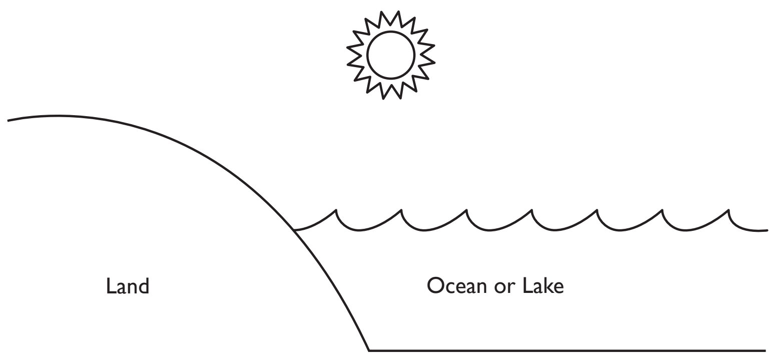


Diagram 1: 11am on a sunny day

    b. In the evening, when the sun goes down, the land will cool down, which cools the air above it. Because of this, the air over the land will **rise / fall** and the pressure over the land will **increase / decrease**. Because of this, the wind will blow **toward / away from** the ocean and **toward / away from** the land.

On Diagram 2 below, draw in arrows to show where air is rising and falling and in which direction the wind will flow.

INDICATE THE WIND DIRECTION
Label high & low pressure areas

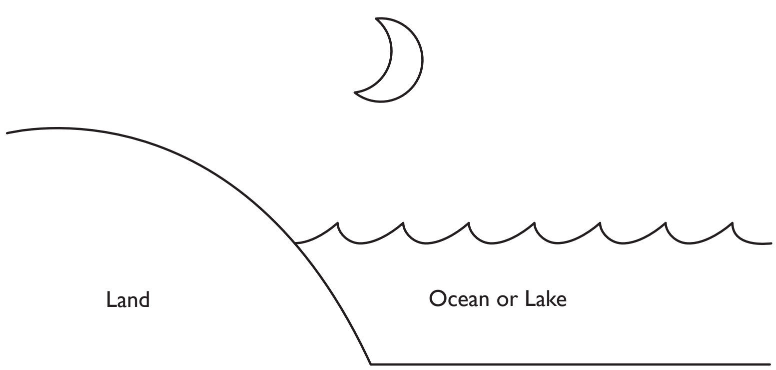
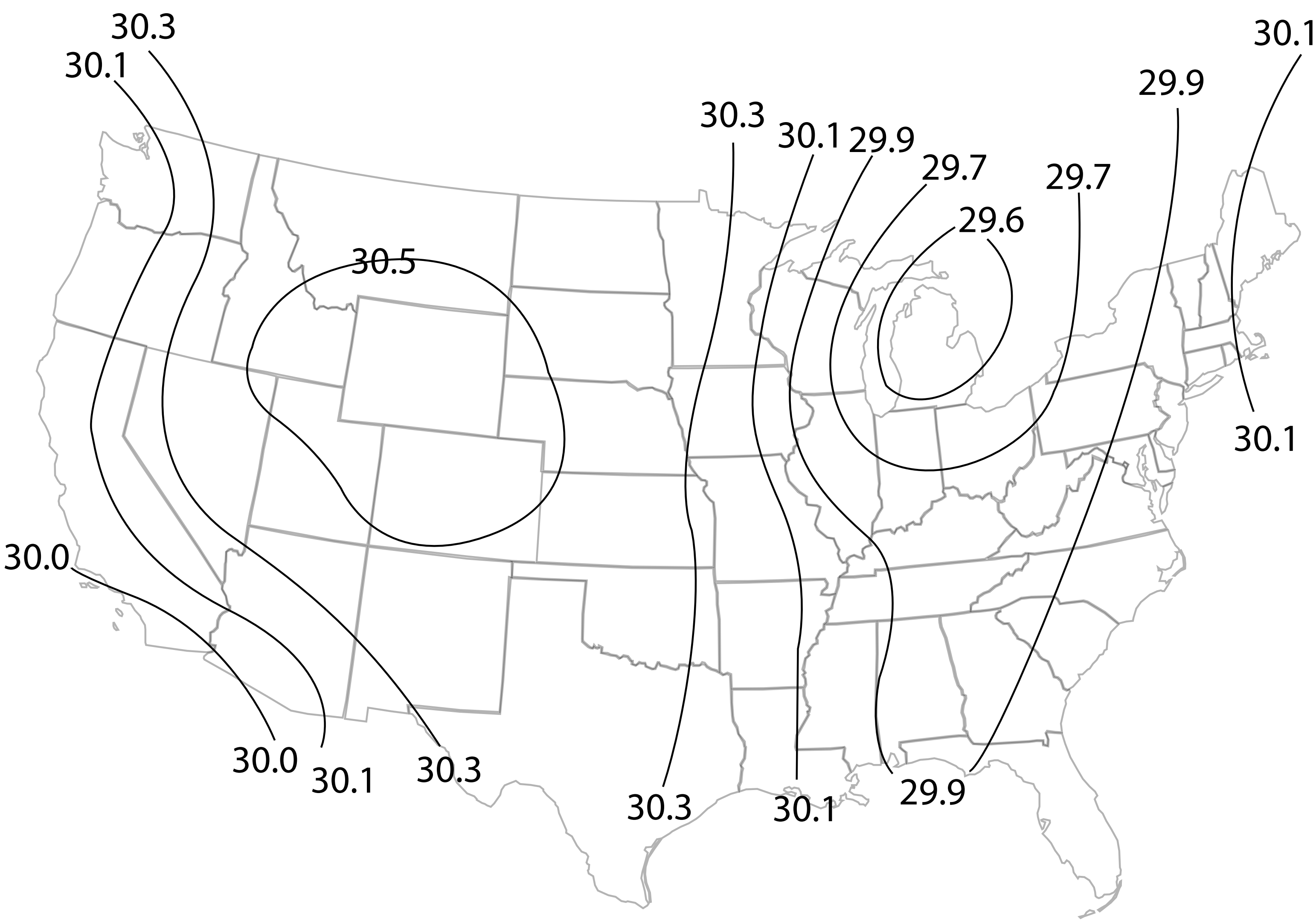


Diagram 2. 11pm on a clear moonlit night

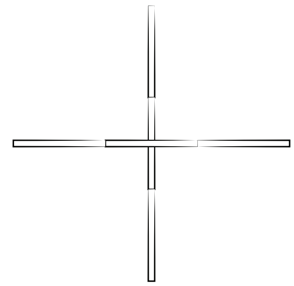
Label the map with High and Low Pressure. Where is air rising? Falling?

Optional: go online to find air pressure maps. What is the barometric pressure at your school?



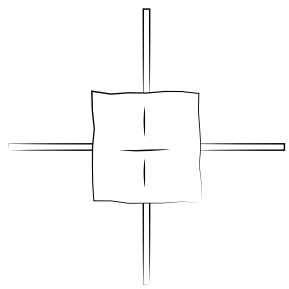
EXTENSION: HOW DOES A HOT AIR BALLOON WORK?

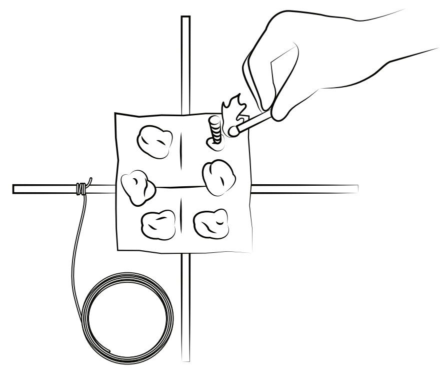
A hot air balloon has gas heaters to heat the air inside the balloon. As the air is heated, the air molecules begin to move faster which causes them to move farther apart. As they move farther apart, the overall density of the air in the balloon becomes less than the density of the air outside the balloon. The balloon begins to rise because the less dense hot air lifts the balloon and "floats" on top of the denser, cooler air around it. To bring the balloon down, some of the hot air is let out in openings at the top and cooler air is brought in through the bottom (the heat is turned off). This increases the density of the balloon and causes it to descend.



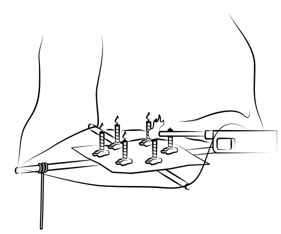
Procedure

1. Measure the diameter of the opening to the garbage bag. Multiply that number by .75 to find how long to make the straws for the base. Example: if the opening is 24 inches, then the straws need to be 18 inches long.
2. Make a straw base by making a ½ inch slit in one end of a straw and inserting that end in the end of another straw. Continue until you reach the length calculated above. Repeat for the second straw.
3. Form a cross with two straws so that the two straws form right angles. Tape the two straws together using a small amount of tape.
4. Attach the 5-inch square piece of aluminum foil in the center of the base by taping it to the four straws.





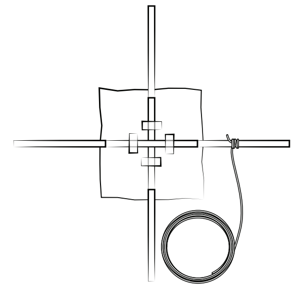
5. Cut the birthday candles in half and attach the six pieces to the foil.
6. Insert the base into the opening of the bag. Have a partner hold the top of the bag while you tape the bottom of the bag to each end of the four straws.



⚠ CAUTION!

You will be using plastic bags and small candles. You must be very careful *not* to let the candle burn the plastic bags you are using as the hot air balloon.

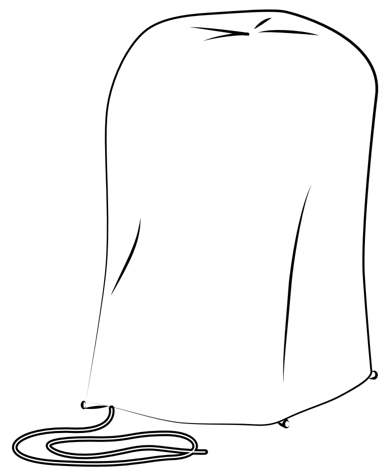
7. Attach a lightweight string to one of the straws

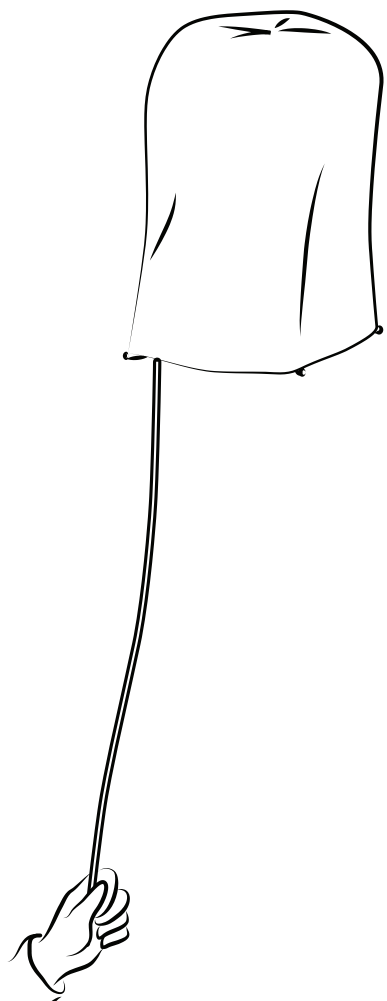


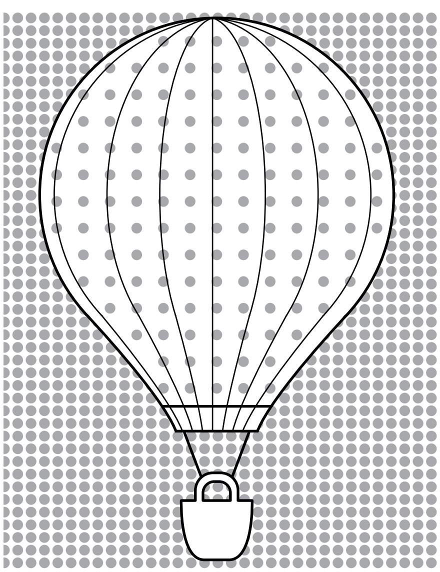
8. While your partner holds the completed balloon vertically, carefully light the six candles. (Fireplace lighters work, but keep the flame away from the bag.)
9. Continue to hold the bag vertically as it fills with hot air.
10. Once the bag is fully filled, gently set it down on the floor. It should remain fully extended while on the floor.
11. In a few minutes, the bag will begin to rise. Use the string to keep it at a desired height. If it fails to rise after a few minutes, check to see if all the candles are lit.

It will stay up until the candles burn out (4 to 5 minutes) and then sink slowly.

The balloon rises because the air in the bag is displaced. As the hot air rises, cooler air comes in to replace the displaced air and we have wind.





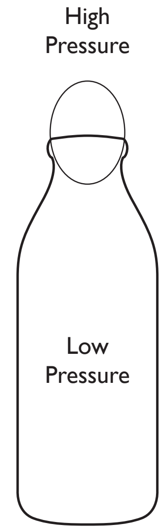


Heating air causes it to expand and become less dense.

Hard question
If you know the volume and mass of the balloon, you can determine how much air you need to displace to lift a given mass. Using this number, students can calculate the size of the bag that could lift a member of the class.

WHAT CAUSES WIND

Relationship between Temperature and Pressure



1. What happened to the egg on top of the bottle you were observing?

   Student observation

2&3. Why did this happen? Label pressure areas on the drawing.

Heat inside the bottle warmed the air, causing it to expand (molecules farther apart) and escape, which created lower pressure inside the bottle. The egg then blocked the entrance, causing a barrier to form between the higher pressure outside the bottle and the lower pressure inside. As the air inside the bottle cooled, the air contracted (molecules now closer together) and the higher pressure air from outside pushed the egg into the bottle.

Label the diagram with "Lower Pressure" on the inside of the bottle and "Higher Pressure" on the outside above the egg.

Bag Experiment

4. Could you blow the bag up when it was under a book?

   Student observation

5. Why or why not?

   Explanation: As the bag is blown up, it inflates due to higher pressure introduced inside. This higher pressure exerts a force that can lift objects, such as books.

Air Can Exert a Force

13. a. On sunny days, the Sun heats the land in the morning more quickly than it heats the nearby ocean. Because of this, the air over the land will **rise / fall** and the pressure over the land will **increase / decrease**. Because of this, the wind will blow **toward / away** from the ocean and **toward / away** from the land.

On Diagram 1 below, draw in arrows to show where air is rising and falling and in which direction the wind will flow.

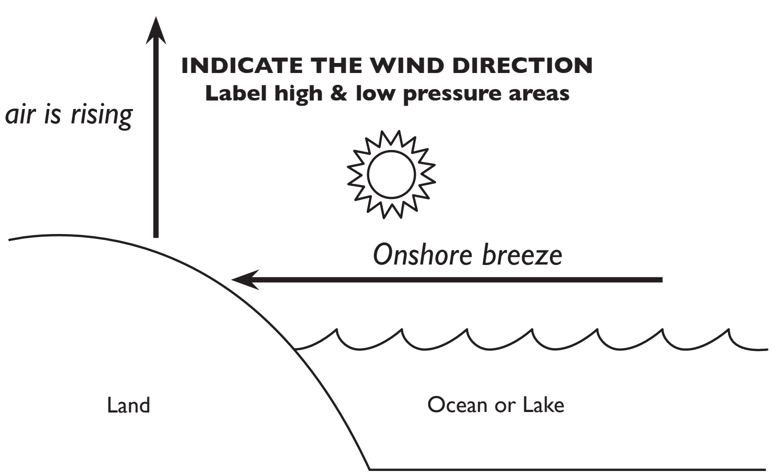


Diagram 1: 11am on a sunny day

b. In the evening, when the sun goes down, the land cools down which cools the air above it. Because of this, the air over the land will **rise / fall** and the pressure over the land will **increase / decrease**. Because of this, the wind will blow **toward / away** from the ocean and **toward / away** from the land.

On Diagram 2 below, draw in arrows to show where air is rising and falling and in which direction the wind will flow.

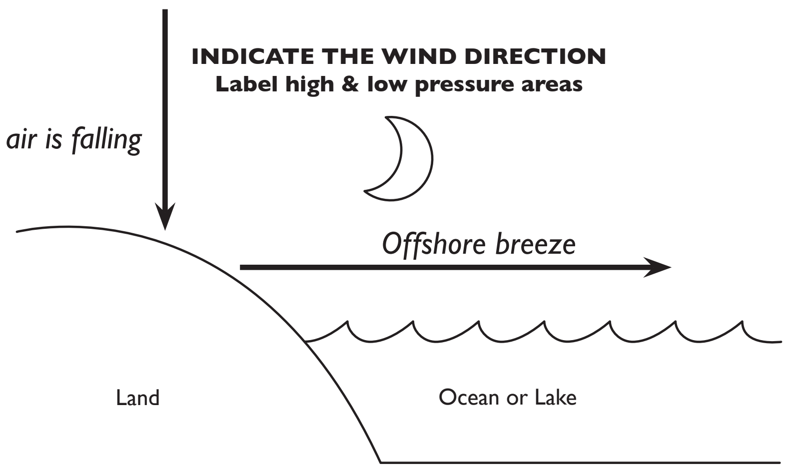
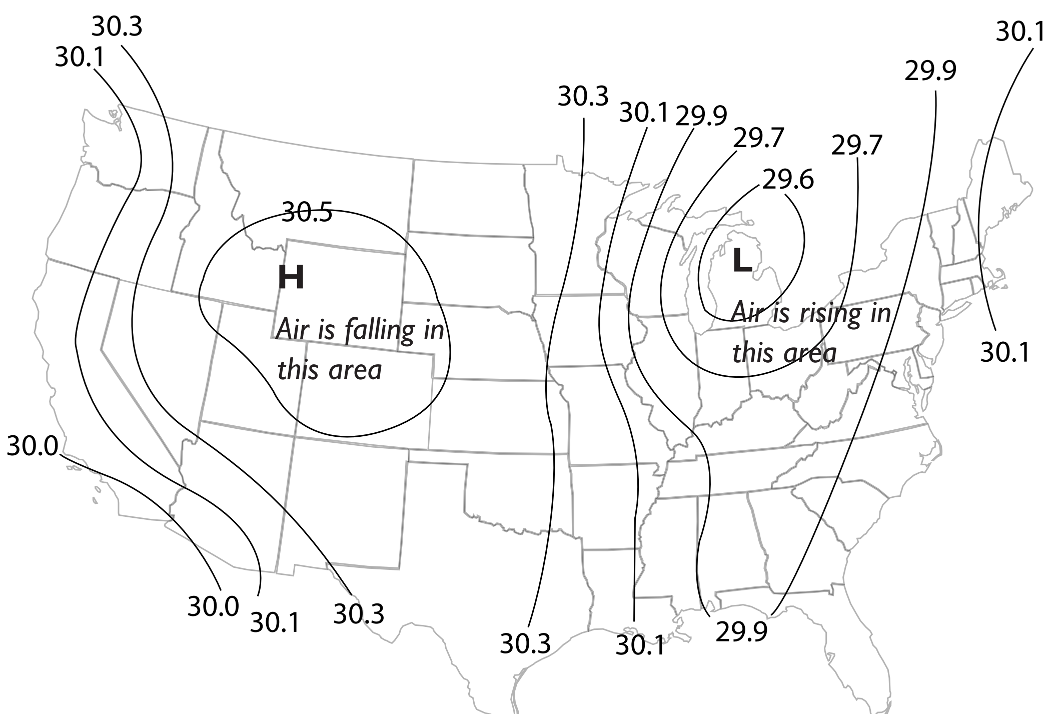


Diagram 2. 11pm on a clear moonlit night

US Map with Isobars

High pressure is over the western states centered over Wyoming with a pressure of 30.5 inches of mercury. Air is falling in this area.

Low pressure is over the Midwest centered over Michigan with a pressure of 29.6 inches of mercury. Air is rising in this area.



WHERE IS IT WINDY?

LESSON 5

KEY CONCEPT

Students learn how topography and elevation affect wind speeds and will identify optimal locations for wind farms based on wind speed.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Earth Science
Social Studies

KidWind PROJECT®

www.KidWind.org

BACKGROUND

Wind turbines produce more power at higher wind speeds than at lower wind speeds. This lesson helps students understand how topography and elevation affect wind speed. Students analyze maps and make predictions on where wind farms may be located based on regional topography.

OBJECTIVES

At the end of the lesson, students will:

- understand how topography and elevation affect wind speed
- be able to identify optimal locations for wind farms based on wind speed
- know how to interpret topographic and wind speed maps

METHOD

Students will create a three-dimensional landscape and identify where it is windy in relation to the topography, using a box fan and wind flags. Students will then examine a topographic map of the US and predict the optimal locations for wind farms. Students will compare their predictions with the actual wind speeds and wind farm locations.

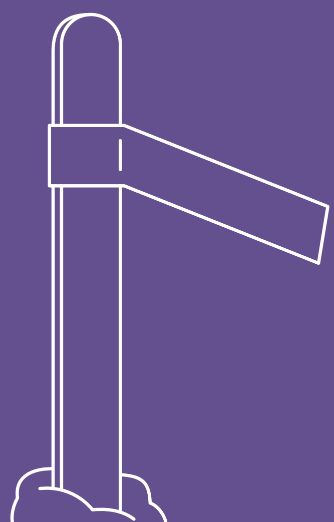
MATERIALS

- ❑ Box fan (more than one is better)
- ❑ Objects of different sizes that will not blow away
- ❑ 20 wind flags for the model. (Tape some string or tissue paper to a popsicle stick and place it in a piece of clay to hold it up.)
- ❑ New York State Elevation Map US Elevation and Shaded Relief Map*
- ❑ New York State Wind Speed Maps at 70 m US Wind Resource Map*
- ❑ New York State Wind Farm Map Utility Scale Wind Turbines in United States Map*
- ❑ Overhead projector (if available)
- ❑ Student reading passages and student worksheets*

*included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

WIND FLAGS



Tie tissue or string to a popsicle stick and stick it in a piece of clay to make a simple wind flag.

GETTING READY

- Collect materials for creating the topography. For example, books, backpacks, blankets or weighted boxes can be stacked to create mountains and valleys.
- Make 20 "wind flags." (You could have students do this, as well.)
- Make a copy of the US Elevation and Shaded Relief Map and worksheet for each student.
- Make a transparency of all maps or prepare to project them from a computer to use for class discussion. Maps can also be found on the "Where is it Windy?" activity page of the WindWise website.
- If you have access to a color copier, print wind maps.

ACTIVITY

Step 1: Beginning questions for students

- Where do you typically find wind?
- Where is it often calm?
- Where would you go to fly a kite?
- What geographical features influence the speed of the wind?
- Do we have wind farms in our state? If so, where are they located?
- Is it windier in a forest or a field? On a hill or in a valley?
- What parts of the US have the "best" wind for energy production?

Guide students to consider how beaches or open areas such as fields may have more wind than an area with many buildings or trees. Help them extrapolate their local understanding of where it is windy to a regional or national level where larger topographical features come into play, such as mountains or coastlines.

Step 2: Create a model landscape and wind farm

Using various objects around the classroom, tell students to create a model landscape. Students can use notebooks, textbooks, backpacks, weighted boxes, etc. Help students think about creating a variety of landscape features, such as a mountain range, rolling hills, valleys, plateaus, and open areas.

Tell students to create a wind farm by placing the wind flags where they think they will get the most wind. Number the flags so you can easily track them on your worksheet. Place the box fan next to the landscape and turn it on. Ask students to record which wind flags are blowing and at what height they are blowing.. Reposition the fan and again record which flags are blowing. Are there some flags that always move and others that never move? Discuss the role that landscape plays in wind patterns.

Step 3: Analyze a state elevation map

Give each student a topographic map of the US and discuss how to read it by showing high and low points on a projected version of the map. Ask students to predict where they feel there is the most wind by shading in these areas.

Step 4: Compare predictions to data
Using a computer or overhead, project the US Wind Resource Map for students and ask them to compare their predictions with this map. Pass out maps if you can. Were students' predictions similar to the actual wind speeds?

Step 5: Where are the wind farms in the US?
Overlay a transparency of Utility Scale Wind Turbines in United States Map with the US Wind Resource Map. Distribute copies of the maps if you can. Ask students to look for relationships among this map and the topographical and wind speed maps and answer the questions on the worksheet.

Step 6: Wrap up
Use the following questions to discuss the relationships among wind speed, elevation, and wind energy.

- Where are the windiest areas?
- Are there any trends? If so, what trends do you notice?
- How do wind speeds change as elevation increases?
- Why do you think this is the case?
- Where do you think the most desirable areas for wind farms are?
- Why do you think utility scale wind farms are located where they are?
- What role do you think elevation plays in the height of turbines? Where are the wind farms in the US?
- Are turbines always in the windiest spots? Why or why not?

EXTENSION

- Ask students to examine a topographic map of the US and make predictions about wind speed and wind farm locations. Compare their predictions to real data. Use some of the web resources from the end of this lesson.
- Tell students to create a scale drawing of their topography.

Another way to visualize wind flow in a miniature landscape is to use a bubble gun and blow the bubbles through the landscape. If you watch closely, you will see eddies where bubbles get caught and where the flow is the fastest. Give it a try! It can be lots of fun!

VOCABULARY

anemometer – An instrument that measures wind speed

convection – Air movement due to density differences as heated air rises and is replaced by cooler air.

Coriolis effect – The Earth's rotation causes the wind to flow in a curved path rather than a straight line.

pressure gradient force – The difference in air pressure that causes air molecules to move causing wind

surface roughness – A measure of surface texture. Trees, houses and other obstacles increase roughness, causing the wind to become more turbulent.

topography – The study and mapping of the shape of surface features of the Earth such as mountains, valleys, rivers, and lakes

turbulence – An irregular or unstable movement of a gas or liquid

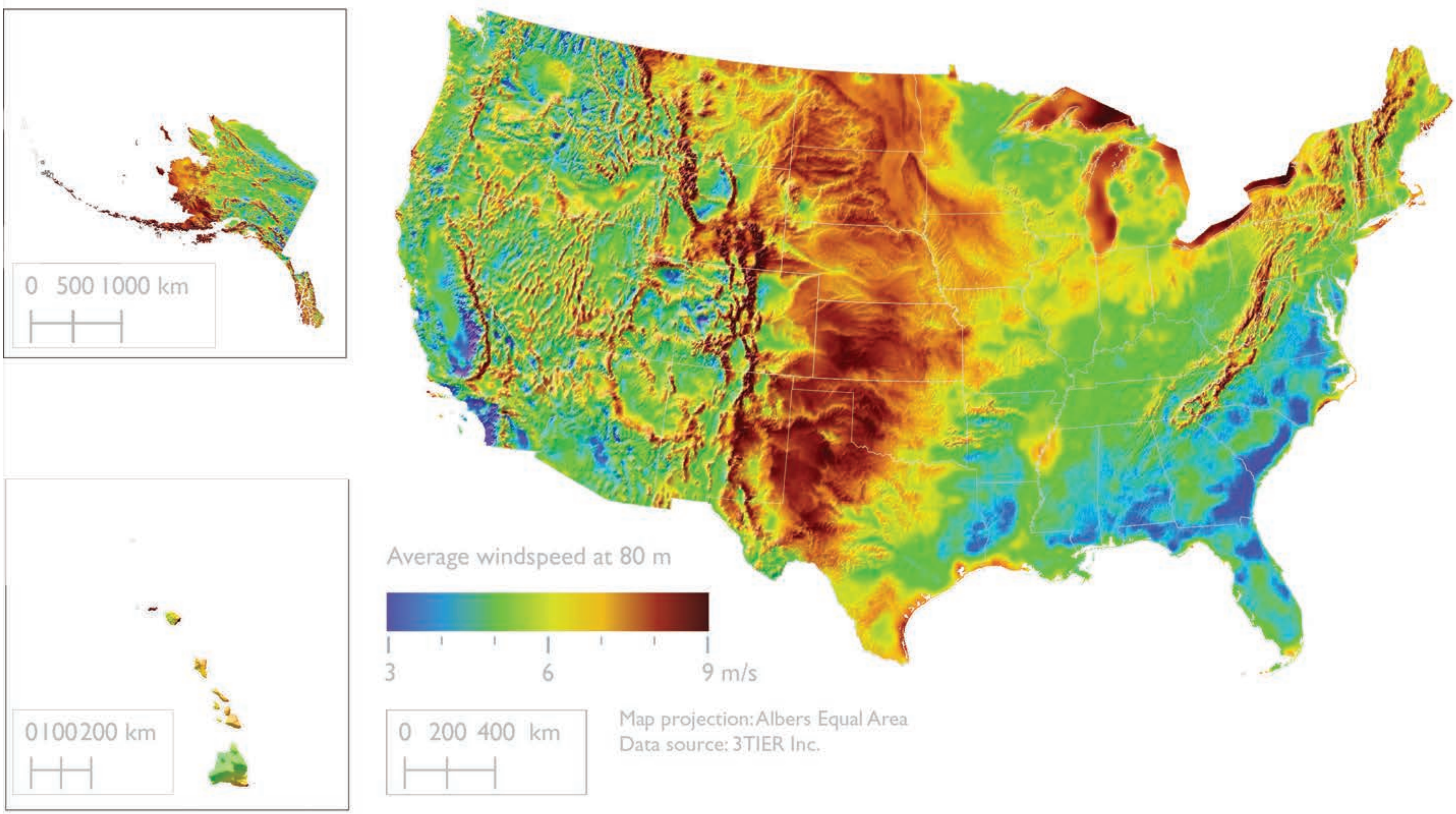
wind speed – The rate at which air is moving horizontally past a given point

wind speed units – Wind speed is measured in meters/second (m/s) or miles per hour (mph). 1 m/s = 2.24 mph.

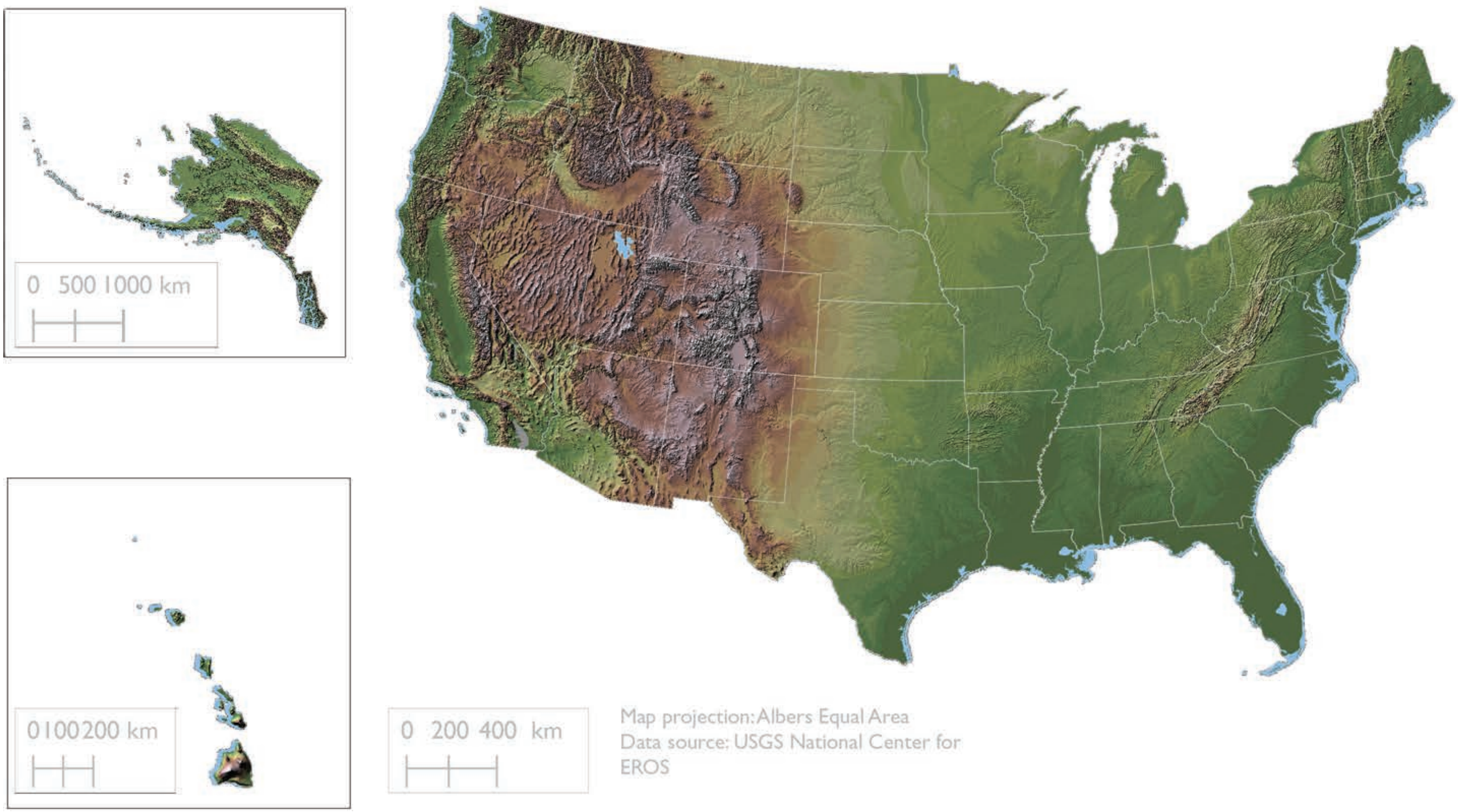
RELATED ACTIVITIES

- Lesson 4: What Causes Wind?

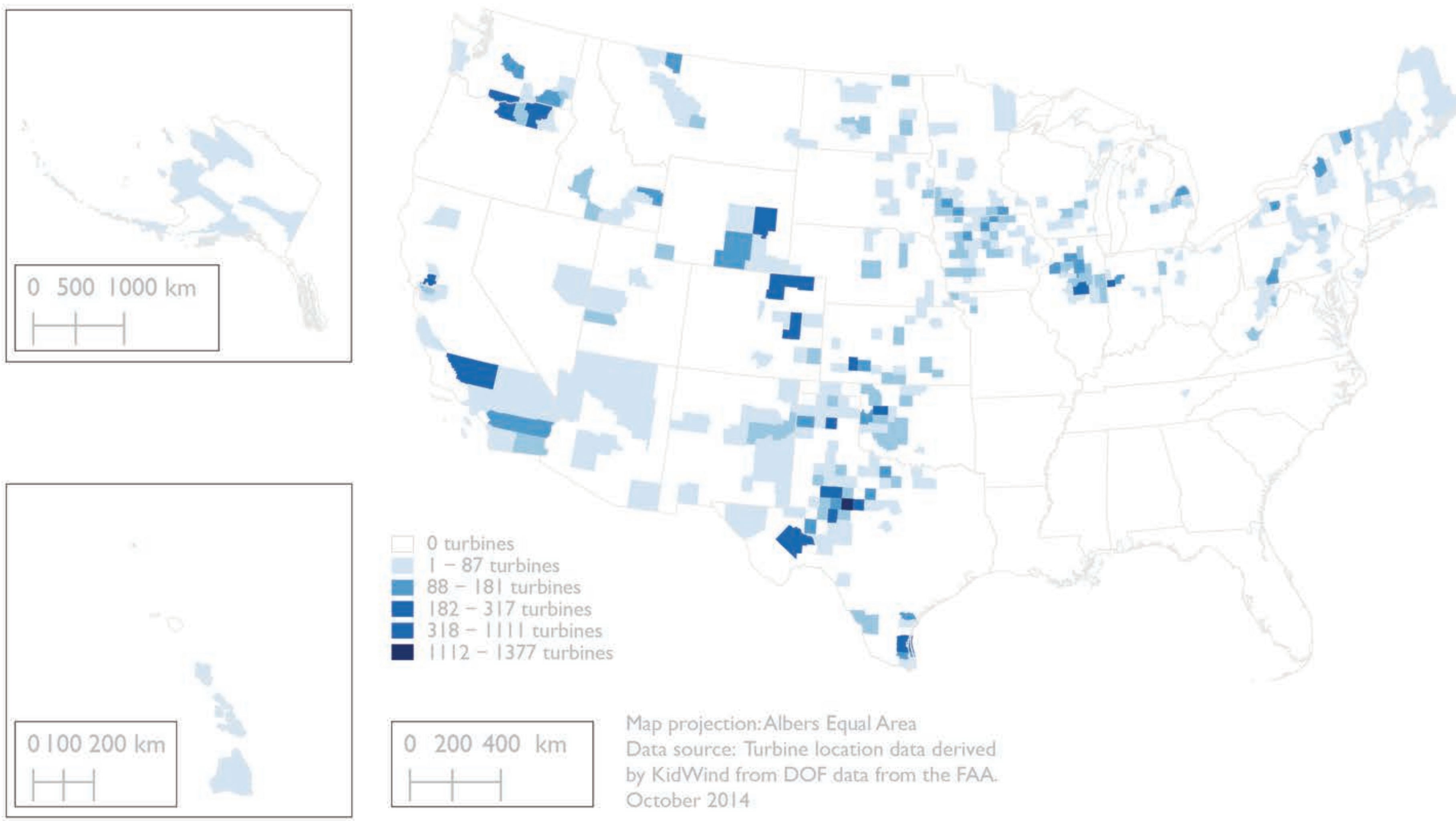
US WIND RESOURCE



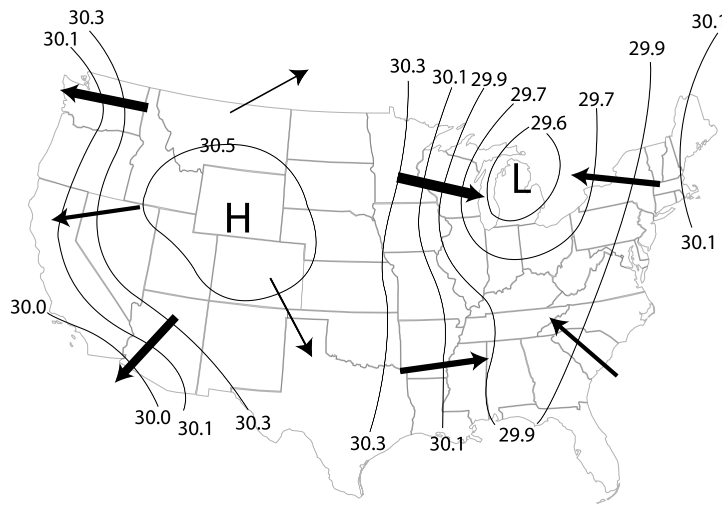
US ELEVATION AND SHADED RELIEF MAP



MAP OF UTILITY SCALE WIND TURBINES IN UNITED STATES



READING PASSAGE



Wind is the result of air moving from areas of high pressure to areas of low pressure. Air pressure changes are created by the uneven heating of the Earth. As parts of the Earth heat up, the air heats up, becomes less dense, and rises. As the hot air rises (convection), cooler air moves in, creating a breeze. This pressure difference, which causes wind, is called the pressure gradient force.

A number of factors determine the speed and direction of wind. Some factors, like the rotation of the Earth, create large-scale wind patterns, while other factors, such as the type of landscape, only affect local wind speeds. Wind developers may look at large-scale wind patterns to determine in what region to place a wind farm. When determining an exact location for the turbines, however, the wind developer collects years of wind data from proposed turbine locations.

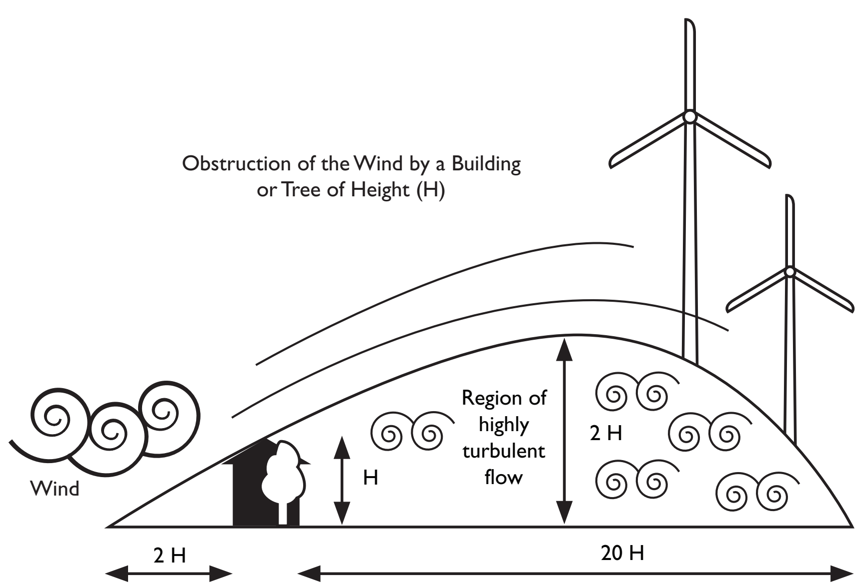
Earth's Rotation

While wind is the movement of air from high to low pressure areas, the wind does not actually move in a straight line. Why not? The Earth's rotation actually causes the wind to flow in a curved path rather than a straight line. This is known as the Coriolis effect. The winds in the Northern Hemisphere turn to the right and the winds in the Southern Hemisphere turn to the left. The effect is zero at the equator. Find an animation of how the Coriolis effect impacts wind direction at: http://learn.kidwind.org/windwise/.

Surface Roughness

Rough landscape surfaces tend to slow wind speeds, while smooth surfaces allow for higher wind speeds. For instance, a forested area creates more friction for moving air, resulting in slower wind speeds than a prairie. This is called surface roughness and can be defined according to different classes. An open sea provides very little friction for air and would be a class 0, whereas a large city with skyscrapers is a class 4. When siting a wind farm, it's important to look at the surrounding area to determine how the surface roughness will alter the local wind speeds.

Obstruction of the Wind by a Building or Tree of Height (H)



Topography

Topography can impact wind speeds in two ways. First, land masses tend to heat up more quickly than oceans during the day. This results in warm air above the land rising and cooler air from the water blowing toward the land, creating "ocean breezes." A second impact of topography is natural or manmade obstacles that can block air movement. For example, a mountain range is an obstacle that winds have to move around. This can increase the wind speed in some areas while reducing it in others. Obstacles can also create turbulence in the air movement. Turbulence happens when the air moves irregularly, which creates the bumps you sometimes experience on an airplane flying over a thunderstorm or mountain.

Elevation

Wind speeds generally increase with elevation. As elevation increases, there are typically fewer obstacles, allowing wind to blow at faster speeds. Also, the friction with the Earth is reduced higher above the ground, so wind moves faster. Over time, engineers have designed turbines to be taller so that they can capture these faster winds.

CAREER PROFILE: ROLF MILLER, TECHNICAL CONSULTING SERVICES MANAGER

I am a Technical Consulting Services Manager for a wind resource assessment and wind energy forecasting company. We provide wind farm developers, financiers, and utilities with highly accurate estimates of how much clean, renewable energy a wind farm will produce. In my current role, I work with a team of meteorologists and analysts to gather data from a variety of sources and help our customers understand how the weather will affect their wind farm.

As with many in the wind industry, I did not start out here. My undergraduate degree is in geology. At school, I wanted to meld the power of computers with studying natural systems. Geology had the irresistible appeal of working outdoors and a wide variety of things to study—fossils, plate tectonics, and mineral structures. For my senior thesis, I compiled a database of rock samples and mapped them with some of the earliest versions of geographic information system (GIS) software. I still use GIS software on a regular basis.

After school, I worked as a groundwater scientist for a consulting company, where I compiled one of the largest groundwater chemistry databases of its kind at the time. I also became interested in groundwater modeling, which uses computers to simulate the flow of water in the ground. It can predict where contaminants in the groundwater are likely to flow. I liked it so much that I enrolled in graduate school, where I studied groundwater flow.

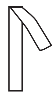
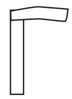
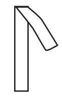
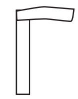
Over time, I have held many jobs for the company, including research scientist, software designer, programmer, manager, and salesperson. My current job is exciting because I can help our customers solve challenging problems that also have significant financial impacts. My motivation is providing customers with valuable information that results in well-designed and efficient wind farms.

Name____ Date_________________ Class__________

WHERE IS IT WINDY?

Model Landscape and Wind Farm

1. Place a check under the appropriate angle for each flag in the model landscape.

	TRIAL 1			TRIAL 2		
FLAG						
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2. Were there some flags that never received any wind? If so, where were they located in the landscape?

3. Were there some flags that always received a lot of wind? If so, where were they located in the landscape?

4. Why do you think some flags received a lot of wind and others not as much?

WIND IN THE UNITED STATES

Where are the highest wind speeds in the United States?
Using the elevation map of the US, shade the areas that you believe might have the highest wind speeds.

Were your predictions correct?
Compare your predictions to the US Wind Resource Map.

1. Are your predictions similar to the actual wind speeds?

What happens to the wind speed as you go higher in the atmosphere?

2. How do wind speeds change as elevation increases?

3. Why do you think this happens?

4. What role do you think elevation plays in the engineering design of turbines?

Where are the wind farms in the United States?

Compare elevation and wind speed maps with the map of Utility Scale Wind Turbines in United States.

1. What is the wind speed and topography of the wind farm locations in the US?

2. Why do you think these locations were selected as opposed to areas where wind speed is the highest?

1. Place a check under the appropriate angle for each flag in the model landscape.
   Student observation

2. Were there some flags that never received any wind? If so, where were they located in the landscape?
   Student observation

3. Were there some flags that always received a lot of wind? If so, where were they located in the landscape?
   Student observation

4. Why do you think some flags received a lot of wind and others not as much?
   Landscape features can get in the way of the path of wind. In nature, wind speeds increase as elevation increases.

WIND IN THE UNITED STATES

Where are the highest wind speeds in the United States?

Using the elevation map of the United States, shade the areas that you think might have the most wind.

Were your predictions correct?

Compare your predictions to the US Wind Resource Map.

1. Are your predictions similar to the actual wind speeds?
   Answers will vary depending on student's predictions.

What happens to the wind speed as you go higher in the atmosphere?

2. How do wind speeds change as elevation increases?
   The wind speed increases with elevation.

3. Why do you think this happens?
   There are fewer obstructions as elevation increases.

5. What role do you think elevation plays in the engineering design of turbines?
   Over time, engineers have increased the height of turbines to access the higher wind speeds. With this increase in elevation, engineers have had to consider other issues, such as transportation of the wind turbine parts and the potential impacts on wildlife.

Where are the wind farms in the United States?

Compare topography and wind speed maps with the map of Utility Scale Wind Turbines in United States.

1. What is the wind speed and topography of the wind farm locations in the US?
   See the map.

2. Why do you think these locations were selected as opposed to areas where wind speed is the highest.
   Sites are typically selected for a number of reasons: proximity to population centers (closer proximity means less loss due to transmission), land availability, and ability to get the project approved in a cost-effective way.

WHAT ARE WIND SHEAR AND TURBULENCE?

LESSON 6

KEY CONCEPT

This activity helps students understand the concepts of wind turbulence and wind shear—or the smoothness and speed of the wind at different altitudes above the ground.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Mathematics
Earth Science

KidWind PROJECT®

www.KidWind.org

BACKGROUND

The speed and smoothness of the wind in a given area is an important factor for wind farm developers in deciding where to place wind turbines. Gusty, turbulent winds can cause turbine components to wear out faster, reducing the lifespan of the turbine and increasing the maintenance costs. It makes the most sense to place turbines in locations with smooth, straight wind flow.

Wind shear refers to a change in wind speed or direction at different heights above the ground. Imagine that at ground level the wind is blowing 4 meters/second. At 80 meters in the air, which is the hub height of a typical utility scale turbine, the wind speed may be 12 meters/second. This change in wind speed is called wind shear.

Wind engineers and developers want to site turbines in areas with smooth, fast, and predictable wind patterns. To do this, they must have a good understanding of wind shear and turbulence.

OBJECTIVES

At the end of the lesson, students will:

- understand and be able to explain the concept of wind shear
- understand and be able to explain the concept of wind turbulence
- know how wind shear and turbulence affect wind turbine performance
- understand how trees, buildings, and other obstacles contribute to turbulence

METHOD

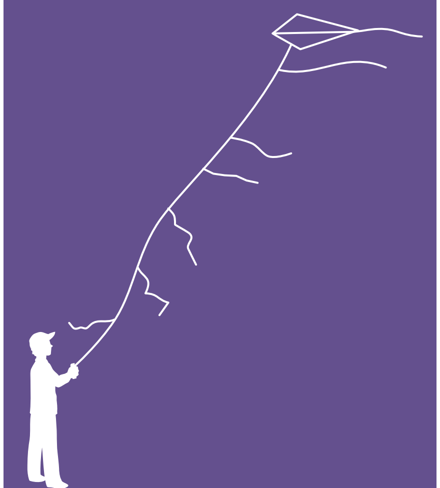
Students use a kite or large helium balloon with streamers attached at intervals along the string to visualize the effect of wind shear and turbulence. After measuring the height of the kite in the air, they estimate how high above the ground a turbine would have to be in order to be clear of turbulent winds.

MATERIALS

- ❑ A large sturdy, single-line kite. (A large helium balloon will also work.)
- ❑ Streamers, caution tape, or field marking tape
- ❑ Measuring tape
- ❑ Protractor
- ❑ Medium-sized bucket or box
- ❑ Student reading passages and student worksheets*
- ❑ Wind speed meter (recommended)

*included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.



By watching the streamers attached to the string of the kite students will be able to see the wind and make observations about how it is moving.

GETTING READY

- Cut 20 sections of "streamers," approximately 1 meter long each.
- Tell students to read the passage about wind shear and turbulence before class.
- Distribute the data collection worksheet for students to review before going outside for the experiment.
- Try to do this on a windy day; you will need enough wind to fly the kite.
- Find a good place to fly the kite during class time.

ACTIVITY

Step 1: Beginning questions for students

- Where was the windiest place you have ever been?
- Is it windier on top of a mountain or in the valley?
- What does the wind feel like on a windy day in a city?
- What does the wind feel like on a windy day in a field?
- What does the wind feel like on a windy day at the ocean or a large lake?
- Why are wind turbines placed so high in the sky?
- Have you ever experienced "turbulence" on an airplane?

Step 2: Prepare the kite

The streamers should already be cut out. Attach the streamers at 3 meter intervals along the kite string. Students can do this for 60 meters—or more if there is enough kite string. The more streamers students attach, the higher the kite can go, and the more data they can collect. The kite string will also get heavier with each streamer added.

With the streamers attached, winding the string back up can be a challenge. It is much easier if students wind the string around a bucket or medium sized box. This will prevent tangling of string and streamers.

Step 3: Go outside and launch the kite

An open field is a great place to do this experiment. It is also helpful if the field is bordered by some obstructions which will disrupt the smooth flow of the wind. This will help students "see" the lower wind speeds and turbulence caused by trees, buildings, and other objects.

If you have a wind speed meter, ask students to take an average reading at ground level for a few minutes. Make sure this wind speed is recorded on students' worksheets. If you are feeling risky you can try to attach your wind speed meter to the kite. Reset the meter before launching—so that you can get a reading of average wind speed and peak wind speed.

Launch the kite with streamers attached. Once the kite is high in the air and flying steadily, tie it down and ask the students to observe the streamers. The effect will be especially dramatic if you have some objects obstructing the wind at low altitudes upwind from where you are flying the kite.

Step 4: Make observations and record data
Ask students to make a few general observations about the streamers and the kite.

- Was it hard to launch the kite? Did it seem to "take off" after it got to a certain height?
- Are all the streamers doing the same thing, or do they look very different?
- Compare the streamers that are close to the ground to those that are very high in the sky.

Tell students to record some observations and fill in data on their worksheet.

Step 5: Calculate the height of the kite (Grade 9–12 math)
Knowing the length of the string let out and the angle of the kite string relative to flat ground, students can calculate the kite's height off the ground using a simple trigonometry formula. The kite string is like the hypotenuse of a right triangle (c)—and students are trying to calculate the length of the side of the triangle opposite from the kite string handle (a).

Students can figure out how many meters of string were let out based on the number of streamers flying. Remember that the streamers were attached at 3 meter intervals. Tell students to multiply the number of streamers by 3 to determine how much string is out. This value is the hypotenuse of the right triangle formed by the kite (c).

Next, tell students to use a protractor to measure the angle of the kite string relative to flat ground (A).

Now students can use the formula: sin A = opposite (a)/hypotenuse (c)

Therefore opposite (a) = hypotenuse (c) × sin A

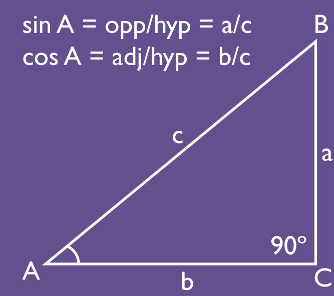
For example: If you let out 20 streamers, this is 60 meters of string. So the hypotenuse (c) is 60 meters. The angle of your kite string (A) is 68 degrees.

Sin (68) = 0.927

0.927 × 60 meters = 55.63 meters

Step 6: Estimate the height required to avoid turbulence (Grade 9–12 math)
Ask students to select the lowest streamer that they determine is not experiencing a high degree of turbulence. This streamer should be flying relatively straight—without flapping around dramatically. Students can use the same process used above to calculate the height of this streamer.

This time, the hypotenuse will be a different number—which can be calculated by counting the number of streamers down the kite string from the selected streamer. Once again, multiply the number of streamers by 3 to calculate the length of string (in meters) before the selected streamer.



Using simple trigonometry students can calculate the height of the kite.

A = student

B = kite

C = directly below the kite

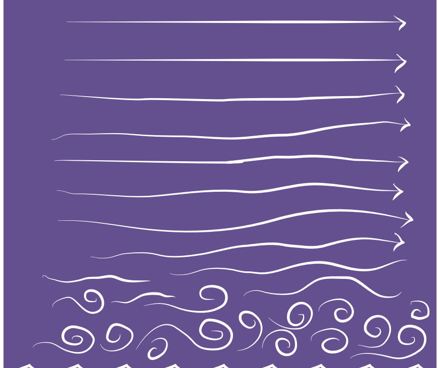
a = height of kite above ground

b = distance from student to directly below kite

c = how much string you have let out

Wind turbulence over obstacles

Wind turbulence over a flat surface



Once students have done their calculations, follow up with these questions:

- How high in the sky does a wind turbine have to be before it does not encounter a great deal of turbulence?
- What do you think would happen as the wind turbine goes even higher off the ground?
- What tools could scientists and engineers use to conduct a more detailed study of wind turbulence and wind shear?
- What do you think would happen to a wind turbine in very turbulent winds?

Step 7: Follow up

Return to the classroom and ask students to finish incomplete sections on their worksheets. Follow up the activity with a discussion about wind shear and turbulence.

- What happened to the streamers as they got higher and higher off the ground?
- Why would the wind be smoother at higher elevations?
- Why would the wind be faster at higher elevations?
- Considering the effect of turbulence, what locations around town might be best for a wind turbine?
- Do you think putting a wind turbine on a rooftop would be a good idea?
- Would a wind farm located a few miles offshore experience as much turbulence as a wind farm on land? Why or why not?
- How does friction affect the wind?
- Knowing that winds get stronger and smoother higher in the atmosphere, why are manufacturers not building turbines that are 300 meters tall?

EXTENSION

- This lesson can go much further if you have actual wind speed data. Using an anemometer like the Inspeed Hand Held meter or WindWare Data Collector can give you some great wind speed data. Many schools have Davis or Weatherbug weather stations that may keep track of average wind speeds. If you have a hand-held anemometer, students can walk around the school searching for locations with the best wind speed and least turbulence. This is known as "micro-siting."
- Tell students to research "wind shear coefficient." This is a value that will help you extrapolate the wind speeds at different elevations if you only know the wind speed at one elevation. Different locations will have a different wind shear coefficient, depending on topography and surface roughness.

VOCABULARY

ground drag – The friction that occurs between the surface of the Earth and the moving air molecules (wind) that flow over it. Ground drag reduces the velocity of the wind.

surface roughness – A measurement of the smoothness of the surface the wind is blowing over. High surface roughness (urban areas, forested hills, etc.) leads to increased ground drag, greater turbulence, and a more dramatic wind shear. Low surface roughness (smooth prairie or sea) has very little turbulence and less shear.

wind shear – A change in wind speed or direction at different heights above the Earth

wind shear coefficient – A value used to calculate the variation in wind speed with respect to height.

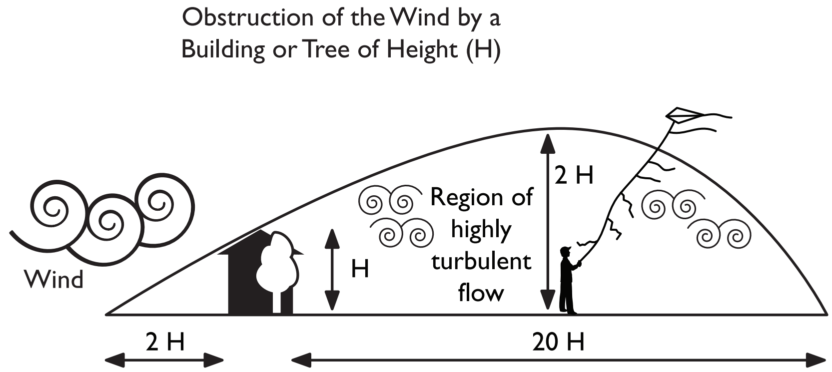
wind site assessment (siting) – The process of analyzing local wind resource and obstacles to determine the best location to place a wind turbine.

wind turbulence – Wind passing over or around obstacles will tumble, swirl, slow, and change direction. This turbulent wind is not good for a wind turbine.

RELATED ACTIVITIES

- Lesson 5: Where Is It Windy?
- Wind Data Appendix
- Lesson 17: Where Do You Put a Wind Farm?

READING PASSAGE



You may have noticed that wind turbines are typically installed on very tall towers. Have you ever thought about why these towers have to be so tall? What do you think happens to the wind speed as you go higher and higher off the ground?

It turns out that winds get much stronger as you go higher above the Earth. The main reason for this is known as "ground drag." Ground drag is the friction that occurs between the surface of the Earth and the moving air molecules (wind) that flow over it. Ground drag reduces the velocity of the wind, thereby reducing the kinetic energy available in that wind. This is particularly important for wind power, since the output of a wind turbine is proportional to the cube of the wind speed. That means that doubling the wind speed can give you eight times the kinetic energy available in the wind!

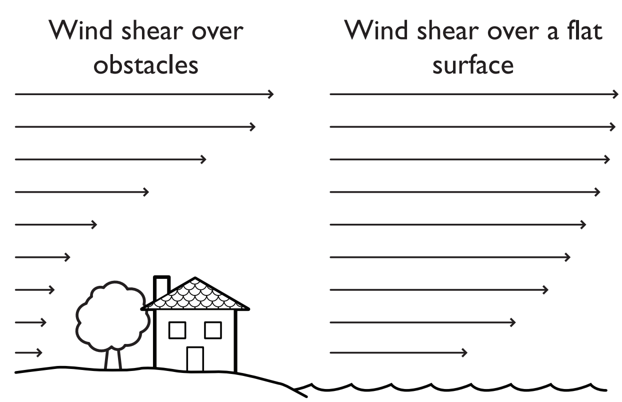
This difference in wind speed at different elevations above Earth is known as wind shear. Wind shear is a very important concept for wind turbine developers and installers to understand—since a small difference in wind speed can make a huge difference in power output.

Landscapes with buildings and trees create much more ground drag than open fields or oceans—which is why some of the best wind resources in the United States are in the Great Plains regions and offshore areas like the Atlantic Ocean, the Gulf Coast, and the Great Lakes.

Trees, buildings, and other obstacles also cause a lot of turbulence in the wind. This means that the wind tumbles and swirls around rather than flowing smoothly. Turbulence is particularly bad for wind turbines, because it slows the wind down (reducing kinetic energy in the wind) and also causes a great deal of wear and tear on the turbine. A wind turbine placed in a turbulent wind area would require more maintenance and would have a shorter life span.

Some inventors and designers are experimenting with "airborne wind turbines." These giant kite-like wind machines are able to float hundreds of meters above ground level, capturing the strong, smooth winds higher in the atmosphere. They are tethered to the Earth with a cable that also transmits the electricity produced. Though the concept is not yet fully proven, the theory of raising a wind generator higher in the sky while using fewer materials is very promising.

Since wind is the "fuel" for a wind generator, it makes sense to place a turbine where it will receive the most fuel. As wind power guru Mick Sagrillo has been known to say, "Putting a wind turbine on too short of a tower is like putting a solar panel in the shade!" When installing a wind turbine, whether it is a small residential machine or a large industrial turbine, it is very important to build towers tall enough to avoid turbulence and reach high wind speeds.



KITE TURBULENCE ACTIVITY: OBSERVATION WORKSHEET

Rank each kite streamer on a 1–5 scale

1	Most turbulent	Streamer moves around wildly and changes direction frequently.
2	More turbulent	Streamer moves back and forth and waves around considerably.
3	Somewhat Turbulent	Streamer waves around but does not move back and forth much.
4	Less Turbulent	Streamer waves a little but always points in the same direction.
5	Not Turbulent	Streamer is almost always straight out with very little waving.

STREAMER NUMBER	DISTANCE FROM KITE (METERS)	TURBULENCE RANKING (1–5)	DRAWING OF STREAMER
1	3 meters		
2	6 meters		
3	9 meters		
4	12 meters		
5	15 meters		
6	18 meters		
7	21 meters		
8	24 meters		
9	27 meters		
10	30 meters		
11	33 meters		

STREAMER NUMBER	DISTANCE FROM KITE (METERS)	TURBULENCE RANKING (1–5)	DRAWING OF STREAMER
12	36 meters		
13	39 meters		
14	42 meters		
15	45 meters		
16	48 meters		
17	51 meters		
18	54 meters		
19	57 meters		
20	60 meters		
21	63 meters		
22	66 meters		
23	69 meters		
24	72 meters		
25	75 meters		

ON GRADING THE WIND SHEAR AND TURBULENCE ACTIVITY

While worksheet answers will vary to some extent, students should observe a general trend towards the wind getting less turbulent as the streamers get higher off the ground. Streamers that are higher above ground clutter and obstructions will get into the more smooth, laminar winds that are less turbulent. These winds are also generally faster.

CAN WIND POWER YOUR CLASSROOM?

LESSON 7

KEY CONCEPT

Students conduct a simple energy audit for the classroom and estimate what size wind turbine could power their classroom under local wind conditions.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Physical Science
Technology/Engineering
Mathematics

www.KidWind.org

BACKGROUND

The power coming from wind turbines varies with wind speed, just as the power we consume fluctuates throughout the day depending on what we turn on or plug in. This lesson will give students a sense of how much electricity they use on a daily basis and what it would take for a wind turbine to provide that amount of electricity. Students will learn how to determine how much power their classroom is consuming, analyze real wind turbine data, interpret wind speed and turbine power output graphs, understand basic wind energy economic concepts, and understand the difference between energy and power.

OBJECTIVES

At the end of this lesson, students will:

- understand the relationships among wind speeds, power generation, power consumption, and economic value
- know how to analyze wind data
- know how to interpret wind speed and power output graphs
- understand the difference between energy and power
- discuss energy consumption concepts

METHOD

Students will estimate classroom power consumption by adding the average power draw of all electronic appliances in the room. Next, students will examine wind energy data to understand the relationship between wind speed and turbine power output. Using these data, students can assess the potential and economic feasibility of powering their classroom or school with a wind turbine.

MATERIALS

- ❑ Real-time data from wind turbines (data websites or supplied data sheets*)
- ❑ Computer with Internet access
- ❑ LCD projector (recommended for displaying live data sites)
- ❑ Student reading passages and student worksheets*

Optional

- ❑ Classroom wind turbine models
- ❑ Box fans
- ❑ Wind speed meters
- ❑ Anemometer

*included in this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

POWER

Watt (W)	Joules / Seconds
kilowatt (kW)	1000 Watts
megawatt (MW)	1,000,000 Watts

Students have been exposed to the concepts of energy and power. Take a few minutes to discuss and clarify the difference between these terms, as this can be very confusing. For helpful analogies and explanations, refer to the “Difference Between Energy and Power” table.

GETTING READY

- Before class, check out the various live data sites. Find 3–4 turbines of various sizes and in various geographic regions. If possible, find a turbine geographically close to your school.
- To save time during the classroom energy audit in Step 3 (Worksheet 1), make a list of all the electronic appliances in your classroom and how much power they draw. If you do not know this information, check out the “average power consumption” website found under additional resources.
- The energy audit can also be conducted in students’ homes as a homework assignment. It might be simpler to look at one room at a time.

ACTIVITY

Step 1: Beginning questions for students

- What happens to a wind turbine as the wind speed increases? What if the wind stops?
- Is there such a thing as too much wind for a wind turbine? Could this be dangerous?
- How many watts would a wind turbine have to generate to power your whole home or classroom?
- How do homes with wind turbines get electricity when the wind is not blowing?
- What happens when a residential wind turbine produces more electricity than a home uses?

Step 2: Estimate classroom power consumption

Ask the students to look around the room and name all the things currently using electricity—lights, computers, projector, fans, clock, etc. List all of these electric devices in the table under Question 1 on the “Can Wind Power Your Classroom” worksheet (page 126).

Estimate the power draw (in watts) for each device, using the average power consumption website found under Additional Resources. How much electricity is required to power your classroom? How many kilowatts is this? (1 kilowatt = 1,000 watts.) Complete the table under Question 1.

Difference between energy and power

	ENERGY	POWER
	Quantity	**Rate**
Unit	Kilowatt-Hour (kWh)	Watt, kW, MW
Water Analogy	Gallons	Gal/Min
Car Analogy	Number of gallons of gas in the tank?	Engine HP
Wind Turbine Application	Electricity produced and sold to the utility company	Rated Capacity

Step 3: Sample wind turbine power output
Now look at the power curve for the wind turbine. Is this turbine capable of powering your whole classroom? What wind speed would be required for the turbine to power the classroom?

How often do you think the wind actually blows this fast? According to the "Wind Speed Probability" graph below, what percentage of the time does the wind blow this fast or faster? Answer Questions 2, 3, and 4 on the worksheet.

Step 4: Research your local wind speed
Find your current local wind speed. If you have an anemometer, you can measure the wind speed outside your school. If you do not have an anemometer, see the WindWise resources pages — http://learn.kidwind.org/windwise/ — to find websites to determine your current local wind speed

Look back to the wind turbine power curve. Based on your current local wind speed, how much electricity would the turbine produce if it were located near your school? Is this enough to power your classroom based on the energy audit you conducted previously? Answer Questions 5 on the worksheet.

Step 5: Analyzing sample wind turbine data
Using the sample wind turbine data (page 132) found in this lesson, answer the questions under the "Sample Wind Turbine Data" section of the worksheet.

Step 6: Analyzing live wind turbine data
Using the wind turbine data websites, answer the questions in the "Live Wind Turbine Data" section of the worksheet.

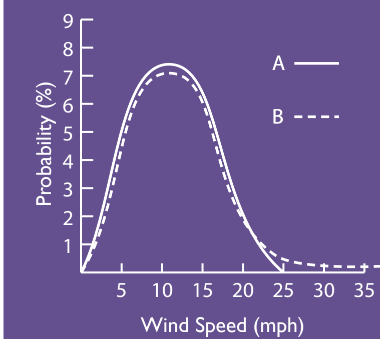
Step 7: Wrap up
Once students have finished their worksheets, follow up with these questions:
- How much electricity does your classroom draw?
- Estimate how much power your whole school might consume on average.
- Is the wind around your school adequate for a wind turbine?
- What are some ways you could use less electricity in your classroom?
- Should your school buy a wind turbine?

EXTENSION

Using Data to Understand Residential Wind Energy Economics
In many states, wind turbine owners can sell excess energy to the utility company. For example, in Minnesota, if a wind turbine produces more electricity than the owner consumes in a month, the utility company would send a check at the end of the month instead of a bill. Most states and Washington, D.C., have similar programs; some are state mandated and others are voluntarily offered by utilities.

Complete the Extension Activity Worksheet.

WIND SPEED PROBABILITY DISTRIBUTION



A wind speed probability (or distribution) graph shows the percentage of time the wind blows in a given range of wind speeds. While these two distribution curves may have the same "average" wind speed, a turbine sited at a location with curve "B" is likely to produce more energy over time due to the occurrence of higher wind speeds.

VOCABULARY

energy – The capacity for doing work; usable power (as heat or electricity); the resources for producing such power.

kilowatt (kW) – One thousand watts. A useful unit of power when discussing household electrical consumption. 1 kW = 1000W.

kilowatt-hour (kWh) – A unit of energy useful for quantifying household energy use. One kilowatt-hour of energy is equal to the power used at a rate of one kilowatt for a period of 1 hour.

megawatt (MW) – One million watts or one thousand kilowatts. This unit of power is useful when discussing industrial scale wind turbines or large power plants. 1MW = 1,000kW = 1,000,000W

megawatt-hour (MWh) – One million watt hours, a useful measure of energy when discussing large power plants and wind farms. 1 MWh = 1000 kWh

power – The rate at which energy changes form from one form to another, or the rate at which work is done.

power draw – The amount of electrical power used by an appliance. Measured in watts.

rated capacity – The maximum output rating of a wind generator. A wind turbine with a 1.5 MW rated capacity will produce a maximum of 1.5 MW.

watt (w) – A unit of electrical power, or how fast electrical energy is transformed into heat and or light. One electrical watt of power is equal to a current of one ampere times a potential difference of one volt. Power = amps times volts. ($P = I \times V$) One watt is equivalent to one joule of electrical energy transformed each second.

wind speed probability distribution – A graph showing the percentage of time that the wind blows at different wind speeds. The taller the bar, the more likely it is that the wind will blow at that wind speed. An important tool for predicting how much power a turbine will produce in a given location.

CAREER PROFILE: JOHN ANDERSON
SENIOR SYSTEM OPERATOR, MIDWEST ISO

An Independent System Operator (ISO) controls and monitors the operation of the electric power system of a state. My job is to simultaneously monitor and match electric consumption and production. If the generators (power plants) are producing more electricity than the cities and towns in the system are using, some power can be diverted to external systems that may not have enough electricity. If the generators are not making enough electricity, we can import some power from external systems. If there is too much electricity or not enough electricity to go around, this can lead to power outages.

As you have learned from this lesson, wind energy is a variable resource; the power coming from wind turbines varies with the wind speed. The variability of wind power makes my job interesting, but even more challenging, since a wind farm could go from producing 200 MW to 0 MW in a matter of minutes if the wind speed slows down. My coworkers and I must analyze wind forecasts to predict when a wind farm will be producing electricity and how much power it will be making. We also predict how much electricity consumers will be using at any time. The production and consumption of electricity has to match up.

To get an idea of the challenges I face in my job, try monitoring and controlling this virtual power grid: http://tcipg.mste.illinois.edu/applet/pg/. After you become familiar with the system, try the five challenges on the left sidebar.

Name______________________________ Date______________ Class________

CAN WIND POWER YOUR CLASSROOM?

watt (W)	joules / second
kilowatt (kW)	1000 watts
megawatt (MW)	1,000,000 watts

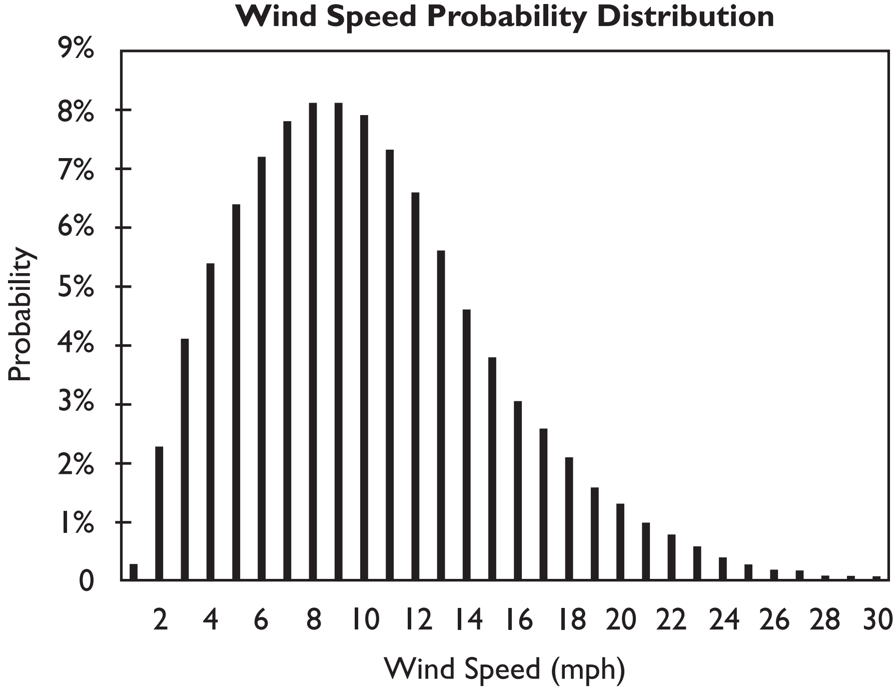
Do an energy audit for your classroom

1. Complete the table. List all the appliances and devices using electricity in your classroom. Estimate the total amount of electricity being used in the classroom right now (in watts). Find resources to help you estimate here: http://learn.kidwind.org/windwise/.

DEVICE	WATTS
TOTAL POWER	watts
	kilowatts (W/1000)

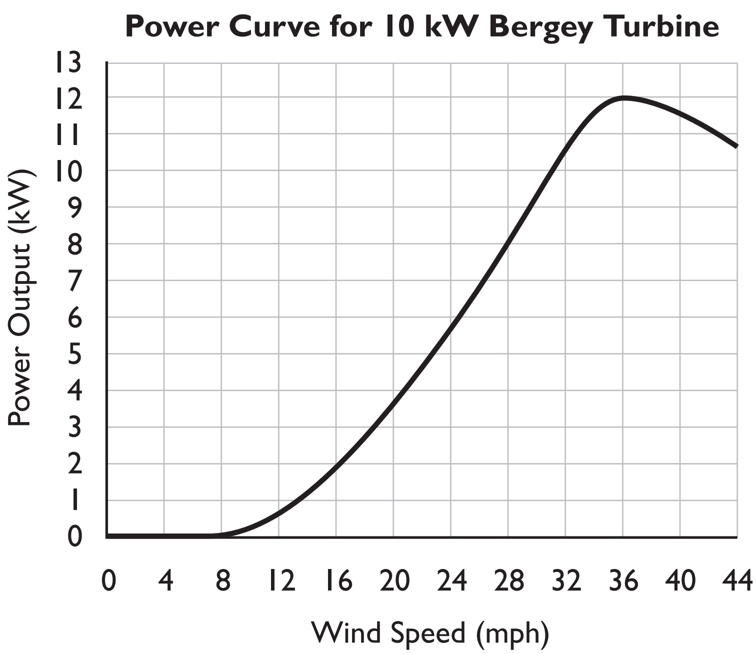
2. Look at the sample wind turbine power curve provided on the next page. Could this wind turbine make enough power for your classroom? (Remember: 1 kW = 1,000 watts.) If so, how fast does the wind have to be blowing to make enough electricity for your classroom?

3. Look at the “Wind Speed Probability Distribution” graph. What percentage of the time does the wind blow at the wind speed that you identified in your answer to Question 2? Is the wind normally faster or slower than this?



This curve shows the percentage of time that the wind blows at a given wind speed. The sum of the bars equals 100%. The taller the bar, the more likely it is that the wind will blow at the speed of that bar.

4. Examine the power curve and the wind speed percent of time graph. What percentage of the time does the wind blow at a speed that makes 4 kW on the power curve?



Name________________________________ Date______________ Class_________

5. How fast is the wind currently blowing? (Use an anemometer or check here: www.wunderground.com) Would this be enough wind to power your classroom if you were using this turbine?

Sample wind turbine data

1. Look at the wind turbine data sheet. Imagine that wind turbine 3.A is outside your school powering your classroom. The wind is blowing at 4.5 mph, and the turbine is barely spinning and is producing 21 watts. What percentage of your classroom electric consumption is this turbine currently supplying?

2. Suddenly a cold-front starts coming through and the wind picks up to 18.9 mph. The turbine starts spinning very fast and is now producing 1.3 kW (1,300 watts). Is the turbine supplying enough electricity for your whole classroom now? If not, what percentage is it supplying?

3. Where do you think your electricity comes from when the wind turbine is not producing enough power for your classroom (what energy source or "fuel")?

Live wind turbine data

To answer these questions, find a turbine on the Internet producing live data.

1. Where is this wind turbine located?

2. What is the rated capacity of this turbine? (How many kW can it produce?)

3. How fast is the wind blowing? (mph *or* m/s?)

4. How much power (watts or kilowatts) is the turbine currently producing? What percentage of full capacity is this?

5. How much energy has the turbine made today? This week? This month? This year? (kWh)

6. Divide the energy produced this week by 168 (the number of hours in a week) to find the average power produced by the turbine.

7. Since you already know how much power your classroom uses on average, did this turbine produce enough electricity on average over the week to power your classroom?

Name______________________________________ Date________________ Class_________

CAN WIND POWER YOUR CLASSROOM? EXTENSION ACTIVITY

1. Electricity is bought and sold in units of energy such as kilowatt-hours (kWh). The average cost of electricity in the US today is about 11.4 cents per kWh. The average US household uses about 950 kWh in a month. That means that the average American spends about $108 per month on electricity! How much power is the average American house consuming at any given moment (in kW)?

2. Look at the "average monthly power output" on the sample wind turbine data sheets. Given that the average household uses about 950 kWh per month, which turbine would provide about all the electricity needed for a house?

3. Imagine your family uses the average amount of electricity in a month (950 kWh). You have turbine 2.A in your backyard, and this month it produced 912 kW. How much energy will your family pay for this month? If your electricity costs the average US price (11.4 cents per kWh), how much will you owe the utility company this month?

4. You are tired of paying electric bills, so your family starts conserving electricity. You swap out incandescent light bulbs, unplug your cell phone chargers, and switch off unused lights and power strips. The next month you have reduced your consumption to 800 kWh. Congratulations! It also happened to be a very windy month, and your turbine produced 1,025 kWh. At the end of the month, the utility company will pay you the wholesale rate of electricity (4.5 cents per kWh) for your net excess generated electricity.

    a. How much money will the utility company owe you at the end of the month?

    b. If you did not have a wind turbine and you had to buy all of your electricity from the utility company, how much would you have owed this month?

5. Explain the change that Independent Service Operator Jim Anderson would have noticed when your family stopped purchasing electricity from the utility company and began selling excess energy instead.

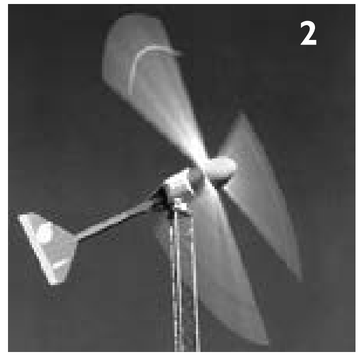
WIND TURBINE DATA SHEETS FOR WINDWISE LESSON

1.A

Turbine Rated Capacity	100 kW
Wind Speed	13.1 mph
Power Output	14.3 kW
Generated Today	23 kWh
Generated This Year	57,340 kWh
Average Monthly Energy Output	6,332 kWh

1.B

Turbine Rated Capacity	100 kW
Wind Speed	20.3 mph
Power Output	60.0 kW
Generated Today	225 kWh
Generated This Year	57,993 kWh
Average Monthly Energy Output	6,404 kWh



2.A

Turbine Rated Capacity	10 kW
Wind Speed	12 mph
Power Output	1 kW
Generated Today	4.6 kWh
Generated This Year	11,122 kWh
Average Monthly Energy Output	930 kWh

2.B

Turbine Rated Capacity	10 kW
Wind Speed	24.1 mph
Power Output	5.7 kW
Generated Today	19.2 kWh
Generated This Year	12,083 kWh
Average Monthly Energy Output	1010 kWh

3.A

Turbine Rated Capacity	1.8 kW
Current Wind Speed	4.5 mph
Current Power Output	21 watts (0.021 kW)
Generated Today	2.2 kWh
Generated This Year	1,916 kWh
Average Monthly Energy Output	177 kWh

3.B

Turbine Rated Capacity	1.8 kW
Wind Speed	18.9 mph
Power Output	1.3 kW
Generated Today	5.1 kWh
Generated This Year	2,596 kWh
Average Monthly Energy Output	240 kWh

4.A

Turbine Rated Capacity	20 kW
Wind Speed	9.3 mph
Power Output	1.3 kW
Generated Today	7.7 kWh
Generated This Year	19482 kWh
Average Monthly Energy Output	1766 kWh

4.B

Turbine Rated Capacity	20 kW
Wind Speed	21.6 mph
Power Output	11.8 kW
Generated Today	46.7 kWh
Generated This Year	21,322 kWh
Average Monthly Energy Output	1810 kWh

CAN WIND POWER YOUR CLASSROOM?

Do an energy audit for your classroom

1. Complete the table. List all the appliances and devices using electricity in your classroom. Estimate the total amount of electricity being used in the classroom right now (in watts). Use this website to help you estimate: www.absak.com/library/power-consumption-table

   Student observations

2. Look at the wind turbine power curve. Could this wind turbine make enough power for your classroom? (Remember: 1 kW = 1,000 watts) If so, how fast does the wind have to be blowing to make enough electricity for your classroom?

   Yes, this turbine should be able to power your classroom. Wind speed required will vary depending on your consumption, most likely between 12 and 20 mph.

3. Look at the "Wind Speed Probability Distribution" graph. What percentage of the time does the wind blow at the wind speed that you supplied in your answer to Question 2? Is the wind normally faster or slower than this?

   Answers will vary. This should be between 1 percent and 6 percent. Wind is normally slower than this.

4. Examine the power curve and the wind speed probability graph. What percentage of the time does the wind blow at a speed that makes 4 kW on the power curve?

   According to the power curve, the turbine will make 4 kW at 21 mph. According to the wind speed probability curve, the wind blows at 21 mph 1 percent of the time.

5. How fast is the wind currently blowing? (Use an anemometer or check here: www.wunderground.com) Is this enough wind to power your classroom if you were using this turbine?

   Student observation

Sample wind turbine data

1. Look at the wind turbine data sheet. Imagine that wind turbine 3.A is outside your school powering your classroom. The wind is blowing at 4.5 mph, and the turbine is barely spinning and is producing 21 watts. What percentage of your classroom electric consumption is this turbine currently supplying?

   Answers will vary depending on electric consumption, but this will be a VERY small percentage.

2. Suddenly a cold-front starts coming through and the wind picks up to 18.9 mph. The turbine starts spinning very fast and is now producing 1.3 kW (1,300 watts). Is the turbine supplying enough electricity for your whole classroom now? If not, what percentage is it supplying?

   Answers will vary, but this will be a larger percentage, possibly more than enough electricity.

3. Where do you think your electricity comes from when the wind turbine is not producing enough power for you classroom (what energy source or "fuel")?

   Acceptable answers include: coal, nuclear, natural gas, hydroelectric, solar, oil, etc.

Live wind turbine data

To answer these questions, find a turbine on the Internet producing live data.

1. Where is this wind turbine located?
   Student observations

2. What is the rated capacity of this turbine? (How many kW can it produce?)
   Student observations

3. How fast is the wind blowing (mph *or* m/s)?
   Student observations

4. How much power (watts or kilowatts) is the turbine currently producing? What percentage of the full capacity is this?
   Student observations

5. How much energy has the turbine made today? This week? This month? This year? (kWh)
   Student observations

6. Divide the energy produced this week by 168 (the number of hours in a week) to find the average power produced by the turbine.
   Student observations

7. Since you already know how much power your classroom uses on average, did this turbine produce enough electricity on average over the week to power your classroom?
   Student observations

CAN WIND POWER YOUR CLASSROOM? EXTENSION ACTIVITY

1. Electricity is bought and sold in units of energy such as kilowatt-hours (kWh). The average cost of electricity in the US today is about 11.4 cents per kWh. The average US household uses about 950 kWh in a month. That means that the average American spends about $108 per month on electricity! How much power is the average American house consuming at any given moment (in kW)?
   950 kWh per month / 30 days in a month / 24 hours in a day = 1.32 kW

2. Look at the "average monthly power output" on the sample wind turbine data sheets. Given that the average household uses about 950 kWh per month, which turbine would provide about all the electricity needed for a house?
   Turbines 1A, 1B, 2B, 4A, 4B

3. Imagine your family uses the average amount of electricity in a month (950 kWh). You have turbine 2.A in your backyard, and this month it produced 912 kW. How much energy will your family pay for this month? If your electricity costs the average US price (11.4 cents per kWh), how much will you owe the utility company this month?
   Your family would pay for (950 – 912) = 38 kWh this month. 38 kWh x $0.114 = $4.33

4. You are tired of paying electric bills, so your family starts conserving electricity. You swap out incandescent light bulbs, unplug your cell phone chargers, and switch off unused lights and power strips. The next month you have reduced your consumption to 800 kWh. Congratulations! It also happened to be a very windy month, and your turbine produced 1,025 kWh. At the end of the month, the

utility company will pay you the wholesale rate of electricity (4.5 cents per kWh) for your net excess generated electricity.

a. How much money will the utility company owe you at the end of the month?
1,025 – 800 = 225 kWh sold. 225 kWh x $0.045 = $10.13

b. If you did not have a wind turbine and you had to buy all of your electricity from the utility company, how much would you have owed this month?
800 x $0.114 = $91.20

5. Explain the change that Independent Service Operator Jim Anderson would have noticed when your family stopped purchasing electricity from the utility company and began selling excess energy instead.
If you stopped buying electricity from the utility company, the Independent System Operator (ISO) would notice a slight decrease in demand for electricity from the grid. If you were selling your excess energy to the utility company, the ISO would have another source of electricity to draw from to meet electric demand.

COLLECTING WIND SPEED DATA AT YOUR SCHOOL

BACKGROUND

Wind speed data is vital to understanding how much energy a wind turbine could produce at a particular site. While you can find general wind data on a number of weather websites, it will usually not be very accurate or relate to your exact location. This lesson helps you collect and analyze wind data from your location using some fairly inexpensive hardware and software.

Wind engineers use anemometers, towers, and sophisticated data logging systems to collect at least a year of data before they install a large wind farm. While this kind of equipment is expensive ($20,000+), it is much cheaper than installing a $1,500,000 wind turbine based on simulated or modeled data.

For smaller wind turbines installed at houses and farms, less data is collected as the costs could be more than the turbine! For these smaller scale systems, homeowners try to find wind speed information from a variety of online sources and make decisions based on the best data they can collect.

Recently some new wind data loggers have become available that make collecting data at your school more affordable and easier to analyze. In this lesson we will explore these tools and how to use them to collect and analyze the promise of a site for wind power.

Please keep in mind that to perform the data collection part of this lesson, you will need to purchase some type of wind data logger. We have suggested a few that are carried at KidWind, but there are many others to choose from. All provide data of varying degrees of accuracy and detail.

OBJECTIVES OF THIS ACTIVITY

Students will learn:

- how to collect and analyze local wind data
- tools used to collect data
- how to graph wind data
- important wind data variables

SUGGESTED LEVEL

High School

TIME REQUIRED

2–3 Class Periods for data analysis
Weeks or Months to Collect Wind Data

MATERIALS REQUIRED

- [ ] wind speed data logger (A variety are described in the lesson)
- [ ] computer with Microsoft Excel or other spreadsheet software

COLLECTING WIND DATA

There are ways to find wind data about your location that do not require you to install a data logging anemometer. Some of these online sources are free and others can be quite expensive, based on the quality of the data.

The list below outlines some online locations where you can start searching for wind data close to your site.

Websites

- Wind Powering America State Maps: http://apps2.eere.energy.gov/wind/windexchange/wind_maps.asp
- Wind maps in your state can be found through search engines. For example, search for: "Wind Map Minnesota."
- Websites for local airports or municipal offices

For siting a small wind turbine at your school, online data will work as long as you can find a location close enough to your school and with similar topography, also consulting with a local wind installer. But this would be too easy!

We encourage you to install an anemometer with a data logging system because analyzing this data can be a very informative process.

To collect wind data, you will need a data collection system. These systems can vary in cost from $100–$1,000. The more you pay, the more data you can collect, the more analysis you can perform, and the more accurate it becomes. There are a number of new systems available from $300–$500 that are quite adequate for collecting and analyzing local wind data. It's not hard; give it a try!

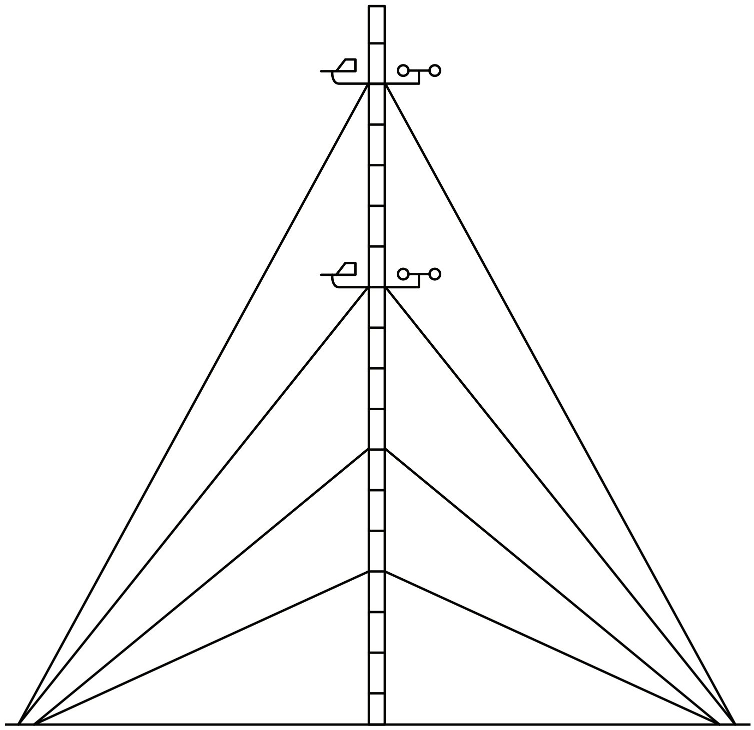
WIND DATA COLLECTION TOOLS

Smartphone Anemometers
Recently a few companies have developed anemometers for smartphones. Vavuud (http://vaavud.com/) makes an affordable smartphone anemometer that can record windspeed and direction over short amounts of time. This data is stored online and can be used with maps within the Vaavud phone app.

InSpeed Anemometers (www.inspeed.com)
InSpeed is a small US-based company that manufactures specialized anemometers and data loggers. They offer a wide variety of products to measure and record wind speed data. The items listed below could be used to collect and analyze local wind data.

Vortex Pole Mount ($100)
This kit includes an anemometer with digital display made from a bike computer. You can mount the sensor on a pole or tripod near a field or a building where you might install a turbine. The anemometer will record wind speeds up to 100 mph and is powered by a coin battery lasting several months under typical use. With this device you can continuously monitor wind speed, maximum speed, and average speed. This anemometer is great for applications where AC power is not available and for when directional data is not needed. We have used this device to log "wind miles" in a day, a week, or a month. Divide the "wind miles" by the number of hours the device has been collecting data and calculate the average wind speed in miles/hour (or kilometers/hour).

WindWorks Data Logging Kit ($290)
If you want a data logging system, the WindWorks platform provides comprehensive, accurate wind speed and direction data. It is compatible with the Inspeed Vortex wind sensor and electronic e-Vane, and includes interface electronics with USB cable and WindWorks software. One of the limitations is that you will need to have the interface plugged into a computer that is always on. The computer will also need to be near where you are in order to mount the wind and direction sensors. This can be problematic if your site is far from your classroom.


Commercial anemometer tower

Davis Weather Stations (www.davisnet.com/weather) ($500–$1,000)
Davis sells a number of home and business weather systems that can log wind and temperature data to a computer that is connected (by wire or wirelessly) to your weather system.

The data that is collected is transferable to Excel so you can do some basic analysis.

Logic Energy WindTracker (www.windlogger.co.uk/products/windtracker-unit-1) ($300)
Logic Energy makes a very robust data logger that can be used with anemometers made by Davis or InSpeed. Data is stored to a logger that does not need to be connected to a computer. This device is designed so that the logger can take data from two anemometers simultaneously, allowing you to measure wind shear. Stored data is collected on an SD card and can then be transferred to your computer for analysis. Once you have copied the data to your computer, it can be analyzed using Excel, software included with the Logic Energy data logger, or other tools.

Windographer Software (www.windographer.com) ($400)
For more sophisticated analysis of wind data, we recommend Windographer software. Windographer is the industry leading tool for analyzing wind resource data. This intuitive software is extremely powerful and allows for an in-depth understanding of the wind resource in your area.

Once you have collected enough data, the software will allow you to visualize frequency distributions, wind roses, and shear. (These will be explored in the next section.) It calculates the air density, wind power density, turbulence intensity, power law exponent, and surface roughness for every time step. This software also lets you visualize and analyze data collected in many graphical formats. Lastly, you can apply this data to a variety of turbine power curves and see how much energy a turbine would produce at your school. This is the software that the professionals use!

ANALYZING THE DATA

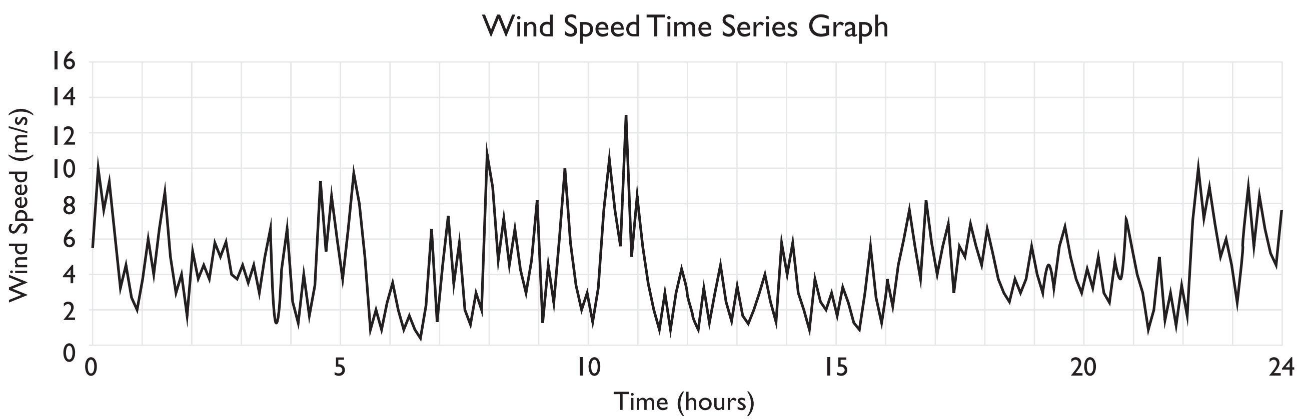
Once you have collected data, you need to perform analysis to see if your location is a high quality wind site. If you were planning to build a large wind farm, you would collect data for at least a year, probably more. For small wind sites or experimentation, you can collect data for any time frame you find interesting. Collecting a year of data would allow you to explore seasonal variability. You could also compare potential sites around the school simultaneously.

Let's assume you have collected piles of data. Below are some ways you can analyze your data. You can use Excel to perform some of these functions or purchase commercial software like Windographer.

SIMPLE WAYS TO ANALYZE WIND DATA

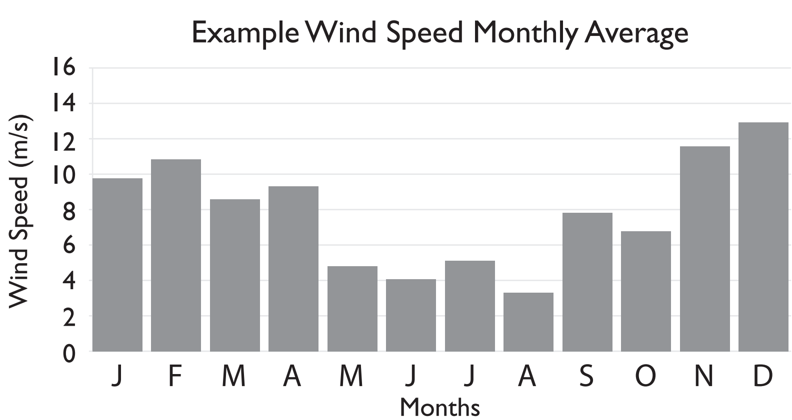
Time Series

This is a graph showing wind speed variation over a short period of time such as a day. This type of graph can give you some insight into the steadiness of your winds and their temporal variability. You can use Excel to generate these graphs.

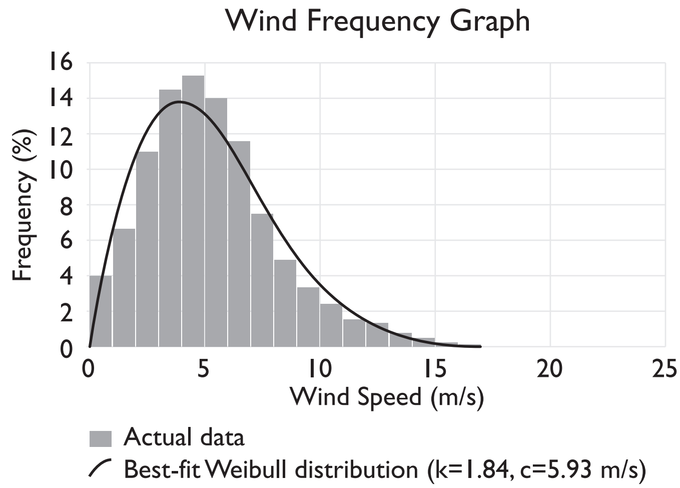


Monthly averages

By calculating daily, monthly, or weekly averages, you can explore daily or seasonal variations, answering questions like: When is it windier at our site? Morning or Night? Winter, fall, spring or summer? Use Excel to generate this data using the AVERAGE function.

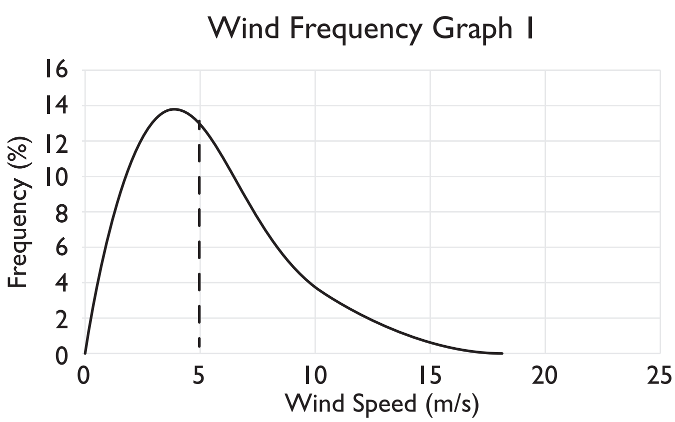


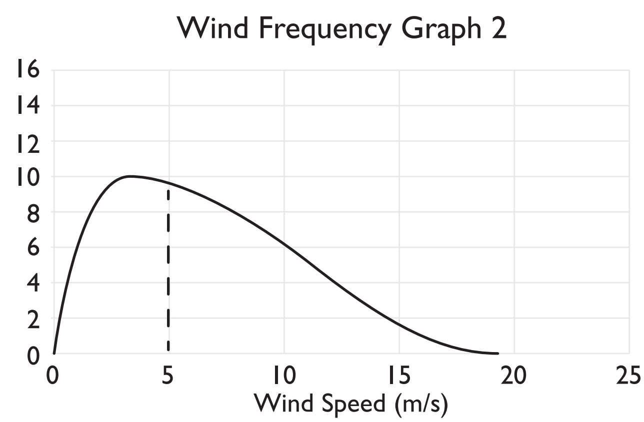
Wind Speed Distributions/Frequency
A frequency graph shows the percentage of time the wind has blown in a given velocity range. Understanding the frequency of wind speeds will offer you a better picture of the winds found at your site. The highest percentage may differ from the average wind speed, which can be important when determining how much energy you can generate. You can use Excel to generate this data using the function, but it can be a bit complicated to set up this analysis.



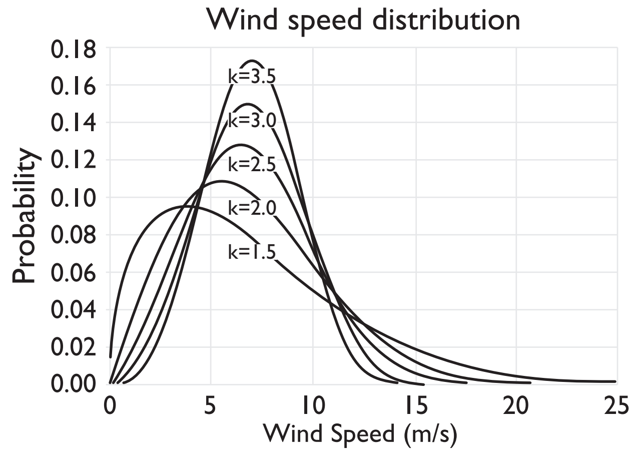
Why does the frequency matter?
Assume that you have two sites that have the same average wind speed, but one site may have lots of high wind-speed readings coupled with low wind-speed readings (the "either it's blowing or it isn't" phenomenon). The other site might have wind speeds clustered around the average. Even though the averages are the same, the site with the really high wind speeds will probably produce more electricity over the course of a year; this is due to how you calculate power in the wind (more on this later). See Lesson 7 for more information about wind speed and power output.

The graphs below show two locations with the same average wind speed but very different distributions. These distributions of wind would produce very different amounts of energy as the line with a value K=3.5 does not have as many high wind speeds as the K=1.5.





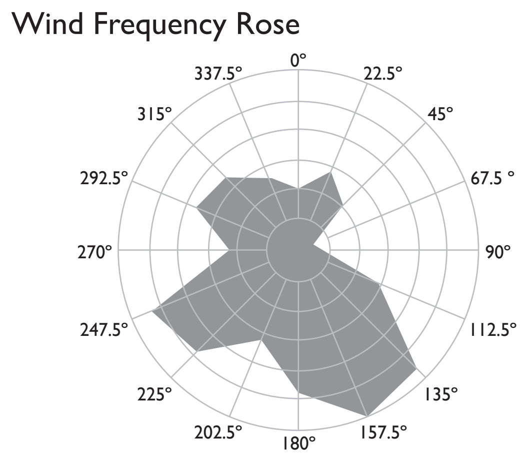
How does distribution affect energy output?
If you did not perform a frequency analysis before siting a wind farm, you could significantly underestimate or overestimate your production by using the average wind speed. The power in high wind speeds is vastly greater due to the fact the power in the wind is determined by the velocity cubed.



MORE ADVANCED WAYS TO ANALYZE WIND DATA

While you can use Excel to perform some of this advanced data analysis, this is where Windographer and other programs really show off their talents. Once you import the data, the software does all the work! Many of the images in this section are from Windographer software, using data from KidWind HQ in fall 2011.

Wind rose
A diagram that depicts the percent of time the wind comes from a particular direction and the average speed from that direction. This data can be very useful in siting turbines in complex topographies with building and other structures.



Wind shear and turbulence
Wind engineers usually place towers with three or four anemometers recording data at different heights above the ground. Wind speeds are typically faster and cleaner at greater heights as friction (ground drag) effects are reduced.

Understanding shear and wind speed
As altitude increases, the wind speed typically increases due to reduced friction between the moving air and the ground. There is a simple equation we can use to determine how much faster the wind is moving at altitude. This is critical as often we cannot install our anemometers at the same height we will be installing our wind turbine.

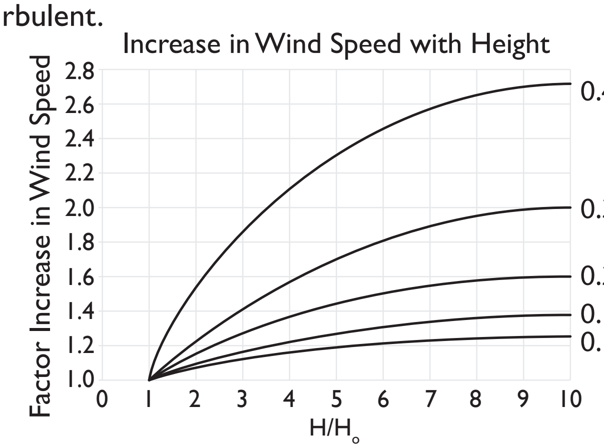
Calculating Wind Shear
V = wind speed at new height
V_o = wind speed at original height
H = new height
H_o = original height
a = wind shear exponent

$$\frac{V}{V_o} = \left(\frac{H}{H_o}\right)^a$$

We can record wind velocity at a standard height quite easily using mounted anemometers. The wind shear exponent is a factor of how rough a surface the wind is blowing over. A smooth surface, like an ocean or ice, might have a shear exponent of .07. A rough surface, like suburbs or forests, may have a value of 0.4.

If we know that that wind is blowing over a flat surface like the ocean at 3 m/s at 5 meters in height, we can figure out how fast the wind is blowing at 50 meters. Solve for V and we find that wind velocity at 50 meters is around 3.5 m/s or around 16 percent faster.

As height increases (in this case the ratio of H/H_o), wind speed increases. This also shows that over rougher surfaces with a higher shear exponent, this increase in speed can be dramatic. With a shear value of .4 (as with suburbs or woods), winds can be two times faster at seven times the height. The problem is that with a high shear factor, these winds may be quite turbulent.



APPLYING YOUR WIND DATA

Why all this worry about wind speed, distribution and direction?

Wind engineers care about wind speed because the power that can be extracted from the wind relies primarily on velocity. This is why engineers spend so much time collecting wind data. Wind is fuel for the wind turbine, and the engineers and bankers need to understand how much fuel they have before they invest in constructing a wind farm! Residential owners should do the same so they do not install a wind turbine in a bad location.

The power in the wind is described by the following equation:

$$P=\frac{1}{2}\rho AV^3$$

ρ= density of the air (kg/m^3) (1.2754 kg/m^3 at standard temperature and pressure)

A = area of turbine blades (m^2) (calculated $A=\pi r^2$ for the wind turbine you want to install)

V = wind velocity (m/s)

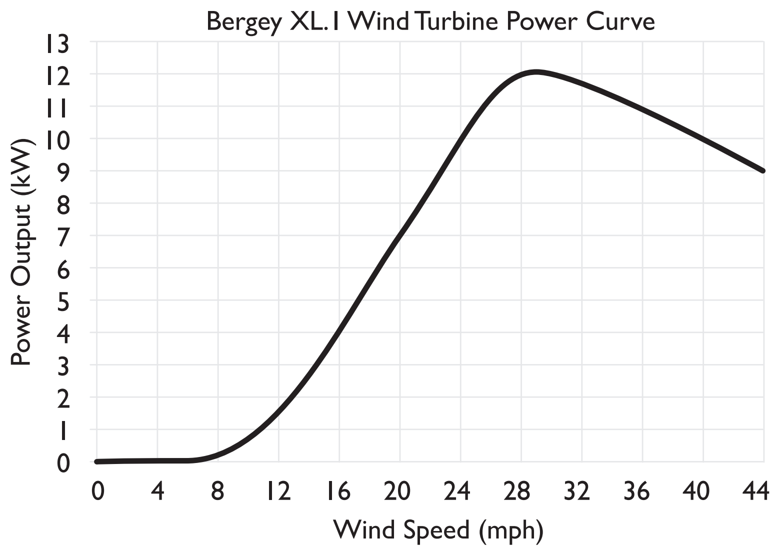
This equation allows you to calculate how much power is available in wind moving at a specific instantaneous velocity. Power output depends on two main variables: how fast the wind is moving and the swept area of your turbine. Look closely at this equation, above. A doubling of wind speed leads to eight times the amount of power due to the cubic function of velocity. This variable can make a huge difference and determines where developers site wind farms.

This equation sets the maximum amount of power that could be generated based on the velocity of the wind and the size of the column of wind being measured. In reality, wind turbines do not generate this much power because we cannot convert 100 percent of the wind into usable power. Most engineers are happy if their turbines can extract 40 percent to 45 percent of this maximum!

HOW MUCH POWER WILL MY TURBINE GENERATE IN THESE WINDS?

Wind power curves describe how much power a particular wind turbine can extract from the wind at a variety of different wind speeds. While these curves share a similar shape, they are specific to a particular turbine and offer insights when choosing a wind turbine for an individual location.

To the right is a basic wind power output curve for a Bergey XL.1 small wind turbine. From these types of curves, you can tell a great deal about the characteristics of a particular turbine such as when it will start making power, its maximum power output, and in what type of wind regime it will comfortably generate power.



Cut-in speed

This is the wind speed at which the wind transfers enough force to the blades to rotate the generator shaft. This number takes into account how smoothly the generator operates, the number and design of blades, and whether or not there are any gears or other frictional elements in the drivetrain.

Start-up wind speed

At the start-up wind speed, the wind turbine blades are moving fast enough and with enough torque that the turbine will start to generate electricity. While these numbers are pretty close to the cut-in speed, they are not the same. On a Bergey XL.1, the cut-in speed is around 5.6 mph, but the start-up wind speed is a little over 6.5 mph. While the wind turbine may be generating some electricity, at 5.5 mph it may not be enough to charge batteries or a sustain a connection to the electrical grid.

Maximum power output

This is the maximum amount of power the turbine can produce and is the peaking part of the curve. The maximum amount of power this turbine can produce is around 1,200 watts (1.2 kW) at about 29 mph.

The rated power (or nameplate output) for this turbine is 1,000 watts (1 kW) and, as shown in the graph this happens at around 24 mph.

These links will take you to some specification information from a variety of small turbine manufactures. You can examine their output curves and read more about the characteristics of small wind turbines. Some major manufacturers of small and large wind turbines include:

Bergey Windpower	http://bergey.com
Xzeres Wind	www.windenergy.com/
GE Windpower	https://renewables.gepower.com/wind-energy.html
Vestas	www.vestas.com
Suzlon	www.suzlon.com

HOW MUCH ENERGY WILL MY WIND TURBINE PRODUCE?

All the previous work leads us to the real question! The power a turbine can produce is helpful, but it does not tell you how much energy the turbine will produce. That is determined by how fast the wind blows and how much time wind is blowing that fast; that is why the frequency curve is so important. A huge wind turbine put in a place with no wind makes no energy! A small wind turbine put in a windy place produces lots of energy. When you are shopping for a wind turbine, it is more important to calculate how much it will produce, not its maximum output.

Combining the data you have collected about wind speed distribution with a wind turbine power curve will allow you to predict the amount of energy that the turbine could produce at your site. You could do this using Excel, but there are many specialized programs that make this calculation very easy. For example, once Windographer collates your frequency data, you can quickly calculate predicted energy output for a wide range of wind turbines.

CONCLUSION

Collecting and analyzing wind data can be quite a rich experience for students. Understanding the wind resource is critical to determining whether or not a particular site is appropriate for wind energy. Using some basic tools and analysis, students can get an idea of the wind energy potential of a site.

UNIT 3: TURBINES

HOW DOES A WINDMILL WORK?

LESSON 8

KEY CONCEPT

Students learn the fundamental parts of a windmill, how different rotor designs affect performance, and how energy is transferred from wind into usable mechanical energy.

TIME REQUIRED

2 class periods

GRADES

6–8
9–12

SUBJECTS

Physical Science
Technology/Engineering

BACKGROUND

Windmills are the ancient ancestors of modern wind turbines. To understand how wind turbines work, one must first understand a basic windmill. This lesson will help students understand how a windmill captures the energy of the wind and converts it into usable mechanical energy, which is the basis for understanding modern wind turbines. Students will use the engineering design process and the scientific method to design, build, test, and improve their models.

OBJECTIVES

At the end of the lesson, students will:

- know the fundamental parts of a windmill
- be able to use the scientific method to isolate and adjust variables in a model windmill
- understand energy conversions/transfers and how a windmill converts moving air into usable mechanical energy

METHOD

Students will use a limited amount of materials to design and build functioning windmill models. They will use these models to convert wind into usable mechanical energy to lift weights. Using the scientific method, they will conduct trials, change variables, and work to improve the performance of their windmills.

MATERIALS

Each group needs

- ❑ 1 small electric fan
- ❑ 1 3/8" Wooden Dowel 16"
- ❑ 1 piece of ½" PVC pipe (10" long)
- ❑ 4–8 index cards (4" × 6")
- ❑ 4 wooden shish kebab skewers (10" long)
- ❑ 4 feet of string
- ❑ 1 12-ounce paper deli cup
- ❑ 1 16-ounce plastic cup
- ❑ 1 foam cylinder
- ❑ 1 cork
- ❑ 4 straight pins or T-pins
- ❑ Clear Scotch Tape (18")
- ❑ 1 pair of scissors
- ❑ 15 steel washers
- ❑ Student reading passages and worksheets *included in this activity

Classroom materials to share

- ❑ Staplers
- ❑ Various simple tools (pliers, screwdriver, etc.)

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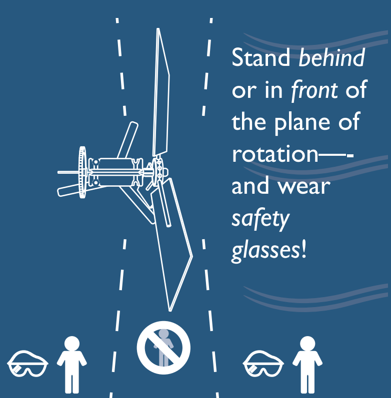
⚠ CAUTION!

- Do not stand in the plane of rotation of the rotor! (See diagram below.) You could be hit if your blade flies off during testing.
- The spinning rotor blades and metal rod can be dangerous. Make sure students work with caution.
- Be careful when working with the metal rod. Do not swing or play with the rod! The ends can be protected with tape, foam, cork, etc.
- Wear safety glasses when testing windmills. Safety glasses must be worn any time blades are spinning.



GETTING READY

- It is strongly suggested that teachers try to build their own windmills before the class begins. This is a valuable preview to the challenges and problems that students will face.
- Separate the materials to distribute to each group. Remember that materials for this activity are intentionally limited, as this encourages creativity and discourages waste. Use small, weak fans (8 inch diameter) to encourage the students to build efficient designs.
- Ask students to do some background reading on windmills and wind power.
- The "Additional Resources" section below offers a great deal of background information. Students should have read the Career Profile before class period 2.
- Make copies of the worksheets for each student group.

ACTIVITY

In the first class period, students should focus on getting their prototypes to spin when placed in front of the fan. In the second class period, students will work to get the windmill to lift a cup of weights (washers) as it rotates.

Class Period 1

Step 1: Beginning questions for students

- Who has seen a real windmill (mechanical or electrical)?
- What are the parts and features of a windmill?
- What are windmills used for?
- How does the wind cause the windmill to rotate?

Step 2: What is a windmill?
Ask a couple of students to draw a windmill on the blackboard. Ask the other students to describe how these windmills work and what they are used for.

Step 3: Distribute materials
Present the windmill design activity to the students and organize them into groups of 3–5. Give each group the required materials. (Do not pass out the string, cups, or washers yet, as these will be distributed at the beginning of the second class period when the weight-lifting challenge is presented.) As you distribute the materials, be sure to mention some ground rules for safety. (See note in margin, on left.)

Step 4: Spin in the wind
Instruct the students to assemble a mechanism that will rotate when placed in the wind. Tell them not to worry about lifting weight yet. The first challenge is just to get the windmill to spin. (Note: there are not enough materials to build a tower. These windmills should be held by hand or attached to the desktop.)

Step 5: Design and testing
Give the groups plenty of time for initial designing and construction. Each group should have a chance to test its windmill with the fan at least once during this first class period. There is no right answer here and many designs are possible. Students will feel confused. That is okay!

Step 6: Wrap up
At the end of class, show the students different pictures of real windmills and wind turbines. Discuss how windmills work and the fundamental parts of a windmill. How do these real windmills differ from their initial designs? What new ideas do the pictures give them?

Other possible questions
- What windmill designs worked best?
- What parts were most difficult to design and make functional?
- How did you attach your blades?
- Where is there friction in your design?
- How did you reduce friction in your windmill?
- How did you pitch or angle the blades?
- Were your blades changing pitch frequently?
- Did the fan work better from the front of the blades or the side?
- What energy transfers were taking place as the windmill spun?

Class Period 2

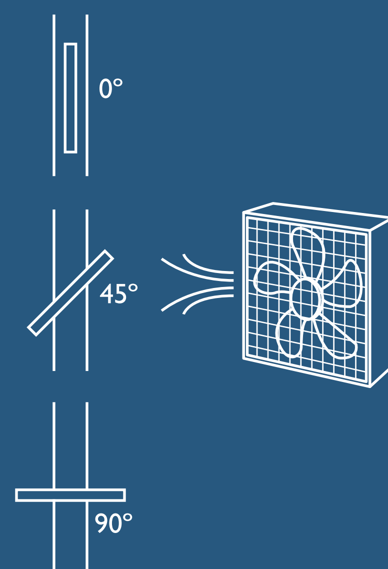
Step 1: Weight-lifting challenge
By the beginning of this class period, most groups should have gotten their windmills to spin in the wind. Now introduce the weight-lifting challenge. Give each group the string, cups, and washers. Their goal is to use the power of the wind to lift as many washers as possible. As students work toward this goal, they will have to isolate and improve certain variables in their designs.

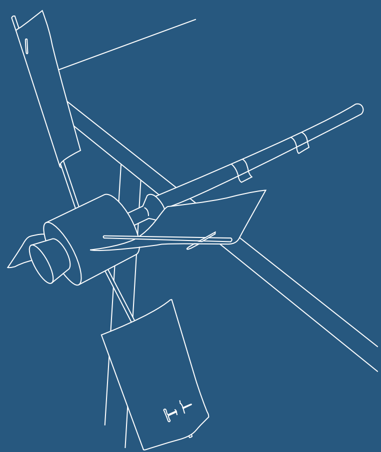
Step 2: Testing variables and improving designs
As students test their weight-lifting windmills, give them guidance and tips on how to improve their designs. Encourage them to focus on one variable at a time; conduct a trial, measure the results, make changes, and repeat the trial. The size, shape, pitch (angle), and number of blades can be explored. The variables of fan setting (speed) and distance from the windmill should be kept constant. Encourage students to use the scientific method as they design and test their prototypes.

Some groups may struggle to get the windmill to lift any weight. Encourage them to look at other groups that have been successful. What techniques work well and what does not seem to work? Remind students that this activity is not a competitive contest, but rather a class effort. Students can learn from and support each other.

BLADE PITCH

Blade pitch is the angle of the blades with respect to the plane of rotation. The pitch of the blades dramatically affects the torque of the rotor. Pitch also affects the amount of drag experienced by the blades. Efficient blades will provide maximum torque with minimum drag.





Tell students to hold their windmills or tape them to a desk.

Step 3: Wrap up

- How many blades worked well for lifting weight?
- Did more blades mean you could lift more weight?
- What blade pitch was best for lifting weight?
- Where did you attach the string? Why?
- How did your design change after the attempt to lift weight?
- How were you able to get more turning force from your blades?
- What energy transfers took place as weight was lifted?
- What ideas seemed to work well?
- What problems did you encounter?
- What skills did you use that Pat Walsh (Career Profile) also uses as a wind turbine technician?
- What parts of your windmill broke or failed? Are those the same parts that Pat Walsh fixes on turbines?

EXTENSION

For a quantitative analysis of different rotor efficiencies, tell students to calculate the energy required to lift the mass they have lifted and the power of their windmill as it lifts that mass. Energy is measured in joules (J). Power is measured in watts (W). Power is a measurement of how fast energy is converted. In this case, power is a measurement of how fast the mass is lifted.

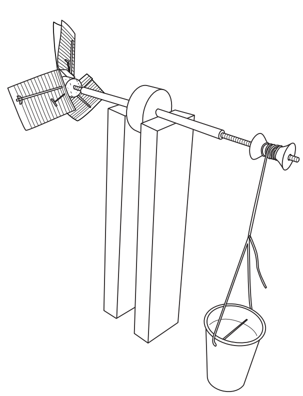
To calculate how much energy is required to lift the washers, students will first need to measure the mass (kilograms) of the washers they are lifting and how high they are lifting the washers (meters).

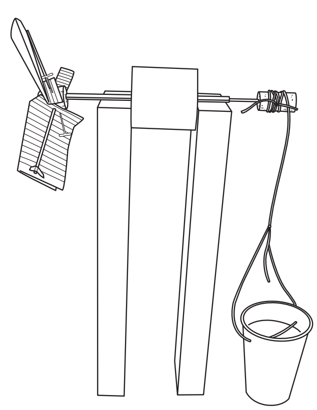
Energy (J) = Mass (kg) × Acceleration of Gravity (9.8 m/s^2) × Height (m)

To measure power, they must also measure how long it takes to lift the mass to that height (seconds). Standardize the height so that every group must lift to the same height (0.5 meter or so).

Power (W) = Energy (J)/Time (s)

Tell students to record their data on the Power and Energy worksheet. Recording these data and calculating power for different prototypes will give the students a quantitative comparison.





VOCABULARY

blade pitch – The angle of the blades with respect to the plane of rotation. (Blades perpendicular to the oncoming wind would be 0 degrees. Blades parallel to the wind would be 90 degrees.)

drag – In a wind turbine, this is also called wind resistance. The friction of the blades against air molecules as they rotate. Drag works against the rotation of the blades, causing them to slow down.

driveshaft – The rod or shaft connected to the hub; it rotates with the rotor.

energy transformation – The conversion of energy from one form to another. For example, when coal (chemical energy) is burned, it produces heat (thermal energy) that is then captured and used to turn a generator (mechanical energy), which transforms the energy into electricity (electrical energy).

force – A push or pull.

friction – A force that resists the relative motion of two bodies in contact.

hub – Central component connecting the blades to the driveshaft.

plane of rotation – The area directly in line with the rotor. This is a dangerous area to stand in case a blade flies out while the windmill is spinning.

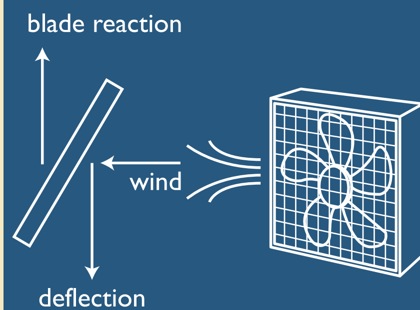
rotor – The rotating section comprised of blades projecting from a hub.

torque – A force times a distance that causes rotation. In a windmill, each blade acts like a lever arm rotating around an axis. The more surface area the blade has, the more torque the wind applies to the blade.

RELATED ACTIVITIES

- Lesson 9: How Does a Generator Work?
- Lesson 10: Which Blades Are Best?
- Lesson 11: How Can I Design Better Blades?

HOW DO BLADES MOVE?



CAREER PROFILE: PAT WALSH, WIND TURBINE TECHNICIAN

A wind turbine technician repairs and maintains wind turbines. That means that every day I get to climb 300-foot towers and fix broken turbines! To be able to repair a wind turbine, I had to become an expert in hydraulics, electricity, wind turbine mechanical systems, and electronics. Technicians must also be physically fit and very safety conscious, as the job can be physically strenuous. Of course, I cannot be afraid of heights, either. While the heights may sound scary, the perks of this job are good. I earn a competitive salary with benefits, not to mention enjoying the spectacular views every day while on the job! In addition, I, like many technicians, got to travel to Europe as part of my training.

Colleges across the United States have begun offering training programs for wind turbine technicians. These 2-year programs teach students everything they need to know to be a certified “wind-smith.” I was trained at Iowa Lakes Community College, but my co-workers came from several different schools. These days, demand for wind technicians is high, and some students are hired by the wind industry while they are still finishing their training.

Name____________________________ Date________________ Class___________ Group_____________

HOW DOES A WINDMILL WORK?

1. Draw a diagram of your windmill design in the space below. Label the following parts: blades, rotor, hub, driveshaft. Label these concepts: force, friction, distance (height of string).

2. Which of the following variables did you explore?
   Number of blades, blade shape, blade size, blade pitch (angle), fan location, wind speed, other (explain).

3. Rank the variables in your design from most important to least important.

4. What effect did the number of blades have on how much weight your windmill could lift?

5. How did the pitch (angle) of the blades affect the amount of weight your windmill could lift?

6. Draw a picture of your wind turbine and label the energy transfers or conversions that took place as you used the wind to lift weight.

7. Explain the windmill design that had the best results. Why do you think this design worked best?

Name______________________ Date______________ Class__________ Group____________

EXTENSION ACTIVITY

WINDMILL DESIGN	MASS (KG)	DISTANCE (M)	TIME (S)	ENERGY (J)	POWER (W)
example	0.1	1	10	0.98	0.098

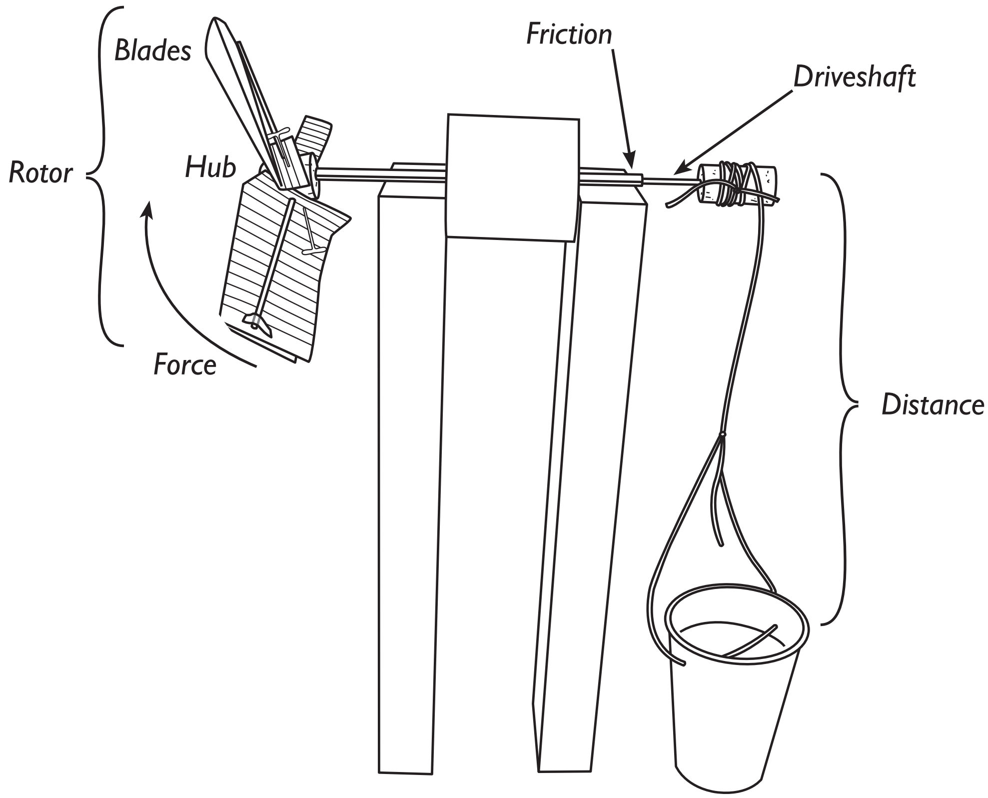
1. Which design had the most power? Why?

2. How is your windmill different from windmills you have seen in real life or pictures?

3. Did you notice any relationship between the *size* of your blades and the *power* output?

1. Draw a diagram of your windmill design below. Label the following parts: blades, rotor, hub, drive shaft. Label these concepts: force, friction, distance (height of string).

   There will be friction wherever the driveshaft rubs against something else. In this case, the driveshaft rubs on a piece of tubing it is going through.



2. Which of the following variables did you explore?

   Student observations.

3. Rank the variables in your design from most important to least important.

   Answers will vary. Wind speed and blade pitch are very important variables.

4. What effect did the number of blades have on how much weight your windmill could lift?

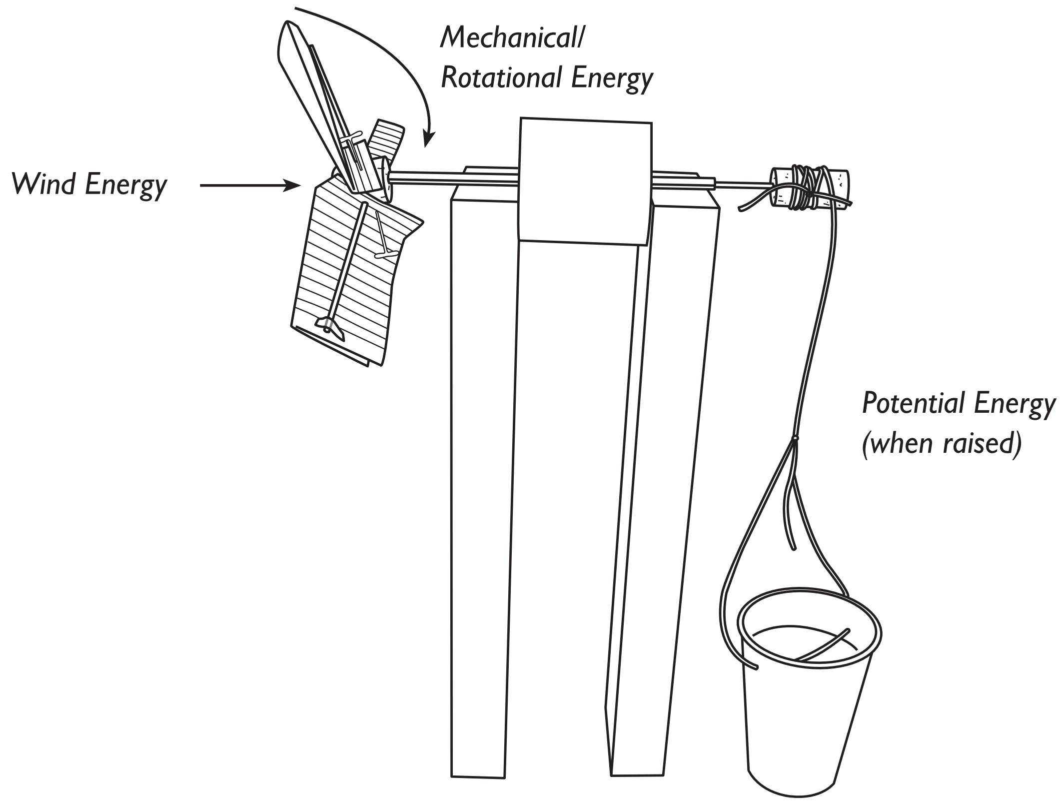
   More blades will give the windmill more torque, which usually allows it to lift more weight. Typically 6 blades can lift more than 3 blades.

5. How did the pitch (angle) of the blades affect the amount of weight your windmill could lift?

   Blade pitch is a very important variable. Shallow pitched (10–30 degrees) blades can spin faster, but more pitch (30–60 degrees) can give the windmill more torque. Typically students find that blades pitched at 30–45 degrees lift the most weight.

6. Draw a picture of your wind turbine and label the energy transfers or conversions that took place as you used the wind to lift weight.

   Energy Transfers/Conversions:
   Wind Energy ➔ Mechanical/Rotational Energy ➔ Potential Energy (elevated mass)



7. Explain the windmill design that had the best results. Why do you think this design worked best?

   Answers will vary. The best windmills will be well constructed with sturdy blades and a bearing system that minimizes friction. They will most likely have 3–6 blades pitched at 30–45 degrees.

LESSON 9

HOW DOES A GENERATOR WORK?

KEY CONCEPT

Students learn how electricity is generated and how design variables affect electricity production.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Physical Science

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BACKGROUND

All wind turbines contain generators that transform the energy of the wind into electricity. Engineers are constantly trying to improve the performance of these generators, allowing the turbines to transform more energy of the wind into electricity. This lesson explores the physics of how generators work and some variables to improve performance.

OBJECTIVES

At the end of this lesson students will:

- understand the main parts of an electrical generator and their relationships
- be able to construct a simple generator
- understand how electricity is generated
- be able to use a digital multimeter to record voltage and amperage output

METHOD

Using simple materials, student groups will construct a simple generator to try to light a small bulb. Each group's generator will have a different number of windings and types and numbers of magnets so that the class can collect and compare data on the variables that affect electricity production.

MATERIALS

You will need some materials or a kit to make a generator. We know there are lots of plans and kits out there we are going to highlight two that we really like.

Original plans
Ultra-Simple Electrical Generator by William Beatty.
http://amasci.com/amateur/coilgen.html

Recommended kit
SimpleGen found at www.vernier.com/. This more finished product was inspired by William Beatty's design and allows you to construct a generator that you can place on a tower and make and test turbine blades.

Classroom materials to share

- ❑ Drill
- ❑ Craft knife or scissors
- ❑ Electrical tape or duct tape
- ❑ Windmill from Lesson 8 (optional)
- ❑ Student reading passages and student worksheets*
  *included in this activity

  Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

MOTORS & GENERATORS: WHAT IS THE DIFFERENCE?

It is great to provide students examples of commercially made generators or DC motors, so they can see what is inside. You can usually find these at local electronic or appliance repair shops for very little money; they don't even have to work. The "guts" of these devices have a number of components similar to those in the generator we are building.

Keep in mind that at the scale at which we are working, a motor and a generator can be the exact same object, just used in different ways. When you spin a motor-generator it converts mechanical energy into electrical energy and it becomes a generator. When you put electricity into a motor-generator, it spins and becomes a motor.

GETTING READY

- Before working with students, it is recommended that you build a few of the generators (with different numbers of windings and numbers and types of magnets) to help show variability in the device. This will also help if you have groups that do not build quality generators that can be used for testing and collecting data.
- Make copies of the worksheets for each student and copies of the construction plans for each group.
- As a time-saving alternative for this lesson, have a variety of generators (with different numbers of windings and numbers and types of magnets) pre-constructed from which students can collect data. You can also save generators from the first year for use in later years or activities.
- Separate the materials to pass out to each group or put them in a central location for the student groups to collect.
- (Optional) Track down some sample DC motors and/or DC or AC generators to use as examples of how these are constructed.

ACTIVITY

Step 1: Beginning questions for students

Start a discussion to assess how much your students understand about generators. This is a great time to share any hand-crank generators or other demonstration items you have available. Some questions for discussion include:

- What is electricity?
- What is a generator?
- What parts make up a basic electrical generator?
- How do we generate electricity (Lessons 2)?
- What do we need to generate electricity?
- Has anyone ever seen a generator?
- Where do you find generators?
- What is the difference between a motor and a generator?

Step 2: Similarities of generators

Ask students to examine some of the generators that you have previously constructed for this lesson and any other examples you have. What do these generators have in common? Students may respond that some of the parts are similar (i.e., magnets, wires, and coils) or that the generators all operate in a similar fashion (i.e., they all spin).

Step 3: Examining magnets

Divide the class into groups of two to three students each. Distribute a few magnets to the student groups. Ask the students what they notice about the magnets. Discuss repelling and attracting and north and south poles. Draw a magnet and the magnetic fields on the board. Discuss the importance of the fields (flux) and how they can be of different strength depending on the type of magnets. You can also show students some stronger magnets. (Use care with stronger magnets, as they can snap together with a great deal of force.)

Step 4: Examining magnet wire
Distribute magnet wire to the student groups. Is there anything they notice about this wire? How is it different from other wire they may have seen? The answer is a very thin layer of insulation. What do they notice about the orientation of the wire in the generator examples you have provided? Answers may include observations that there is a lot of wire, that the wire is in straight lines, and that the wires are packed very close together.

Draw a coil of wire next to the magnets you have drawn on the board. This is also a good time to talk about wire sizes (gauge). The larger the gauge number, the smaller the wire: 0 gauge wire is 8.25 mm in diameter; 26 gauge wire is 0.40 mm in diameter.

Step 5: Magnetic fields and wire
Discuss with students how the magnetic fields (flux) might impact the wire or what the wire is composed of. This discussion can refer to any lessons you may have given about induction.

Step 6: Building the generator
Distribute the construction plans, worksheets, and materials. Have each group construct one generator with a different number of windings (from 100 to 400) and different numbers and types of magnets from the other groups so that the class can collect and compare data for the different designs.

Cover the topics listed below before students build their generators:

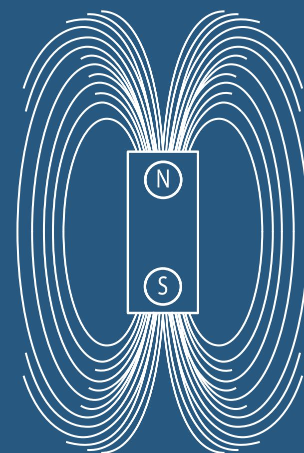
- Windings: be sure to show students a few generator windings in commercially made generators or in your homemade ones. Students should notice how straight the magnet wire is lined up as it is coiled. They should try to duplicate this in their generators.
- Driveshaft: students should make sure they do not put wires over the holes in the box where the driveshaft will be placed as this can cause friction or break the wire.
- Stripping magnet wires: before students connect their wires to the multimeter or LED bulb, they must make sure that the wires have been stripped using sandpaper or the sharp edge of a scissors. It is a good idea to secure the wires to the box once you have them stripped so they do not get tangled.

As students are building the generators, draw a data chart on the board (similar to the one on their student worksheets) to collect class data.

Step 7: Collecting generator output data
Ask each group to hook its generator up to the LED and low-voltage bulbs to see if the generator will light up the bulbs. Generators with less than 100 windings will probably not light the bulbs.

To spin the generators, tell students to first use their hands and record the AC voltage that is created at low speed. Then direct students to hook the

MAGNETIC FIELD



Magnetic fields of flux surround magnetic objects. This field can be felt when you get two magnets near each other or put magnets near other metal objects. The strength of these fields depends on the size, type, shape, and orientation of the magnets. The poles of magnets are often labeled north and south.

generators up to a drill and record the AC voltage that is created at high speed. Have students record the data on their worksheets. After each group has collected their data, record the class data on the board and ask students to record it on their worksheets so they can make a graph of the data.

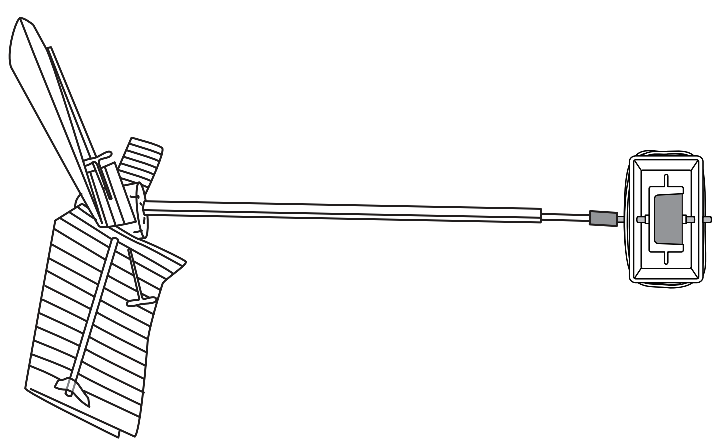
Step 8: Wrap up
Some questions for class discussion include:

- What were some of the problems in building the device?
- How are these problems solved on the commercial generators that have been examined?
- How could your team have improved the design of this generator?
- What generator made the most voltage?
- Why do you think that occurred?
- What was the minimum number of wire turns needed to light a bulb?
- If you had smaller diameter wire, how might it affect your output?
- How did stronger magnets affect the output of the generator?
- How did the rate of spin affect the output?
- When you attached the bulb, was it harder to spin?
- If you got the bulb to light, why did it flicker?

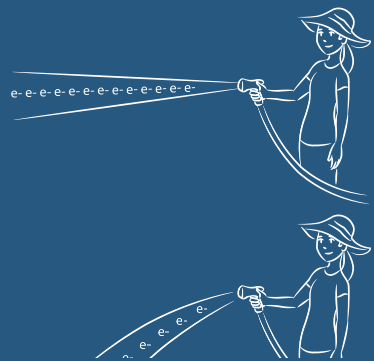
EXTENSION

Extension Activity 1
Students can attempt to connect the windmill they constructed in Lesson 6 to the generator they built in this activity. By attempting this additional activity, students can further explore energy transformations that start with wind energy as the energy source. Students can also use KidWind Hubs that are found in many KidWind kits. These hubs attach to the green quick connect at one end of your driveshaft. You can then attach blades to the hub and see how well the generator will run using wind power.

For example:



VOLTAGE



A negative charge will attract a positive charge. Invisible fields of voltage exist between the charges—kind of like magnetic fields. Voltage causes the attraction between opposite charges. We can quantify this attraction with a simple multimeter.

Using water as an analogy, we can also think of voltage like water pressure. Low voltage would be water under low pressure. High voltage would be water under high pressure. The amount of water is not so important; it is the pressure of the water that matters.

VOCABULARY

alternating current (AC) – Electric current that flows in two directions—back and forth, over and over again. The polarity (+/−) at the generator is constantly reversed by alternating the magnetic poles past the coils. Most household outlets have AC current.

coil – A winding of magnet wire. All generators and motors contain coils that vary in size, number, shape and orientation.

direct current (DC) – Current that flows in one direction. A battery, capacitor, or spinning DC motor all provide DC current.

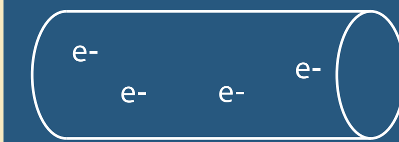
electrical generator – A device that converts mechanical energy to electrical energy.

electromagnet – By putting current through a wire, you can make a wire magnetic.

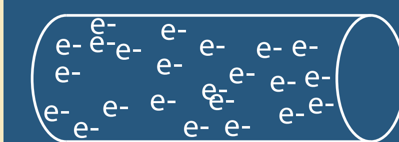
electromagnetic induction – Moving magnets near wires will create electric voltage in the wires. The amount of voltage depends on how quickly you move the magnets past the wires or vice versa. The more wire that interacts with the magnetic flux, the higher the voltage and subsequent current generated.

magnetic field (flux) – The space around a magnet where its force is exerted. This force is stronger the closer you get to the magnet and can be stronger or weaker depending on the type of magnet. Different areas of the magnet have opposite or opposing forces. We typically label these areas the north and south poles.

CURRENT



Less Current



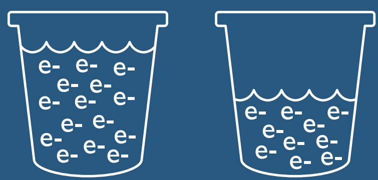
More Current

Current is the flow of electric charge in a conductor.

We can think of this as the amount of water flowing in a tube. The higher the current, the more water is moving in the tube. Low current would be similar to less water flowing in the same size tube.

Current is measured in Amperes (A).

ENERGY



Energy is something that can do work.

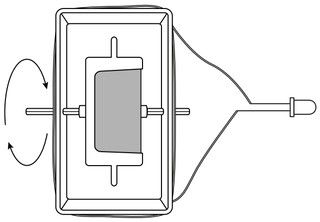
In our water analogy, this would be equivalent to a bucket of water. It is a quantity of energy that can do a certain amount of work. If we had a lot of pressure (voltage) and a lot of water (current) moving through a hose, we could fill up the bucket very fast. In electrical terms, a bucket of energy is kind of like a battery.

RELATED ACTIVITIES

- Lesson 8: How Does a Windmill Work?

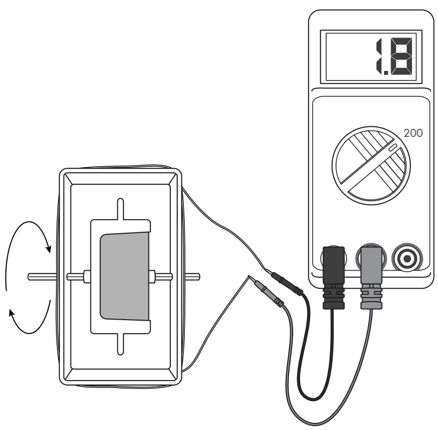
GENERATOR TESTING & TIPS

Below are some basic tips and tests you can perform on the generator that your students construct. We know that you may have made your own generator or used a SimpleGen kit that you have purchased.



LED

Depending on how many turns of wire or the size of the wire used, you may be able to light up an LED as you spin the generator. You can get a rough idea of how much current or voltage you are generating if the LED lights up at all or how brightly it glows.



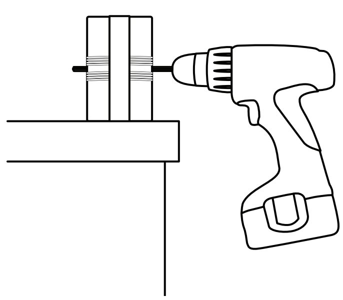
Multimeter

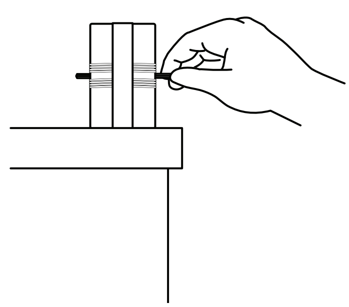
Using a simple multimeter set to measure AC voltage you can collect data on the output of your generator as you conduct comparative experiments. If you want to measure the DC output of your generator you will need to use a rectifier to clean up your output.

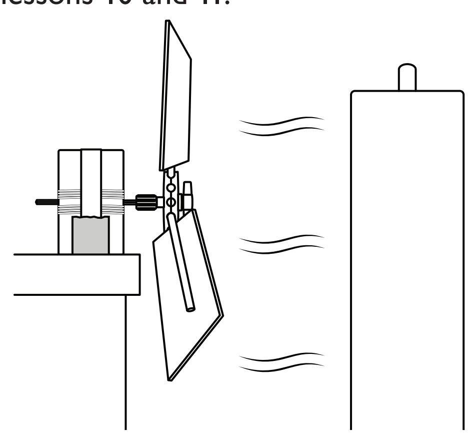
Spinning your generator

You can use your hands or a drill to spin your generator. For experimental purposes it is better to use a drill as you can maintain a constant speed over a longer time.

If you have purchased a KidWind SimpleGen kit then it will be easy to attach a KidWind hub and make and test turbine blades. If you are handy you can also adapt the Ultra-Simple Generator to spin using wind, water or other kinetic forces. For more details on making wind turbine blades, see WindWise lessons 10 and 11.



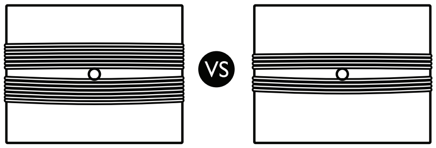




Common problems:

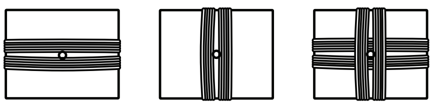
- Make sure you have really cleaned the enamel off the ends of the wires or you will not conduct any electricity.
- Make sure that you have wound enough coils; less than 100 turns will not light a bulb.
- Make sure your coils are straight, tight and neat.

Number of Coils



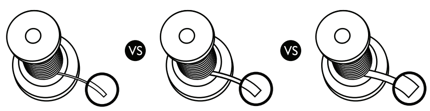
More coils Fewer coils

Orientation of Coils



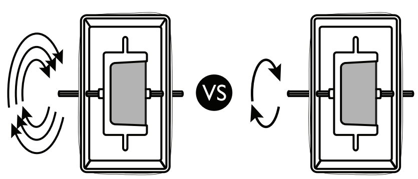
Horizontal coils Vertical coils Horizontal & vertical coils

Size of Wire



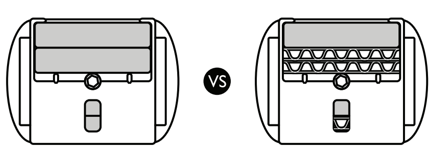
28 gauge wire 22 gauge wire 32 gauge wire

Speed of Spinning



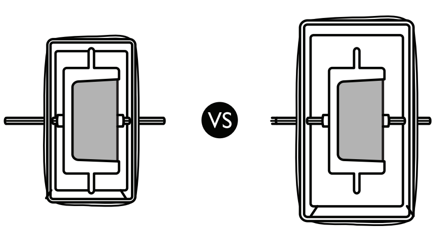
Faster Slower

Number of Magnets



Four magnets Two magnets, two shims

Distance from Magnets to Coils



Smaller box Larger box

GENERATOR EXPERIMENTS

Coils
Number of turns, total number of coils, orientation of coils

How you wind your coils can affect how well a generator works. Try testing generators with different numbers of turns of wire, different orientation of coils, or different numbers of coils.

Size of wire
The size of the wire can affect how many turns of wire you can get close to the magnetic field. Try wrapping the same number of turns using different wire sizes. What happens to your voltage output?

Speed of spinning
How fast you spin your magnets can affect your voltage output. Try spinning your generator at different speeds and see what happens.

Number of magnets
On one generator, use only one magnet on each side of the magnet holder. You can do this by making a cardboard shim and substituting it for one of the magnets on each side. How does this affect your voltage output?

Strength of magnets (*safety issue*!)
You can buy larger neodymium magnets from a number of companies. Look for a size that will fit into the magnet holder. See what happens to your output when you use stronger magnets. Use caution because large neodymium magnets are *very* strong and can cause injury.

Distance from magnets to coils
We have provided a simple box to wind your coils. If you want to get creative, you could build your own box that tries to get the coils closer to the magnets. This can greatly improve your performance.

IMPORTANT NOTE:
The images shown here reflect the original KidWind SimpleGen kit. While the types of experiments that you can do remain the same, the new KidWind SimpleGen kit (2014) looks different and can be placed on a tower.

Name______________________________ Date______________ Class________

HOW TO BUILD A GENERATOR

Understanding generators

1. Draw a magnet. Label the poles and field lines. Next to your magnet, draw a simple wire coil.

2. How might the magnetic fields (flux) interact with the wire?

3. Which is larger: 20 gauge or 30 gauge wire? ______________________

Building & testing your generator

Build your generator using the construction plans and materials provided.

1. How many times did you wind the wire on your generator? ___________

2. What size is the wire? ______________________________

Voltage output

NUMBER OF MAGNETS AND TYPE	VOLTAGE OUTPUT (HAND)	VOLTAGE OUTPUT (DRILL)	DID IT LIGHT A BULB?

Once you have collected your own data, share it with others and put it on the board.

3. Draw a picture of the generator your team built and label the coils, magnets, and driveshaft.

4. Where do you think the magnetic fields are affecting the wires the most?

5. How does your generator compare to the commercial generators that you were able to see inside? How were they different or similar? (Optional, depending on materials)

6. What parts of the generator had a great deal of friction? How could you improve the design and performance?

Analyzing generator performance

Graph the class data. Show the number of windings versus AC voltage at low speed (hand) and at high speed (drill).

STUDENT GROUP	NUMBER OF WINDINGS	# OF MAGNETS	MAGNET TYPE	AC VOLTAGE (HAND)	AC VOLTAGE (DRILL)	DID IT LIGHT A BULB?	DESIGN PROBLEMS

Name_______________________________________ Date________________ Class_________

1. What are the independent and dependent variables?

Answer the following questions using the class data:

2. What generator made the most voltage?

3. What was the minimum number of wire turns needed to light a bulb? ____________________

4. How might smaller diameter wire affect the output?

5. If stronger magnets were used, how did they affect the output of the generator?

6. How did the rate of spin affect the output?

7. When you attached the bulb, was the generator harder to spin?

8. If you got the bulb to light, why did it flicker?

1. Draw a magnet. Label the poles and field lines. Next to your magnet, draw a simple wire coil.

2. How might the magnetic fields (flux) interact with the wire?
   Students observations. Students might say the wire is attracted and repelled. It is doubtful that students will make the leap to electrons moving in the wires, unless coached. The magnetic fields of force will cause the electrons in the wires to move. As the field switches from north to south as the magnets spin, the electrons will move back and forth.

3. Which is larger: 20 gauge or 30 gauge wire? *20 gauge*

Building & testing your generator

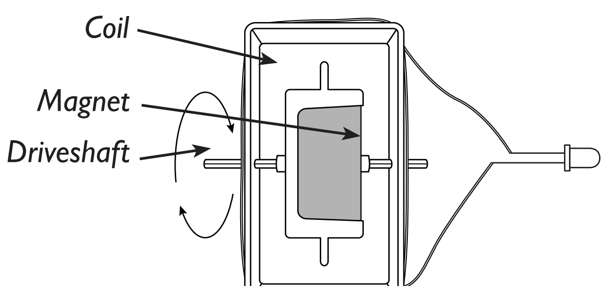
Build your generator using the construction plans and materials provided.

1. How many times did you wind the wire on your generator? *Student observation*

2. What size is the wire? *28 gauge (but teachers might have different sizes)*

3. Draw a picture of the generator your team built and label the coils, magnets, and driveshaft.

4. Where do you think the magnetic fields are affecting the wires the most?
   With the basic ceramic magnets, the wires at the end of the generator are most impacted by the magnetic fields.



5. How does your generator compare to the commercial generators that you were able to look inside? How were they different or similar? (Optional, depending on materials)
   Both devices will have coils of wire and magnets. On many of the motors and generators, the coils of wire will be the part that spins and the magnets are stationary.

6. What parts of the generator had a great deal of friction? How could you improve the design and performance?
   The place where the nail touches the box can produce a great deal of friction. Making the hole larger or using a bushing can improve this. There might also be slipping of the magnets on the driveshaft as it spins; securing them with tape or glue can solve this as well.

Analyzing generator performance

Graph the class data. Show the number of windings versus AC voltage at low speed (hand) and at high speed (drill).

If the generators are built with care, then what you should see on the graphs is that more windings equals higher voltage. Also, faster spinning should increase voltage output.

1. What are the independent and dependent variables?
   The independent variable is the wire winding. The dependent variable is the voltage.

Answer the following questions using the class data:

2. Which generator made the most voltage?
   This should be the generator with the most windings, but this can be greatly impacted by the quality of construction and the neatness of the wire windings.
3. What was the minimum number of wire turns needed to light a bulb? *Student observations; around 150.*
4. How might smaller diameter wire affect the output?
   Smaller wire would allow for packing more windings in a smaller space. More windings will increase voltage. But watch out! If the wire is too small, the resistance of the wire can impede the flow of electrons and start to heat up and become less efficient.
5. If stronger magnets were used, how did they affect the output of the generator?
   Stronger magnets should increase voltage because they have more magnetic flux.
6. How did the rate of spin affect the output?
   Faster spin charges the magnetic field more quickly, which should increase voltage, but this depends on how well the device is wound.
7. When you attached the bulb, was the generator harder to spin?
   When you put a load (light bulb, motors) in the circuit, the generator should be harder to spin. This may be somewhat noticeable with hand spinning but probably not with the drill.
8. If you got the bulb to light, why did it flicker?
   The generator produces alternating current (AC) as the magnet spins around near the coils. If you wire the output to the red LED, you will get a pulsed light because LEDs only accept one direction of current flow. If you can count fast, you may be able to count the LED light pulses and figure the frequency of the AC being generated. Say it blinks 10 times/second, that would be 10Hz.

WHICH BLADES ARE BEST?

LESSON 10

KEY CONCEPT

Students learn through experimentation how different blade designs are more efficient at harnessing the energy of the wind.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Physics
Technology/Engineering
Mathematics

KidWind PROJECT®

www.KidWind.org

BACKGROUND

The blades of a wind turbine have the most important job of any wind turbine component; they must capture the wind and convert it into usable mechanical energy. Over time, engineers have experimented with many different shapes, designs, materials, and numbers of blades to find which work best. This lesson explores how engineers determine the optimal blade design.

OBJECTIVES

At the end of the lesson, students will:

- understand how wind energy is converted to electricity
- know the process of scientific inquiry to test blade design variables
- be able to collect, evaluate, and present data to determine which blade design is best
- understand the engineering design process

METHOD

Students will use wind turbine kits to test different variables in blade design and measure the power output of each. Each group of students will isolate one variable of wind turbine blade design, then collect and present data for that variable. If time allows, students can use their collected data to design an optimal set of wind turbine blades using the next lesson, "How Can I Design a Better Blade?"

MATERIALS

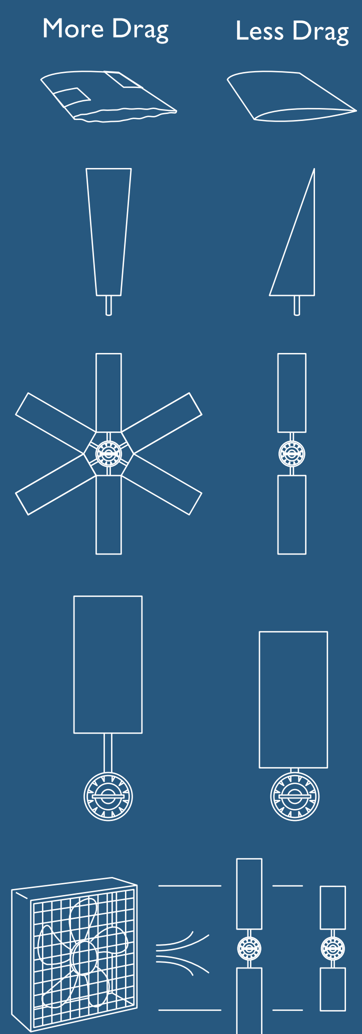
You will need one set of the following materials for each group:

- ❑ 1 model turbine on which blades can quickly be interchanged
- ❑ 1 multimeter or voltage/current data logger
- ❑ 1 box fan
- ❑ Milk cartons, PVC pipe, or paper towel rolls (optional)
- ❑ Ruler
- ❑ Pictures of wind turbine blades
- ❑ Sample blades of varying sizes, shapes, and materials
- ❑ Balsa wood, corrugated plastic, card stock, paper plates, etc.
- ❑ ¼" dowels
- ❑ Duct tape and/or hot glue
- ❑ Scissors
- ❑ Protractor for measuring blade pitch
- ❑ Safety glasses
- ❑ Poster-size graph paper (optional)
- ❑ Student reading passages and student worksheets*

*included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

REDUCE DRAG



GETTING READY

- Students should already have a basic understanding of wind energy, including the following:
  - what a wind turbine is
  - the fundamental parts of a wind turbine
  - how wind turbines transform energy from the wind
  - basic variables that impact turbine performance
- Most of this background was covered in the lesson "How Does a Windmill Work?" The additional resources listed at the end of this lesson also provide helpful information.
- The Blade Design PowerPoint found in the Additional Resources section will also be helpful for this lesson. This slideshow features descriptions of different blade designs and close-up pictures of wind turbine blades.
- Set up a safe testing area. Clear this area of debris and materials. Make sure the center of the fan is aligned with the center of the wind turbine. If you are working with multiple turbines, set them up so students will not be standing in the plane of rotation of a nearby turbine.
- Prepare three or four simple blade sets as samples for students to begin to see several variables and figure out how to build blades. Make sure the sample blade sets display different blade variables, such as length, material, and number of blades.
- Make copies of worksheets.

ACTIVITY

Step 1: Beginning questions for students

- What do you think makes one turbine work better than another?
- What variables affect the amount of power a turbine can generate?
- Do some variables matter more than others? (For example, is turbine height more important than the number of blades?)
- What do modern wind turbine blades look like? Is this similar to those on older windmills? Why?
- How many blades do most wind turbines have? What do you think would happen with more or fewer blades?

Step 2: Brainstorm blade variables

Provide students with photos of different turbine designs, using the Blade Design PowerPoint or other photos found in the Additional Resources. Ask students to brainstorm some of the variables that affect how much energy the blades can capture while they are looking at the photos.

Variables may include:

- blade length
- number of blades
- weight/distribution of weight on blade
- blade pitch/angle
- blade shape
- blade material
- blade twist

Step 3: Determining variables
Organize students into small groups. Four students per group is optimal. Give each student a worksheet. Have each group select one variable to test. Length, number, pitch/angle, and shape are easy variables to test, but students can come up with additional variables as well. Before constructing blades, groups should determine what needs to be held constant in order to effectively test their variables.

If you are conducting this exercise as a demonstration, ask students which variable will perform better and why before testing it. Students will complete their worksheets while the teacher tests each variable. Students can take turns attaching blades or reading the multimeter.

Step 4: Building blades
Depending on the variable being tested, some groups will have to build multiple sets of blades, while other groups will only build one set. For example, the group testing blade material will have to build one set of identical blades with each material being tested. The group testing pitch/angle, however, will only build one set of blades and then test the angle of these blades on the turbine. Groups should collect their blade materials, then work together to construct blades.

Step 5: Testing blades
The group will attach each set of blades to the turbine and test it at both high and low wind speeds. The group can change wind speed by moving the turbine away from the fan or turning the fan lower. Wind coming from a fan is very turbulent and does not accurately represent the wind a turbine would experience outside. To clean up this turbulent wind, students can make a wind tunnel by building a honeycomb in front of the fan using milk cartons, PVC pipe, or paper towel rolls. This will slow the wind coming off the fan, but it will also straighten it out.

Be sure students understand what blade pitch (angle) is and how they will measure it or keep it constant. This concept was introduced in "How Does a Windmill Work?"

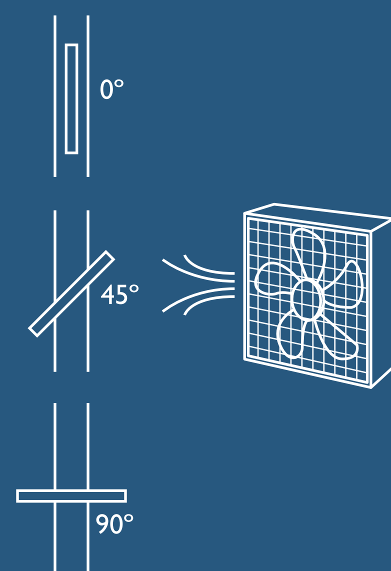
Make sure that students keep pitch constant while testing other variables or the results can be problematic.

Students will measure the voltage with a multimeter and record their data on the worksheet. If time permits, ask students to do three replications of each variable and average their results.

Step 6: Analysis
Once students have collected their data, tell them to answer the questions on the worksheet and make a graph of their data to present to the class. If poster-size graph paper is available for students, ask them to replicate the graph on this paper for their presentations.

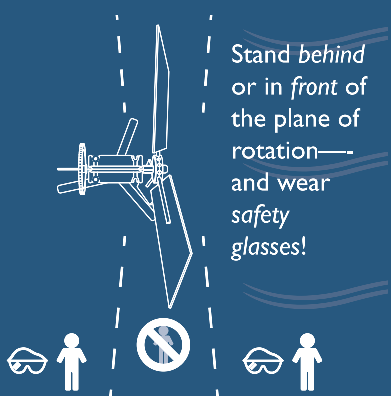
BLADE PITCH

Blade pitch is the angle of the blades with respect to the plane of rotation. The pitch of the blades dramatically affects the amount of drag experienced by the blades. Efficient blades will provide maximum torque with minimum drag. Measure pitch with a protractor.



⚠ CAUTION!

- Do not stand in the plane of rotation of the rotor! You could be hit if your blade flies off during testing.
- The spinning rotor blades and metal rod can be dangerous. Make sure students work with caution.
- Be careful when working with the metal rod. Do not swing or play with the rod! The ends can be protected with tape, foam, cork, etc.
- Wear safety glasses when testing windmills. Safety glasses must be worn any time blades are spinning.



Step 7: Presentation

Each group will have five minutes to present its data to the class. Students should discuss their variables, how they designed the blades, and the results. Ask all the students to record the results from each group on their worksheets so they have all of the class results.

Step 8: Wrap up

Wrap up the lesson with some of the following questions:

- What variable has the greatest impact on power output?
- What type of blades worked best at low speeds? High speeds?
- What number of blades worked best?
- What shapes worked best?
- What length worked best?
- What problems did you encounter?
- Did longer blades bend backward in the wind? Was this a problem?
- What happened when the diameter of the turbine rotor was bigger than the diameter of the fan?

Ask students to analyze the class data and describe an optimal blade design. If time permits, this can be used as a starting point for the extension lesson: "How Can I Design a Better Blade?"

EXTENSION

The following extension may be made for grades 9–12:

- Ask students to also collect amperage data and calculate power. Discuss voltage, amperage, and power and how they relate to one another.
- Ask students to determine the efficiency of their turbines. The efficiency of a turbine is a comparison between the theoretical power available in the wind and the actual power output of the turbine. To calculate the theoretical power in the wind, students can use this equation:

$$P = \tfrac{1}{2}\, \varrho\, (\pi r^2) V^3$$

P = total power available in the wind
ϱ = air density (1.23 kg/m^3 at sea level)
π = pi (3.14)
r = rotor radius (length of one blade)
V = velocity of the wind

Turbine efficiency is equal to the total power output of the turbine divided by the theoretical power available. Do not be surprised if your efficiency is under 5 percent. The maximum theoretical efficiency of a wind generator is 59 percent. Research Betz Limit to learn more about this.

VOCABULARY

amperage – A measure of the rate of flow of electrical charges.

$$1 \text{ ampere} = \frac{1 \text{ volt}}{1 \text{ ohm}} = \frac{1 \text{ watt}}{1 \text{ volt}} \text{ or } 1 \text{ amp} = \frac{V}{R} = \frac{P}{V}$$

blade pitch – Angle of the blades with respect to the plane of rotation. (Blades perpendicular to the oncoming wind would be 0 degrees. Blades parallel to the wind would be 90 degrees).

drag – In a wind turbine, also called wind resistance. The friction of the blades against air molecules as they rotate. Drag works against the rotation of the blades, causing them to slow down.

lift – A force encountered by the blades that is perpendicular to the oncoming flow of air. Lift is a force working to speed up the rotation of the blades.

multimeter – An electronic instrument that can measure voltage, current, and resistance.

power – The rate at which energy changes form from one form to another, or the rate at which work is done

voltage – The electrical pressure or potential difference that drives the electric current. 1 volt = 1 amps × 1 ohm = 1 watts / 1 amps

wattage – the metric unit of power. In electricity, one watt of power is equal to one ampere of electric current being forced to move by one volt of potential difference. One watt is also equivalent to one joule of energy per second. 1 watt = 1 volt × 1 amp.

RELATED ACTIVITIES

- Lesson 8: How Does a Windmill Work?
- Lesson 11: How Can I Design Better Blades?
- Advanced Blades Appendix

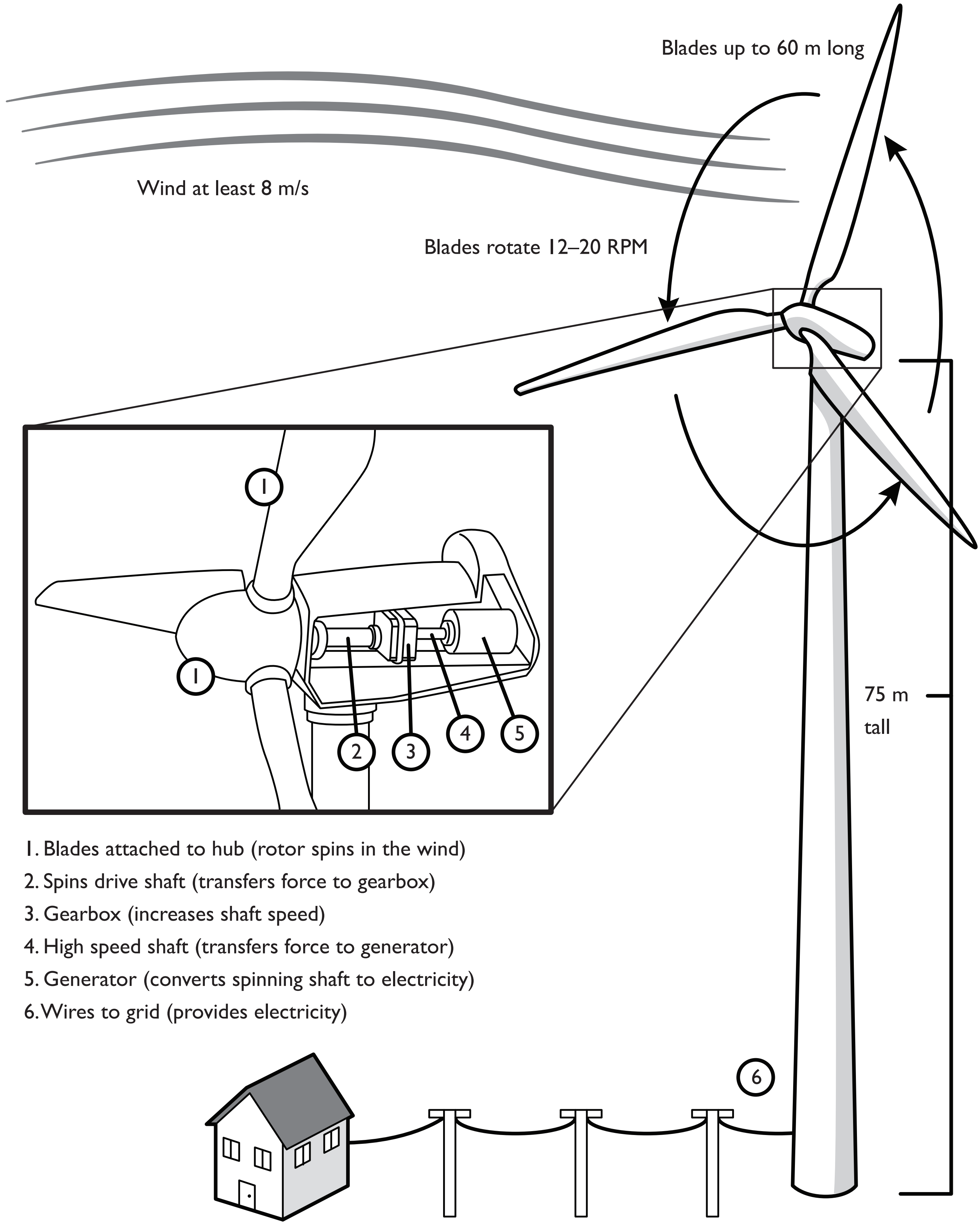
USE A MULTIMETER WITH YOUR WIND TURBINE

Students need to know how to record voltage and amperage with a simple multimeter. Make sure you have done this yourself and can explain it to the students. It is important to ensure that the units are correct. If you multiply volts by milliamps, you will get a confusingly large and incorrect number for power. It is okay to just record voltage, which can make things easier.

Small DC motors do not produce much power when spun slowly. A wind turbine without gears will not get more than 2 volts. On a wind turbine with gears, power output can be increased (2–8 volts) using gears to spin the shaft of the generator faster than the hub.

For videos on using a multimeter see additional resources at http://learn.kidwind.org/windwise

ENERGY TRANSFERS AND CONVERSIONS IN A TURBINE



1. Blades attached to hub (rotor spins in the wind)
2. Spins drive shaft (transfers force to gearbox)
3. Gearbox (increases shaft speed)
4. High speed shaft (transfers force to generator)
5. Generator (converts spinning shaft to electricity)
6. Wires to grid (provides electricity)

Name______________________________________ Date________________ Class_________

Variable

What variable will you test for your experiment? _______________________________________

Constants

What variables do you have to keep the same (constant) as you perform this experiment?

Experimental design

Describe how you will perform this experiment.

1. What materials will you use?

2. How many times will you test your variable?

3. How long will you run the test?

4. How will you change your variable?

5. What will you use to measure your output?

Hypothesis

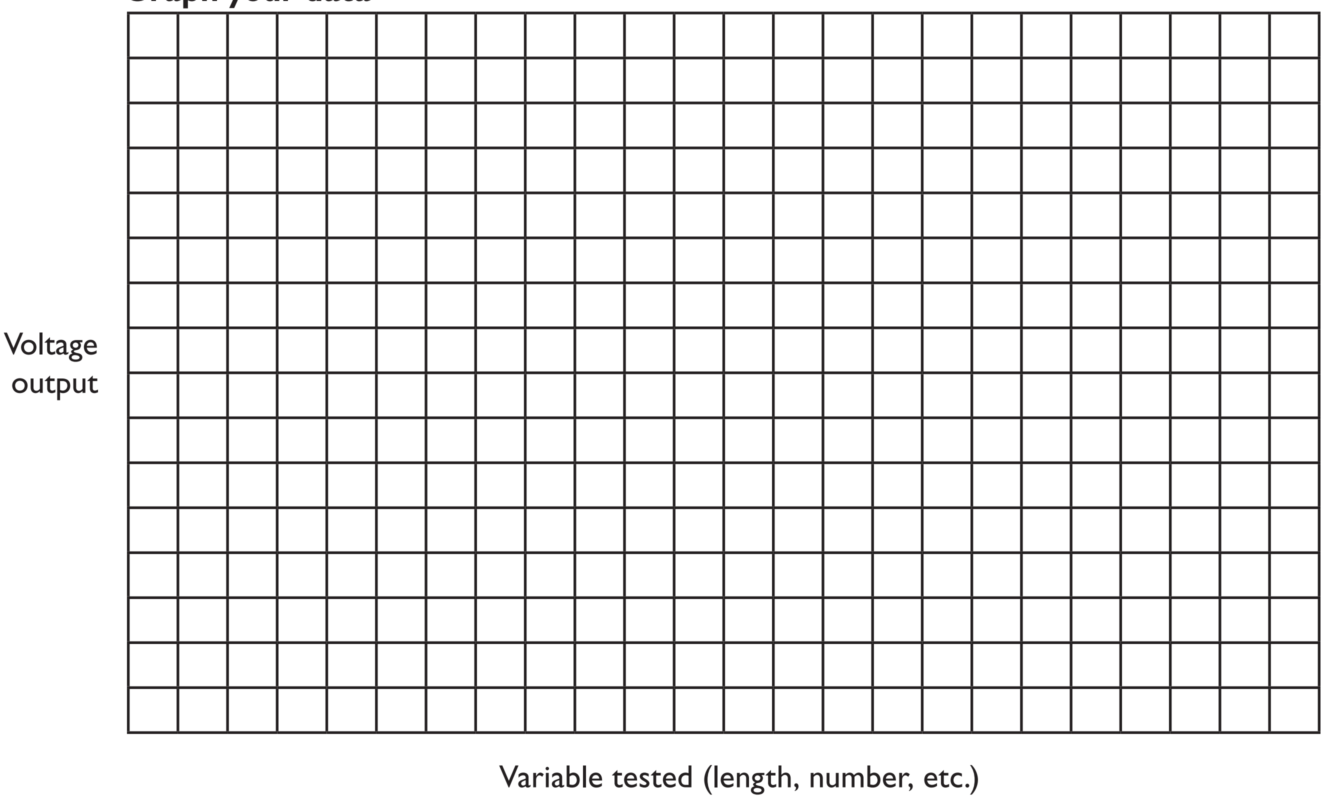
1. What do you think will happen?

2. Why do you think this will happen?

Data tally sheet: grades 6–8

	LOW SPEED	HIGH SPEED
VARIABLE (e.g., length, in cm)	**VOLTAGE** (mV *or* V)	**VOLTAGE** (mV *or* V)

Graph your data

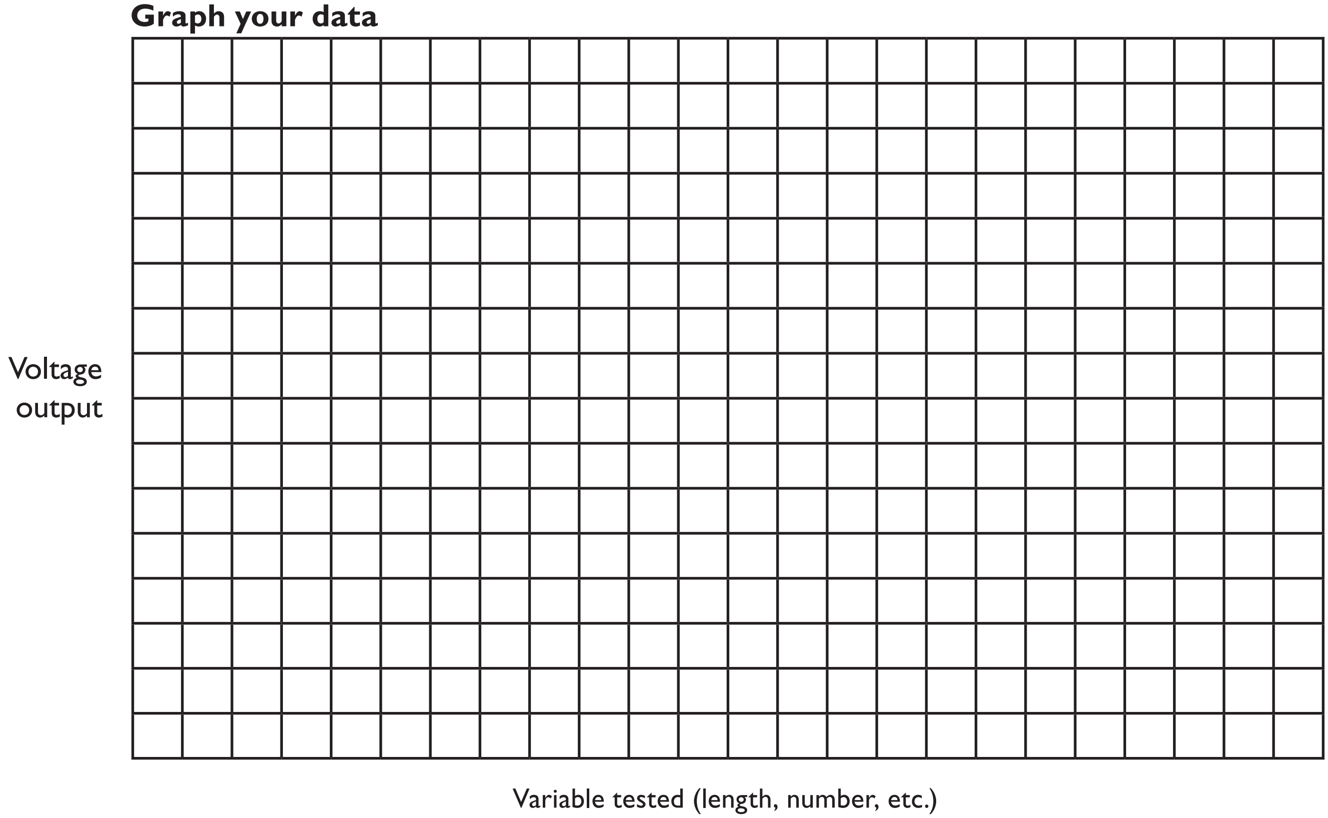


Data tally sheet: grades 9–12

LOW SPEED			
VARIABLE (e.g., length, in cm)	**VOLTAGE** (mV *or* V)	**AMPERAGE** (mA *or* A)	**(V × A) = POWER** (mW *or* W)

HIGH SPEED			
VARIABLE (e.g., length, in cm)	**VOLTAGE** (mV *or* V)	**AMPERAGE** (mA *or* A)	**(V × A) = POWER** (mW *or* W)

Graph your data



Name______________________________ Date______________ Class_________

What happened?

1. How did the voltage change as a result of manipulating the variable?

2. What was the optimal setting for the variable that you tested?

3. Do you think that the variable that you tested has a large or small effect on how much power the turbine can make?

4. What problems did you encounter as you performed your experiments? How could you fix these problems?

Class results

Record the results from the class experiments in the table below.

Power = Voltage (V) × Current (A)

Make sure you are recording volts and amps (not milliamps). 1 A=1,000 mA

VARIABLE	VOLTAGE (V)	AMPERAGE	POWER OUTPUT
(e.g. length cm)		(extension) (mA or A)	(optional) (mW or W)
15 cm	1.7	**100 mA**	**0.17 W**

1. If you were a lead design engineer, what would you recommend your company do to their turbine blades based on the class results? Why?

Variable

What variable will you test for your experiment?

Answers will vary. Example variables: Blade pitch, blade shape/size, material of blades, number of blades, etc.

Constants

What variables do you have to keep the same (constant) as you perform this experiment?

Answers will vary. Example variables: Blade pitch, blade shape/size, material of blades, number of blades, etc.

Experimental design

Describe how you will perform this experiment.

1. What materials will you use?
   Answers will vary. Balsa, corrugated plastic, paper plates, cardboard, etc.

2. How many times will you test your variable?
   Variables should be tested at least twice.

3. How long will you run the test?
   Answers will vary. Trials should last at least 20 seconds.

4. How will you change your variable?
   Answers will vary.

5. What will you use to measure your output?
   Output should be recorded using a multimeter or other quantitative measurement.

Hypothesis

1. What do you think will happen?
   Students should hypothesize about how changing their chosen variable will affect the power output of the wind turbine.
2. Why do you think this will happen?
   Students should explain why they think changing the variable will affect power in this way.

What happened?

1. How did the voltage change as a result of manipulating your variable?
   Changing the variable should cause the voltage to increase or decrease.

2. What was the optimal setting for the variable that you tested?
   Which trial yielded the most voltage? For example, if the test variable is "blade pitch," students may answer "Blades pitched at 20 degrees produced the most voltage."

3. Do you think that your variable has a large or small effect on how much power the turbine can make?
   Answers will vary.

4. What problems did you encounter as you performed your experiments? How could you fix these problems?

    Answers will vary. One common problem is that it is hard to keep all other variables constant while testing one specific variable.

Class results

Record the results from the class experiments in the table below.

Power = Voltage (V) × Current (A)

1. If you were a lead design engineer, what would you recommend your company do to their turbine blades based on the class results? Why?

    Students should describe the optimal blade design based on class results. This answer should discuss at least three variables—e.g., length of blades, number of blades, blade pitch, blade material, etc.

LESSON 11

HOW CAN I DESIGN BETTER BLADES?

KEY CONCEPT

Students learn how to design and construct different turbine blades to maximize the power output of a wind turbine.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Physical Science
Technology/Engineering
Mathematics

KidWind PROJECT®

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BACKGROUND

Blade design and engineering are two of the more complicated and important aspects of current wind turbine technology. Today engineers strive to design blades that extract as much energy from the wind as possible in a variety of wind speeds, while making sure that they remain durable, quiet, and affordable. This engineering process requires a great deal of scientific experimentation, modeling, and testing.

OBJECTIVES

At the end of the lesson, students will

- be able to participate in the engineering design process
- understand how blade design variables affect power output
- know how to improve and optimize wind turbine blades

METHOD

Students will use a variety of materials to design blades that optimize the power output of a model wind turbine.

MATERIALS

You will need one set of the following materials for each group:

- ❑ 1 model turbine on which blades can be quickly interchanged
- ❑ 1 multimeter or voltage/current data logger or multimeter box
- ❑ 1 box fan
- ❑ A ruler
- ❑ Pictures of wind turbine blades (see the Blade Design PowerPoint show in Additional Resources)
- ❑ Student reading passages and student worksheets*

Blade building materials

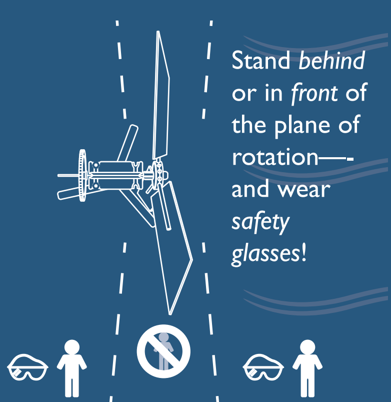
- ❑ Balsa wood, corrugated plastic, card stock, paper plates, plastic cups, index cards, etc.
- ❑ ¼" dowels
- ❑ Duct tape and/or hot glue
- ❑ Scissors, Exacto knives
- ❑ Protractor for measuring blade pitch

*included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

⚠ CAUTION!

- Do not stand in the plane of rotation of the rotor! You could be hit if your blade flies off during testing.
- The spinning rotor blades and metal rod can be dangerous. Make sure students work with caution.
- Be careful when working with the metal rod. Do not swing or play with the rod! The ends can be protected with tape, foam, cork, etc.
- Wear safety glasses when testing windmills. Safety glasses must be worn any time blades are spinning.



GETTING READY

- Students should have completed the "Which Blades Are Best?" lesson.
- It is useful to have some blades, turbines, and hubs ready so you can demonstrate how to safely use the tools and turbines.
- Set up turbine testing stations:

  Place all of the materials in one central location where students can select items and you can monitor their use to make sure that students are using them safely.

  Having the same fans at each station would be ideal, but sometimes it is not possible. Therefore, make sure that students use the same fan and at the same speed when testing the blades.
- Factor into planning that there can be a wait at the testing stations. While students only need a few minutes to test and then change their blades, having a few stations set up reduces the wait time.
- Consider telling students to begin the design process at home in order to save some classroom time, because the construction and revision of the blades can be time consuming.

ACTIVITY

Step 1: Beginning questions for students
Review the results from the "Which Blades Are Best?" lesson. Discuss which variables had the most impact.

Step 2: Blade design and construction
Tell all students to analyze the data on their own and come up with their own individual designs. Ask students to create a design plan (this may include drawings and/or descriptions). Approve it before construction.

Design constraints

- Any materials found in the classroom resource area can be used.
- Metal cannot be used
- Manufactured blades or propellers cannot be used
- Blades cannot be more than 20" long
- Blades must have no sharp points or edges

Ask students to use their data sheets to keep track of the materials they use.

If students are constructing their blades in the classroom, set limits on how long they can work on them. You can also limit supplies or attach costs to supplies they must purchase with a set budget. This cuts down on waste and requires students to put more thought into selecting materials.

Have students test their blades at low and high speeds. To simulate low speed, turn the fan down or move the wind turbine back 2 meters from the fan. Students should test their blades at least once and optimally twice before presentation time (once with the initial design and a second time after any design revisions have been made).

As the designs progress, encourage students to experiment with advanced ideas, such as using the airfoil shape and/or making blades with twisted pitch.

Step 3: Competition
Students' blades can be evaluated in three ways. (You may pick one or use all three.) Evaluating projects in all three ways gives students with different skills a chance to succeed.

- Quality of construction
- Level of innovation
- Power output at low and high wind speeds

Quality of construction and innovation can be evaluated by the whole class, using the voting sheets on the worksheet. This allows students to compare power output to other characteristics that are important. Students can display their blades with a name label and spend ten minutes walking around and evaluating each of the blades. Students can also predict which blade designs will be the best and why. Tally the votes using this scale: 1^{st} = 3 points, 2^{nd} = 2 points, 3^{rd} = 1 point. The student with the most points wins that category.

Power output can be evaluated by testing the blades at low and high wind speeds. Students can act as recorders, timers, and multimeter experts. Let students mount and set their own blades. Ask students to describe to the class the main features of their blades (length, materials, number of blades, etc.). Place the turbine at about 1 meter away from the fan and let the fan run at high speed for 30 seconds. Record the highest voltage number you see in 30 seconds. Tell students to record these data on their worksheets. Do the same in low speed conditions. To simulate low speed, turn the fan down or move the wind turbine back 2 meters from the fan. If after a few seconds students want to adjust the blades, allow them to do so only once to limit the amount of time on each blade set. After measuring voltage and current, calculate power using the equation: P=VI (watts = voltage × amperage).

Step 4: Wrap up
Wrap up the lesson with some of the following questions

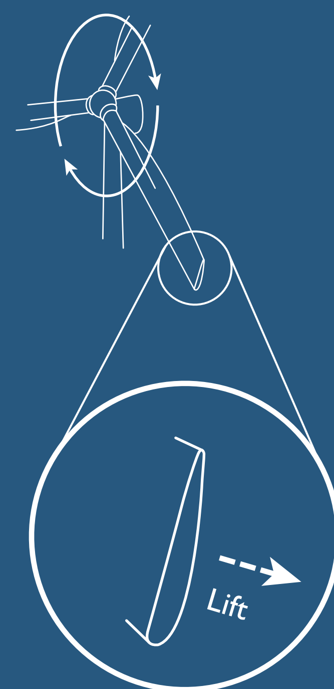
- Which type of blades worked best at low speeds? High speeds?
- Why do you think these blades performed the best?
- What problems did you encounter?
- Which features did you incorporate from modern turbine designs?

EXTENSION

Measure the power output and efficiency of different blade configurations. See Lesson 10 "Which Blades Are Best?" (page 177), for more information about measuring power output and efficiency. Read the Advanced Blades Appendix (page 201) to learn about airfoil blades, lift, drag, torque, and other advanced concepts in wind turbine blade design.

AIRFOILS

The airfoil shape of wind turbine blades creates lift while minimizing turbulence.



VOCABULARY

airfoil – "Teardrop" shaped cross-section used for wind turbine blades. The airfoil shape is most efficient because it creates lift while minimizing air turbulence.

rotor solidity – Measurement of how "solid" the rotor is. A rotor with high solidity does not have a lot of space between blades. A rotor with low solidity (like most modern turbines) has fewer blades and more empty space in the rotor.

twisted pitch – Blades of commercial wind turbines have higher pitch near the root and less pitch at the tip. This is called twisted pitch and it greatly reduces drag at the blade tips to increase performance.

RELATED ACTIVITIES

- Lesson 8: How Does a Windmill Work?
- Lesson 10: Which Blades Are Best?
- Advanced Blades Appendix

Name____ Date________________ Class_________

DESIGN YOUR OWN BLADES

Design

1. Sketch and describe the design of your blades (length, shape, number, materials, etc).

2. Explain why you designed your blades this way. Use data from Lesson 10 (if completed) to support your initial design.

Test Run 1

Test your blades 1 meter from the fan for 30 seconds and record your data below.

Power=Voltage × Amps

	VOLTAGE	AMPERAGE	POWER OUTPUT
High Wind Speed			
Low Wind Speed			

Modifications

3. What modifications could you make to your blade set to increase the power output?

4. Why do you think these blades would work better?

Test Run 2

Test your modified blades 1 meter from the fan for 30 seconds and record your data below.

	VOLTAGE	AMPERAGE	POWER OUTPUT
High Wind Speed			
Low Wind Speed			

Competition

NAME	NUMBER OF BLADES	MATERIALS	LENGTH (CM)	ADDITIONAL DESIGN FEATURES	POWER IN HIGH WIND	POWER IN LOW WIND	AVERAGE

Name______________________________________ Date________________ Class_________

Questions

1. Describe the blades that seemed to perform the best. What characteristics did they have?

2. Why do you think they performed so well?

Name________________________ Date______________ Class________

Voting form

Use these forms to vote on other students' blade designs.

QUALITY OF CONSTRUCTION	
1ST	
2ND	
3RD	
INNOVATION	
1ST	
2ND	
3RD	

QUALITY OF CONSTRUCTION	
1ST	
2ND	
3RD	
INNOVATION	
1ST	
2ND	
3RD	

QUALITY OF CONSTRUCTION	
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1ST	
2ND	
3RD	

QUALITY OF CONSTRUCTION	
1ST	
2ND	
3RD	
INNOVATION	
1ST	
2ND	
3RD	

DESIGN YOUR OWN BLADES

Design

1. Sketch and describe the design of your blades (length, shape, number, materials, etc).
   Student observations.

2. Explain why you designed your blades this way. Use data from Lesson 10 (if completed) to support your initial design.
   Student observation, but it is a good idea for students to keep their data from Lesson 10 so that they have ideas on which to base their designs.

Test Run 1

Test your blades 1 meter from the fan for 30 seconds and record your data below.

Power=Voltage × Amps

	VOLTAGE	AMPERAGE	POWER OUTPUT
High Wind Speed			
Low Wind Speed			

Modifications

3. What modifications could you make to your blade set to increase the power output?
   Student observations.

4. Why do you think these blades would work better?
   Student observations. Look for changes to their blades based on the analysis of Test 1 performance and data from Lesson 8.

Test Run 2

Test your modified blades 1 meter from the fan for 30 seconds and record your data below.

	VOLTAGE	AMPERAGE	POWER OUTPUT
High Wind Speed			
Low Wind Speed			

Questions

1. Describe the blades that seemed to perform the best. What characteristics did they have?

   Student observations.

   Some common themes (these will depend on type of turbine used: direct drive vs. geared vs. weightlifting device):

   - *Blades match fan size*
   - *Blades are smooth*
   - *Blades go all the way to base of hub*
   - *2–4 blades in total*
   - *Blades are wider at the root than at the tip*
   - *Blades might have a twist along length of blade (20 degree pitch at base, 0 degree pitch at tip)*
   - *Blade angle is low, around 5–10 degrees*
   - *Blades have an airfoil shape to increase rotational lift and increase blade velocity*

2. Why do you think they performed so well?

   Student observations. Students can relate better performance to the observations above. Great blades capture the energy of the wind without causing too much drag and slowing themselves down.

ADVANCED WIND TURBINE BLADE DESIGN AND AIRFOILS

BACKGROUND

Blade design and engineering are two of the more complicated and important aspects of current wind turbine technology. Engineers strive to design blades that extract as much energy from the wind as possible in a variety of wind speeds, while making sure that they remain durable, quiet and affordable. This engineering process requires a great deal of scientific experimentation, modeling, and testing.

With some simple materials and a bit of creativity, you can experiment with advanced concepts in wind turbine blade design, including airfoil shapes and twisted-pitch blades. You may want to try building three-dimensional blades that will outperform the standard flat turbine blades used on most KidWind turbine kits. This guide will help you understand the science and aerodynamics behind real wind turbine blades and how they are designed.

OBJECTIVES OF THIS ACTIVITY

Students will learn:

- design techniques to optimize wind turbine blades
- how wind turbine blades move due to Newton's third law and Bernoulli's principle
- how the forces of lift and drag affect turbine blades
- why the airfoil shape helps make turbine blades more efficient

SUGGESTED LEVEL

6–8
9–12

TIME REQUIRED

1–2 class periods

SUBJECTS

Physical Science
Technology/Engineering, Mathematics

MATERIALS REQUIRED

These materials are suggested for designing/testing advanced blades:

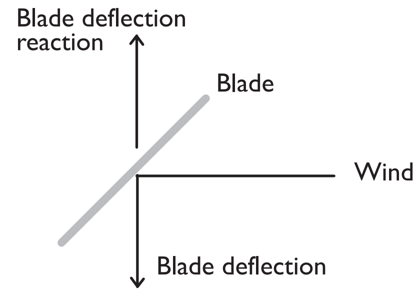
- ❑ Model turbine that allows for interchanged blades
- ❑ Multimeter or voltage/current data logger
- ❑ Box fan
- ❑ Ruler
- ❑ Chipboard or card stock
- ❑ Corrugated plastic sheets
- ❑ Balsa wood sheets
- ❑ Cardboard tubes
- ❑ Airfoil-shaped balsa wood
- ❑ Protractor for measuring blade pitch
- ❑ Scissors, Exacto knives
- ❑ Dowels
- ❑ Hot glue

Additional Resources for can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

WHY DO WIND TURBINE BLADES MOVE IN THE WIND?

There are two important reasons why wind turbine blades are able to spin in the wind: Newton's third law and the Bernoulli's principle.

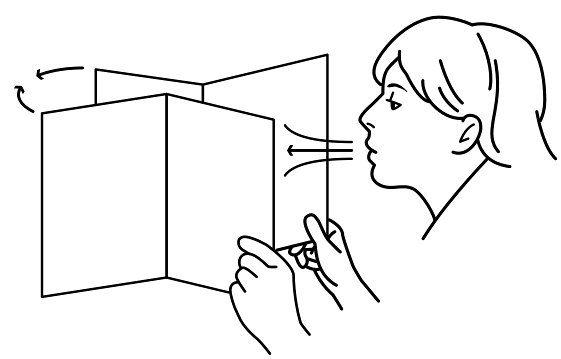
1. Newton's third law states that for every action, there is an equal and opposite reaction. In the case of a wind turbine blade, the action of the wind pushing air against the blade causes the reaction of the blade being deflected, or pushed. If the blade has no pitch (or angle), the blade will simply be pushed backwards (downwind). But since wind turbine blades are set at an angle, the wind is deflected at an opposite angle, pushing the blades away from the deflected wind. This phenomenon can be viewed on a simple, flat blade set at an angle. If you push the blade with your finger from the direction of the oncoming wind, the blade will deflect away from your finger.



2. Bernoulli's principle tells us that faster moving air has lower pressure. Wind turbine blades are shaped so that the air molecules moving around the blade travel faster on the downwind side of the blade than those moving across the upwind side of the blade. This shape, known as an airfoil, is like an uneven teardrop. The downwind side of the blade has a large curve, while the upwind side is relatively flat. Since the air is moving faster on the curved, downwind side of the blade, there is less pressure on this side of the blade. This difference in pressure on the opposite sides of the blade causes the blade to be "lifted" towards the curve of the airfoil.

Airfoil shape
(blade cross section)

You can do a small, simple experiment to demonstrate Bernoulli's principle. Take two small pieces of paper and fold them slightly in the middle. Hold the two pieces of paper in your hands so that the outside creases of the folds are facing each other. Then blow air in between the two pieces of paper. When you blow air between the papers, would you expect them to push apart or pull together? Were you surprised?

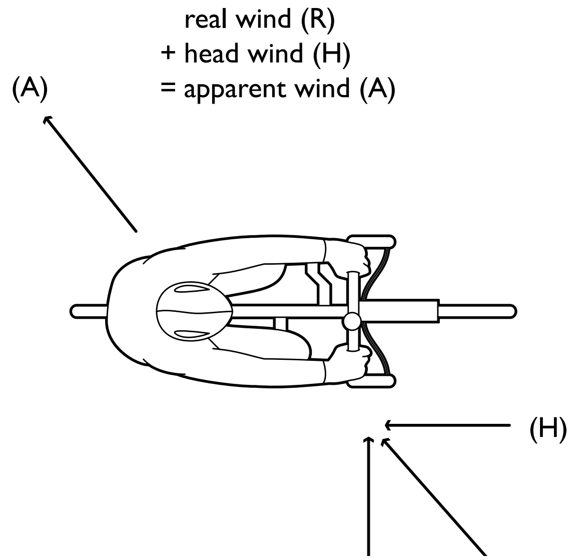


When you blow air between the papers, the speed of the air is higher between the two pieces of paper than outside the papers. Bernoulli's principle tells us that this higher velocity will lead to a lower pressure between the papers. That is why the papers are sucked in towards each other!

IMPORTANT CONCEPTS IN WIND TURBINE BLADE DESIGN

Wind turbine blades must be optimized to efficiently convert oncoming winds into mechanical energy to rotate the main driveshaft. But in the design of turbine blades, the real wind is only one part of a larger equation; good blades must also account for the apparent wind that is experienced as the blade passes through the air.

Imagine riding your bike with a fresh breeze at your side. As you begin to ride and pick up speed, you feel this wind from the side, but also wind pushing back at you from the direction in which you are moving. When you stop riding, there is just the wind from the side again. This wind that is "created" as you are moving is known as headwind. The headwind, combined with the real wind, is known as apparent wind. A wind turbine blade encounters apparent wind as it passes through the air. This apparent wind is from a different direction than the "real" wind that has caused the blade to begin moving. Since the tips of large turbine blades may be moving through the air at speeds up to 322 km/h (200 mph), this apparent wind can be very significant!



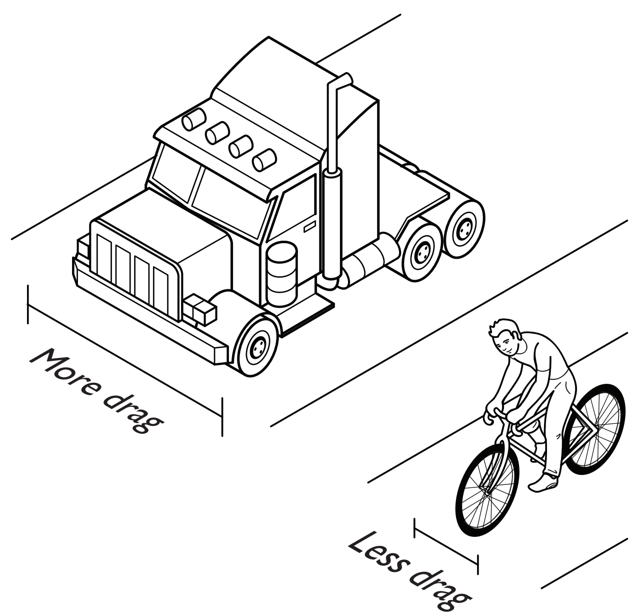
The efficiency of a wind turbine blade depends on the drag, lift, and torque produced by the blade. These factors are affected by the size and shape of the blades, the number of blades, and the blade pitch.

What is drag?

Drag, or air resistance, is a force that is working against the blades, causing them to slow down. Drag is always important when an object moves rapidly through the air or water. Airplanes, race cars, rockets, submarines, and wind turbine blades are all designed to have as little drag as possible.

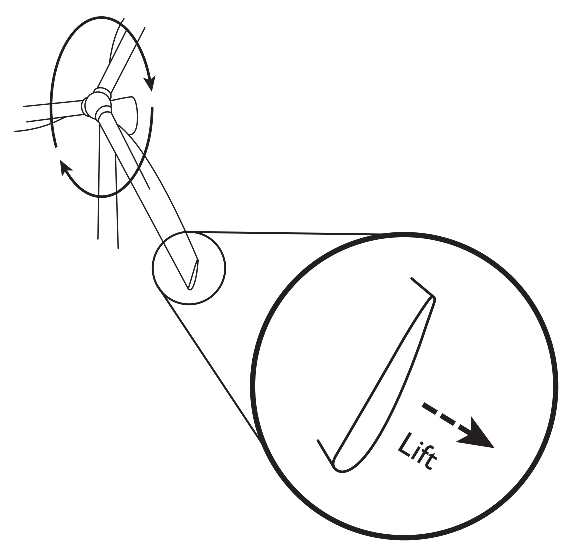
Imagine riding your bike down a big hill. To go faster, you might tuck your body to expose as little of it to the apparent wind as possible. This is a trick to reduce drag. Now imagine you have a big parachute strapped to your back when you ride down the hill. The parachute increases the drag significantly and this drag force slows you down. But you would sure be happy to have all that extra drag if you were jumping out of a plane!

Drag increases with the area facing the wind; a large truck has a lot more drag than a bicyclist moving at the same speed. Wind turbine blades have to be streamlined so they can efficiently pass through the air. Changing the angle of the blades will change the area facing the apparent wind. This is why blade pitch angles of 10 degrees to 20 degrees tend to have much less drag than greater blade pitch angles.



Drag also increases with wind speed. The faster an object moves through the air, the more drag force it experiences. This is especially important for wind turbine blades, because the blade tips are moving through the air much faster than the base of the blade. The shape and angle of wind turbine blades changes along the length of the blade to reduce drag at the blade tips.

What is lift?



Lift is the aerodynamic force that allows airplanes and helicopters to fly. The same force applies to the blades of wind turbines as they rotate through the air. Lift opposes the force of drag, helping a turbine blade pass efficiently through air molecules. The main goal of a well-designed wind turbine blade is to generate as much lift as possible while minimizing drag.

The amount of lift a blade or wing can generate is determined by several factors—the shape of the blade, the speed of the air passing around the blade, and the angle of the blade relative to the apparent wind.

The airfoil shape of the blade helps to generate lift by taking advantage of Bernoulli's principle described above. Wind turbine blade designers have experimented with many different airfoil shapes over the years in an effort to find the perfect shape that will perform well in a range of wind speeds. Even minor changes in this blade shape can dramatically affect the power output and noise produced by a wind turbine. To get some ideas about different airfoils used in airplane wings and wind turbine blades, research the United States National Advisory Committee for Aeronautics (NACA). This group was responsible for designing a wide range of airfoils in the 1940s.

The airfoil profile (shape) of a turbine blade will actually change along the length of the blade, generally getting flatter and narrower toward the tips of the blades. This is to optimize the lift and minimize drag. The faster the blade is moving, the more drag it encounters, but the lift force will also increase as the blades move faster.

The tips of wind turbine blades travel much further with each rotation of the blades, and therefore move through the air much faster than the roots of the blades. Since they are traveling the furthest distance with each rotation (distance/time = speed), the tips of turbine blades encounter more resistance or drag. The roots, or bases, of the blades do not encounter as much drag because they are passing through the air much more slowly.

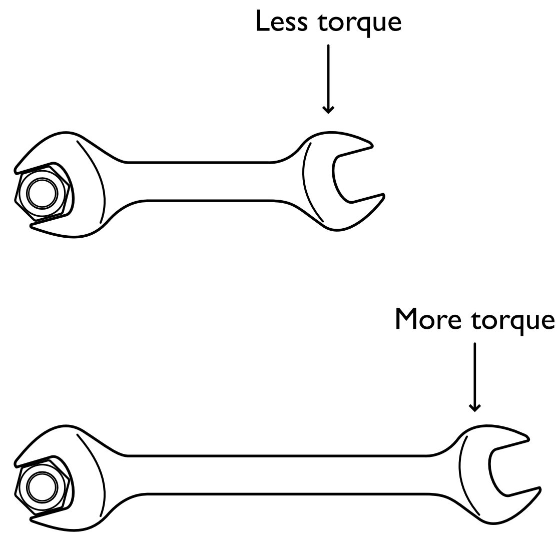
The faster the air molecules pass over a blade or wing, the more lift can be generated. So the tips of real turbine blades generate much more lift than the roots. Some large wind turbines have blade tip speeds over 322 km/h (200 mph)!

The angle of the blade relative to the plane of rotation of the blades is known as the pitch angle. The angle of the blade relative to the wind is called the angle of attack. The angle of attack is very important, but also complicated because it will change as the wind speed changes and the speed of the blade changes. On most airfoil blades shapes, an angle of attack of 10 to 15 degrees creates the most lift with the least drag.

Commercial wind turbine blades typically have a twisted pitch—meaning the blade angle is steeper at the root of the blade and flatter further away from the hub. Once again, this is because the tips move so much faster through the air. Because of the twisted pitch, the blades are able to take advantage of a more ideal angle of attack along the length of each blade. The tips of a real turbine blade may have close to a 0 degree pitch angle, but this section of the blade generates a great deal of lift.

What is torque?

Torques produce rotation. When you use a wrench on a bolt or twist a screw loose with a screwdriver, you are generating torque. If you are trying to turn a wrench, sometimes you need a lot of torque to loosen a tight bolt. Wind turbine blades are like big levers—but instead of being turned by muscles, they are turned by the force of the wind.



Torque is equal to the force applied to the wrench multiplied by distance the length of the wrench. This means that the longer your blades are, the more torque you can generate. For example, imagine you are trying to loosen a tight bolt. Pushing with all your might, you can exert 100 pounds of force. If your wrench was 1 foot long, you would be exerting 100 pound feet of torque. If you applied the same force to a 2 foot long wrench, you would then be exerting 200 pound feet of torque on the bolt. This additional torque makes it much easier to loosen the bolt!

On a commercial wind turbine, the long blades of the turbine generate lot of torque to the generator. Utility-scale wind turbines often have large gearboxes that increase the RPM of the rotor by 80 or 100 times. This big gear reduction demands a lot of torque from the blades. Think about riding your bicycle—when you shift into a higher gear, it may be harder to pedal. A higher gear ratio demands more force which generates more torque.

Various load devices that you try to power with your wind turbine may require more torque as well. A simple illustration of this is to use your model turbine to power a small LED light bulb and a small incandescent light bulb. (Incandescent Christmas tree light bulbs work well.) The LED bulb does not require much torque, so small turbine blades will generally work. The incandescent bulb, on the other hand, requires a lot more amperage to light up, so more torque is needed from the blades. Very small blades may not work under a load like an incandescent bulb or a small water pump.

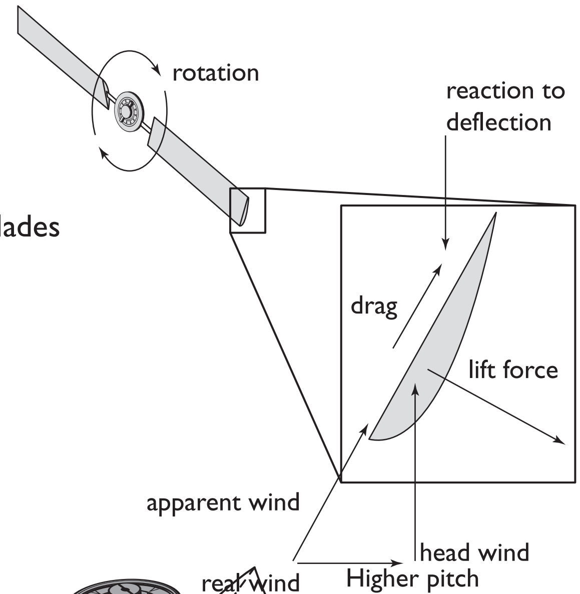
Increasing the torque generated by your blades also often increases the drag they encounter as they rotate. For example, longer blades will generate more torque and more drag. Increasing the blade pitch will generally increase the torque and increase the drag. Increasing the number of blades will generally give you more torque and more drag. For this reason, it is important to design your blades to match your load application. If you are using a windmill to lift a bucket of weights, a slowly spinning rotor that generates *lots* of torque will be best. A turbine with a large gear ratio will also need a lot of torque. But if you are using a direct drive turbine to light a string of LED bulbs wired in series, you will need a rotor that spins very rapidly with very little drag.

Real wind turbine blades are optimized to generate a lot of torque and lift with very little drag. This is not an easy task! Wind turbine blade engineers have degrees in aeronautical engineering and expensive computer software at their fingertips. But by understanding the relationship between torque, drag, and lift, you can design some great blades with simple materials.

DESIGNING ADVANCED WIND TURBINE BLADES

Wind turbine blade variables to explore:

- blade shape
- blade size
- number of blades
- angle (pitch) of blades
- blade material
- airfoil shapes
- twisted pitch blades

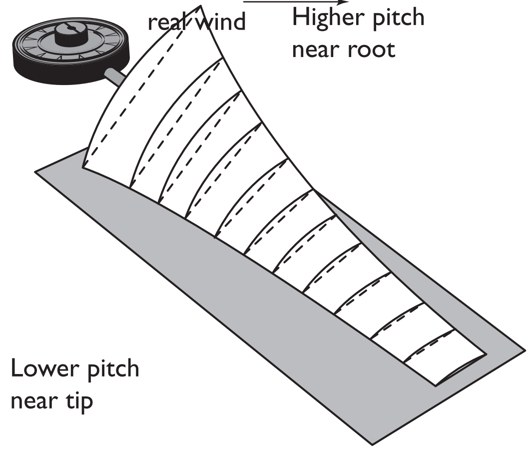


Curved or twisted pitch blades

Many modern wind turbine blades have a twisted pitch. At the root of the blade (near the hub), the pitch may be close to 20 degrees from the plane of rotation. The pitch will flatten along the length of the blade so the tips are close to 0 degrees. This is a great way to reduce the drag encountered by your blades, while also maintaining the length needed to generate more torque.

You can design twisted blades by bending corrugated plastic or cardboard into a twisted shape. Remember that you want more pitch near the hub, and almost no pitch at the tips. One trick is to get chipboard wet, then curve it into the desired shape and hold it in place until it dries. It will hold this curved shape when it dries.

You can also make some great twisted blades by cutting blades out of a cardboard poster tube. If you cut a triangle shape into the cardboard tube, the resulting curved triangle will make a great turbine blade!



Airfoil blades

Well-designed airfoil blades will greatly reduce the drag encountered by your blades, while also generating more lift! Remember that the airfoil shape is like an asymmetrical teardrop. One side is relatively flat, and the other side has a tapered curve.

On a turbine blade, the curved side faces downwind. The real wind will hit the turbine blade on the flatter side. This way, as the turbine starts to rotate, lift is generated on the backside of the blade which "pulls" the blade efficiently through the air.

Making your own airfoil blades can be very interesting and challenging. Try a few different designs and you will find that they perform much more efficiently than a flat blade. Here are a few ideas to get you started in designing airfoil blades:

- Shape a wet piece of chipboard. Bend chipboard into an airfoil shape.
- Attach a curved surface to flat surface: Start with a flat piece of corrugated plastic, or balsa wood. Tape a piece of card stock or thin flexible plastic to one side, to act as the airfoil shape.
- Use airfoil shaped balsa wood or Styrofoam designed for model airplane wings

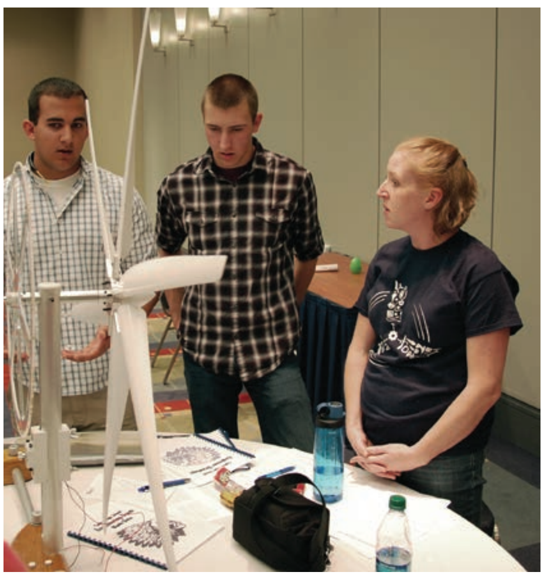
USING WINDWISE TO PREPARE FOR A KIDWIND CHALLENGE

WHAT THE KIDWIND CHALLENGE?

The KidWind Challenge is a hands-on application of renewable energy education. Student teams put their knowledge of wind power to work as they design and construct wind turbines that will produce as much power as possible.

Teams earn points for efficiency, creativity, and power output, but at its core the competition is about exploring wind energy and making learning fun. Participating in a KidWind Challenge Event or Online can be a great way to complete a wind energy unit using WindWise lessons.

Unlike many other student competitions, teachers can cover a number of standards as student teams build their turbines and prepare to compete.



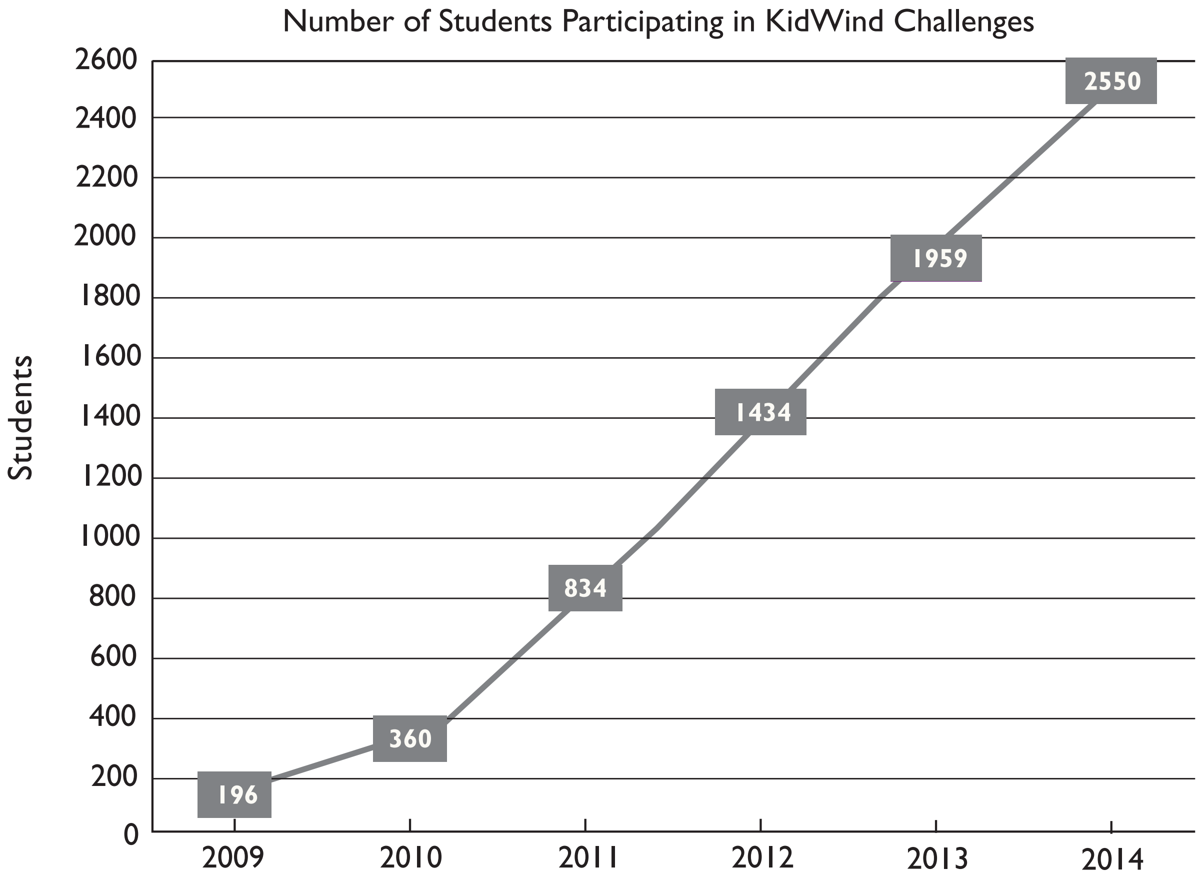
Students talking to judges at the 2014 National KidWind Challenge.

Student testing their blades at the 2013 MN Renewable Energy Challenge

The main goals of the KidWind Challenge are to:

- Get students excited about the promise and opportunities of renewable energy—specifically wind power—and its relationship to global climate change.
- Foster opportunities for students to build, test, explore, and understand wind energy technology at a manageable scale.
- Get students—particularly girls and underrepresented populations—excited about careers in STEM fields related to renewable energy.
- Build capacity of teachers, coaches, and other educators to better understand the technology, opportunity, challenges, and limitations of wind energy.
- Connect students to mentors and role models in the renewable energy industry.

You will not be alone if you decide to participate in a KidWind Challenge. KidWind has been holding student challenges for 5 years. Since the first Challenge Event was held in New York in 2009, over 5000 students have competed in 75+ Events across the country.



Our 2013-14 Challenge season

- 350 turbines submitted to the KidWind Challenge Online
- 27 KidWind Challenge Events hosted across 13 different US states, Washington DC, Canada, and the US Virgin Islands
- 1500 participants engaged in KidWind Challenge Events
- 1000 educators and coaches trained – through in-person workshops to extend the reach of KidWind's expertise across the world
- 52,550 students impacted – through classroom curriculum, Challenges, teacher workshops, and more

If you are curious in learning more we recommend visiting the KidWind Challenge website to find the rules and guidelines. This document introduces a number of ideas and concepts to get you started.

TWO KINDS OF KIDWIND CHALLENGES

KidWind Challenge Online

This is a space for student teams of all ages from around the world to build the best turbine they can, calculate their own performance, and upload self-reported results for judging. The Online KidWind Challenge is free and always open for teachers and students to use.

The KidWind Challenge Event
This event brings together teams of students in grades 4-12 to test the efficiency and design of their wind turbines in the high-speed KidWind Wind Tunnel and to be judged by wind industry experts. Registration is required and details vary by location. Typically the schedules are released in August or September of each school year.

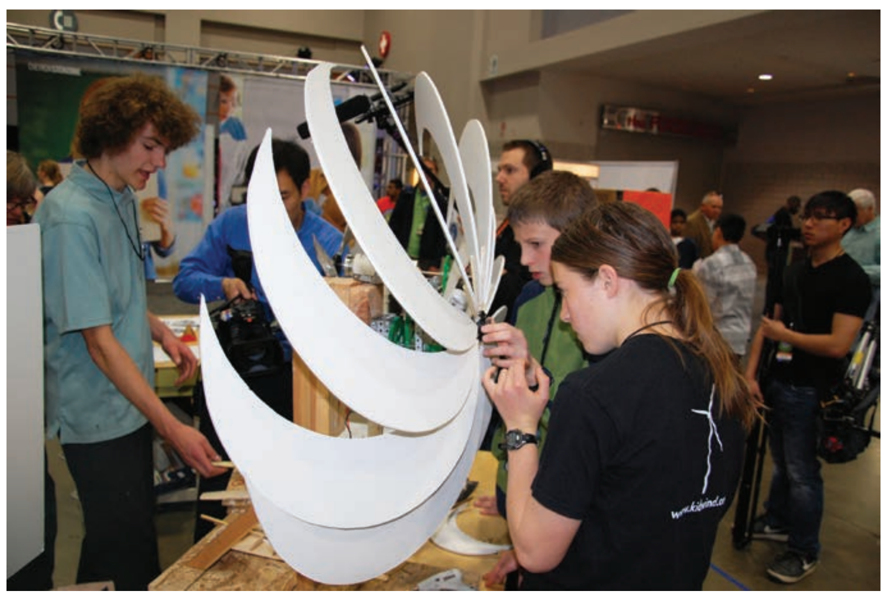
USING WINDWISE MATERIALS TO PREPARE FOR A KIDWIND CHALLENGE

Getting a team ready for a KidWind Challenge may seem a little intimidating at first. Not only do teams have to build a whole turbine from scratch, they also must understand basic science and technology about wind energy along with the environmental and social impacts of wind development.

Many students can start tinkering around with materials and successfully build a wind turbine without doing these lessons, but using WindWise materials as a foundational tool will successfully prepare your team for the competition and the turbine construction.

There is more to the KidWind Challenge than simply building and testing a classroom-scale wind turbine. Successful teams also demonstrate knowledge regarding the challenges and opportunities that wind energy presents from a social, biological and economic perspective.

Below are some lesson pathways based on the amount of time that you have to get your team ready for a KidWind Challenge. With these pathways the expectation is that your teams will have additional time after school or at home to work on the construction of their turbine. If you do not have this luxury, you should plan to give student teams at least 7-10 class periods to build and test a functional wind powered device. This can be longer or shorter depending on the materials you have in your classroom and the experience of your students.



Middle school students doing their final tweaks at the the 2014 National KidWind Challenge.

By having your students build and test blades and then upload them to the KidWind Challenge Online you can give them a feeling for the performance data we collect at a KidWind Challenge Event.

Materials needed to participate in a KidWind Challenge
Although KidWind has lots of kits and equipment that you can use to explore wind power and participate in a challenge, you really only need one part–the KidWind Wind Turbine Generator (Vernier Part # KW-GEN) After that you can use anything you want to build your turbine. For more details read the rules and guidelines document at http://challenge.kidwind.org.

4-5 Class Periods: A quick dip

With this much time you should focus on making and testing blades, which greatly affect overall turbine performance.

- Start with WindWise Lesson # 10–Which blades are best? This lesson will let students explore the fundamentals of blade design.
- If you have more time move to WindWise Lesson #11–How can I design better blades? To see if they can start optimizing design.
- Finally, have students upload their data to the KidWind Challenge Online.

8-10 Class Periods: Swim around and explore

With this much time you can help to situate your learning about wind energy.

- Learn about the different sources and forms of energy using WindWise Lesson #1 – Understanding sources and forms of energy.
- Explore ancient windmills by doing a MacGyver Windmills project using WindWise Lesson #8–How does a windmill work? Students need to take a bag of junk and build a wind turbine that lifts weights. This is one of our most popular lessons and teaches students to be creative with limited materials!
- Graduate to understanding basic blade dynamics and power output using WindWise Lessons #10 & #11. If you have some time upload your results to the KidWind Challenge Online.
- Finish your unit with some sociology in Lesson #15 – How do people feel about wind power?

15 + Class Periods: Go deep

With this much time you can really dig into complicated subjects and learn about how turbines work, how wind power fits into the current electrical system, and the biological and social impacts of wind power.

- Learn about the different sources and forms of energy using WindWise Lesson #1 – Understanding sources and forms of energy.
- Understand where your electricity comes from using WindWise Lesson #2 – Understanding electric power generation.
- Explore topography and wind interactions using WindWise Lesson #5 – Where is it windy?
- Explore ancient windmills by doing a MacGyver Windmills project using WindWise Lesson #8–How does a windmill work? Students need to take a bag of junk and build a wind turbine that lifts weights. This is one of our most popular lessons and teaches students to be creative!
- Learn how a generator works using WindWise Lesson #9 – Building a generator. If time allows, try to hook up the windmill you made in WindWise lesson #8 to the generators you build in Lesson #9.
- Graduate to understanding basic blade dynamics and power output in WindWise Lessons #10 & #11.

- Learn how wind can impact birds and bats by exploring WindWise Lessons # 13 and #14, or examine how people feel about wind power with Lesson #15.
- Next build some turbines and head over the KidWind Challenge Online or an Event near you and you will be rocking experts!

CONCEPTS RELATED TO PREPARING FOR A KIDWIND CHALLENGE

While the KidWind Challenge is an open-ended design event, it is underpinned by a diversity of skills and concepts that are important to all types of educators in the STEAM space. Below are list of concepts that WindWise lessons can help to introduce. This is highly dependent on how much time you spend on the WindWise lessons and what lessons you introduce to the students

Inquiry and science process
Students set up experiments and collect data on how well their turbine performs as they make design changes. They use both simple and sophisticated tools as they travel through the design, test and evaluation process.

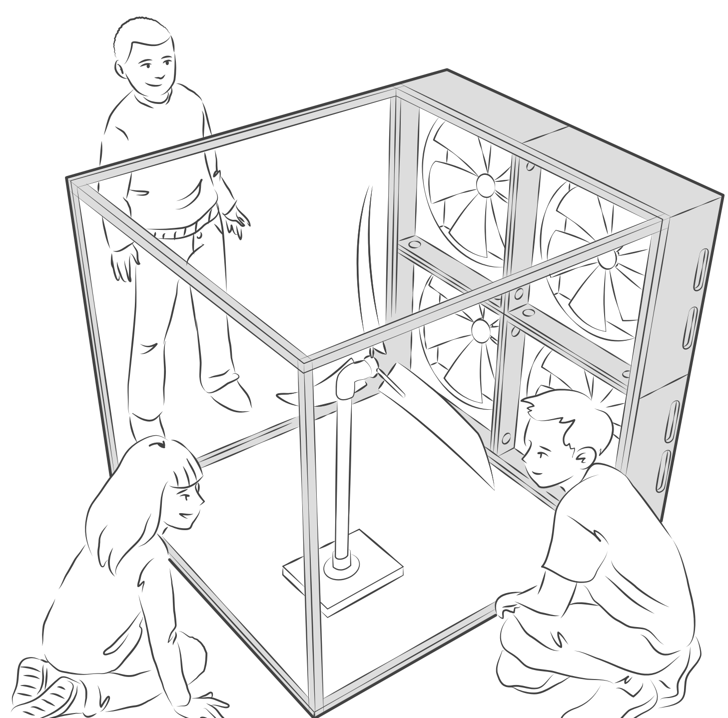
A wind turbine uses many different systems (blades, generators, drive train, towers and loads) that all function together in the wind environment. To build a successful turbine, students will need to be analytical as they determine the major drivers of performance in each system, and understand how they influence one another.

#8 – How does a windmill work?
#9 – How does a generator work?
#10 – Which blades are best?
#11 – How can I design better blades?

Energy and energy transfer
At the KidWind Challenge, students build and refine an energy transformation device: moving air is transformed into rotating blades, which rotate a generator, which in turn transforms this movement into electricity which can be converted into light, sound or motion.

During each step of this process, students focus on the forces acting upon the turbine, and must understand how energy works in order to optimize the transformation process.

#1 – Understanding sources and forms of energy
#2 – Understanding electric power generation
#8 – How does a windmill work?
#9 – How does a generator work?



Physical science

From understanding how a generator works to analyzing action and reaction forces acting on a spinning blade, there are a number of physical science concepts that can be explored while building a wind turbine.

#8 – How does a windmill work?
#9 – How does a generator work?
#10 – Which blades are best?
#11 – How can I design better blades?

A typical entry to a KidWind Challenge Event.

Earth science

We cannot talk about how a wind turbine operates without thinking about the fundamentals of where wind comes from. Understanding the flow of wind and what causes it is vital to siting wind energy facilities, forecasting wind resources, optimizing wind turbines, and more.

#4 – What causes wind?
#5 – Where is it windy?
#6 – What are wind shear and turbulence?
#16 – What factors influence offshore wind?

Biology & human impacts of natural resource use

The understanding that humans contribute to environmental issues like climate change has required us to start thinking more holistically about where our energy comes from and where it goes. One of the major reasons society is looking to generate more energy from the wind is that wind power is a renewable resource that reduces carbon emissions. Students engage in lessons that illuminate costs of relying on conventional energy sources, and cover the materials necessary to have informed discussions about other energy source like wind.

#3 – What is the cost of inefficiency?
#12 – How does energy affect wildlife?
#17 – Where do you put a wind farm?

Engineering design

The KidWind Challenge revolves around hands-on engineering and design to build and test a functional wind turbine. Students think critically to define the problem to be solved, design and evaluate proper solutions, and optimize their design to build the best turbine possible. There is always lots of tinkering, crafting, and good old trial-and-error involved, making the process—and the lessons extracted from it—memorable.

#8 – How does a windmill work?
#9 – How does a generator work?
#10 – Which blades are best?
#11 – How can I design better blades?

For a full list of standards related to WindWise Lessons please see page 19 of WindWise.

Participants at the Collegiate Wind Competition making final adjustments.

If the KidWind Challenge gets your students really excited, let them know that this is a young, growing industry. We are going to need engineers, environmental scientists, biologists, and a wide range of other experts to move toward a responsible energy future.

If you want to provide further inspiration and a possible “next step” for your students, check out the Collegiate Wind Competition. Think of it like a KidWind Challenge for college students!

The Collegiate Wind Competition challenges undergraduate students from multiple disciplines to design, build, and test a wind turbine to perform according to a customized, market data-derived business plan; and to deliver formal presentations demonstrating their knowledge of key market drivers and deployment acceleration opportunities. The DOE Collegiate Wind Competition contests are designed to interest students from a variety of engineering and business programs, engaging them in a project—a complex task with no single solution, a test that inspires ingenuity—that provides real-world experience as they prepare to enter the workforce.

Webpage — http://wind.energy.gov/windcompetition/

OTHER ENERGY CHALLENGES, COMPETITIONS AND OPPORTUNITIES

By participating in a KidWind Challenge you can build skills for high school and college and get ready for the other energy-based student challenges that are offered around the country.

We know wind is not the only energy source out there so if your students are excited by energy-focused challenges there are lots of opportunities out there to explore.

Middle School Only
AMERICA’S HOME ENERGY EDUCATION CHALLENGE—http://homeenergychallenge.org/—America’s Home Energy Education Challenge gives students the chance to LEARN about energy, DEVELOP techniques for reducing energy consumption, and SAVE money in their own homes by reducing household energy use.

FUTURE CITY—http://futurecity.org/—The Future City Competition is a national, project-based learning experience where students in 6th, 7th, and 8th grade imagine, design, and build cities of the future. Students work as a team with an educator and engineer mentor to plan cities using SimCity™ software; research and write solutions to an engineering problem; build tabletop scale models with recycled materials; and present their ideas before judges.

JUNIOR SOLAR SPRINT (JSS)—http://jrsolarsprint.org/—Students experience the automotive design process they research, build and race a solar power model car.

High School Only

MAINE WIND BLADE CHALLENGE—http://mainewindbladechallenge.com/—More than 50 Maine high school teams compete each year to create an energy-producing set of wind blades in the annual Wind Blade Challenge. Produced through hands-on science and engineering school course work, students design, infuse, manufacture and test blades, going up against competitors during the one-day challenge. Educators and manufacturers collaborate on this successful and growing STEM (science, technology, engineering and math) challenge, hosted by UMaine each year, raising career aspirations for students and developing a workforce for Maine's growing composites industry.

SOLAR ROLLERS—http://www.energeticsed.org/solar-rollers/—Solar-powered remote control cars, hand-built and raced by high school teams.

Elementary, Middle & High School

SIEMENS WE CAN CHANGE THE WORLD CHALLENGE—http://www.wecanchange.com/—The Siemens We Can Change the World Challenge is a national environmental sustainability competition for grades K-12 students. Through project-based learning, students learn about science and conservation while creating solutions that impact their planet.

NATIONAL SCIENCE BOWL—http://science.energy.gov/wdts/nsb/middle-school/—The U.S. Department of Energy (DOE) National Science Bowl® is a nationwide academic competition that tests students' knowledge in all areas of science and mathematics. Teams face-off in a fast-paced question-and-answer format, being tested on a range of science disciplines including biology, chemistry, Earth science, physics, energy, and math.

MATHMATICS ENGINEERING SCIENCE ACHIEVEMENT (MESA)—http://mesa.ucop.edu/—MESA works with thousands of educationally disadvantaged students so they excel in math and science and graduate with math-based degrees. MESA is nationally recognized for its innovative academic development program. The occasionally have competitions on energy related subjects. They have chapters in AZ, CO, MD, NM, OR, PA, UT, WA, NV.

Science Fairs

Take your wind turbine research to the next level and enter it into one of these national science fairs.

DISCOVERY YOUNG SCIENTIST—http://www.youngscientistchallenge.com/

GOOGLE SCIENCE FAIR—https://www.googlesciencefair.com/en/

INTEL INTERNATIONAL SCIENCE AND ENGINEERING FAIR—https://student.societyforscience.org/intel-isef

UNIT 4: WIND & WILDLIFE

HOW DOES ENERGY AFFECT WILDLIFE?

LESSON 12

KEY CONCEPT

Students learn that different electricity generation sources have very different effects on wildlife.

TIME REQUIRED

1 class period

GRADES

9–12

SUBJECTS

Living Environment
Earth Science
Environmental Science

BACKGROUND

To accurately compare the effects of different electricity generation sources (or energy sources, such as coal, nuclear, hydroelectricity, and wind), the complete life cycle of each electricity generation source is examined along with an assessment of their direct and indirect effects on wildlife. This information is then used to predict the total wildlife impacts of each electricity generation type. The results of this assessment yield balanced information that can be used to make informed decisions about which type of energy to use in a community.

OBJECTIVES

At the end of this lesson, students will:

- understand the different wildlife effects and risks from electricity generated by coal, nuclear, hydro, and wind
- complete a thorough life cycle analysis of each of the fuels to understand how the different phases are related to the different wildlife effects

METHOD

Students will work in teams of two to four. Teams will use the fact sheets and worksheets to research and compare the effects of four electricity generation sources on wildlife. They will then compare and discuss their findings with the class and be prepared to write a summary report.

MATERIALS

- ❑ Student reading passages and student worksheets*
  *included with this activity

  Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

KidWind PROJECT®

www.KidWind.org

GETTING READY

- Provide students with basic information about the energy sources used to generate electricity.
- Make copies of fact sheets, worksheets, and the reading passage for each team.

ACTIVITY

Step 1: Beginning questions for students

If students have not discussed energy generation and wildlife before, begin the class by asking students what they know about these topics.

- What types of energy sources are used to generate electricity?
- What is the difference between renewable and nonrenewable energy sources?
- Which sources are renewable and which are nonrenewable?
- Which energy sources do you think have the greatest impacts on wildlife populations? Why?
- Which energy sources are extracted and purified?
- Which energy sources produce pollution? What kinds of pollution?

Step 2: Form teams

Form teams of two to four students for this activity.

Step 3: Reading passage

Tell the students to read the reading passage. (Reading may be assigned as homework before the lesson.)

Step 4: Life cycle assessment

Provide each student with Table 1 and the fact sheets. Each student in the team should select one or two electricity generation sources to research (using the fact sheets) and complete the corresponding column(s) in Table 1. The fact sheets are based on a NYSERDA research document, "Comparison of Reported Effects and Risks to Vertebrate Wildlife from Six Electricity Generation Types in The New York/New England Region." Students can also use the internet or other sources available to them.

Step 5: Rank energy sources based on effects

Provide each team with Table 2. Based on the information they completed in Table 1, each team will rank the electricity generation sources on Table 2 from lowest to highest for effects on wildlife. Use 1 for the lowest effect and 4 for the highest. Students should provide a reason for their decisions.

Step 6: Class discussion

After each team has completed Table 2, hold a brief class discussion about team members' initial thoughts and feelings and the ranks they have assigned to each source. Some sample questions:

- Did team members' original thoughts and feelings about the different electricity generation sources hold true after the life cycle assessment? Why or why not?
- Is there general agreement among the teams about the ranking for each source? Why or why not?

VOCABULARY

Energy life cycle – The phases needed to produce energy, including extraction, transportation, construction, operation, transmission, and decommissioning.

extraction – Removal, most often from the ground.

decommissioning – Closing down a facility and removing it from service.

habitat – The environment in which an organism or group normally lives.

habitat fragmentation – Isolation of patches of habitat through land clearing and deforestation.

mortality – The number of animals killed.

risk (to wildlife) – The probability that loss or other adverse effects will occur to wildlife.

transmission – To move from one place to another. In energy, this is moving energy from its source to the location where it will be processed.

wildlife effect – The result of something causing harm to an animal or population of animals. Death, injury, and loss of habitat are examples of effects.

READING PASSAGE

The New York State Energy Research and Development Authority (NYSERDA) recently produced a report titled "Comparison of Reported Effects and Risks to Vertebrate Wildlife from Six Electricity Generation Types in The New York/New England Region." This report compared the effects and risks to wildlife from six different electricity generation sources: coal, oil, natural gas, hydro, nuclear, and wind.

The study identified the stages involved in most types of electricity generation and called these the "life cycle" for energy generation: extracting the fuel, transporting the fuel to the power generation site, construction of the power generation facility, operation of the facility, transmission and delivery (via power lines) of the electricity generated, and decommissioning of the facility at the end of its lifespan. Fuel extraction and transportation are not required for renewable energy sources, such as hydro and wind, because they are harnessed at the location where the electricity is generated.

To make an accurate comparison, the effects to wildlife were assessed for each life cycle stage of each electricity generation source. An effect is something that has a negative impact on wildlife. There are four types of direct effects on wildlife: injury, mortality (death), disruption of normal behavior, or destruction and damage of habitat.

To accurately assess and compare the wildlife effects from different electricity generation sources, the study authors considered all four types of effects to wildlife. Researchers also considered the risks to wildlife. Risk is the probability of an effect (injury, death, disruption of normal behavior, or destruction and damage to habitat) actually occurring.

Wildlife can be injured or killed when they come in contact with equipment and facilities used in all stages of the electricity generation cycle. Exposure to harmful chemicals can have toxic effects on wildlife that also result in injury or mortality. Noise and other disturbances associated with the life cycles stages of electricity generation can affect (or disrupt) normal movements, home range, or breeding behaviors of wildlife. Destruction and damage to wildlife habitat occurs when vegetation is removed or cleared from an area. It also occurs when habitat is divided up and goes from being one large area to several small areas that are isolated from one another (called habitat fragmentation). Habitat destruction includes damage to the ecosystem, trees, plants, soil, and food sources.

Examples of effects on wildlife from electricity generation include:

- Bird or bat injury or mortality from collisions with structures such as smoke stacks, power lines, or wind turbine blades
- Bird mortality from contact with an oil spill
- Fish and other aquatic animals becoming trapped in cooling water intake systems at power plants
- Mercury pollution from burning fossil fuels, particularly coal. Mercury escapes into the atmosphere, travels many miles on air currents, dissolves in rain, and returns to the Earth where it becomes toxic and enters the food chain.
- Fish being prevented from migrating up a river to spawn due to construction of a dam
- Power line corridors, service roads, and elevated pipelines all change and fragment habitat, which can impact the ability of wildlife to survive by making it more difficult to find food, shelter, and breeding partners.
- Carbon dioxide and methane released from burning fossil fuels. These greenhouse gases contribute to global climate change, which threatens many of the world's wildlife and ecological systems.

There are also indirect effects from electricity generation that can impact wildlife. Climate change is one of the biggest environmental, economic, and social challenges in the world today. Carbon dioxide (CO_2) and other gasses found in the atmosphere act as "greenhouse gases," which means that they trap heat energy and hold it in the atmosphere. The more greenhouse gases present, the more heat is trapped. It is similar to adding a blanket to your bed on a cold night; the blanket will trap more of your body heat and prevent it from escaping so that you stay warmer.

Many natural sources of CO_2 supply the atmosphere, such as volcanic eruptions, natural biological decay, and forest fires, which combine to account for about 95 percent of annual emissions. These have been present on Earth for many millennia. While there is natural variation from year to year and millennium to millennium, the amount of CO_2 emitted by natural sources is roughly equal to the amount absorbed by plants during photosynthesis and by the ocean.

However, human sources have accounted for the dramatic rise in CO_2 through the last two centuries, principally from CO_2 released when fossil fuels are burned. The industrial revolution in Europe and North America in the latter half of the 19^{th} century marked the beginning of civilization's reliance on fossil fuels for energy. Today about 70 percent of US electrical energy is made by burning fossil fuels in power stations, and about 82 percent of the associated emissions of greenhouse gases are attributed to coal by the US Department of Energy.

Already there have been documented wildlife effects globally and regionally from climate change and there is great concern that those effects will continue and expand. Here are a few examples.

- Climate change has been found responsible for massive coral bleaching that has decimated numerous coral reef habitats around the world.
- Polar habitats have become threatened due to increased and more rapid melting of sea ice, which diminishes foraging opportunities for polar bears.
- Climate change has also resulted in range expansion of pest species such as the mountain pine beetle and may contribute to the spread of Lyme disease with more temperate conditions increasing tick populations.

The continued warming of the Earth's atmosphere from greenhouse gasses will have dramatic effects on wildlife in the coming decades.

FACT SHEET: COAL POWER

Electricity generation from coal power produces wildlife effects at every stage of its life cycle.

Extraction

In the resource extraction stage, the wildlife effects and risks from coal are high because 62 percent of US coal is extracted through above ground mining. Aboveground mining poses high risks to wildlife populations because of resulting large-scale habitat destruction. For example, mountaintop mining removes the top of a mountain to uncover coal seams (a layer of coal between rock) near the surface. The spoils from the removal are dumped in nearby valleys. The wildlife effects are substantial and impact all types of wildlife and habitats including those in the area of the mining and in valleys where the spoils are dumped. Coal mining is extensive in the Appalachians in both West Virginia and Pennsylvania where much of the coal for the New York/New England region originates. In 2002 alone, 65,000 acres in West Virginia were permitted for mountaintop removal coal mining. Aboveground mining includes strip mining, open pit mining, and mountaintop mining, and valley fill. Underground coal is extracted using mining machines or explosives to expose the coal, which is then dug up and removed from the mine. Underground deep shaft mining causes minimal harm to forest habitats in comparison to strip mining.

Both aboveground and underground mining cause habitat degradation, direct injury and death to wildlife from toxic runoff into bodies of water. Mine wastes and coal processing wastes are highly acidic and often contain trace elements at toxic concentrations. Seventy-five percent of acid runoff is associated with underground mining. This acid runoff from mine tailings (acid mine drainage) can reach streams and injure and kill fish and other aquatic wildlife. It is estimated that about 6,400 streams in the mid-Atlantic and southeastern US have been affected by toxic mine drainage and runoff, primarily from coal mining.

Transportation

The coal is transported via truck and train to the power plants where it is burned. There is a low risk of injury or death to wildlife from vehicle collisions and from any fuel spills.

Construction

Construction of coal facilities has a low risk of destruction of habitat from land clearing for facilities, of fragmentation of habitat, and of disturbance of wildlife from construction noise and activity.

Operation

Burning the coal produces energy, which heats water that turns to steam. This steam turns turbines that produce electricity used to power homes, buildings, and electrical devices.

Because coal is a fossil fuel, when it burns during the power generation stage it releases multiple emissions that cause regional and global wildlife effects. As a result, electricity generation from coal is a significant contributor to acidic deposition (acid rain and acid deposits), climate change, and mercury bioaccumulation (release of mercury into the environment), which create very high risks to wildlife. Other wildlife effects associated with power generation from coal include bird collisions with power plant facilities and effects to aquatic wildlife from power plant cooling (once-through cooling) and chemical discharges to surface waters. These pose medium risks to wildlife. Coal-fired plants produce large amounts of waste heat that is disposed of in cooling lakes or towers. In lakes, this represents thermal pollution that causes medium risk wildlife effects.

Transmission

Effects associated with transmission and delivery include injury and mortality to wildlife from collisions and electrocutions associated with power lines, which pose medium potential risks.

Decommissioning

The operation of coal-fired power stations has a low potential to contaminate local aquatic systems from waste churned up when sites are decommissioned.

FACT SHEET: NUCLEAR POWER

Electricity generation from nuclear power effects wildlife at every stage of its life cycle.

Extraction

Similar to coal, the effects from resource extraction from aboveground surface mining have a very high potential risk to wildlife because of the amount of surface habitat that is destroyed. Underground mining is considered to have a low risk because of the limited habitat disturbance compared to surface mining. Toxic runoff from mine tailings (acid mine drainage) has medium risk for injury and death to wildlife locally.

Transportation

The quantities of uranium needed for operation of a nuclear power station are small and so transportation has low risk of wildlife effects. Trucks and trains are used for transportation. There is a low risk of injury or death to wildlife from vehicle collisions and from any fuel spills.

Construction

Construction of nuclear facilities has a low risk of destruction of habitat from land clearing for facilities, fragmentation of habitat, and disturbance of wildlife from construction noise and activity.

Operation

Nuclear plants create energy when nuclear fission splits uranium atoms, releasing heat that boils water to produce steam. This steam is used to turn turbines producing power for homes and businesses.

Nuclear plants, like coal-fired plants, create large amounts of heat and require water to cool the generator. If the cooling process involves drawing water from a lake, river, or ocean (such as in once-through cooling), it poses medium potential risks to wildlife. The warm water discharge from cooling systems and the potential for chemical discharge in the water pose medium risk to wildlife.

Nuclear energy has a low risk for accidental or catastrophic release of radioactive materials. In the event of radioactive release, the wildlife effects would be large. However, there have been no such occurrences in the US. The worst example outside the US was the Chernobyl accident in the former Soviet Union where there were major impacts on the ecosystem. The likelihood of a similar instance in the US is very low because the faulty Chernobyl-style reactor design and its lack of containment for radioactive materials would not be licensed in the US. The most serious accident in the history of US nuclear facilities was a partial meltdown of the Three Mile Island 2 reactor core in 1979. This resulted in only very small offsite releases of radioactivity with an end result of substantially enhanced safety regulations. There is also a very low risk of radioactive release during normal operation that may cause injury and mortality. There may be some bioaccumulation of strontium-90, but this would likely be limited to individuals and not populations.

Transmission

Effects associated with transmission and delivery include injury and mortality to wildlife from collisions and electrocutions associated with power lines, which pose medium potential risks.

Decommissioning

There is a low risk of contamination of aquatic systems from radioactive leaks. There is also a low risk of habitat disturbance and displacement from the demolition process due to noise and activity.

FACT SHEET: HYDROELECTRIC POWER

Hydroelectric (hydro) power is the renewable energy source that produces the most electricity in the US. In 2008, it accounted for 6 percent of the total US electricity generation and 67 percent of generation from renewables. Electricity generation from hydroelectric has only four stages in its life cycle and each has wildlife effects.

Extraction and transportation

Water does not need to be extracted and transported the way coal or nuclear does. Hydroelectric power is a renewable energy source, and the water needed to generate electricity is harnessed at the source.

Construction

The risk to wildlife from construction of a hydropower plant is very high because of the terrestrial and aquatic habitat clearing and the inundation (flooding) of these habitats when the area behind the dam is filled with water. The loss of habitat includes not only the inundated land, but also the stream or river habitats, which poses risks to spawning, foraging, and nesting habitats for fish. This stressor can affect hundreds of acres of terrestrial habitats and tens of miles of stream habitat within the watershed when the reservoir is filled with water. There is also risk of reduction or change in wildlife and fisheries biodiversity. Changes in the numbers and types of fish caused by dams blocking upstream movement of these fish can have large-scale reproduction implications for fish (e.g., blocking normal fish movement and migration to spawning habitat). Depending upon the location of the dam, there could be a threat to species survival regionally and biologically significant habitat loss for endangered or threatened species. The consequences of the risk are continuous as long as the dam is in place.

Operation

The amount of available energy in moving water is determined by its flow or fall. Swiftly flowing water in a big river, like the Columbia River that forms the border between Oregon and Washington, carries a great deal of energy in its flow. Water descending rapidly from a very high point, like Niagara Falls in New York, has a lot of kinetic energy. In either instance, when energy is harnessed from moving water, the water flows through a pipe, then pushes against and turns blades in a turbine to spin a generator to produce electricity. In a river system, the force of the current applies the needed pressure, while in a storage system, water is accumulated in reservoirs created by dams, then released as needed to generate electricity.

Many reservoirs are very deep and the water released is cold water from the depths of the lake. These releases of very cold water can dramatically change downstream habitats in warmer regions and be very damaging to native fish and invertebrate populations. Greenhouse gases and methylmercury are emitted from the impounded water of a hydroelectric dam and pose medium potential risks to wildlife from the effects of climate change. During dam operation, upstream fish have a medium risk of being injured and killed during releases of water when they become trapped (entrainment and impingement) in the discharge of water.

Transmission
Effects associated with transmission and delivery of hydro power include injury and mortality from collisions and electrocutions associated with power lines. These pose medium potential risks.

Decommissioning
Hydropower generation poses high potential risks during the decommissioning. It causes mortality to aquatic wildlife and degradation of downstream aquatic habitat from release of sediments during the draining of the reservoir. Sediments often build up in large quantities in dammed lakes. The dismantling also results in the loss of the artificially created upstream lake habitat. Mortality or higher predation rates for fish can occur as water drawdown proceeds, leaving fish stranded in shallow pools. The risk is considered a medium risk for the fish and other aquatic life that have been using these created habitats.

FACT SHEET: WIND ENERGY

In 2008, wind power produced about 1.5 percent of worldwide electricity usage and it is growing rapidly, having doubled in the three years between 2005 and 2008.

Electricity generation from wind has only four stages in its life cycle and each has wildlife effects.

Extraction and transportation
This type of energy comes directly from wind, so no extraction or transportation is needed. Like hydro, wind is a renewable energy source, and the wind needed to generate electricity is harnessed at the source.

Construction
Wind farm construction requires the placement of multiple turbines on the landscape. This has a low potential for destruction or fragmentation of habitat, especially if the areas between the turbines are minimally disturbed, as is often the case.

Operation
Wind turbines harness the wind to generate electricity. Like old fashioned windmills, today's wind turbines use blades to collect the wind's kinetic energy. The wind flows over the blades, creating lift—like the effect on airplane wings—which causes the blades to turn. The blades are connected to a drive shaft that turns an electric generator to produce electricity. A local transformer is then used to step up the electrical voltage, so that the electricity can be sent through transmission and distribution lines to homes, businesses, and other users.

The most commonly cited effect from wind power generation is injury and mortality to birds and bats from collision with wind turbines. For birds, this is considered medium risk. Local mortality to individuals is likely to occur with no population-level effects and a high degree of species recovery. Biodiversity declines are unlikely for birds. Endangered or threatened bird species may be exposed to potential injury or mortality. For bats, especially tree bats, the risk posed by wind turbines may be high, but this is uncertain because of the lack of accurate population information and mortality studies at wind farms. Ongoing research looks at the effects and risks to birds and bats from wind farms, but at this time there are no documented population-level effects. However, based on the few available studies, there is general consensus from the scientific community that bats are likely to be at the greatest risk.

The potential effects of wind turbines to birds and bats are to a large extent dependent upon decisions made during the siting process. If turbines are not sited in areas that are heavily used by birds and bats (such as migration corridors for birds and near heavily used roosts for bats) then potential mortality can be reduced.

Transmission
Effects associated with transmission and delivery of wind energy include injury and mortality from collision and electrocution associated with power lines. These pose medium potential risks.

Decommissioning
Decommissioning of a wind farm requires rehabilitation of the site. The footprint of each of the actual turbines is very small, even though the turbines are spread out over a large area. There will be some disturbance when turbines are removed. Much of the land upon which wind farms are built is agricultural or open land, so rehabilitation can be accomplished quickly.

Name________________________ Date______________ Class________

WORKSHEETS

Use the fact sheets provided and any additional information that you have available to fill in Table 1. For the Method boxes, list how this method (extraction, transportation, etc.) happens for each energy type. In the Effects box, record what effects these actions have on wildlife.

Table 1: Life cycle analysis of effects to wildlife from electricity generation sources

	COAL	NUCLEAR	HYDRO	WIND
Extraction Method				
Extraction Effects				
Transportation Method				
Transportation Effects				
Construction Method				
Construction Effects				
Operation Method				

	COAL	NUCLEAR	HYDRO	WIND
Operation Effects				
Transmission Method				
Transmission Effects				
Decommissioning Method				
Decommissioning Effects				

Table 2: Rank electricity generation sources based on their effects

Rank the electricity generation sources from lowest to highest based on their effects on wildlife. Assign 1 for the lowest and 4 for the highest. Provide a justification for each rank.

FUEL	RANK	STATEMENT OF JUSTIFICATION
Coal		
Nuclear		
Hydro		
Wind		

Name________________________ Date______________ Class_________

Assignment

1. List four things that you learned about wildlife effects caused by the four electricity generation sources while you were doing this activity.

2. Describe anything that surprised you about electricity generation while you were doing this activity.

3. Assume that you are on a committee that is charged with recommending the type of power a community should use to increase its electrical capacity by 10 megawatts. The community's choices are building an extension of an existing coal-fired power station or building a brand-new wind energy facility with five 2-megawatt wind generators. You represent the state's natural resource management department on this committee, and the other committee members are looking to you for an assessment of which new power-generation facility will have the least impact on local wildlife populations.

Based on the work you have done in this lesson, write a one-page summary report to the rest of the committee that provides a recommendation for a course of action and with a clear justification for your recommendation..

Assignment

1. List four things that you learned about wildlife effects caused by the four electricity generation sources while you were doing this activity.
2. Describe anything that surprised you about electricity generation while you were doing this activity.
3. Assume that you are on a committee that is charged with recommending the type of power a community should use to increase its electrical capacity by 10 megawatts. The community's choices are building an extension of an existing coal-fired power station or building a brand-new wind energy facility with five 2-megawatt wind generators. You represent the state's natural resource management department on this committee, and the other committee members are looking to you for an assessment of which new power generation facility will have the least impact on local wildlife populations.

Based on the work you have done in this lesson, write a one-page summary report to the rest of the committee that provides a recommendation for a course of action, along with a clear justification for your recommendation.

For answer sheets: Answers will vary by student.

Table 1: Life cycle analysis of effects to wildlife from electricity generation sources (completed version for reference)

	COAL	NUCLEAR	HYDRO	WIND
Extraction Method	*Mining—aboveground and underground*	*Subsurface mining of uranium*	*N/A*	*N/A*
Extraction Effects	*Water pollution, habitat destruction, direct injury and death*	*Surface mining destroys habitat; runoff from mining could impact water*	*N/A*	*N/A*
Transportation Method	*Trains*	*Trains and trucks*	*N/A*	*N/A*
Transportation Effects	*Collisions with wildlife*	*Collisions with wildlife*	*N/A*	*N/A*
Construction Method	*Built—central power station*	*Built—central power station*	*Built—dam on river*	*Built—on open land often on hill tops*
Construction Effects	*Habitat destruction from land clearing*	*Habitat destruction from land clearing*	*Habitat changes and destruction due to flooding when blocking river*	*Habitat disturbance from building roads and foundations.*
Operation Method	*Coal burned to heat water to produce steam to turn turbines*	*Uranium used to split atoms to heat water to produce steam to turn turbines*	*Water pressure created behind dam is used to turn turbines*	*Wind turns turbines*

Operation Effects	*Acid rain and acid deposits, climate change, mercury bioaccumulation, bird collisions, chemical discharge into water*	*Drawing water from lake, river, or ocean, chemical discharge into water*	*Movement of fish up and down river is disrupted. Habitat change due to dam on river. Fish and wildlife killed when trapped in dam*	*Bird and bat death from collision with turbines*
Transmission Method	*Power Lines*	*Power Lines*	*Power Lines*	*Power Lines*
Transmission Effects	*Habitat destruction during installation, birds colliding with power lines and bird electrocutions*	*Habitat destruction during installation, birds colliding with power lines and bird electrocutions*	*Habitat destruction during installation, birds colliding with power lines and bird electrocutions*	*Habitat destruction during installation, birds colliding with power lines and bird electrocutions*
Decommissioning Method	*Removal of structure and rehabilitation of site*	*Removal of structure and rehabilitation of site*	*Removal of structure and major rehabilitation of site*	*Removal of structure and rehabilitation of site*
Decommissioning Effects	*Pollutants may remain; habitat may take a while to recover*	*Long-term contamination with radioactive material. Possibility of radioactive release*	*Original river habitats destroyed by released sediment and changed water levels*	*Limited intrusion of site requires limited restoration*

Table 2: Rank electricity generation sources based on their effects

Rank the electricity generation sources from lowest to highest based on their effects on wildlife. Assign 1 for the lowest and 4 for the highest. Provide a justification for each rank.

FUEL	RANK	STATEMENT OF JUSTIFICATION
Coal	*Rankings will depend on student answers*	*Students should consider the possible effects as well as the potential risk when creating their rankings. For example, nuclear could produce radioactive leaks, but this is a very low risk, so leaks should be considered a minor factor when deciding rankings.*
Nuclear		
Hydro		
Wind		

LESSON 13

WHAT IS WIND POWER'S RISK TO BIRDS?

KEY CONCEPT

Learn how bird behavior and ecology are related to avian impacts from wind turbines and how scientists study these impacts.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Technology
Mathematics
Living Environments

BACKGROUND

A common question when discussing wind energy is, "Will the turbines kill birds?" Scientists called ornithologists study this issue to provide information on whether or not, and to what degree, birds may be impacted by turbines. This lesson teaches students about bird behavior and ecology, after which they will use data to perform an avian risk assessment at a potential wind farm site.

OBJECTIVES

At the end of the lesson, students will:

- know about some avian behaviors such as feeding, migrating, and nesting
- be able to collect, evaluate, and use data from a variety of sources
- understand how birds can be impacted by turbines

METHOD

Students will play the role of ornithologists studying potential impacts to birds at the proposed Chautauqua wind farm in New York. They will read about how birds can be impacted by wind turbines and then answer questions based on reading passages. They will then use the information from the reading passages, along with data on birds and wind farms, to determine potential risk to raptors (birds of prey such as hawks and eagles) at the proposed wind farm site.

MATERIALS

- ❑ Student reading passages and student worksheets*
- ❑ Calculators

*included with activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

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GETTING READY

Make copies of the activity reading passages and student worksheets.

ACTIVITY

Step 1: Beginning questions for students

If students have not discussed wind energy and wildlife before, begin the class by asking students what they know about it:

- Have you ever seen a wind farm?
- What have you heard about wildlife and wind turbines?
- Do you think turbines are very dangerous to birds? Why?
- What do you think birds are doing when they collide with turbines?

This may bring up a wide range of thoughts and preconceptions about wind energy. Continue the discussion by asking students how they think a scientist might conduct studies to determine the potential impacts to birds at proposed wind farm sites.

- How can scientists find out what types of birds may be in an area where they want to build wind turbines?

  Scientists can observe birds at the site, look at published information on birds found in that location, and look at maps with information on bird locations, and knowledge of the habitat of local bird species. Special radar systems can also be used to see where birds are flying at a particular site, even at night.

- What would you want to know if you were studying birds at a wind farm?

  Information would include the type of birds, how high they fly, whether or not they fly in the area of the turbines, whether the species avoids areas containing wind turbines, whether the species' vulnerability to impacts from wind farms has been demonstrated at other existing facilities etc.

Step 2: Initial research

If time and resources allow, ask students to conduct their own online research by typing "birds and wind turbines" into a search engine. This will produce a wide variety of information from pro-wind and anti-wind energy groups as well as scientific papers. Have a brief discussion about what students find.

Step 3: Learning about birds and turbines

Tell students to read the first reading passage, "Birds and Turbines," and then answer the Step 1 questions on the student worksheet. Students can be divided into small groups, if you like.

Step 4: Learning about risk assessment

Ask students to read the second reading passage, "Project and Avian Risk Assessment Overview," and then answer the corresponding questions on the student worksheet. Part of this exercise will require the students to calculate the potential mortality (deaths) to raptor species at the proposed wind farm site.

Students will finish the activity by answering the Step 2 questions requiring them to apply what they have learned and consider what the risk assessment results really mean for raptors at the proposed Chautauqua wind farm site.

Step 5: Wrap up

At the end of the lesson, discuss how developers, communities, and policymakers could balance the potential wildlife impacts with the desire for developing wind energy. Consider posing the following questions:

- When would bird mortality be one of the most important issues in siting a wind farm?

    Bird mortality would be an important issue when a threatened or endangered species is involved, when a wind farm is near environmentally sensitive areas such as national parks or local bird refuges, when the potential wind farm site is in the migratory path of birds, and when there is a large amount of community concern about potential impacts to birds. For example, the endangered whooping crane migrates along the path where there is the greatest potential for wind energy.

- How would a developer monitor the site after the wind farm is built to document and report any bird issues?

    Researchers conduct surveys of dead birds, called carcass surveys, to determine if birds are being killed and, if so, what kind. Researchers can also determine if birds are being displaced, or not using the site as they normally would.

- How do you think developers, scientists, and policymakers should balance the desire for wind energy with potential impacts to wildlife?

    They should consider populations of animals, not just individuals, and the costs and benefits of all types of energy production.

EXTENSION

In this section, students come up with ideas for wind turbine designs that will minimize potential impacts to birds. They will look online for a wide variety of wind turbine designs and consider power production along with wildlife impacts. Turbines have been designed in many ways in order to increase power production and decrease wildlife impacts.

VOCABULARY

migrate – Movement of animals from one location to another, often across very long distances, in search of food, water, and breeding opportunities.

mortality – The number of animals killed.

ornithologist – A scientist who studies birds.

raptors – A category of birds that includes all vultures, hawks, falcons, kites, harriers, and eagles. They are often called "birds of prey."

risk (to wildlife) – The probability that loss or other adverse effects will occur to wildlife.

rotor swept zone (RSZ) – The airspace covered by the turning of turbine blades.

siting – The process used to determine the specific location of a wind energy facility and its turbines.

utilization – The total number of birds flying in the space where wind turbines are spinning at a wind farm.

utilization rate – The number of birds per unit of time (hour) in the space where turbines are spinning at a wind farm.

RELATED ACTIVITIES

- Lesson 12: How Does Energy Affect Wildlife?
- Lesson 14: Can We Reduce Risk to Bats?
- Lesson 15: How Do People Feel About Wind?

READING PASSAGE 1: BIRDS AND TURBINES

A common question when discussing wind energy is, "Will the turbines kill birds?" Many people have heard accounts of birds being hit and killed by wind turbine blades. However, most research shows that wind turbines kill relatively few birds, at least compared with other human-made structures.

Table 1. Number of estimated annual bird deaths from human causes.

HUMAN CAUSE	ASSOCIATED BIRD DEATHS PER YEAR (US)
Cats	Hundreds of millions
Power lines	130 million to 174 million
Windows (residential and commercial)	100 million to 1 billion
Pesticides	70 million
Automobiles	60 million to 80 million
Lighted communication towers	40 million to 50 million
Wind turbines	10,000 to 40,000

It has been estimated that from 100 million to well over 1 billion birds are killed annually in the US due to collisions with human-made structures, including vehicles, buildings and windows, power lines, communication towers, and wind turbines. Recent US studies indicate that bird mortality at wind turbine projects varies from less than one bird per turbine per year to 7.5 birds per turbine per year, with an average of 4.72 birds per turbine per year. This means that between 10,000 and 80,000 birds may be killed each year at wind farms across the country; less than 1 percent of these are thought to be raptors (birds of prey). This is important because many species of raptors are threatened or endangered.

Although some birds are struck by turbine blades, turbine strikes are a very small risk to birds in general and are only a minor contributor (less than 1 percent) to bird fatalities caused by humans. Nevertheless, avian impacts from turbines are a concern for developers, scientists, and regulators.

Raptors (such as hawks, eagles, and vultures) are often studied at potential wind farms because they are at the top of the food chain and have naturally smaller populations than other more common species. (In addition, some raptors, such as eagles, are protected by law.) Top predators concentrate a lot of the biological processes of the ecosystem in a relatively small number of individuals. Thus removing "x" number of individuals from the population of a top predator can have more of an overall impact on the population and the ecosystem than would removing the same "x" number of individuals from a species at the bottom of the food chain that has a much larger population. For example, both grass and lions are important parts of the Serengeti ecosystem, but taking out 100 lions would have a much bigger impact than would taking out 100 grass plants.

Research has shown that birds can be impacted by wind energy production in three major ways: collisions, avoidance, and direct habitat impacts.

Collisions

Collisions with turbine blades, towers, power lines, or with other related structures are the most recognized impact from turbines. These collisions happen when birds are flying in the vicinity of the structures. Scientists observing birds have found that there are several behavioral factors that contribute to bird collisions with structures at wind farms.

Migration: Bird species that do not live in one place for the entire year are called migratory birds. Migratory birds travel from one location to another, or migrate, in the spring and fall. Some of these migrations can be over very long distances, and birds need to conserve as much energy as possible when they fly. One way birds save energy during migration is by traveling on air currents. Air currents are moving streams of air. Birds use these streams of air to help move them over their long migration route. Migrating birds come into conflict with turbines when their migration paths take them through wind farms, since wind turbines are placed to take advantage of the high-volume air currents, often on high ridges and hilltops.

Feeding: When birds are going after prey such as an insect, small mammal, or another bird, they are very focused on that prey and may not see dangers around them, such as spinning turbines.

Breeding: Some bird species spend most of their time low to the ground (and out of potential harm from turbine blades) until breeding season begins. Then these birds put on a display for prospective mates, during which they jump and fly into the air. These breeding behaviors may put some birds at risk from a turbine strike.

Roosting and Nesting: All energy sources (such as wind, coal, oil, natural gas, nuclear, and hydroelectric) use the power grid to move energy from where it is generated to your home or school. This grid consists of power lines that most often run above ground. Power lines can cause bird injury and death from collisions and electrocutions. When birds roost or nest on power line structures, they are at increased risk. For example, when a bird stretches its wings and touches two energized parts of the structure, it can be electrocuted by the powerful electrical current.

Avoidance

Some birds will only nest and feed in open areas with little vegetation. For such species, areas containing tall objects may be perceived as too dangerous to inhabit, as the tall objects represent places where predators could be hiding. These birds will only live in areas with low-lying vegetation and will refuse to nest or feed in an area if a tall object (such as a tree, building, or turbine) is present.

Direct habitat impacts

Wind farms can have direct impacts on bird habitat. Building and installing turbines and related support structures such as roads, power lines, and buildings can disturb bird habitat. All energy types create this impact. Comparatively, a wind turbine has a very small footprint (the space that each turbine, as well as associated roads and buildings, takes up), so habitat impacts from the turbines are minimal.

READING PASSAGE 2: PROJECT OVERVIEW AND AVIAN RISK ASSESSMENT

Chautauqua Wind Farm proposed site information

In 2003, Chautauqua Windpower LLC proposed to install and operate an approximately 50 megawatt (MW) wind energy facility in the towns of Ripley and Westfield in Chautauqua County, New York. The facility would consist of up to 34 wind turbines, an electrical substation, and power line interconnection to an existing 230 kilovolt transmission line. All of this was planned for a 3-square-mile area.

Turbines

The project proposed 34 turbines. These turbines would have a maximum blade height of approximately 398 feet (121 meters) and a rotor diameter of approximately 253 feet (77 meters) (Figure 1). Each turbine would have a maximum generating capacity of approximately 1.65 MW. With 34 turbines, this is enough to power over 13,000 homes.

Avian Risk Assessment

As part of the planning for the wind farm, in compliance with state and federal standards, an avian risk assessment (ARA) was conducted to address the project's potential impact on birds. An ARA is used to determine which bird species are present at a potential wind site and what risk the turbines may pose to those species. This ARA was conducted using several data sources, including bird observations, background information on the wind site, radar, and past studies and research.

The ARA used a "Utilization, Avoidance, Mortality" (UAM) method to calculate potential impacts to birds at the Chautauqua site. Of specific concern were raptors because raptor mortality (death) has been recorded at other wind farms.

The UAM method of conducting an ARA looks at the presence of birds, characteristics of bird behavior, and mortality studies at similar locations to determine the likelihood of a bird being killed by a turbine. There are three steps in a UAM ARA analysis:

1. Determine Utilization
2. Determine Avoidance
3. Determine Potential Mortality

Determine Utilization (U)

Utilization is the number of birds that fly through the project area in a given period of time (a year, in this case). Avian researchers conduct visual counts in various locations over a period of days to get an idea of how many raptors are present. They do this by searching the sky for several hours at a designated study area and writing down the number of birds seen, how high they were flying, and what direction they were going. In addition to visual counts, the Chautauqua site had information on birds from radar data that was collected as well. By combining this information, researchers were able to get an average number of birds that accessed the study area over a period of a year (Table 2).

Researchers estimated that they were able to "sample" or conduct their observations on 16 percent of the potential wind farm site. Researchers feel very confident that the bird species and abundance (numbers of birds seen) shown in Table 2 are a good representative sample of the whole Chautauqua site.

Table 2: Raptors observed accessing the study area during 1 year

SPECIES	NUMBER*
Black Vulture	<1
Turkey Vulture	4,850
Osprey	151
Mississippi Kite	<1
Bald Eagle (T, US-T)	33
Northern Harrier (T)	179
Sharp-shinned Hawk (SC)	1,327
Cooper's Hawk (SC)	59
Northern Goshawk (SC)	6
Red-shouldered Hawk (SC)	292
Broad-winged Hawk	7,055
Red-tailed Hawk	1,341
Rough-legged Hawk	33
Golden Eagle (E)	6
American Kestrel	280
Merlin	17
Peregrine Falcon (E)	14
Gyrfalcon	<1
Unidentified Raptor	123
Total	15,766*

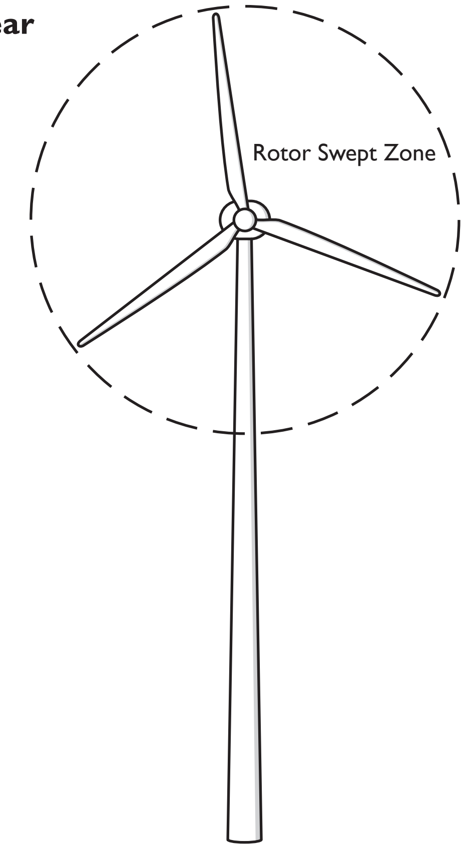

Figure 1: Rotor Swept Zone

*Sampling was conducted for 16% of the total project site. This number represents only 16% of total raptors at the site.

Note: State-listed species designated as E= Endangered, T= Threatened, and SC= Special Concern. Federally listed species designated as US-T= Federally Threatened

Determine Avoidance (A)

Research has documented and established that most birds using the area within the RSZ (see Fig. 1) do not collide with wind turbines. Overall, there is a low probability of a bird collision with a wind turbine. A very high percentage of birds also actively avoid wind turbines by flying over individual turbines, flying around or in between individual turbines, or passing through rotating turbines unharmed. For birds using a wind farm, estimates of avoidance are more than 98 percent (i.e., less than 2 percent of birds are hit and die).

Avoidance rate is calculated using data from similar wind energy facilities. This method uses data collected on number of birds present and number of birds killed at these facilities and is the ratio of fatality rate to passage rate (number of fatalities to number of birds) in the RSZ. The avoidance (A) factor for Chautauqua was determined to be .042 percent.

Determine Potential Mortality (M)

Potential mortality is assessed by multiplying site utilization (U) by the avoidance factor (A). The result equals the approximate number of birds that may be killed by turbines at the wind farm in a year. To calculate the number of birds each turbine may kill, divide overall site mortality (M) by the number of turbines.

Name________________________________ Date______________ Class_________

When a wind farm is being planned, scientists called ornithologists are often hired to assess the location for potential impacts to birds. They look at a variety of factors, from types of birds present to behaviors that might indicate which birds would be affected by the turbines. The scientists complete an analysis of which birds may be impacted, why they may be impacted, and how many may be impacted. They then report the results of this analysis to the wind farm developer.

Ornithologists have designed models that allow them to determine how many birds may be hit by the turbines on a wind farm. This information is critical when determining what types of impacts the turbines may have on the environment.

Your research team collected background information and conducted bird counts at the proposed Chautauqua wind farm site in New York. A summary of the team's findings can be found in the activity reading passages. Use this information to answer the questions on your worksheet. Your answers will help in designing an avian risk assessment for the site.

After reading the passage, answer the following questions:

1. How do wind turbines and wind farms affect birds?

2. What are some of the leading human causes of bird death (mortality) in the US?

3. What is a raptor and why are scientists and regulators concerned about the impact of wind farms on raptors?

After reading the passage, answer the following questions.

4. What is an avian risk assessment and why is it done?

5. What is the rotor swept zone (RSZ)?

6. What is an avoidance rate and how is it calculated?

Name______________________________ Date______________ Class_________

7. Answer the following questions based on the raptor observation data in Table 2.

   a. How many raptor species were identified at the Chautauqua site?

   b. Which of these species are classified as state or federally threatened, endangered, or of special concern?

8. Based on the information in the risk assessment reading passage, calculate potential avian mortality at the proposed Chautauqua wind farm site by answering the following questions.

   a. Calculate utilization: How many raptors are estimated to be using the Chautauqua research area in a year? Make sure you calculate how many would be found at 100 percent of the Chautauqua site, not just how many were observed by researchers. The table only represents 16 percent of the entire site.

      U=

   b. Determine avoidance: What is the avoidance factor used for the Chautauqua site?

      A=

   c. Calculate potential mortality for the entire wind farm site using this equation:

      $(U) \times (A) = M$

d. How many raptors may be killed by each turbine annually?

$$\frac{M}{\text{\# of turbines}}$$

9. Is the potential raptor mortality at the Chautauqua site higher or lower than what you thought it would be?

10. What recommendations would you make to the developer who hopes to build a wind farm on this site? What would you tell the developer about potential impacts on raptors?

Weather patterns play an important role in raptor migration. During migrations, raptors often use thermals. A thermal is a column of warm air that rises as the Earth warms. Raptors fly in circles in these thermals to rise higher in the air with less work. Once raptors reach a sufficiently high altitude, they can glide to the next thermal without flapping their wings. Thermals only form over land and are greater on sunny days and over surfaces that absorb a lot of heat (such as a parking lot). There are places where thermals and wind patterns cause large numbers of migrating birds to concentrate. One of these is the Derby Hill Bird Observatory.

The Derby Hill Bird Observatory, located on the southeastern corner of Lake Ontario in Oswego County, NY, is one of the premier hawk watches in the northeastern US. It is located on the edge of Lake Ontario where many migrating birds concentrate. Hawk counts at the site were started in the early 1960s and since 1979 have been conducted every year in a standardized way. On average, 40,000 raptors are counted each spring as they migrate northward, making this site one of the best spring observation sites in the country.

For more information and to see radar maps of hawk migratory flight patterns, go to: http://learn.kidwind.org/windwise/.

Step 1: Read the reading passage called "Birds and Wind Turbines."
After reading, answer the following questions:

1. How do wind turbines and wind farms affect birds?
   Birds can be struck by turbine blades. The presence of turbines can cause birds to avoid using that area as habitat. Habitat can be disturbed by the installation of turbines, power lines, and buildings.

2. What are some of the leading human causes of bird death (mortality) in the US?
   Leading causes are cats, power lines, windows, pesticides, automobiles, lighted communication towers.

3. What is a raptor and why are scientists and regulators concerned about the impact on raptors from wind farms?
   A raptor is a bird of prey such as a hawk, eagle, and vulture. Raptors are a focus of concern because they are at the top of the food chain and have naturally smaller populations than other more common species.

Step 2: Read the reading passage called "Project Overview and Avian Risk Assessment."
After reading, answer the following questions.

4. What is an avian risk assessment and why is it done?
   An avian risk assessment is a study used to determine which bird species are present at a potential wind site and what risk the turbines may pose to those species.

5. What is the rotor swept zone (RSZ)?
   This is the circular area used by the turbine blades as they rotate.

6. What is an avoidance rate and how is it calculated?
   An avoidance rate is the rate at which birds stay away from wind turbines. It is calculated using data from similar facilities, looking at numbers of birds present and numbers of birds killed, and is the ratio of numbers of fatalities to numbers of birds.

7. Answer the following questions based on the raptor observation data in Table 2.

   a. How many raptor species were identified at the Chautauqua site?
      Nineteen

   b. Which of these species are classified as state or federally threatened, endangered, or of special concern?
      Bald Eagle (T, US-T), Northern Harrier (T), Sharp- shinned Hawk (SC), Cooper's Hawk (SC), Northern Goshawk (SC), Red-shouldered Hawk (SC), Golden Eagle (E)

8. Based on the information in the risk assessment reading passage, calculate potential avian mortality at the proposed Chautauqua wind farm site by answering the following questions.

   a. Calculate utilization: How many raptors are estimated to be using the Chautauqua research area in a year? Make sure you calculate how many would be found at 100 percent of the Chautauqua site, not just how many were observed by researchers. The table only represents 16 percent of the entire site.
      U= 98,538

b. Determine avoidance: What is the avoidance factor used for the Chautauqua site?
A= .042

c. Calculate potential mortality for the entire wind farm site using this equation:

(U) × (A)= M
M=41

d. How many raptors may be killed by each turbine annually?
1.2 raptors per turbine per year

9. Is the potential raptor mortality at the Chautauqua site higher or lower than what you thought it would be?
Student answers.

10. What recommendations would you make to the developer who hopes to build a wind farm on this site? What would you tell the developer about potential raptor impacts?
Student answers.

CAN WE REDUCE RISK TO BATS?

LESSON 14

KEY CONCEPT

Students analyze bat behaviors and propose a wind farm operational plan that could reduce the risk of bat mortality.

TIME REQUIRED

1 class period

GRADES

6–8
9–12

SUBJECTS

Living Environments
Technology

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BACKGROUND

A wind developer must determine when it will operate the turbines in order to generate enough electricity to maximize profitability while doing what is necessary to protect the environment. Whether the turbines are turned on or off can influence the level of bat mortality at a wind farm. In this lesson, students will learn about the behaviors of different bat species and create a schedule of when the turbines can be turned on and off to reduce the potential for bat mortality.

OBJECTIVES

At the end of the lesson, students will:

- understand the behavior of different bat species
- explore the relationship between technology and nature

METHOD

Students will work in small groups to learn about the behaviors of different bat species near a wind farm. Based on these data, students will design a dispatch schedule for a wind farm that lowers the risk of bat mortality. Each group will present its dispatch schedule to the class for discussion of the pros and cons.

MATERIALS

You will need one set of the following materials for each group:

- ❑ Student reading passages and student worksheets*
- ❑ Information packets for each team (bat fact sheets, bat mortality data)*

*included with activity

GETTING READY

Prepare copies of the worksheets, reading passage, and information packets for all of the students.

ACTIVITY

Step 1: Beginning questions for students

If students have not studied wind energy before, begin the class by asking students what they know about wind energy and how wind turbines affect wildlife. Ask some specific questions about bat behaviors to get students thinking about how bats may be impacted by wind farms.

- When do bats fly?
- Where do bats live?
- What do bats eat?
- Where do bats go in the winter?
- What can happen when bats fly in the area of a wind turbine?

Provide students with the reading passage and career profile either before the lesson or for homework afterward.

Step 2: Creating a dispatch schedule

Organize students into teams of four. Present this scenario to each team:

> *Last year, the Eco3Wind Company installed a 360 MW (megawatt) wind farm with 120 turbines. Each turbine has a maximum capacity of 3 MW. Recently, the Bat Protection Coalition, a local citizens group, has expressed concern about the impact of the wind farm on local bat populations. In response to these concerns, the company is looking for ways to reduce the likelihood of bat mortality on its wind farm. The company has hired a bat biologist to identify which bat species are present on or near the wind farm.*
>
> *Your team has been asked to examine the data collected by the bat ecologist and recommend a schedule for when to turn the turbines on and off. This schedule, called a dispatch schedule, will be designed to reduce the risk of bat mortality while also generating enough power to make the company profitable. Your proposal should include an explanation of which bat species your team has prioritized (if any) and how your schedule will help protect them.*

Provide students with the worksheet. Each student in the group will select one bat species to read about and will complete the corresponding column of the table. When the table is complete, ask each team to discuss the behaviors of all 4 bat species and determine which bat species they will prioritize (if any). Tell students to design a schedule of when they would recommend turning the turbines on and off, based on the species information.

Step 3: Wrap up
After every team has completed its dispatch schedule, hold a class discussion to compare results. To make comparisons easier, summarize results in a table.

Use some of the following questions to generate a discussion about the exercise:
- Were there any significant similarities or differences among the dispatch schedules?
- Did any of the groups prioritize 1 or 2 bat species over the others and, if so, why?
- Which dispatch schedule appears to provide the best protection for bats and why?

VOCABULARY

barotrauma – Trauma caused by rapid or extreme changes in air pressure; in the case of bats, barotrauma results in death.

cut-in speed – The minimum wind speed at which the wind turbine will generate usable power. For most turbines, this is typically between 7 and 10 mph.

dispatch schedule – The “brains” of the wind turbine, the mechanism that collects data (such as wind speed) and tells the turbine when to turn on and off.

echolocation – A system of making high-frequency sounds to determine the direction and distance of objects.

endangered species – A species in danger of extinction throughout all or a significant portion of its range.

hibernate – To spend the winter in a dormant or torpid state.

migrate – The movement of an animal from one location to another, often across very long distances, in search of food, water, and breeding opportunities and locations.

start-up speed – The speed at which the rotor and blade assembly begins to rotate.

RELATED ACTIVITIES

- Lesson 12: How Does Energy Affect Wildlife?
- Lesson 13: What Is Wind’s Risk to Birds?

ECHOLOCATION

EASTERN RED BAT

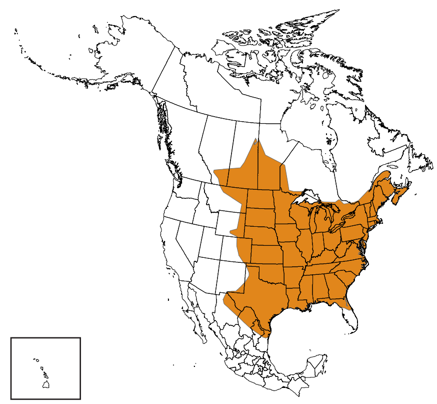
Lasiurus borealis (lay-zee-your-us bor-ee-al-is)

Photo © Merlin D. Tuttle

The eastern red bat has reddish-orange fur with a brownish-black tail and wing membranes. This bat lives or roosts in trees during the day. When hanging by one foot in trees, the bat will swing slightly, which make it look like dead leaves or pine cones. This provides excellent camouflage from potential predators such as opossums.

Eastern red bats often fly in a diving pattern to catch insects. They begin foraging about 1 to 2 hours after sunset and will focus their feeding within ½ mile of their day roosts. While foraging can occur throughout the night, activity appears to peak within the first 4 hours after sunset. They are often found feeding near lights, which attract insects, and along the edges of forests and clearings.

Range of Eastern Red Bat



Eastern red bats can fly up to 40 mph when on a straight, level course. These bats have been seen flying well above the tree canopy (30 m and higher), but when foraging, they are found at lower altitudes (15 to 30 m). As with most bats, they are less likely to fly at higher altitudes when wind speeds are above 6 to 8 m/sec.

These bats are typically solitary, but will come together in groups to mate and migrate. They mate in August and September and often give birth to twins. In the fall (September/October), these bats migrate in large groups over 900 miles to southern parts of their range until the following spring (May/June).

The life span of the eastern red bat is thought to be as long as 12 years. Eastern red bats are not considered threatened.

Sources:

- Bat Conservation International
- www.esf.edu/aec/adks/mammals/red_bat.htm
- Saunders, D. A. 1988. *Adirondack Mammals*. State University of New York, College of Environmental Science and Forestry. 216pp.
- Shump, K.A. Jr., and A.V. Shump. 1982. "*Lasiurus borealis*." *Mammalian Species*, 183:1-6.
- William Caire, et al. Capture Heights and Times of *Lasiurus borealis* (Chiroptera: Vespertilionidae) in Southeastern Oklahoma
- Photo: Merlin D. Tuttle, Bat Conservation International, www.batcon.org
- Map data: National Atlas of the United States and Bat Conservation International

HOARY BAT

Lasiurus cinereus (lay-zee-your-us sa-near-ee-us)

The hoary bat is often found roosting 10 to 15 feet above the ground in deciduous and coniferous woodlands.

Hoary bats typically begin feeding after dark and will feed all through the night until about an hour before sunrise. They are most active about five hours after sunset and forage as far as 24 miles from where they roost.

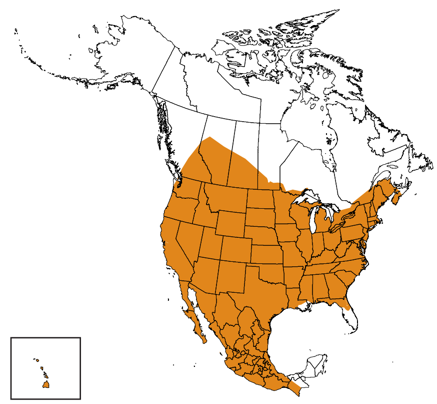
Hoary bats can reach speeds of 13 mph. They often forage near tree tops. These bats have been seen flying well above the tree canopy (30 meters and higher), but when foraging, they are found at lower altitudes (15 to 30 meters). Hoary bats feed on insects, especially moths. As with most bats, they are less likely to fly at higher altitudes when wind speeds are above 6 to 8 m/sec.

These bats are solitary, but migrate in large groups and may even fly with groups of birds. During migrations, they can be found flying as early as sunset. Traveling over 900 miles, they reach Florida around October/November in the fall. They begin their return migration between February and May.

Due to its abundance, the hoary bat species is not considered threatened.

Photo © Merlin D. Tuttle

Range of Hoary Bat



Sources

- Bat Conservation International
- Photo: Merlin D. Tuttle, Bat Conservation International, www.batcon.org
- Map data: National Atlas of the United States and Bat Conservation International

BIG BROWN BAT

Eptesicus fuscus (ep-tess-a-cus fuss-cuss)

Photo © Merlin D. Tuttle

Big brown bat is a very abundant species and lives in a wide range of habitats, from forests to suburbs to agricultural areas. These bats live in large maternity colonies in buildings, barns, bridges, bat houses, and beneath loose bark or in small openings of trees.

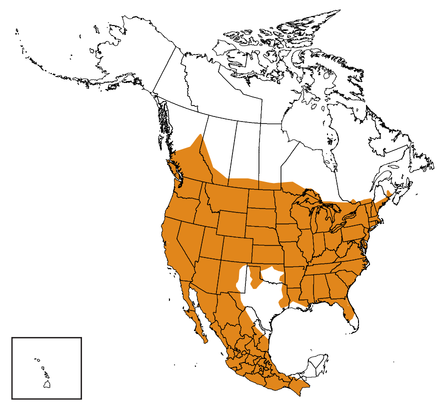
These bats eat insects, especially small beetles. They typically forage between 0.6 and 1.2 miles from where they roost. Big brown bats typically starts foraging about 18 minutes after sundown, fly continuously while eating, and spend about 90 minutes a night foraging. They have been observed to catch between 5 and 20 insects in a minute. Big brown bats prefer to forage along the edge of forests, over land or water, in clearings, and lake edges. They can eat the equivalent of their body weight in a single night.

Big brown bats migrate distances of less than 300 miles. They will typically hibernate in the winter, and the length of hibernation depends on the length of the winter.

Big brown bats typically fly at an altitude of 6 to 50 meters over forests and roadways. As with most bats, they are less likely to fly at higher altitudes when wind speeds are above 6 to 8 m/sec.

Due to their abundance and ability to live in more populated areas, this bat is not a threatened species.

Range of Big Brown Bat



Sources

- Bat Conservation International
- Whitaker et al. 1977
- Photo: Merlin D. Tuttle, Bat Conservation International, www.batcon.org
- Map data: National Atlas of the United States and Bat Conservation International

INDIANA MYOTIS

Myotis sodalis (my-oh-tis so-dal-is)

Photo © Merlin D. Tuttle

The Indiana myotis is a small gray bat that roosts in crevices or under the loose bark of trees during the summer. Indiana myotis bats tend to move regularly between roosts.

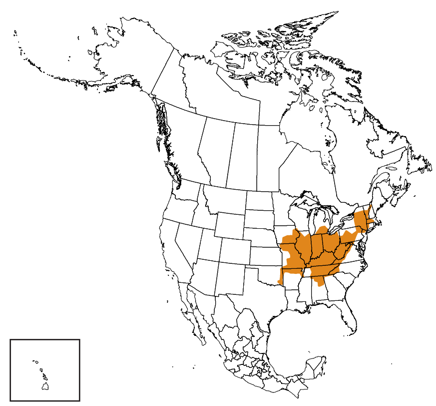
Indiana myotis bats primarily eats insects and typically forages within a mile of the roost tree. These bats tend to be most active just after sunset, with their peak activity occurring within the first 2 hours following sunset. Indiana bats usually forage and fly within an air space from 2 to 30 m above ground level.

Indiana myotis bats migrate up to 500 miles between winter hibernacula and their summer roosts. They hibernate in caves during the winter, with the majority of them found in Indiana, Kentucky, and Missouri.

While no Indiana bat fatalities have been confirmed at active wind energy facilities, other *Myotis* species (*Myotis sp*) that exhibit similar life history characteristics and behaviors have been killed; therefore, there may be some risk associated with this species.

The Indiana myotis is federally identified as an endangered bat. One of the contributing factors to the bat's decline could be a loss of adequate habitat. While caves where the Indiana myotis hibernates have been largely protected, the loss of forested areas where the bat roosts in the summer are not protected.

Range of Indiana Myotis



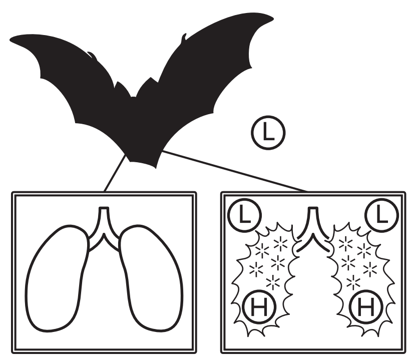
Sources

- Bat Conservation International— www.batcon.org/resources/media-education/species-profiles— Species profiles
- Animal Diversity Web— http://animaldiversity.org/site/accounts/ information/Lasiurus_cinereus.html—Hoary Bat profile
- Normandeau. Zephyr Duke Michigan Fatal Flaw Report
- Humphrey et al. 1977
- Photo: Merlin D. Tuttle, Bat Conservation International, www.batcon.org
- Map data: National Atlas of the United States and Bat Conservation International

READING PASSAGE: BATS AND WIND TURBINES

Bats sometimes have a bad reputation based on movie and Halloween images. Despite this, it is important to realize that bats are very helpful to people. The US is home to 45 different species of bats, nearly all of which eat insects. Some bats can eat their weight in insects every night. Millions of bats eating insects every night is what you call great bug control! Just consider what life would be like without bats.

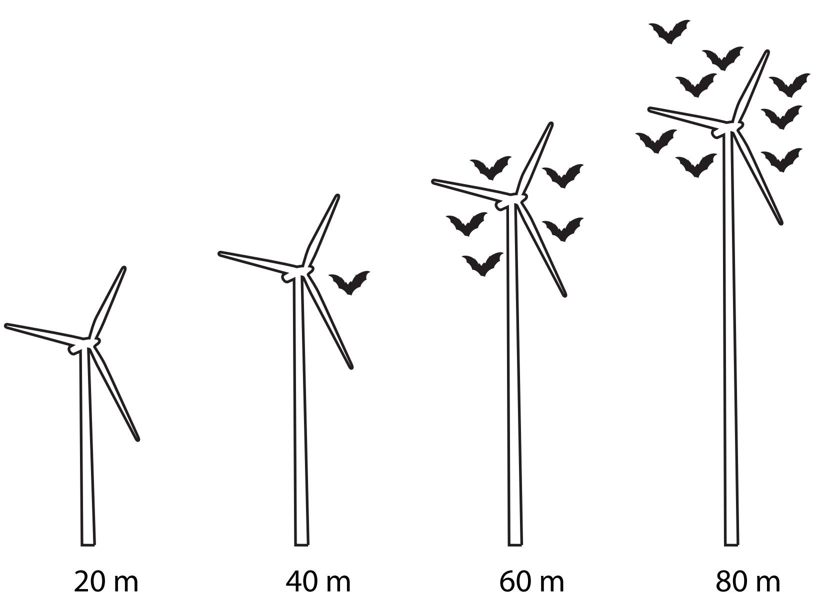
Bats are unique and interesting animals found to have been living as long as 50 million years ago. Bats are the only mammals that fly. While many people think of bats as living or roosting in caves, many bats roost in trees, buildings, or even underneath the bark of trees. Bats use echolocation to navigate and find food, but they also have excellent vision. When colder weather arrives, some bats migrate to warmer areas while others hibernate. Bats can live a long life—in some cases more than 30 years—but they have a slow reproductive cycle in which they typically have only one baby or "pup" at a time. Four species of bats in the US have been categorized as endangered, meaning that there is a threat of extinction if their populations do not increase.



Barotrauma occurs when sudden changes in pressure cause a bat's lungs to burst. Moving turbine blades can cause such a drop in pressure close to the rotor.

While researchers are learning more about bats every day, there are still many things we do not know about them. One of the great mysteries of bats is how they are impacted by wind turbines. Dead bats have been found near wind farms around the world. While in some cases the bat hit the turbine, many bats die from barotrauma, which is caused by extreme change in air pressure close to the moving wind turbine blades. Researchers have found that the majority of bat deaths occur in the summer and fall (June–September) during the migration season. Three bat species that roost in trees and make long-distance migrations tend to be killed more than any other species. These deaths often occur in the autumn. As the height of wind turbine towers has increased, the mortality of bats has increased as well.

Researchers face many challenges when trying to learn about and protect bats. It is difficult to count bats; thus, the actual population of each species is unknown. While some technologies are available for detecting bats, we are still unable to determine the exact number of bats in a particular area. Researchers also have many questions about bats and their relationship to wind turbines. While researchers believe that the bats may be attracted to areas with wind turbines, they are not sure why. Are the bats attracted to the clearings around wind turbines or are they considering the turbines as potential roosting sites because bats often select the tallest trees? Or are they drawn to the insects?



While there are many unanswered questions, as researchers find more answers, wind farms will be better equipped to lower their impact on bat populations. Recently, researchers have found that bat mortality is higher on nights with low wind speeds. It is believed that bats are more likely to fly when wind speeds are lower. Some experiments have been conducted where wind turbines were turned off until the wind speeds reached a higher threshold—called the cut-in speed. This has been found to be an effective mechanism for lowering fatality rates.

Sources

- USGS powerpoint presentation: www.mesc.usgs.gov/Products/Publications/22170/22170.pdf
- Bat Conservation International
- Barclay et al. 2007; Can. J. Zool. 85:381–387
- Arnett et al. 2008; J. Wild. Man. 72: 61–78
- Johnson 2005, Bat Research News 46: 45–49
- Cryan and Brown 2007, Biological Conservation 139: 1–11

CAREER PROFILE: ALLISON POE, BAT BIOLOGIST

I didn't grow up wanting to be a bat biologist; I didn't even know there was such a thing! After I completed a B.A. in psychology with a minor in sociology, I worked as a white water rafting guide in Colorado. It was there that I developed a deep appreciation for wildlife and decided to pursue a career in wildlife biology. I began by volunteering for a local environmental consulting firm where I joined a bat research trip, which was a creepy, scary, and very exciting experience. After we caught a few bats, I was hooked. Later I participated in a number of life-changing internships. I spent five months studying sea birds on a remote island in Alaska and helped with a Hawksbill sea turtle project and a bat project in Hawaii. I got my master's degree at the University of Western Ontario, where I focused on bats.

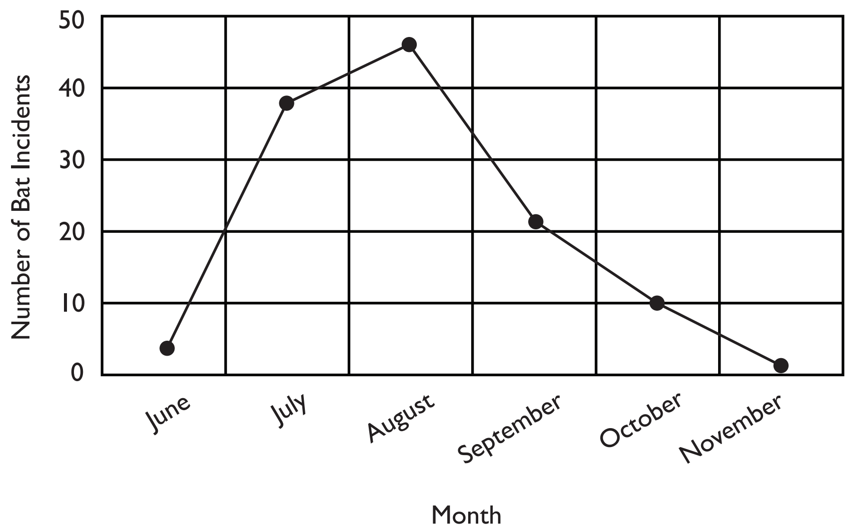
As a bat biologist, I do a variety of things, all pertaining to understanding bats and their biology and ecology. My focus is on the effects that wind farms have on bat populations. I use special acoustic bat detectors to survey areas in which wind farms are proposed to assess the levels of bat activity and what species of bats are present in the area. I use computer software that allows me to see the recorded bat echolocation calls. This is called a spectrogram. Because different bat species sound different when they echolocate, I use the spectrogram to identify the species of bat that emitted the echolocation call. This is important because bats are difficult to capture. Using this software eliminates the need to see the bat up close to know what kind it is. With this information, we can show wind developers where the high risk areas are and help them make decisions that will minimize impacts to bats.

I really enjoy my work because of the variety. I get to go out in the field to potential wind farm sites and install bat monitoring equipment on meteorological towers, drive around at night looking for bats with acoustic bat detectors, and analyze echolocation call data in an effort to understand where the bats are and when they appear in an area. I work closely with other biologists and computer specialists to come up with new and improved methods to monitor bat activity. The work that I do is very rewarding and always keeps me on my toes.

BAT MORTALITY DATA AT THE ECO3WIND FARM

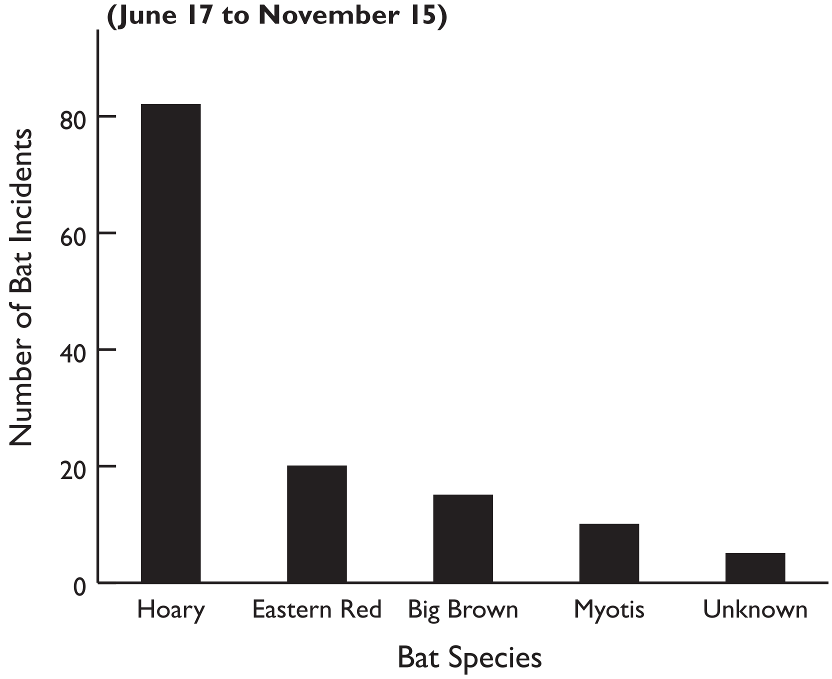
The following are bat mortality data that the Eco3Wind Company has collected at its wind farm during the months when bats are present in the area.

Number of bats found (June 17 to November 15)



Distribution of bat incidents by species

(June 17 to November 15)



Name________________________________ Date______________ Class_________

WHAT DO WE KNOW ABOUT LOCAL BAT POPULATIONS?

Each team member will select one bat species, read the information packets (fact sheets on each species, range maps, tables, etc.), and complete the portion of the table that corresponds with his or her bat species. When the team's table is complete, discuss the questions below and begin creating your team's dispatch schedule.

	BAT SPECIES *Lasiurus borealis (Eastern Red Bat)*	*Lasiurus cinereus (Hoary Bat)*	*Eptesicus fuscus (Big Brown Bat)*	*Myotis sodalis (Indiana Bat)*
RANGE Does this species live in New York?				
MIGRATION Does this species migrate?				
If so, what months are these bats probably present?				
FLIGHT TIMES What time of day do these bats fly?				
HABITAT Where do the bats live and forage?				
THREATENED OR ENDANGERED SPECIES Is the species threatened or endangered?				
WIND SPEEDS At what wind speed does this species fly?				
PRESENCE Has this bat species been found at this wind facility?				
MORTALITY Is this species known to die near wind turbines? If so, has it been found at this wind farm?				

Questions to discuss with group members

1. Compare and contrast the four species. Identify the factors you think are most important.

2. Does the team want to prioritize any bat species? If yes, why?

Design the dispatch schedule

The dispatch schedule is the computer system or "brains" of the wind turbine, the mechanism that collects data (such as wind speed) and tells the turbine when to turn on and off.

Determine the dispatch schedule specifications that your team would recommend for reducing potential bat mortality.

Consider the following questions when completing the table below:

- At what times of day is the risk of bat mortality highest?
- At what wind speeds do the bats fly?
- Are there times of the year when the bats are more likely to be at risk?

	LOW RISK OF BAT MORTALITY *(when to turn the turbine ON)*	**HIGH RISK OF BAT MORTALITY** *(when to turn the turbine OFF)*
TIME OF DAY		
MONTHS		
WIND SPEED		

WHAT DO WE KNOW ABOUT THE LOCAL BAT POPULATIONS?

	BAT SPECIES *Lasiurus borealis (Red Bat)*	*Lasiurus cinereus (Hoary Bat)*	*Eptesicus fuscus (Big Brown Bat)*	*Myotis sodalis (Indiana Bat)*
RANGE Does this species live in New York?	*Yes*	*Yes*	*Yes*	*Yes, part of New York*
MIGRATION Does this species migrate?	*In the fall (September/October), these bats migrate in large groups over 900 miles to southern parts of their range until the following spring (May/June).*	*Traveling over 900 miles, they reach Florida around October/November in the fall. They begin their return migration between February and May.*	*This species migrates distances of less than 300 miles. These bats typically hibernate in the winter, and the length of hibernation depends on the length of the winter.*	*This species migrates up to 500 miles between winter hibernacula and summer roosts. They hibernate in caves during the winter, with most of them in caves in Indiana, Kentucky, and Missouri.*
FLIGHT TIMES What time of day do they fly?	*This species begins foraging 1–2 hours after sunset and they focus their feeding within ½ mile of their day roosts. While foraging can occur throughout the night, activity appears to peak within the first 4 hours after sunset.*	*This species begins feeding after dark and feeds all through the night until about an hour before sunrise. These bats are most active about 5 hours after sunset and forage as far as 24 miles from where they roost.*	*This species starts foraging about 18 minutes after sundown, flies continuously while eating, and spends about 90 minutes a night foraging.*	*These bats tend to be most active just after sunset, with peak activity occurring within the first 2 hours following sunset.*
HABITAT Where do the bats live and forage?	*This species lives or roosts in trees during the day; are often found feeding near lights, which attract insects, and along the edges of forests and clearings. When foraging, they are found at lower altitudes (15–30 m).*	*This species roosts 10–15 ft above the ground in deciduous and coniferous woodlands. This species has been seen flying well above the tree canopy (30 m and higher), but when foraging, these bats are found at lower altitudes (15–30 m).*	*These bats live in large maternity colonies in buildings, barns, bridges, bat houses, and beneath loose bark or in small openings of trees. This species prefers to forage along the edge of forests, over land or water, in clearings, and lake edges.*	*This species roosts in crevices or under the loose bark of trees during the summer. These bats tend to move regularly between roosts.*

THREATENED OR ENDANGERED SPECIES Is the species threatened or endangered?	*No*	*No*	*No*	*Endangered*
WIND SPEEDS At what wind speed does this species fly?	*This species is less likely to fly at higher altitudes when wind speeds are above 6 to 8 m/sec.*	*This species is less likely to fly at higher altitudes when wind speeds are above 6 to 8 m/sec.*	*This species is less likely to fly at higher altitudes when wind speeds are above 6 to 8 m/sec.*	*Unknown*
PRESENCE Has this bat species been found at this wind facility?	*Yes*	*Yes*	*Yes*	*No*
MORTALITY Is this species known to die near wind turbines? If so, has it been found at this wind farm?	*Yes, Yes*	*Yes, Yes*	*Yes, Yes*	*None confirmed, No*

Questions to discuss with group members

1. Compare and contrast the four species. Identify the factors you think are most important.

   Students may decide to focus on different factors depending upon how they view the information.

2. Does the team want to prioritize any bat species? If yes, why?

   Students may decide to focus on different species depending upon how they view the information.

Design the dispatch schedule

Consider the following questions when completing the table below:
Determine the dispatch schedule specifications that your team would recommend for reducing potential bat mortality.

The dispatch schedule suggested will vary from student to student. Students should factor in which bats they are prioritizing, the time of day those species fly, the months the species lives in the area, and the wind in which they are most likely to be flying.

- At what times of day is the risk of bat mortality highest?

  Bats are most at risk when they are foraging (after sunset and before dawn).

- At what wind speeds do the bats fly?

  They are less likely to fly at higher altitudes when wind speeds are above 6 to 8 m/sec.

- Are there times of the year when the bats are more likely to be at risk?

  The bats will be more at risk when they are living in the area of the wind farm. When the bats migrate away from the turbine, the risk will fall.

ARE BIRDS IMPACTED BY SMALL WIND TURBINES?

LESSON 15

KEY CONCEPT

Students will conduct field studies to learn how biologists study wind turbine impacts on birds. Data collected will be shared as part of a citizen science project.

TIME REQUIRED

4+ class periods

GRADES

6–12

SUBJECTS

Science
Technology
Living Environments

NOTE

This activity is intended for schools with a wind turbine on site. However, it can be conducted at non turbine schools as well. Research findings in non turbine sites are of great value for comparison.

KidWind PROJECT®

www.KidWind.org

BACKGROUND

Birds and wind turbines may occupy the same air space, and sometimes turbines are placed in locations where birds fly. People are concerned about the potential impacts that turbines could have on birds. Other impacts to birds, such as birds striking building windows, are also a concern.

Wildlife biologists conduct research on different animals, including birds, at wind turbine locations in order to assess risk. These scientists carry out research according to standard procedures, and checks are made to assess the accuracy of the information collected. Information collected helps to inform decision making.

The public can contribute to scientific understanding by collecting data and sharing it with others via citizen science projects.

OBJECTIVES

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

- Accurately distinguish and identify several common local birds using identification tools
- Design and carry out experimental procedures involving transects
- Illustrate the importance of recording accurate data
- Investigate the impact that citizen science can have on our knowledge of the world around us

METHOD

Students observe birds around their school. They use transects to conduct field work to assess whether birds are being impacted by turbines or other human-made structures.

Data collected is recorded in an online database.

MATERIALS

- ❑ Items that look like birds for assessing searcher error—see sidebar for ideas
- ❑ Hot dogs for assessing scavenger rate
- ❑ 4 foot sections of string—1 piece of string per 2 students
- ❑ Markers for the transect area and found items (e.g. survey flags)
- ❑ GPS for marking transect areas and found items (optional)
- ❑ Camera for recording birds seen during observation time and for recording any mortality events (optional)
- ❑ Internet access to upload data collected and to access online resources
- ❑ Binoculars (optional)
- ❑ Student reading passages and student worksheets*

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

BIRD IDENTIFICATION RESOURCES

- Bird field guide such as Peterson's
- Local bird identification information—local nature centers, parks and birding clubs may have a printed guide to use
- Merlin bird identification application for Apple and Android (free) http://merlin.allaboutbirds.org/
- Birdsleuth K–12 resources (free) from Cornell Laboratory of Ornithology http://www.birdsleuth.org
- Cornell Laboratory of Ornithology's guide to bird watching www.allaboutbirds.org

GETTING READY

Ask your students the following questions:

- Why are people concerned about birds around wind turbines?
- Why do birds get hit by wind turbines?

Read at least one article about birds and wind turbines. These are some good options:

- http://science.howstuffworks.com/environmental/green-science/wind-turbine-kill-birds.htm
- http://news.nationalgeographic.com/news/energy/2014/04/140427-altamont-pass-will-newer-wind-turbines-mean-fewer-bird-deaths
- www.motherjones.com/environment/2014/01/birds-bats-wind-turbines-deadly-collisions
- http://ecowatch.com/2014/04/16/wind-energy-threat-birds-overblown

Watch a video about birds and wind. These are good links:

- Wind Energy and Wildlife Part 1: Texas Parks and Wildlife: www.youtube.com/watch?v=N6sx-dmQlnU
- Wind Energy and Wildlife Part 2: Texas Parks and Wildlife: www.youtube.com/watch?v=ceCwBTXFuC8

Learn more about how wind fits into the nation's energy portfolio:

- WindWise Introduction and Lessons 1–3
- http://www.npr.org/2009/04/24/110997398/visualizing-the-u-s-electric-grid
- http://www.eia.gov/totalenergy/data/monthly/pdf/flow/electricity.pdf

Have a general discussion with your students about wild birds, and ask what human-made dangers (including wind turbines, building window strikes, and other threats) could put birds at risk.

Talk about the concept of citizen science—data collected by the public in order to support scientific research—and its use in many efforts to understand our natural world www.scientificamerican.com/citizen-science/. Learn more about engaging students in birding citizen science projects www.birdsleuth.org/tips-for-cit-sci-engagement/.

Additional questions for students:

- How does siting play a role in lowering the impact wind turbines may have on wildlife?
- Is there any correlation between flyways and wind turbine sites? Why?
- What are regulatory agencies and the wind industry doing to decrease impacts to birds from wind turbines?

Note about working with wildlife:
It is extremely important to use caution around wildlife. If you find a dead or injured bird or bat, do not touch it. Animals could carry disease such as rabies in bats, West Nile in birds, etc. If an animal is injured, contact your local wildlife rescue. Some species are protected and should not be handled by anyone other than licensed professionals, contact your state wildlife agency if you think you have encountered a protected species.

ACTIVITY

PART 1: LOOKING FOR BIRDS

Time: One class period

Before your class begins monitoring to see if your school's wind turbine (or other structures on site if you do not have a wind turbine) is causing any bird mortality, take some time to learn what birds are flying around and near your school.

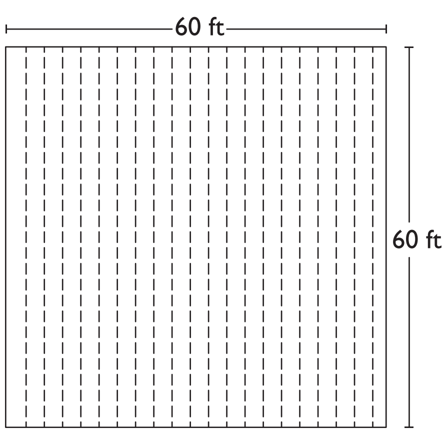
Review and discuss basic bird identification characteristics such as size, behavior, and flight patterns.

Take students outside and give them the bird observation data sheet. Place students in various locations across school grounds. Ask them to remain in that location for 15 minutes, look for birds, and record what they see on the data sheet. You'll notice the data sheet does not require species. It can be hard even for seasoned birders to correctly identify birds, so students can record more general information until they are more confident in making accurate identifications. If you can identify the species, accuracy should be encouraged. Use one of the bird identification resources on the previous page.

PART 2: ASSESS AND CALCULATE SEARCHER ERROR

Time: One class period

Everyone makes mistakes, right? When biologists look for birds that have been hit by wind turbines, they often have a tough job on their hands. Many birds blend into their environment. For example, a bird may have a tan coloration that camouflages it in tall, dry grass around a wind turbine. In addition, most birds that are hit by wind turbines are smaller so they can be harder to find. The possibility that a researcher will miss finding a bird needs to be considered when calculating the total number of birds impacted by a wind turbine. This error, called searcher error, is a calculation that is conducted for each person searching. Since every place is different, this calculation is done at all wind turbine research sites.



Step 1: Set up the transect areas.
A transect is a path along which searchers collect information. The transects in this activity will be conducted in a square area on school grounds that measures 60 feet by 60 feet. The transect paths that the student teams will walk will be 3 feet across. Transect areas either extend around the ground surrounding a wind turbine

CITIZEN SCIENCE OPPORTUNITY!

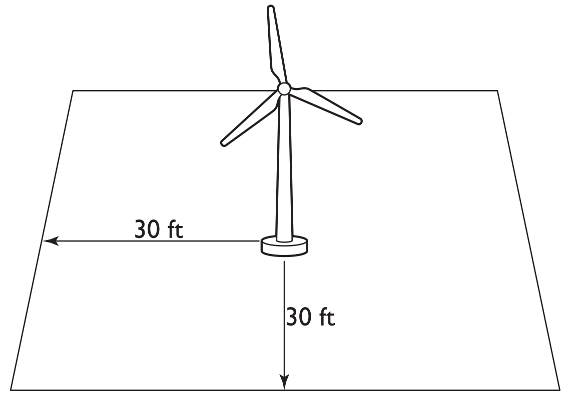
- You can add your bird observations into Ebird, a globally recognized citizen science database of bird observations compiled by people like you and used for a variety of scientific applications: www.ebird.com.
- Ebird also provides educators with guidance on how to work with school groups: http://dl.allaboutbirds.org/usingebirdwithgroups

TEST FOR SEARCHER ERROR

Some ideas for items to put in the transect area to assess searcher error:

- Tied or glued bundle of brown feathers
- Crumpled brown paper
- Brown dyed cotton balls

or are placed in a grassy area adjacent to the school building and near windows. This will allow you to search areas where birds could be impacted by turbines or building windows. The transect area should be walkable. Students will be divided up into groups of four and then teams of two to complete this activity.

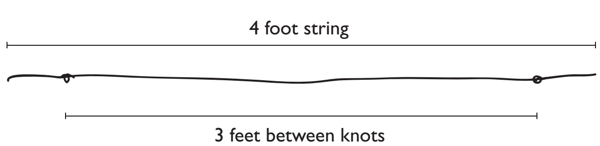


Set up enough transect areas so that each group of four students can conduct a survey of a transect for the searcher error calculation.

First, create a transect area around your school's turbine (or in the grass near your school if you do not have a turbine). The area should extend 30 feet from the turbine and be square in shape. Mark the perimeter of the transect area using flags, string, stakes, etc. If you have a turbine on site and the area where you are conducting transects has a fenced area with electrical circuiting, students will need to look inside the fence to ensure that they do not miss anything. Create additional transect areas of the same size around the school grounds and mark them in the same way as the turbine transect area. These additional areas will allow multiple teams to do this part of the activity. As much as possible, the transect areas should all be in the same type of ground cover and look the same (e.g., all in grass if that is what is around the turbine). The morning before your students come out to conduct the activity, place 15 items that are a brown color (see sidebar) randomly throughout each transect area, keeping note of how many you put out. It is important that the color of what you put out is similar to a bird.

Step 2: Conduct Surveys of the Transects

The purpose of this part of the activity is to assess the likelihood that searchers will miss finding a bird that was hit by the wind turbine. Once the items have been placed, bring the class to the transect areas. Break the class into groups of 4. Each group will have their own transect area. Give each group 2 pieces of string 4 feet long. Each team of 2 students will hold either end of a piece of string and should have 3 feet of string between them. Tie knots in the string so students have 6 inches of string (as a handle) on either side (see graphic).



Each group should then break into 2 teams with each team surveying one-half of the transect area. Surveys are conducted by teams each holding one end of the string tight and then conducting transects by walking side by side (3 feet apart) and marking any of the items that are found. Each team will cover one half of the transect area, conducting ten 60 foot transects. Marking can be done with survey flags, or any other item that works (can also use hand held GPS if available). Students should record the number of items they find on their data sheet.

Once students have completed surveying transects, teachers should inform students how many items were in their transect area so they can calculate searcher error. Determining searcher error will provide an estimate for the likelihood that a bird would be found by the student searcher team later on.

$$\text{Searcher error \#} = \frac{\text{Total items}}{\text{Number of items found}}$$

For example: If 10 of 15 items were found, the searcher error would be 1.5 and you would apply this factor to the number of birds found (# birds found x 1.5). So, using this example, if two birds are found when you conduct Part 4, it is likely that one other bird that was hit you did not find, or 3 birds total.

PART 3: ASSESS AND CALCULATE SCAVENGER RATE

Time: 4 half class periods (2 total)

To find food, a predator has to hunt and a scavenger has to scavenge! In addition to searcher error, finding birds hit by wind turbines is challenging because a bird may have been carried away or eaten could be taken away by scavengers and predators—such as dogs, cats, fox, larger birds (such as crows and vultures), and raccoons—before searchers get the chance to find it. To account for this potential, researchers calculate a scavenger rate.

To calculate a scavenger rate:
Place pieces of hot dog in the transect areas (established in Part 2). Have students note the number of pieces and mark where they were placed with survey flags or other marking item. Leave the hot dog pieces out overnight.

The next day, ask students to find the hot dog pieces that they placed outside. Determine how many were removed by scavengers in the night. Leave the remaining pieces out and repeat the search at least 3 nights and record results on the data sheet. The scavenger rate tells you if you find a bird, how likely it is that other birds may have been hit but not found due to removal by scavengers. For example, if 5 hot dog pieces are taken out of 15, then the scavenger rate is 1.5.

$$\text{Scavenger rate \#} = \frac{\text{Total number of items}}{\text{Number of items remaining}}$$

WHY PUT THIS INFORMATION ONLINE?

- Scientists are very interested in what, if any, impacts there are to birds from small wind turbines. This is a citizen science project that provides important information to scientists. Whether you have a turbine on site or not, providing data related to bird mortality on your school campus contributes to a greater understanding of human-caused impacts to birds.
- Add your class's findings at www.kidwind.org/apps/birddata

TECHNOLOGY IDEAS

You can conduct transects using technology. Some ideas if you have access include:

- Use hand held GPS or a smartphone to create and record the location of transects
- Plot the transects on Google Earth as pinpoints
- Use a camera to photograph any dead birds for identification
- Use handheld GPS or smartphones to pinpoint and record the location of any bird mortalities

PART 4: CONDUCTING TRANSECTS

Time: 15 minutes per day 2 times per week or more

Finally, after learning how to look for birds and calculating searcher error and scavenger rate, the actual surveying can begin. This part of the activity should focus on either the area around your turbine (if you have one on site), near the windows of your school building, or both. Teams of students should conduct transect searches on regular (minimum 2-3 times per week) basis for at least a month. Ideally, searches would be conducted for an entire school year. However, because there are likely going to be days that searches cannot occur, keeping track of when searches occurred and what was found will be important to project success. The transect area should extend 30 feet from the turbine base and 60 feet from the school building wall (see Part 2).

Searchers should carefully conduct transects using the 3 foot string with their partner during the search. Use the same method for transects that you used when conducting the searcher error assessment. The location of any birds found should be marked using survey flags. Findings should be recorded on the data sheet and then uploaded to the KidWind database, www.kidwind.org/apps/birddata/.

If you use the same transects created in Part 2, you should have enough for your whole class to do. If not, teachers can either rotate each team to conduct transects or bring the whole class out and conduct bird observations (Part 1) while the transect team works.

If you find something that has died, you can mark its location and note its condition over time. This will help better understand scavenger rates.

RELATED LESSONS

- Lesson 13: What is Wind Power's Risk to Birds?

EXTENSION

Join Cornell Laboratory of Ornithology's *yardmap* project. Go online, map your school, and contribute to this citizen science project designed to improve knowledge of habitat creation and low-impact land use. http://content.yardmap.org

Name________________________ Date____________ Class________

BIRD OBSERVATION DATA SHEET

Type of bird	*or* **description of bird (if type unknown)**	**Number seen**	**Behaviors** Indicate number of birds doing this behavior			
	Size S = e.g. sparrow, cardinal M = e.g. crow L = e.g. hawk, vulture	**How Many of this type of bird did you see?**	**Perching? Where?**	**Flinging?** **How?** F = flying through S = soaring above P = flying from one perch to another 0 = not flying	**Flight Height** G = ground level B = below treetops A = Above treetops T = within 30 ft of the turbine blades	**Other** e.g. feeding, calling, collecting nest materials, etc.
Robin		3	Tree = 1 Ground = 2	P = 1 0 = 2	B = 1	Feeding = 2 Calling = 1
?	L, black shaggy feathers	3	Tree = 3	P = 3	B = 3	Calling = 2

Name_______________________________ Date_____________ Class________

SEARCHER ERROR DATA SHEET

Describe how you and your partner conducted transects to look for the items on the ground.

Tally the number of items you found in your half of the transect area.

Total tally marks for your half of the transect areas _____________

Total tally for the other teams half of the transect area __________

Were they easy to find?

How many items were there in total (the teacher will have to tell you)?

Calculate the searcher error

$$\text{Searcher error \#} = \frac{\text{Total items}}{\text{Number of items found}}$$

What is your searcher error?

Name______________________________ Date_____________ Class________

SCAVENGER RATE DATA SHEET

Total number of hot dogs left out: _______________

How many hot dog pieces were removed after the first night?

Note: do not add more hot dog pieces after night 1. Leave the pieces out for 3 days.

How many after Night 2?

How many after Night 3?

Calculate your scavenger rate:

Scavenger rate for 1 night # = $\dfrac{\text{Total number of items}}{\text{Number of items remaining}}$

Scavenger rate for 1 night # = ________________

Scavenger rate for 2 nights # = $\dfrac{\text{Total number of items}}{\text{Number of items remaining cumulative over the 2 days}}$

Scavenger rate for 2 nights # = ________________

Scavenger rate for 3 nights # = $\dfrac{\text{Total number of items}}{\text{Number of items remaining cumulative over the 3 days}}$

Scavenger rate for 3 nights # = ________________

Name______________________________ Date______________ Class_________

TRANSECT DATA SHEET

Transect data should be inputted for each team after each transect. This is especially important if birds were found, because searcher error applies to individual searchers and scavenger rate applies to the number of days between searches.

Area where transects were conducted (around turbine, next to school, etc.): ______________________

____

Time between last search and this one: ____

Number of birds found: ____

Species (if known): ____

If birds were found, apply the searcher error calculation and scavenger rate calculation

Total potential birds impacted # = total birds found × searcher error (see previous worksheet) × scavenger rate for the number of days it has been since the last search (if 1, use scavenger rate for 1 day, 2 for 2 days, 3 for 3 days. If it has been more than 3 days, use the 3 day scavenger rate).

UNIT 5: SITING WIND TURBINES

HOW DO PEOPLE FEEL ABOUT WIND ENERGY?

LESSON 16

KEY CONCEPT

Students explore what effects media can have on people's perception of wind energy.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Language Arts
Social Studies

BACKGROUND

As with many topics, wind energy is portrayed both positively and negatively in the media. Understanding the sources and motives of different media is an important skill. By examining the words and images used in media, students will learn how to decipher media messages and the methods of persuasion.

OBJECTIVES

At the end of the lesson, students will:

- understand the persuasion concepts of ethos, pathos, and logos
- know how to analyze the language and images used in wind energy media (literature, articles, print and video ads)
- be able to develop their own media product using one of the methods of persuasion (if using the extension section of this lesson)

METHOD

Students will analyze media materials related to wind energy to determine which tools are used to create an image and inform opinion. Students will use the concepts of ethos, pathos, and logos to categorize their analyses. Following their analyses, they will write a persuasive argument for or against wind energy.

MATERIALS

- ❑ Student reading passages and student worksheets*
- ❑ Media packets for each small group (ads, print media, articles, etc. found in this activity and on the WindWise Education website)*

  *included with this activity

Optional

- ❑ Examples of magazine or newspaper advertisements

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

KidWind PROJECT®

www.KidWind.org

GETTING READY

Make copies of the worksheets, reading passage, and media packets. If computers are available, students can view the materials online (see Additional Resources).

ACTIVITY

Step 1: Beginning questions for students

Tell students to read the reading passage. Supply students with a couple of common product names and slogans such as

- "Just do it" (Nike)
- "The few, the proud, the Marines" (US Marines)
- "The happiest place on earth" (Disney)
- "Your Top 40,000" (Apple iPod)
- "Crest Cavity Protection Toothpaste was the first ever to be accepted by the American Dental Association" (Crest toothpaste)

Ask students the following questions about the slogans.

- What do you think when you hear this slogan?
- What do you feel when you hear this slogan?
- Does the make you want to buy the product?
- Which method of persuasion was used?

Step 2: Examine media packets

Distribute the media packets and worksheets to students. Explain to students that their task is to decipher what the writer's key message is and how words, phrases, and photos are used to persuade the audience to think one way or another about wind energy. Ask the students to read the packets and complete all but the last question on the worksheet.

Step 3: Class discussion

Discuss students' responses to the questions on the worksheet.

Step 4: Write a persuasive argument

Ask students to write a one paragraph persuasive argument for or against wind energy, using words, phrases, facts, and images from their media packets.

EXTENSION

Ask students to design their own media by creating persuasive flyers, video, signs, and advertisements either for or against wind energy.

VOCABULARY

bias – Favoring one perspective or side of an issue over another.

ethos – Refers to credibility. In marketing, this is often seen when an authority figure or perceived expert, such as a doctor, recommends a product.

logos – Refers to logic and is applied in marketing through the use of statistics or facts.

pathos – The process of eliciting emotion and appealing to the consumer's values.

persuasion – A type of communication whose purpose is to induce a belief or action.

READING PASSAGE

Marketing is not only big business; it shapes the way we think and act. Various sources estimate that the average American is exposed to between 300 and 3,000 advertising messages a day. Each message has a purpose—from getting the user to purchase a product to supporting a cause. It is the marketer's job to convince the user to take the desired action with a short and simple message that may use words, sounds, images, or any combination thereof. Marketing can take the form of many types of media, such as print, online advertising, radio, television, direct mail, and outdoor marketing (billboards, signs).

Many marketing campaigns use techniques of persuasion to convince a consumer to purchase a product. The Greek philosopher Aristotle identified three methods of persuasion: Ethos, Pathos, and Logos. Whether the advertisement is in a magazine, on television, or on a social network site such as Facebook, one or more of these techniques are typically used.

- Ethos refers to credibility. In marketing, this is often seen when an authority figure or perceived expert, such as a doctor, recommends a product.
- Pathos is the process of eliciting emotion and appealing to the consumer's values.
- Logos refers to logic and is applied in marketing through the use of statistics or facts.

In an effort to "sell" a product or idea, marketers sometimes provide misleading, incomplete, or biased information to the consumer in order to appeal to a consumer's desires (pathos). For instance, the packaging for an item may have a photo showing items that are not included or it may make the item look bigger than it actually is. With photo-editing software, photos can easily be changed, creating images that are different from reality. This is particularly true in terms of modeling photos. You can see an example of this in Dove's 2006 short video called "Evolution" (posted on YouTube and distributed widely through social networking sites), which shows how a billboard photo of a woman is created and altered in such a way that the final photo looks dramatically different from the real person.

Marketing messages often only provide partial information, leaving consumers to interpret or assume the meaning. For example, a radio station uses the logos technique of persuasion by proudly announcing that they have "27 percent fewer commercials." The listener is supposed to assume that this means this station is better than other stations because they have fewer commercials and, therefore, more music. The station, however, does not provide all of the information. There are 27 percent fewer commercials than what? Fewer than they had five years ago? Fewer than they had last week? Fewer than another radio station? It's also possible that the station is playing fewer commercials, but has longer commercials. The station may also not count radio show hosts talking about specific products as "commercials" even though they are marketing a product.

All marketing messages have a bias. In other words, they are trying to promote one thing over another or they want consumers to buy their product instead someone else's. Marketing messages will never provide you a balanced choice. For instance, a car company is not going to show how great another company's car is. Instead, it may show a famous person tell consumers how much better its car is. Smart consumers look beyond the initial marketing message to determine the pros and cons of every message and avoid being swayed by any single powerful marketing message.

Marketing plays a key role in wind energy development. As with many topics, wind energy is portrayed both positively and negatively. In communities where wind farms are controversial, marketing can sway a town's decision to approve or deny the installation of a wind farm. Pro-wind messages may focus on job creation, a clean and renewable energy source, or reduction of greenhouse gas emissions. Anti-wind messages, on the other hand, may target negative impacts to the ecosystem, visual aesthetics, or safety hazards for air and sea navigation. Understanding the source and motive of marketing messages helps citizens make informed decisions about wind energy.

CASE STUDY

Trieste Associates is a public relations firm in Saratoga Springs, New York, whose work focuses on promoting clean energy and water protection. Its goal is to balance development goals with protecting the environment. Trieste uses traditional public relations techniques such as publications and the internet to inform people about topics such as wind power. They also use a less traditional public relations technique called grassroots organizing, which involves educating the community about wind power technology.

Some wind energy projects can be controversial in a community because of concerns about aesthetics, noise, or financial impacts. Community opposition can delay or prevent installation of a wind farm. Trieste is hired to educate and engage the community in which controversial wind projects are being proposed. Through educational forums, fact sheets, and open houses, Trieste provides community residents with information about the proposed wind farms. Trieste also assists key community members in advocating for a wind project. When the community voices support for a wind project, the likelihood of success is much greater.

For example, Trieste Associates has helped citizens organize groups such as Voters for Wind in New York that educates the public about the benefits of renewable energy resources. Voters for Wind filed and won a law suit against the elected officials who voted to prohibit a wind farm in the town of Lyme, New York.

One technique that Trieste Associates has found to be particularly compelling is a “comparative graphic.” Often the terms used in the energy sector such as “megawatt” and “ton of CO_2” have little meaning to people unless they can relate it to a real life example. Trieste creates graphs or charts to simplify complicated information. These easy-to-understand visual tools help people make more informed decisions about future green energy projects.

Name______________________ Date____________ Class________

HOW DOES MEDIA IMPACT OUR PERCEPTION OF WIND ENERGY?

1. Read through your wind energy media packet. As you read, write down the words and images that you think are intended to influence your opinion of the subject and record how they make you feel or think.

WORD, PHRASE, OR IMAGE (DESCRIBE THE IMAGES)	POSITIVE (+) OR NEGATIVE (-)	HOW DOES IT MAKE YOU FEEL OR THINK?	WHO IS THE INTENDED AUDIENCE?	WHICH MODE OF PERSUASION DOES IT USE? HOW? (ETHOS, PATHOS, LOGOS)

WORD, PHRASE, OR IMAGE (describe the images)	POSITIVE (+) OR NEGATIVE (-)	HOW DOES IT MAKE YOU FEEL OR THINK?	WHO IS THE INTENDED AUDIENCE?	WHICH MODE OF PERSUASION DOES IT USE? HOW? (Ethos, Pathos, Logos)

Name_______________________________ Date_____________ Class_________

2. Based on information in your media packet, list reasons why you feel a community may be for or against wind energy.

FOR WIND ENERGY	AGAINST WIND ENERGY

3. Write a persuasive paragraph about wind energy—for or against—using some of the words and phrases you have seen in your packet.

EXTENSION

Pick one of the images. How would you subtly change it to show the opposite point of view?

1. Read through your wind energy media packet. As you read, write down the words and images that you think are intended to influence your opinion of the subject and record how they make you feel or think.

   Examples are provided in the table

WORD, PHRASE, OR IMAGE (describe the images)	**POSITIVE (+) OR NEGATIVE (-)**	**HOW DOES IT MAKE YOU FEEL OR THINK?**	**WHO IS THE INTENDED AUDIENCE?**	**WHICH MODE OF PERSUASION DOES IT USE? HOW?** (Ethos, Pathos, Logos)
Alliance to Protect Nantucket Sound—Top 10 Myths *"Known for its beaches and natural beauty, Cape Cod and the islands of Nantucket and Martha's Vineyard are among the top ten tourist destinations in the country. Industrialization of Nantucket Sound by Cape Wind would cause losses in tourism and employment, as well as declines in property values."*	*negative*	*Answers will vary by student.*	*Property owners, business people, citizens who rely on jobs related to tourism*	*Using pathos, the text appeals to the reader's emotional attachment to the beauty of the area.* *Using logos, the text shows how important tourism is to the area; it is among the top ten destinations in the country.*
Alliance to Protect Nantucket Sound—Top 10 Myths *"The Massachusetts Fisherman's Partnership, which represents 18 commercial fishing organizations, says that navigation of mobile fishing gear among the 130 towers would be hazardous or impossible"*	*negative*	*Answers will vary by student.*	*Fishermen* *People who care about safety of fishermen*	*Using ethos, the text relies on the Massachusetts Fisherman's Partnership as being a credible source of information.* *Using logos, the text provides the number of fishing organizations in the partnership as well as the number of towers.*

Alliance to Protect Nantucket Sound *"Save Our Sound" (tag line of organization)*	*negative*	*Answers will vary by student.*	*People who live and work along the sound and see it as a natural amenity*	*Using pathos, the tag line gives a sense of urgency to protect something that will be lost. The acronym for the tag line is "SOS," giving greater emphasis to urgency.*
Alliance to Protect Nantucket Sound *"Not for Sale" sign*	*negative*	*Answers will vary by student.*	*People who want to protect natural areas; people who are opposed to corporations using natural areas*	*The sign uses a pathos to convey the sense that the sound is being purchased and will not be available for everyone in the future.*
"Clean Power Now"	*negative*	*Answers will vary by student.*	*People who see themselves as supporting clean energy* *People who want to see solutions "now"*	*Using pathos, the name of the organization gives a sense of urgency to the need for clean power now, not later. The use of the term "clean" conjures positive images for the reader.*
Clean Power Now's Top 10 Myths *"There is not a single example of a wind farm anywhere in the world hurting tourism, property values or local economy. According to the 2004 Army Corps (Draft EIS), impacts on Cape tourism and the local economy will be favorable and the wind farm development will not harm property values."*	*positive*	*Answers will vary by student.*	*Property owners, business people, citizens who rely on jobs related to tourism*	*Using logos, the text indicates that there are no examples of a wind farm where tourism was impacted.* *Using ethos, the text draws upon the credibility of the Army Corps.*

Clean Power Now's Top 10 Myths *"The 2004 Army Corps DEIS predicted no negative impact on current commercial fishing activity occurring on Horseshoe Shoal. The Shoal is not used by large-scale commercial fisherman since larger vessels could potentially run aground in the shallow area."*	*positive*	*Answers will vary by student.*	*Fishermen* *People who care about the safety of fisherman.*	*Using ethos, the text draws upon the credibility of the Army Corps.* *Using logos, the text says the Shoal area is currently not used by larger vessels.*
Clean Power Now's picture in the brochure that says "Working Families Support Cape Wind"	*positive*	*Answers will vary by student.*	*Residents* *"working families" (non-wealthy residents)*	*Using pathos, the sign indicates that even the "average person" supports the project and that the project may help average people.*

2. Based on your packet, list why you feel a community may be for or against wind energy.

   The answers for the following will vary from student to student and should be the basis for discussion.

   Some examples:
   For wind energy
   - *Clean air*
   - *Renewable energy*
   - *Energy independence*
   - *Jobs*
   - *Aesthetics of wind turbines seen as positive*

   Against wind energy
   - Aesthetics of wind turbines seen as negative
   - *Worried about wildlife impacts*
   - *Worried about impacts to fishing industry*
   - *Opposed to developers using natural areas*
   - *Concerned about oil spills from off-shore electrical service platform*
   - *Desire to protect tribal land and historic properties*

HOW DO PEOPLE FEEL ABOUT WIND ENERGY?

Stop Cape Wind: The Fight is Far From Over!

Cape Wind is a massive industrial development proposed for Nantucket Sound, the vital body of water located to the south of Cape Cod and to the north of the islands of Martha's Vineyard and Nantucket. A private developer wants to transform this national treasure into a 25 square-mile offshore wind energy plant the size of Manhattan – complete with 130 turbines, each taller than The Statue of Liberty, and a 10-story electrical service platform (pictured) – less than five miles from our beaches.

Cape Wind is not a done deal and the fight is far from over.

The Cape Cod Commission has denied Cape Wind a critical permit. The FAA has issued a presumed hazard determination because the project's spinning turbines would cause radar interference to air traffic. Mandatory consultations with the local Wampanoag Tribes and historic agencies are far from complete. Several state permits are being challenged in the courts. The Department of Interior's Inspector General is investigating potential violations in the federal review of Cape Wind. Cape Wind needs each and every one about twenty local, state, and federal permits that govern this project to go forward. One permit denial would preserve Nantucket Sound and protect our economy, our safety, our environment, and our heritage from this industrial project.

There are better and cheaper alternatives that wouldn't ruin Nantucket Sound.

Many other projects are being proposed in less conflicted locations up and down the East Coast. A deep water project is being proposed locally 23 miles southwest of Martha's Vineyard. Small municipal onshore projects are on the rise. We all support wind power, but in the right locations. Thanks to land based projects and advances in deeper water technology, we can say "YES to wind, and NO to Cape Wind."

Visit **www.SaveOurSound.org** to find out you can help stop Cape Wind.

Because once Nantucket Sound is gone, it's gone forever.

Nantucket Sound is absolutely the wrong place for an industrial wind plant.

Nantucket Sound is the engine of our economy, a habitat for several protected species, and a national treasure that deserves long-term preservation.

- **Cape Wind would threaten our economy and raise electric rates.**
  Cape Wind would devastate commercial fishing and decrease tourism and property values. Moreover, Cape Wind's electricity is expensive. The federal government has said Cape Wind's power would cost more than double current wholesale rates. It would raise our electric bills and use up over 1.3 billion hard-earned taxpayer dollars. And after eight years, the developer still hasn't told us if our monthly electric bills would go up 25 dollars, 35 dollars or even more.

- **Cape Wind would put the safety of millions traveling by air and sea at risk.**
  The FAA is calling Cape Wind a "presumed hazard." With 400,000 flights per year over Nantucket Sound, all three local airports oppose Cape Wind. The local ferry lines, which transport more than three million passengers annually, call Cape Wind "an accident waiting to happen."

- **Cape Wind would jeopardize the environment.**
  Dredging, pile driving, and jet plowing to install 130 turbines and nearly 100 miles of cable would devastate the sea floor and fisheries. The project would endanger marine mammals and birds and pose the threat of an oil spill. In fact, there is a 90% chance that, in the event of a spill, the 40,000 gallons of oil held in the electrical service platform would reach our Cape and Islands beaches in fewer than five hours.

- **Cape Wind would desecrate sacred Tribal land and historic properties.**
  Nantucket Sound holds profound religious and cultural significance for the Wampanoag Tribes of Aquinnah/Gay Head and Mashpee. The proposed project would destroy traditional cultural property, erode Tribal religious freedoms and sovereign rights, and adversely affect numerous historic properties on the Cape and Islands.

Help stop Cape Wind. Because once Nantucket Sound is gone, it's gone forever.

Ask your elected officials to find a better location for this industrial project that won't risk our safety, increase our electric bills, and ruin Nantucket Sound – the heart and soul of the Cape and Islands. Volunteer. Donate. Write letters to the editor. Post a "Nantucket Sound Not for Sale" sign on your lawn and an "SOS" bumper sticker on your car.

Visit **www.SaveOurSound.org** or call 508.775.9767 to find out more ways to help.

CLEAN POWER NOW

Top 10 Myths About the Cape Wind Project

	Myth	Response
1	**"Land Grab"** – Cape Wind will occupy public lands for free.	The passage of the 2005 energy bill authorized the Minerals Management Service (MMS) of the Department of the Interior to take over the permitting process for offshore wind projects because of their expertise in permitting offshore oil and gas drilling. The energy bill gives MMS authority to require offshore wind developers to lease public lands for use with 27% of this revenue coming to Massachusetts.
2	**"Paying a Developer to Make Money"** – The Cape Wind project relies heavily on public subsidies.	Unlike fossil fuel-based power plants, Cape Wind will <u>not</u> be subsidized to build this project. The developer must fund the project with their own or borrowed money and pay taxes on any profit. However, because of the project's environmental benefits, Cape Wind may be able to defray 1.8 cents from their annual tax bill <u>for each kilowatt-hour of energy produced in the first 10 years</u> of operation through the Production Tax Credit (PTC). The PTC is available to all renewable energy projects, however, it must be renewed by Congress every two years.
3	**"Project Abandonment"** – If the project fails, abandoned wind turbines will litter the Sound.	Before construction begins, the developer will be <u>required</u> by the federal government to post a bond to ensure that sufficient funds are available for removing the turbines & associated materials and equipment at the end of the project's lifespan.
4	**"Bird Deaths"** –Cape Wind could pose a threat to migratory birds in Nantucket Sound.	After completing a 4-year study of Nantucket Sound, the Massachusetts Audubon Society has given conditional support for the Cape Wind project. The study concludes that the endangered Roseate Terns and Piping Plovers completely avoid Horseshoe Shoal, the proposed wind farm site. Radar studies conducted in Denmark indicate that wind farms have no adverse impact on bird populations, concluding that most bird species exhibit an avoidance reaction to wind turbines, thereby reducing the probability of a collision to less than 1 percent.
5	**"Deep Water is the answer"** – Deep water technology will be viable within 5 years and is a better solution to our energy needs.	While Deep water offshore technology is the hope for the future, it is unlikely to be feasible within the next decade. Deep water wind farms are not economically viable. Currently, only one small scale experimental version is in operation. Near shore experience in shallow waters is necessary for deep water technology to advance. All of the countries proposing experimental deep-water projects have already mastered near-shore wind farms. The near-shore Cape Wind project will lay the foundation for U.S. deepwater technology in the future.

	Myth	Response
6	**"Economic Impacts"** – The project poses calculable economic losses to business, taxes, and property values for Cape Cod. From an economic perspective, the costs of the project exceed the benefits.	There is not a single example of a wind farm anywhere in the world hurting tourism, property values or local economy. According to the 2004 Army Corps Draft EIS, impacts on Cape tourism and the local economy will be favorable and the wind farm development will not harm property values. This has been the case for offshore wind farms in Sweden and Denmark. Residents who were initially opposed to the Nysted wind farm in Denmark say their opinions changed once the wind turbines were built. Several years later, tourism, property values nor local economy have been impacted by the wind farm.
7	**"Commercial Fishing Impacts"** – Cape Wind would severely disrupt the commercial fishing on Horseshoe Shoal	The 2004 Army Corps DEIS predicted <u>no</u> negative impact on current commercial fishing activity occurring on Horseshoe Shoal. The Shoal is not used by large-scale commercial fisherman since the larger vessels could potentially run aground in the shallow area. The turbines will most likely <u>enhance recreational fishing</u>. As barnacles and other mollusks begin to attach to the turbine piles, more fish will be drawn to the area due to the increase in food supply.
8	**"Boating Dangers"** – The wind turbines would crowd navigation channels and create collision risks for ships, ferries, and fishing boats.	The wind turbines would be located in shallow waters <u>outside</u> of shipping and ferry channels. The 2004 Army Corps DEIS found the wind turbines would be "aids-to-navigation" and that the risk of a vessel colliding with a turbine is "low." The turbines will be spaced 6-9 football fields apart allowing for easy navigation within the wind farm. Vessels needing assistance within the wind farm will be able to safely tie up to any of the turbines which are individually numbered for easy location identification.
9	**"Oil Spill Hazard"** – Nantucket Sound will be exposed to the environmental impact of a possible oil spill.	The oil required for the Electrical Service Platform (ESP), is low-toxicity mineral oil, much lighter - and less hazardous - than the exhaust of boats presently using the Sound. Furthermore, the oil is triple-contained for further safety unlike the millions of gallons of fuel that pass through Nantucket Sound each year. The platform itself will be built to the standards set forth by the American Petroleum Institute to withstand hurricane winds and waves.
10	**"Radar Interference"** – Wind turbines produce blind areas where vessels and aircraft cannot be detected by radar.	In 2007, after reviewing the Cape Wind proposal, the US Air Force, operator of the Pave Paws radar station at the Mass Military Reservation, announced that wind farms within a 30km radius would not adversely impact the radar system and that the Cape Wind project in particular would pose no threat to radar operations. The FAA has also given Cape Wind a "no hazard" determination for aviation. In addition, the British government determined wind farms can be sited within 500 meters of a shipping lane based on extensive radar studies. The Middlegrunden wind farm in Copenhagen harbor is within 500 meters of a major international shipping channel, with no collisions indicating that radar interference is not an issue.

What is Cape Wind?

- 25-square mile industrial wind plant less than 5 miles off our beaches
- 130 wind turbines each taller than the Statue of Liberty
- 10-story electrical service platform with 40,000 gallons of oil
- Heavily subsidized, private venture seizing public land

How would Cape Wind harm Cape Cod & the Islands?

- Raise electric rates
- Imperil air and sea travel
- Endanger birds, marine mammals, sea turtles, finfish, and shellfish
- Devastate commercial fishing
- Decrease tourism, property values, and jobs
- Present oil spill threat
- Desecrate sacred Wampanoag Native American Tribal sites and traditions
- Threaten National Historic Landmarks and other historic sites

www.SaveOurSound.org
508.775.9767

SAVE OUR SOUND
alliance to protect nantucket sound

Are there better alternatives?
Yes! Say YES to wind, but NO to Cape Wind!

- Blue H floating deep water wind proposal 23 miles off Martha's Vineyard
- Deeper water proposals for Rhode Island, New Jersey, and Delaware
- Cheaper, less conflicted onshore sites like MA Military Reservation

Is Cape Wind a done deal?
No! The fight is far from over!

- FAA calls Cape Wind a "presumed hazard" because of aviation dangers
- Wampanoag Tribes oppose Cape Wind
- Ocean zoning process incomplete
- No federal permits have been issued
- State permits are being challenged in MA court
- Cape Wind needs many permits to build. Just one permit denial would stop Cape Wind and preserve Nantucket Sound forever!

How can I help?
Visit www.SaveOurSound.org or call 508.775.9767.

Volunteer. Donate. Write letters to the editor. Display a FREE *Nantucket Sound Not For Sale* yard sign or an *SOS* bumper sticker.

Act now! Because once Nantucket Sound is gone...it's gone forever.

SAVE OUR SOUND
alliance to protect nantucket sound

ALLIANCE TO PROTECT NANTUCKET SOUND FLIER

FISHING CONCERNS

Cape Wind Will Harm the Cape's Fishing Industry

In 2004, the Army Corps of Engineers released a DEIS (Draft Environmental Impact Statement) based on the work of consultants hired and supervised by Cape Wind. The DEIS asserted there would be minimal environmental impacts from the construction and operation of the proposed wind factory. But none of the environmental agencies reviewing the DEIS agreed with its conclusions. Three state and federal fisheries management agencies said the DEIS systematically underestimated fisheries resources, commercial and recreational fishing activities, and the potential impacts to the ecosystem and the Cape's economy.*

Nantucket Sound provides essential fish habitat for many important species of finfish and invertebrates, including bluefish, striped bass, scup, summer flounder, black sea bass, and squid. Their commercial and recreational harvest adds tens of millions of dollars to the local economy. Horseshoe Shoal, as the most prominent bottom feature in the Sound, plays an important role in its overall ecology, and is and Essential Fish Habitat for 16 species according to MA Division of MarineFisheries. This shoal provides spawning grounds and nursery grounds, and functions as a predator's supermarket, playing a vital role in the marine food chain. Commercial fishermen, recreational anglers, and charter captains target the area because of its abundance.

The likely impacts to Horseshoe fall into several categories:

1. Permanent habitat alteration:

Cape Wind's construction activities over a 24-square mile area include driving 130 turbine bases into the sea floor, laying more than 100 miles of cable by jet plowing, and dredging large areas otherwise too shallow for work boats. The resulting impacts include mortality of benthic fauna (for example shellfish, crabs, snails and worms) and juvenile fish, destruction of eggs, and dispersal of juvenile and adult fish and invertebrates. Dispersal leads to fewer spawning and feeding opportunities. Overall, loss of fisheries production is a given. The extent and timing of recovery are unknown.

Following construction, the presence of large vertical structures on a shoal marked by strong tidal currents would cause continuous turbulence and turbidity and the formation of scores of gullies and sand bars. In some ways, this might be likened to plowing up a ski slope to make a mogul field. The numbers and kinds of users of the area would likely be drastically altered.

FISHING CONCERNS

2. Changes in fisheries abundance and distribution:

In the case of Horseshoe Shoal, large-scale changes to water flow and sediment transport, combined with the permanent loss and alteration of shoal habitat, would have profound effects on the abundance and distribution of fish, birds, and mammals, which depend on the shoal for feeding and reproduction. Furthermore, once the turbine bases became encrusted with communities of marine organisms, entirely different fish species might favor the area. These changes would ripple throughout the Sound in unpredictable ways, benefiting certain species and having adverse impacts on others. Given the migratory nature of many of the species involved, these changes could impact fisheries up and down the East Coast.

3. Disruption of traditional fishing practices:

The presence of 130 wind towers and a transformer station would limit or even preclude traditional fishing practices in the project area. Mobile gear fishermen could not safely maneuver between the towers while towing a net. Should a boat's fishing gear get "hung up" on a turbine or undersea cable, its ability to haul back and free itself might be severely hampered or even prevented by the towers or the influence of waves and currents as altered by the presence of the towers. Most recreational fishermen are not used to handling boats in the kind of strong eddies that would swirl around the turbines. By fishing in the area, they would risk collisions with the bases of the turbines and other boats. In the event of an accident, U.S. Coast Guard helicopters might not be able to fly within the project footprint to perform rescue activities, particularly during extreme weather conditions when they would be most needed.

4. Possible closure of the area to the public:

Finally, direct closure of the facility (24 square miles) to fishing and boating because of security reasons is a distinct possibility.

* Sources: DEIS reviews by MA Division of MarineFisheries, Atlantic States Marine Fisheries Commission, and the New England Fisheries Management Council.

For further info: www.saveoursound.org

CLEAN POWER NOW POSTCARD

Clean Power Now started on Cape Cod in 2003 and has grown to over 12,000 members strong.

We are a non-profit grassroots organization informing citizens and empowering them to support viable renewable energy projects and policies, and to secure their local and regional benefits.

We believe that the timely development of such projects, in conjunction with energy efficiency and conservation, will bring about a clean, healthy environment, an improved economy and a more secure, sustainable America.

Our immediate focus is to increase citizen support of offshore wind power in Nantucket Sound.

Clean Power Now
PO Box 2717
569 Main St., Ste 9
Hyannis, MA 02601
508-775-7796

Clean Power Now has created a series of fact sheets about the Cape Wind project. Cape Wind will provide 75% of the Cape and Islands energy needs making the region a leader in the clean energy economy.

CLEAN POWER NOW POSTCARD

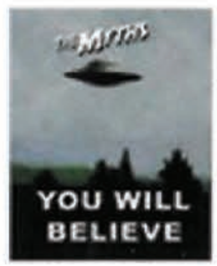
The Allure of Deepwater Wind
Deepwater wind is the future. Cape Wind is NOW.

Climate Change
Cape Wind will be equivalent to taking 175,000 cars off the road _each year_.

Impact on Oil Imports
Cape Wind will offset almost 2 million barrels of oil each year.

Impacts on Birds
Global warming is the single largest threat to birds _not_ wind turbines.

Top 10 Myths
Get the facts on Cape Wind!



Private Use of Public Land
Cape Wind will pay a lease for the use of Horseshoe Shoals.

A View in Perspective
Cape Wind will be the size of your thumbnail when viewed from shore.

Government Oversight
19 government agencies are involved in permitting Cape Wind.

Health Benefits
"the air quality benefits of [Cape Wind] are significant and important to Massachusetts."

CLEAN POWER NOW BROCHURE

Wind Energy is Clean, Powerful, Sustainable, Beautiful...

YES

Benefits of Wind Energy:

- Cleaner Air
- Better Health
- Stable Costs
- Green Collar Jobs
- Energy Independence

"The Cape Wind project is the largest single source of supply-side reductions in global warming pollution currently proposed in the US." Nathanael Greene, Senior Policy Analyst
Natural Resources Defense Council

YES I'll become a sustainable member at the following level:

- ❑ $25 Kilowatt Member
- ❑ $100 Megawatt Member
- ❑ $250 Gigawatt Member

My check made payable to
Clean Power Now is enclosed.

Name: ____________________

Address: ____________________

City: ____________________

State/Zip: ____________________

Phone: ____________________

Email: ____________________

To put your donation on your CREDIT CARD visit:
www.cleanpowernow.org
and click on DONATE NOW

For more information and to sign up for our e-newsletter, check out www.cleanpowernow.org.
Your donation is tax-deductible.
Your support is appreciated.

Thank You!

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CLEAN POWER NOW BROCHURE

CLEAN POWER NOW
www.cleanpowernow.org

CLEAN POWER NOW is a non-profit grassroots citizens' organization informing citizens and empowering them to support viable renewable energy projects and policies, and to secure their local and regional benefits.

We believe the timely development of such projects, in conjunction with energy efficiency and conservation, will bring about a clean, healthy environment, improved economy and a more secure, sustainable America.

As such, Clean Power Now supports Cape Wind, America's first offshore wind farm.

"Clean Power Now has been helping people understand that doing nothing isn't one of the options for our energy future – and they've been succeeding at that task."

Bill McKibben, renowned author and Environmentalist

"Given the persistent and irrational opposition to Cape Wind, Clean Power Now is providing a powerful voice on behalf of the most promising project that could jump-start a clean energy revolution throughout the United States."

Ross Gelbspan, author
The Heat Is On and *Boiling Point*

Clean Power Now's work is vital to the creation of the new clean energy economy, and thus to the future of humankind. Getting Cape Wind built should be one of the highest priorities of anyone who cares about energy independence, the next energy economy, and global warming. And nobody has been more steadfast, or more effective, in seeing the dream of Cape Wind come true."

Michael Shellenberger, co-author
Break Through and *Death of Environmentalism*

"Clean Power Now is vital, and we strongly support their efforts to educate people about the importance of the Cape Wind project."

Nathanael Greene, Senior Policy Analyst
Natural Resources Defense Council

CLEAN POWER NOW
www.cleanpowernow.org

CITIZENS FOR CLEAN RENEWABLE ENERGY!

It's not the view...

... it's the vision.

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ALLIANCE TO PROTECT NANTUCKET SOUND STICKER

ALLIANCE TO PROTECT NANTUCKET SOUND YARD SIGN

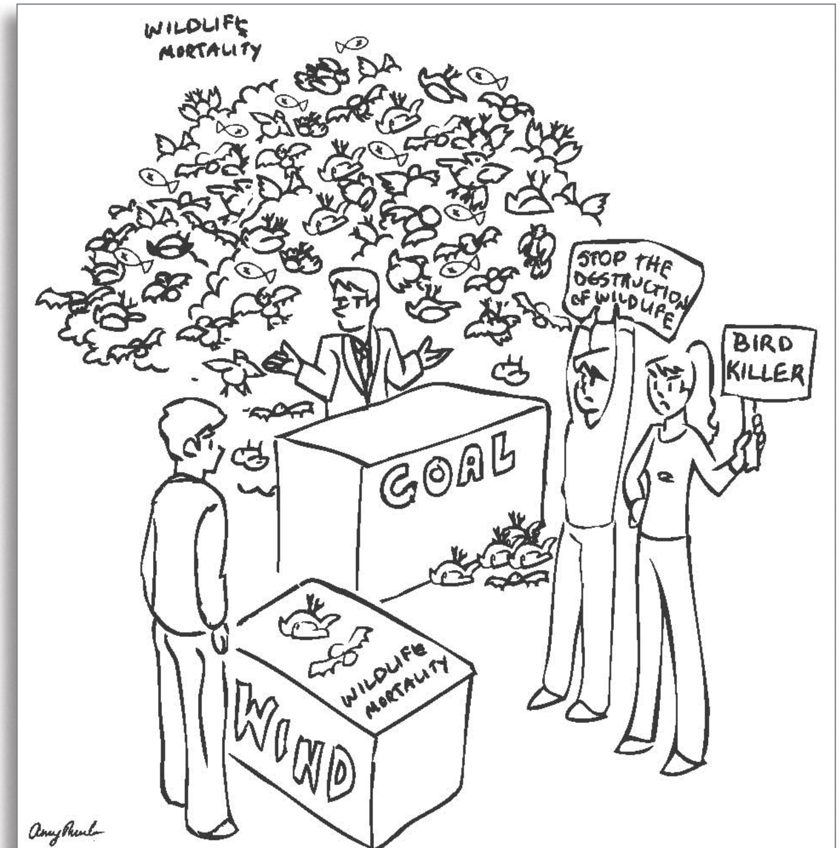
CLEAN POWER NOW STICKER

CLEAN POWER NOW BUMPER STICKER

Media materials provided by Clean Power Now and the Alliance to Protect Nantucket Sound.
For more information and media examples, please see the websites for each of these organizations:

- Clean Power Now—(no longer active)
- Alliance to Protect Nantucket Sound—www.saveoursound.org

POLITICAL CARTOONS



WHAT FACTORS INFLUENCE OFFSHORE WIND?

LESSON 17

KEY CONCEPT

Students explore offshore wind development—comparing maps that illustrate different siting considerations and using scale models to understand the visual impact of an offshore wind farm.

TIME REQUIRED

1–2 class periods

GRADES

6–8

SUBJECTS

Mathematics
Physical Science

BACKGROUND

The strong, smooth, and consistent winds a few kilometers off of the coast line—offshore—are excellent for producing wind energy. While there have been successful offshore wind projects in Europe since 1991, offshore wind development has been slow to start in the United States. Many developers are currently proposing offshore wind farms and examining different locations. Professional and computer-generated scale models are used frequently because offshore wind farm proposals can be very contentious due to their visual impact—the way they might affect landscape views. In this lesson, students use maps to explore several important considerations in offshore wind development. Students also use scale models to explore what a wind farm might look like from a distance.

OBJECTIVES

At the end of the lesson, students will:

- understand the concept of offshore wind
- identify pros and cons of offshore wind development
- understand siting concerns for offshore wind development
- understand how to determine scale and the importance of scale models

METHOD

Students discuss the pros and cons of offshore wind and examine maps to choose the most and least desirable locations for offshore wind development. Students use math to determine the scale of small model turbines. Using these models, they make a scale version of an offshore wind farm—placing the turbines the appropriate distance from "shore" to create a physical simulation of how the offshore wind farm would look.

MATERIALS

- ❑ 4–10 scale model turbines (small models, pinwheels or KidWInd Fireflies)
- ❑ Meter sticks
- ❑ Measuring tape (metric)
- ❑ Images of offshore wind farms
- ❑ Visual simulations of proposed wind farms
- ❑ Copies of maps (print or copy in color)*
- ❑ Student reading passages and student worksheets*

*included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

KidWind PROJECT ®
www.KidWind.org

GETTING READY

- Ask students to read the reading passage that accompanies this lesson to give them a background on offshore wind development.
- Ask students to read a few articles about offshore wind development. These articles should include both pro- and anti-wind development to give students a balanced perspective.
- Distribute copies of maps (in color, if possible) and graphs to student groups. There should be seven maps (US Lights at Night, Electric Transmission Lines, Wind Resource, Offshore Wind Resource, Proposed Offshore Wind Projects, US Bathymetry, and Base Map) and 1 set of graphs (Seabird Foraging Ranges)
- Display or distribute pictures of offshore wind farms to familiarize students with visual impact of this technology.
- Review unit conversions with students for worksheet math calculations.

ACTIVITY

Step 1: Beginning questions for students

- Building a wind farm onshore is extremely expensive—and the cost increases dramatically when building in open water. Why do you think developers are willing to invest the additional money to build wind farms offshore?
- What details would a developer need to consider when deciding where to build an offshore wind farm?
- Why do you think some people might be unhappy about offshore wind farm development?
- Can you think of any special or nostalgic places where you would not want to see anything man-made on the landscape?

PART 1: EXAMINING MAPS & GRAPHS FOR OFFSHORE WIND POWER DEVELOPMENT

A wind farm developer needs to consider many factors where deciding where to build a wind farm. This lesson includes several maps for students to compare different locations for siting an offshore wind project:

- Transmission Lines in the US

If a wind farm is built far from existing transmission infrastructure, new electric lines must be built to transmit the electricity along the grid. It makes the most economic sense to build a new wind farm close to existing transmission lines.

- US at Night Map

The electricity from a wind farm must be transmitted to areas where people are consuming a significant amount of electricity. This map illustrates areas of the country that use the most electricity. Note that over 50 percent of the US population lives within 50 miles of a coastline.

- Seabird Foraging Graphs

These graphs illustrate how far from shore selected birds may be found. As one travels further from shore, the density of birds decreases dramatically.

- Wind Resource Map

The wind speed of a location determines how much power a wind farm can generate. A wind farm should be sited in an area with a lot of wind!

- Bathymetric Map

Most current offshore wind towers can be built in water up to 30 meters deep. Students should examine this map for sites that are shallow enough to build turbines with current technology.

Step 1: Examining maps—choosing suitable locations
Organize students into groups of three to four to examine the maps and graphs provided—paying special attention to offshore areas like the Great Lakes, the Gulf Coast, and the Atlantic and Pacific coasts. Ask each group to choose and defend their top three offshore wind farm project sites based on these maps. Groups should also choose three locations that they consider very poor locations for offshore wind development. Student groups should mark their chosen locations on the blank US map on the worksheet.

Step 2: Compare results to actual offshore wind proposals
Distribute the map of proposed offshore wind projects in the United States. How do the students' proposed locations compare to the proposed offshore wind farm locations on the map?

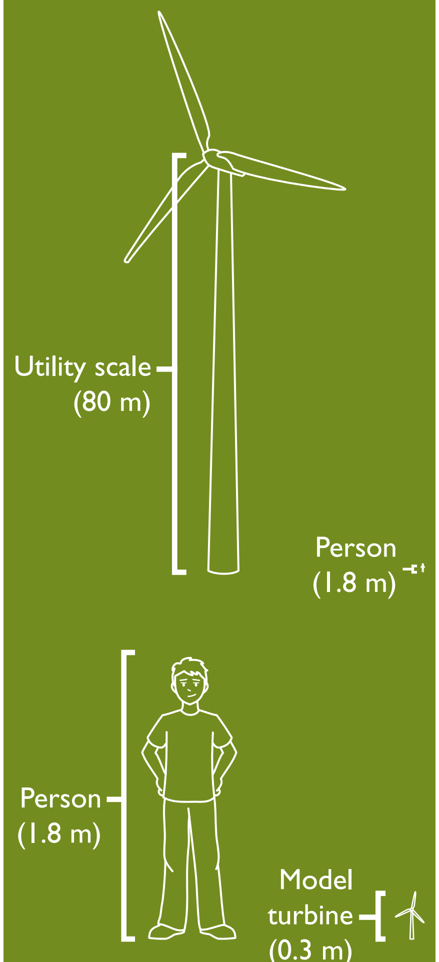
Step 3: Discussion
Use the following questions to discuss offshore wind farm development in the US:

- What other maps do you think would be important for an offshore wind developer to study? (e.g. shipping channels, marine animal density, protected areas, etc.)
- In what ways is offshore wind development similar to and different from offshore oil drilling?
- What are some reasons for the slow acceptance/permitting of offshore wind power in the United States?
- Based on this activity, discuss some pros and cons of offshore wind farms.

PART 2: VISUALIZING AN OFFSHORE WIND FARM WITH SCALE MODELS

We can get a better idea of what a large wind farm will look like by building a scale model. Wind farm developers typically do this using computer simulations, but students will create a physical scale model. Scale models are miniature versions of real things. It is important that students have a basic understanding of the relationship between fractions and ratios before this lesson.

DETERMINING SCALE



Step 1: Determining scale

For students to determine the scale for their models, they need to know the height of the model turbine and the height of an actual turbine. To do this, students must measure the height and blade diameter of the model turbines. They should measure height up to the hub of the turbine.

Model Turbine Hub Height: ~30cm

Model Turbine Blade Diameter: ~30cm

For the actual turbines, students will assume the use of Siemens 3.6 MW turbines—which are the turbines proposed for the Cape Wind project off the coast of Massachusetts.

Siemens 3.6 MW Hub Height: 80 meters
Siemens 3.6 MW Rotor Diameter: 107 meters

Students should determine scale by using the hub height. The model turbine is 0.3 meters high, and the Siemens turbine is 80 meters high. That means the scale is 0.3/80. But when we talk about scale, it is best to have the numerator be a one (refer to the scales on any map). So, students need to divide the numerator and denominator by the numerator.

$$\text{Model Turbine} \quad \frac{0.3}{0.3} = 1$$

$$\text{Real Turbine} \quad \frac{80}{0.3} = 266.67$$

Ask the students to fill out Worksheet 1 to determine scale. Remind students to pay attention to their units of measure! If this task is done correctly, students should come up with a scale of about 1/267. That means that every 1 cm on the scale model is equal to 267 cm on the real turbine!

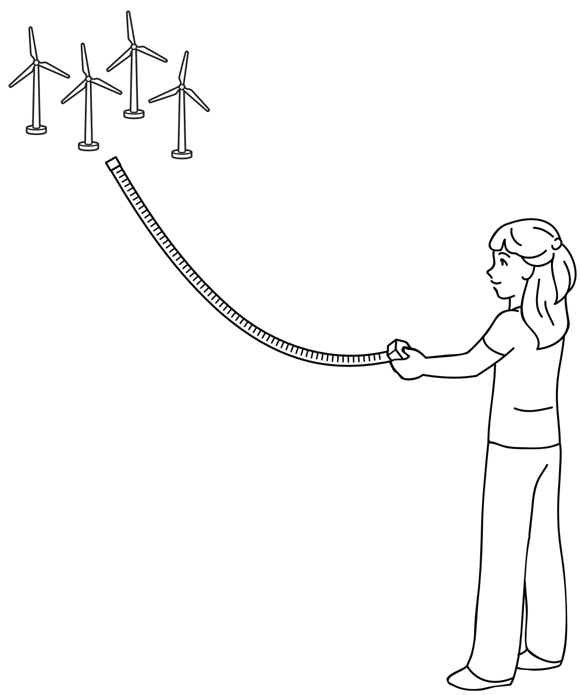
Step 2: Building the scale model wind farm

Find a place where students can set up their model wind farm. A long hallway, a gym, an auditorium or other large room works well.

Now that students have calculated the scale of the turbines, they can determine how far away to place the turbines from their viewpoint. The turbines at Cape Wind will be approximately 9 km from the nearest homes in Cotuit, MA. Tell students to complete Worksheet 2 to determine how far from "shore" to place the model turbines. Make sure students are using the correct units of measure!

$$9\text{ km} \times \frac{1{,}000\text{ m}}{1\text{ km}} = 9{,}000\text{ meters}$$

$$9{,}000\text{ m} \times \frac{1}{267} = 33.7\text{ meters from "shore" for scale model}$$



Once students have placed the model turbines, they should lie down on "shore" to see what they look like. From shore, students should use a ruler to measure the height of the turbines from the perspective of shore. Tell students to draw a picture of the turbines on the ocean view print-out in this lesson to get an idea of how the turbines might look on the horizon. The turbines should be measured and drawn to be the same height as the "perspective" height of the model turbines from shore. Ask students to label the height of these turbines on their drawings.

Step 3: Follow up

Much of the local opposition to large offshore wind farms in the US is based on aesthetics and visual impacts. Scale models help to give us a better idea of how these proposed wind farms might affect the view of the landscape. Encourage students to discuss:

- Based on your model, do you think this wind farm would be an eyesore?
- If you owned beachfront property, do you think wind turbines on the horizon would be an eyesore?
- Why might people be disappointed to see a wind farm near their house?
- Are there places/landscapes you know that you would not want this visual intrusion? Are there any situations where wind turbines would improve landscape views?
- What are the limitations of this scale model?
- There are many types of structures that we rely on to bring us energy and power our lives—coal power plants, power lines, cell towers, nuclear plants, hydroelectric dams, etc. Do you feel there is a difference in the visual impact of these structures versus wind turbines?
- How can we balance the visual impacts of wind farms with our need to generate power in the US?

EXTENSION

- WindWise Lesson 18 (Where Do You Put a Wind Farm?) introduces more on the complexities of wind farm siting.
- Tell students to research protected offshore areas like National Marine Sanctuaries. How would protected areas affect siting of offshore wind farms? This website may be a helpful reference: http://sanctuaries.noaa.gov/pgallery/atlasmaps/welcome.html

VOCABULARY

bathymetric map – A visual presentation that depicts underwater terrain. A bathymetric map portrays underwater topography.

offshore wind – Projects that are constructed in bodies of water to generate electricity from wind.

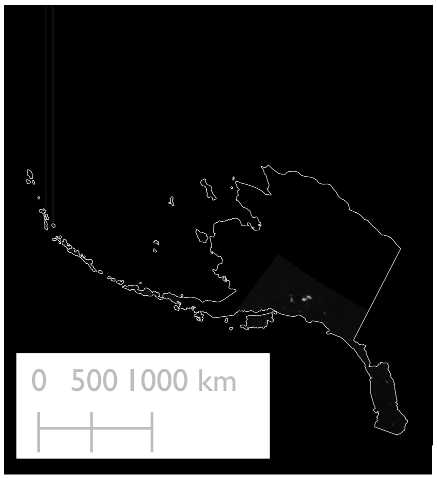
scale model – A physical representation of an object that is larger or smaller than the actual object. A scale model must be in correct proportion to the actual object.

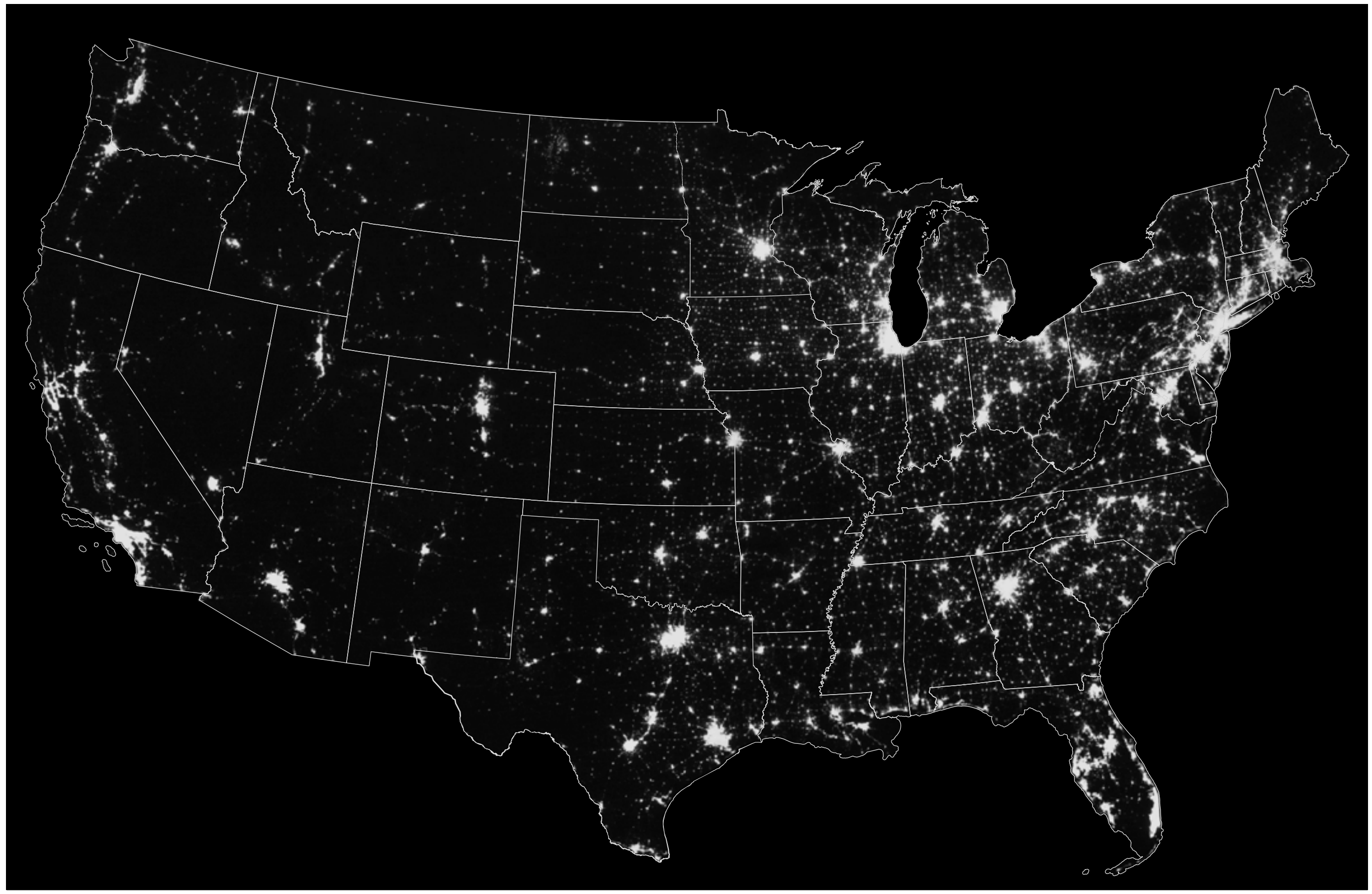
foraging range – The distance a bird may travel from its nest to find food. For shorebirds, this is the distance they may be found offshore.

RELATED LESSONS

- Lesson 5: Where Is It Windy?
- Lesson 13: What Is Wind Power's Risk to Birds?
- Lesson 18: Where Do You Put a Wind Farm?

MAP SHOWING US LIGHTS AT NIGHT

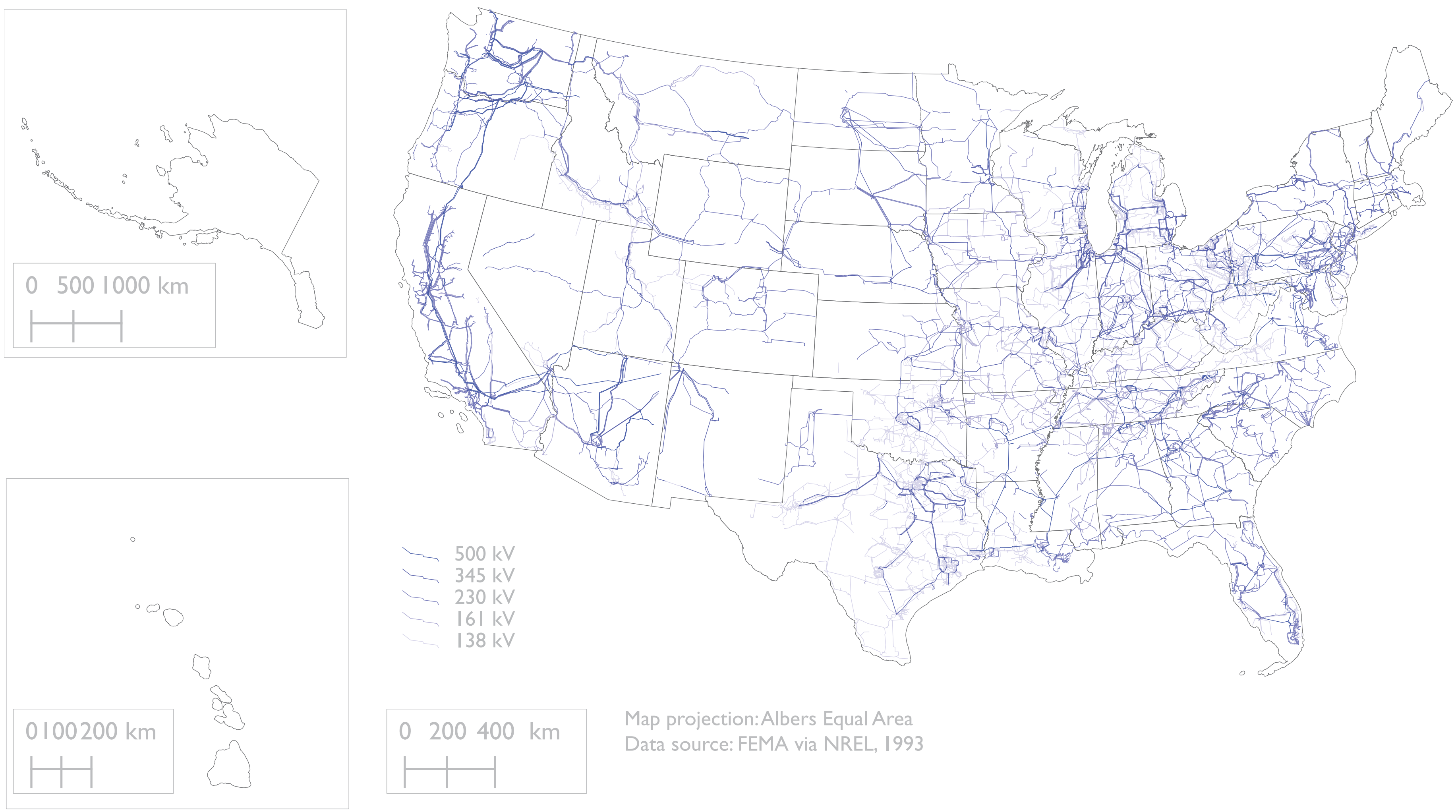




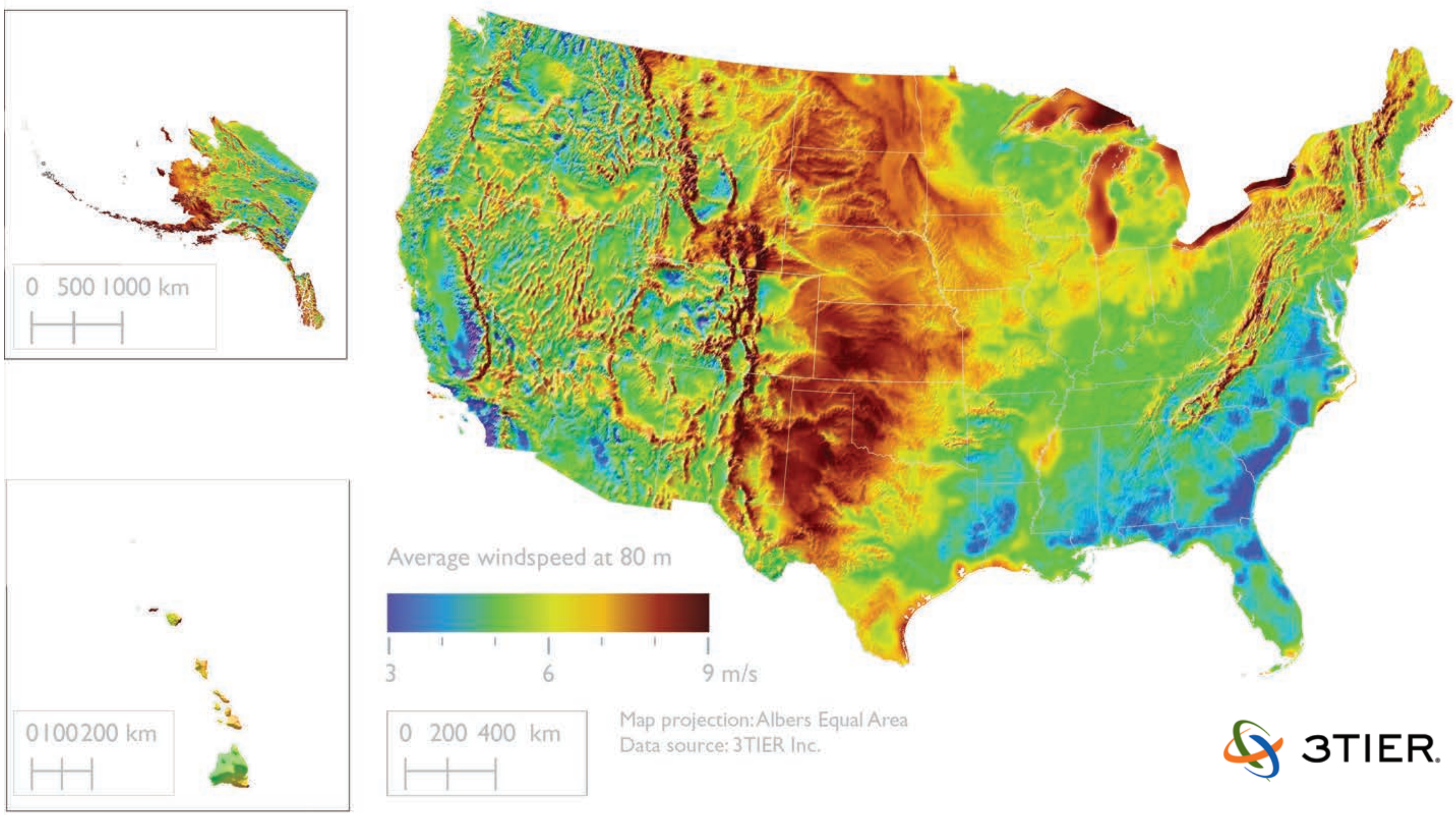
0 200 400 km

Map projection: Albers Equal Area
Data source: NOAA's National Geophysical Data Center. DMSP data collected by US Air Force Weather Agency

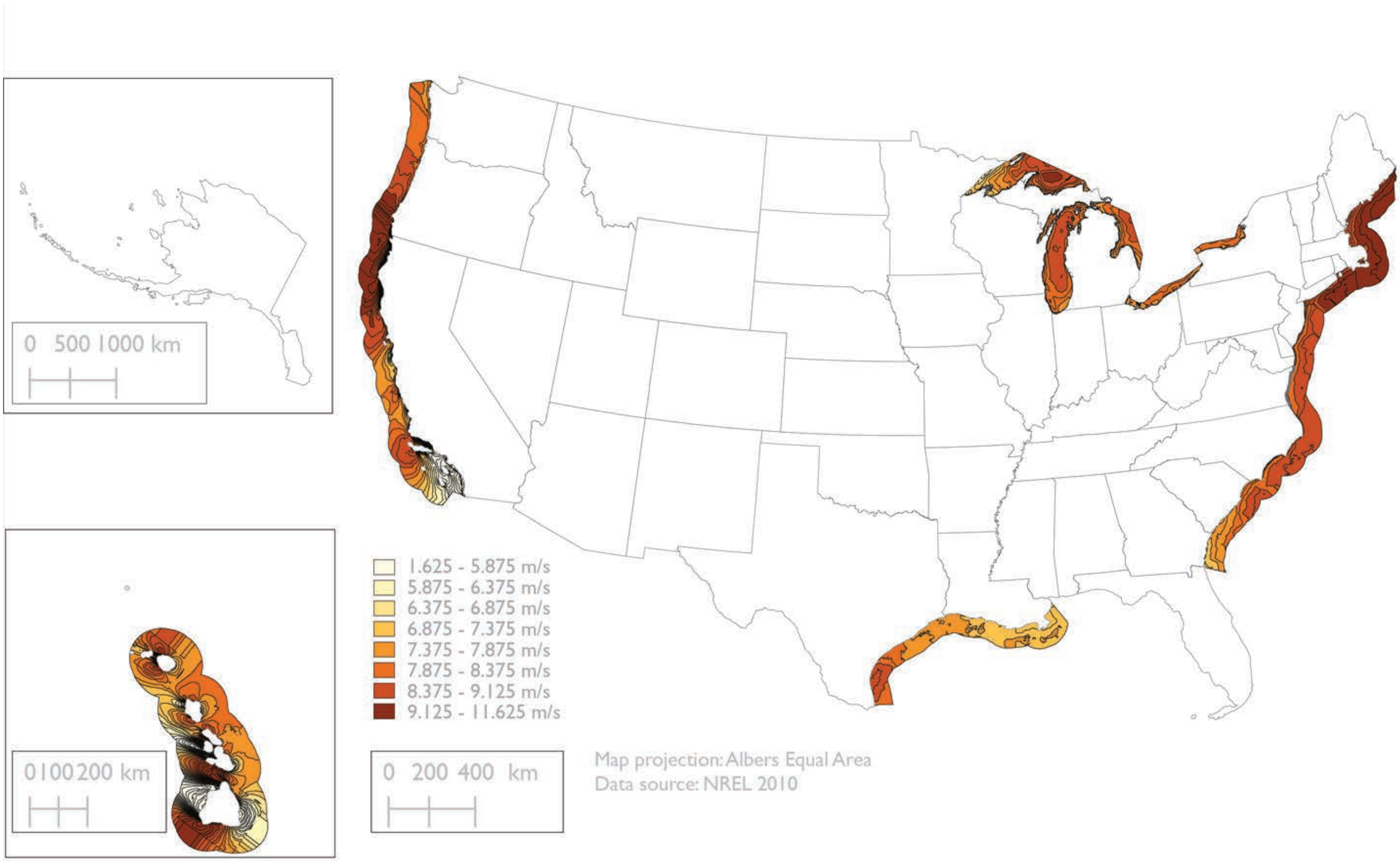
MAJOR ELECTRIC TRANSMISSION LINES IN US



UNITED STATES WIND RESOURCE

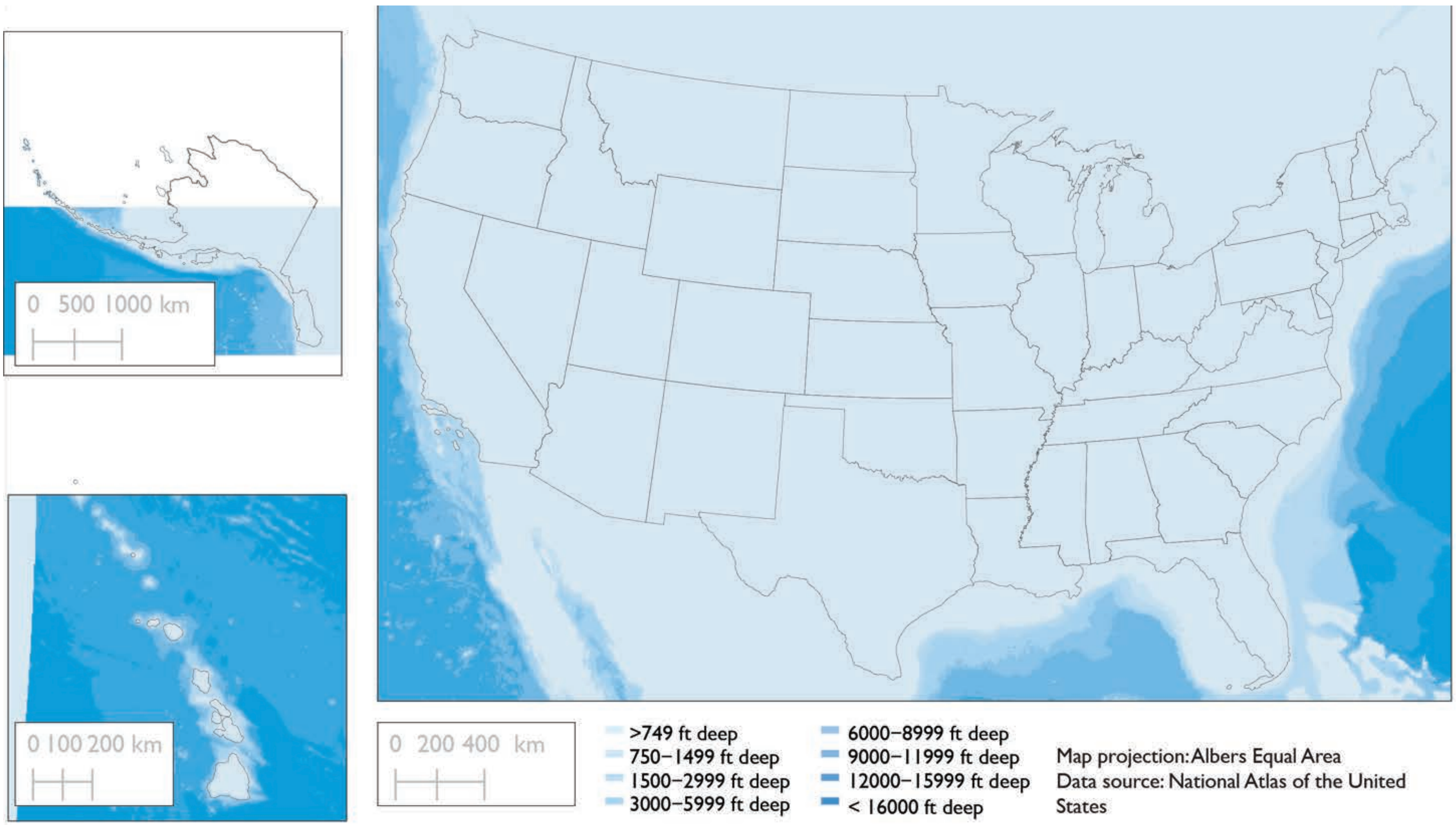


UNITED STATES OFFSHORE WIND RESOURCE



CURRENT PROPOSED OFFSHORE WIND PROJECTS

US BATHYMETRY (SEA DEPTH MAP)



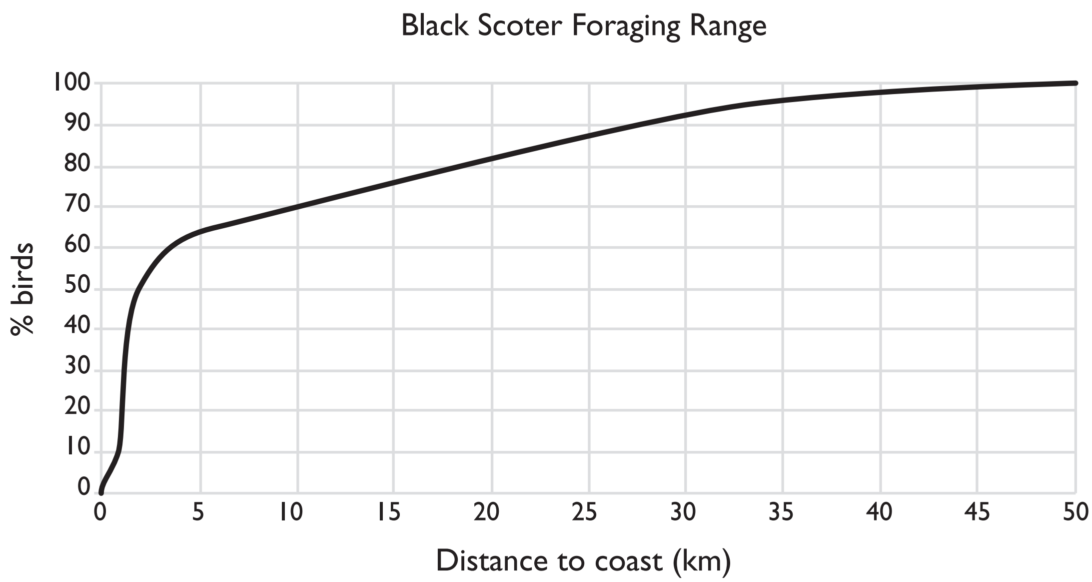
Map projection: Albers Equal Area
Data source: National Atlas of the United States

BASE MAP OF US STATES

Pick three “Best” and “Worst” locations for offshore wind development

PHOTOGRAPH FOR VISUAL IMPACT SIMULATION

GRAPHS OF SEABIRD FORAGING RANGES



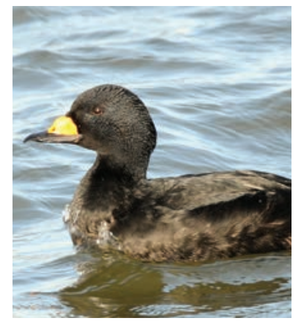
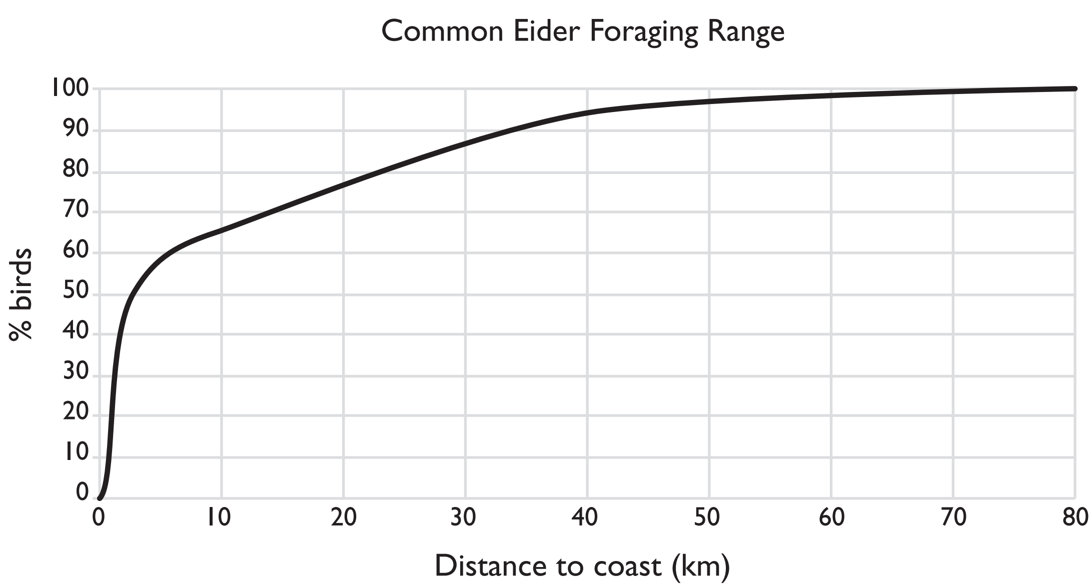


Photo: Peter Massas, CC BY-SA 2.0



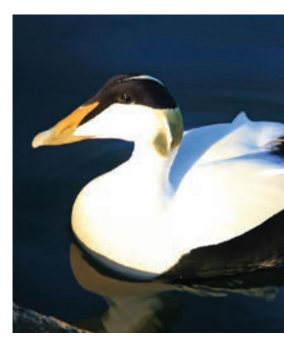
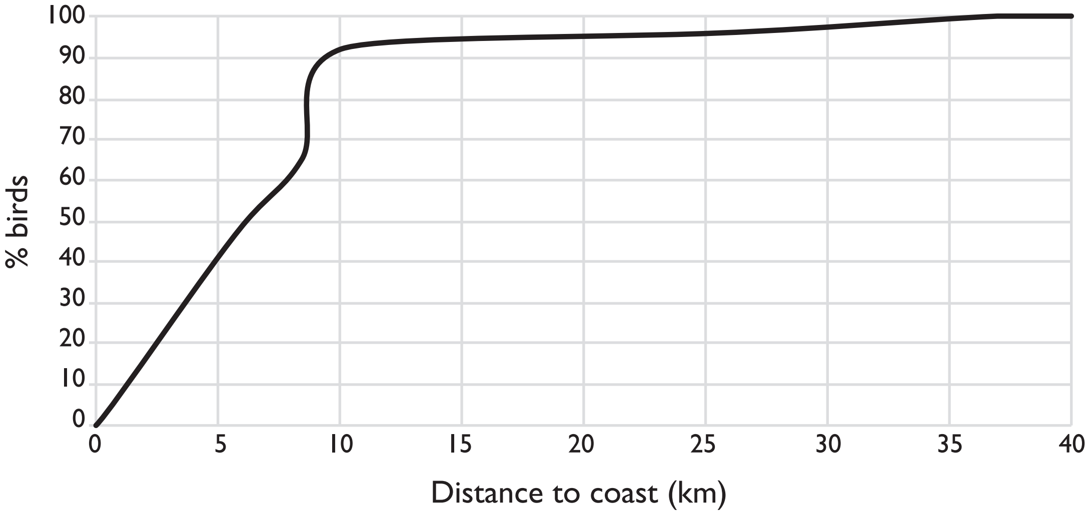


Photo: Laszlo Ilyes, CC BY 2.0

Common Tern Foraging Range



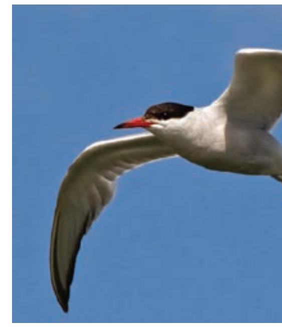


Photo: Tony Hisgett, CC BY 2.0

Roseate Tern Foraging Range

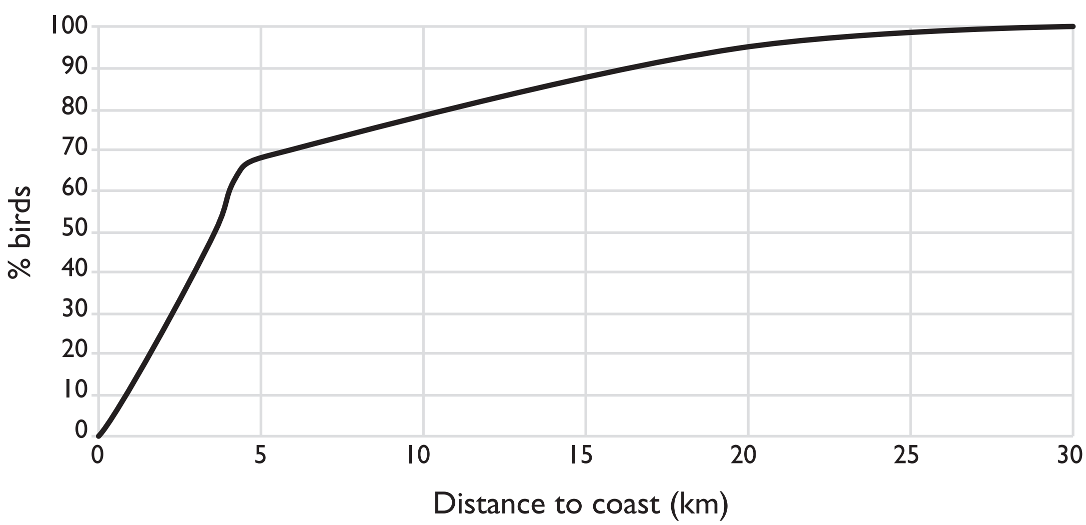


Photo: Sarah Nystrom, CC BY 2.0

Graph data from: Birdlife International. http://seabird.wikispaces.com/ Creative Commons (CC BY-SA 3.0)

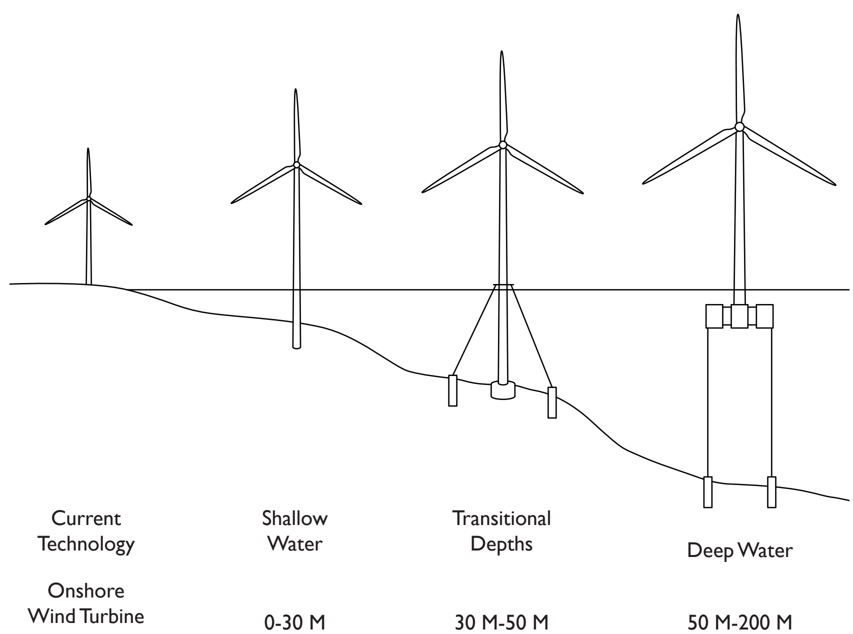
READING PASSAGE

Building wind farms offshore—several kilometers out to sea—is becoming more common. Offshore construction, maintenance/repairs, and transmission of electricity can be much more expensive and complicated than land-based wind development, but for a number of reasons offshore wind development is very attractive.

The wind offshore is outstanding in many locations. The smooth, flat surface of the oceans create very little friction. Without surface roughness and obstructions, the wind blows very fast—while also being smooth with very little turbulence. This fast and smooth wind is perfect for wind energy production, and offshore wind turbines are able to produce a lot of electricity very efficiently. The potential energy produced from the wind is directly proportional to the cube of the wind speed (V^3), so a small increase in wind speed will give a relatively large increase in power output.

Another benefit of offshore wind energy development is proximity to shoreline population centers. In the United States, for example, 53 percent of the total population lives within 50 miles of the coast[1]. It is most efficient and economical to produce power close to where it is used. Offshore wind energy is seen as having great potential to produce electricity close to large population centers.

Offshore wind turbines tend to be considerably larger than land-based turbines. This is because there are fewer physical constraints when transporting and installing large turbine components. Whereas a 60 m blade is difficult to transport on roads, it can be moved with relative ease via water. Additionally, the cost of installing a turbine offshore does not change greatly based on the size of the machine, so it is cost-effective to install a larger turbine that will produce more energy.



Installing an offshore wind farm requires a great deal of scientific data to guide the placement (siting) of the turbines. A developer must be familiar with: water depth, wind resource, transmission access, seabed characteristics, wildlife migration, wave action, and many other factors before installing turbines offshore.

An offshore wind farm must be sited where the water is relatively shallow so that the turbine foundations can be secured to the ocean floor. Currently, 30 meters is the standard maximum depth for constructing offshore turbines. Because of this, developers seek locations that are very windy and have shallow waters.

Researchers and engineers are studying floating offshore wind turbine designs that would allow turbines to be placed in deeper waters—further from land and visual impacts, and out where winds are stronger and more consistent. One floating wind turbine prototype is currently being tested in the North Sea.

[1]National Ocean Service—http://sanctuaries.noaa.gov/pgallery/atlasmaps/welcome.html

Name_______________________________ Date_____________ Class_________

WORKSHEET 1: DETERMINING SCALE

To get an idea of what an offshore wind farm might look like, you can construct a scale model of a wind farm. Scale models are miniature versions in correct proportion, of real things. Your first job is to calculate the proportion, or scale, of your miniature turbines compared to real wind turbines.

Siemens 3.6 MW wind turbine
Tower height: 80 meters

Scale model turbine
Tower height _____________ cm

1. Convert the real turbine tower height to centimeters so all of your units of measure are the same.

$$\frac{80 \text{ m} \times 100 \text{ cm}}{1 \text{ m}} = \underline{\hspace{3cm}} \text{ cm}$$

2. Calculate the scale by dividing the model height by the real turbine height.

$$\frac{\text{Model Height (cm)}}{\text{Real turbine height (cm)}} = \frac{\underline{\hspace{3cm}} \text{ cm}}{\underline{\hspace{3cm}} \text{ cm}}$$

3. The top number (numerator) of a scale should always be 1. Divide both numbers in the fraction by the numerator so that the top number equals 1.

This number is the scale for your model.

WORKSHEET 2: BUILDING THE SCALE MODEL OF THE WIND FARM

After determining the scale of your model, you are now ready to set up your miniature wind farm. The closest wind turbines at this proposed offshore wind farm will be 9 kilometers from shore. The water is shallow here, and the wind resource is outstanding. Residents of the area are wondering what the wind farm will look like—so this scale model will help us understand the visual impact.

Your first step is to determine how far away to place the scale model turbines.

1. Remember: the scale of your model turbine is:_______________

2. This means that 1 centimeter in the model is equal to ____________ centimeters in real life.

3. Your next step is to convert the units so that they are all the same. How far is 9 kilometers in centimeters?

4. $9 \text{ km} \times \dfrac{1000\text{m}}{1\text{km}} \times \dfrac{100\text{cm}}{1\text{m}} =$ __________cm

5. Now multiply this distance by your scale to figure out how far away to place the turbines in your scale model:

   Distance _________ cm × _____________ (model scale) = ___________ (distance from shore in cm)

6. Now measure the length of your stride in cm _______________________ .

7. How many strides from "shore" should you place your turbines?

$$\frac{\text{(Distance from shore in cm)}}{\text{(cm in a stride)}} = \text{(number of strides)}$$

Once you have placed the turbines, head back to shore and lie down so your eyes are close to ground level. Do the turbines look large or small? What kind of impact do they have on the landscape?

Using the "Photograph for Visual Impact Simulation," draw a picture of the wind farm as it appears on the horizon.

WORKSHEET 1: DETERMINING SCALE

To get an idea of what an offshore wind farm may look like, you can construct a scale model of the wind farm. Scale models are miniature versions, in correct proportion, of real things. Your first job is to calculate the proportion, or scale, of your miniature turbines compared to real wind turbines.

Siemens 3.6 MW wind turbine
tower height: 80 meters

Scale model turbine
tower height: *28* cm

1. Convert the real turbine tower height to centimeters so all of your units are the same.

$$\frac{80\text{ m} \times 100\text{ cm}}{1\text{ m}} = \mathit{8000\ cm}$$

2. Calculate your scale by dividing the model height by the real turbine height.

$$\frac{\text{Model Height (cm)}}{\text{Real turbine height (cm)}} = \frac{\mathit{28\ cm}}{\mathit{8000\ cm}}$$

3. The top number (numerator) of a scale should always be 1. Divide both numbers in the fraction by the numerator so that the top number equals 1.

$$\frac{28}{28} \times \frac{28}{8000} = \frac{1}{286}$$

286

This number is the scale for your model.

WORKSHEET 2: BUILDING THE SCALE MODEL OF THE WIND FARM

After determining the scale of your model, you are now ready to set up your miniature wind farm. The closest wind turbines at this proposed offshore wind farm will be 9 kilometers from shore. The water is shallow here, and the wind resource is outstanding. Residents of the area are wondering what the wind farm will look like—so this scale model will help us understand the visual impact.

The first step is to determine how far away to place the scale model turbines.

1. Remember: the scale of your model turbine is: *Scale: 1/286*

2. This means that 1 centimeter in the model is equal to *286* centimeters in real life.

3. The next step is to convert the units so that they are all the same. How far is 9 kilometers in centimeters?

4. $9 \text{ km} \times \frac{1000\text{m}}{1\text{km}} \times \frac{100\text{cm}}{1\text{m}} = \mathit{286\ cm}$

5. Now multiply this distance by your scale to figure out how far away to place the turbines in your scale model:

   Distance *900,000* cm × *1/286* (model scale) = *3147 cm* (distance from shore in cm)

6. Now measure the length of your stride in cm; *~100 cm (varies)*

7. How many strides from "shore" should you place your turbines?

$$\frac{\textit{3147 cm} \text{ (Distance from shore in cm)}}{\textit{\textasciitilde 100 cm (varies)} \text{ (cm in a stride)}} = \textit{\textasciitilde 31.5 strides (varies)} \text{ (number of strides)}$$

Once you have placed the turbines, head back to "shore" and lie down so your eyes are close to ground level. Do the turbines look large or small? What kind of impact do they have on the landscape?

Using the "Photograph for Visual Impact Simulation," draw a picture of the wind farm as it appears on the horizon.

WHERE DO YOU PUT A WIND FARM?

LESSON 18

KEY CONCEPT

Students learn how to analyze data (maps, tables, and written information) to compare and contrast two potential sites for a wind farm.

TIME REQUIRED

2 class periods

GRADES

6–8
9–12

SUBJECTS

Social Studies
Environmental Studies
Earth Science
Mathematics

KidWind PROJECT®

www.KidWind.org

BACKGROUND

A wind farm developer spends a considerable amount of time and money determining the optimal location for a wind farm. A significant part of this process is the environmental screening analysis, in which many and various issues are critically examined—from threatened and endangered species to local zoning laws. This lesson introduces students to the types of data that developers use to prioritize potential sites.

OBJECTIVES

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

- analyze and interpret maps
- synthesize data from a variety of sources
- identify the major variables considered when siting a large wind farm

METHOD

Working in small groups, students use a set of maps, tables, and reading materials to compare and contrast two potential sites for a wind farm. Each group completes an evaluation table by scoring the criteria and then decides which site is optimal. Each group writes a proposal describing the assets of the site and presents it to the class.

MATERIALS

- ❑ Information packets for two proposed wind farm locations in New York*
- ❑ Student reading passages and student worksheets*

*included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

GETTING READY

- Download and print enough color copies of site packets for each group. The information in these packets is hard to decipher in black and white. Consider laminating paper copies for repeated use.
- Make copies of the worksheet for each student.

ACTIVITY

Step 1: Beginning Questions for Students

Help students understand that there are many different factors that determine where a wind farm goes. While no site is perfect, some factors may be more important than others in determining location. Ask students to review the case study and then guide a short class discussion, using the following questions:

- Where do you think wind farms typically are?
- What are some reasons why wind farms may not always be located where wind speeds are highest?
- What factors must wind developers think about, when siting a wind farm?
- Which of these factors do you think are most important?

Step 2: Small group site analysis

Students will work in small groups to analyze two potential sites for a wind farm. Using the maps and reference materials, students will determine which of the two locations is the most viable. Each group will write a one-paragraph report that outlines which site they have selected and why. If time permits, each group can present its proposal to the rest of the class.

Organize students into small groups and present them with the following scenario:

A large wind developer is interested in building a wind farm in New York. The developer has two locations in mind. The developer's investors would like to know which site should be selected. The group's goal is to analyze the information available for each site and make a recommendation to the investors.

After you distribute the information to each group, give them time to evaluate the maps and information. It may be easiest if each student picks one or two features to evaluate for the group. Ask students to look at the questions on the worksheet and determine a score based on the answers to those questions. Encourage students to provide comments on the worksheet to explain the potential problems or advantages of each site.

Each group will evaluate the scores and key factors and select a site. Each student will write a paragraph proposal for the selected site that includes the reasons why the site is preferable. Students could also write this paragraph as homework.

Step 3: Wrap up

Ask each group to summarize which site they selected and provide a reason for their selection. Discuss why each group selected the site. If groups selected different sites, encourage students to talk about why. Were the decisions based upon different pieces of information? Did one piece of information outweigh the others in terms of importance?

EXTENSION

Create a WebQuest for students to obtain additional information on the potential wind farm sites.

VOCABULARY

endangered species – A species in danger of extinction throughout all or a significant portion of its ranges

environmental screening analysis – Also called a preliminary site assessment, this is a process to assess the site's suitability for a wind farm from an environmental perspective.

regulations – Rules, orders or laws issued by an government authority

siting – The process by which the specific location of a wind energy facility, and the specific locations of wind turbines within the facility, are determined

species of special concern – Species for which a welfare concern or risk of endangerment has been documented even though current information does not justify listing these species as either endangered or threatened.

threatened – A species likely to become endangered in the foreseeable future

RELATED ACTIVITIES

- Lesson 13: How Does a Windmill Work?
- Lesson 16: How Do People Feel About Wind?
- Lesson 17: What Are Best Locations for Offshore Wind?

CASE STUDY: CAPE WIND PROJECT

In 2001, Cape Wind began developing the first offshore wind farm in the United States. The 130-turbine wind farm is proposed to be built over 5 miles off the coast of Massachusetts in Nantucket Sound. It is predicted that the wind farm will produce enough energy to meet 75 percent of the electricity demand for Cape Cod and the islands of Martha's Vineyard and Nantucket. As a part of the development process, Cape Wind has had to complete a comprehensive environmental impact review process with 17 federal and state agencies.

In 2007, Cape Wind completed a final environmental impact report with the Commonwealth of Massachusetts. By this time, Cape Wind had spent nearly $30 million on their efforts to gain permissions the wind farm. Delays in the federal permitting process occurred when the regulatory authority for offshore renewable energy projects was transferred from the US Army Corps of Engineers to the US Minerals Management Service (MMS) within the Department of the Interior.

The MMS released the final environmental impact statement in early 2009 and on April 28, 2010, the Department of Interior Secretary Salazar approved the project.

The Cape Wind Project has faced fierce opposition from a number of groups, including The Alliance to Protect Nantucket Sound. Groups opposed the Cape Wind Project for a number of reasons: potential negative impacts to the ecosystem, negative impacts on fishing, economic impacts of less tourism, lower property values, and safety hazards for air and sea navigation. In addition, Cape Cod, Martha's Vineyard, and Nantucket all have numerous historic landmarks that the Massachusetts Historical Commission (MHC) believed would be adversely impacted by the visual presence of the turbines.

Many other groups supported the project, including Clean Power Now, Greenpeace, and the Natural Resources Defense Council. After conducting their own extensive environmental and avian impact studies, the Massachusetts Audubon Society released a statement in 2006 that provided conditional support for the wind farm, asking Cape Wind to "get it right." Groups that supported the project pointed to the positive impacts that the project might have. Positive impacts include: creating new jobs and contributing to stable energy prices; using more clean energy and thus reducing harmful air pollutants and greenhouse gas emissions; and increasing general safety and security by reducing dependence on foreign energy sources, like oil.

Sources

- Alliance to Save Nantucket Sound. www.saveoursound.org/
- Clean Power Now.
- Cape Wind: America's First Offshore Wind Farm on Nantucket Sound, www.capewind.org/
- *Boston Globe*, www.boston.com/news/local/massachusetts/articles/2007/03/31/cape_wind_moves_on_to_federal_review/—News article entitled "Cape Wind Moves on to Federal Review: After State OK, Roadblocks Remain" by Stephanie Ebbert, *Boston Globe*, March 31, 2007.

Additional Resources can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

Name______________________ Date______________ Class__________

WHERE DO YOU PUT A WIND FARM?

A large wind developer is interested in building a wind farm in New York. The developer has two locations in mind. The developer's investors would like to know which site has the fewest obstacles to approval. Your group's goal is to analyze the information available for each site and make a recommendation to the investors.

Step 1: Compare and contrast the sites

To help compare and contrast the two sites, use a scale to rank each feature. If the feature provides an advantage to the site, give it a positive score (+1 to +3), with +3 being the most positive. If the feature appears to put the site at a disadvantage, give it a negative score (-1 to -3), with -3 being the most negative. Think about the questions listed to help you decide how positive or negative the feature is. After evaluating each site, total the score for each site.

-3 -2 -1 0 +1 +2 +3

Negative Attribute **Neutral** **Positive Attribute**

MAP OR RESEARCH INFORMATION Read the packet of information to answer the questions and determine a score.	**SITE 1** Score	**SITE 2** Score	**POTENTIAL PROBLEMS OR ADVANTAGES** Use this space to note important factors, such as average wind speed data, endangered species, or strong public opinion.
PROJECT DESCRIPTION ■ How many turbines will there be? ■ How much energy will they generate and how many homes would that power? ■ How many landowners are there? ■ What is the surrounding land use? ■ Are there other issues that may be important to know about for this location? ■ How many acres will the wind farm take up?			
ELEVATION MAP, LAND USE MAP ■ What are the 2–3 primary land uses near the site? ■ Will the elevation cause problems for construction? ■ Are there nearby towns?			
WIND SPEED MAP What is the average wind speed near the wind farm?			
BIRD SPECIES Are there any threatened or endangered bird species on or near the site?			
BAT SPECIES Are there any threatened or endangered bat species on or near the site?			

Name______________________________ Date_____________ Class________

MAP OR RESEARCH INFORMATION Read the packet of information to answer the questions and determine a score.	**SITE 1** Score	**SITE 2** Score	**POTENTIAL PROBLEMS OR ADVANTAGES** Use this space to note important factors, such as average wind speed data, endangered species, or strong public opinion.
WETLANDS AND PROTECTED AREAS Are there any wetlands near the turbine locations? If so, how close are they?			
TRANSMISSION CONSIDERATIONS ■ How much will the transmission connection cost? ■ How difficult will it be to get the transmission line approved? ■ Are there other issues that will make the transmission connection either easier or harder?			
VISUAL / AESTHETIC CONSIDERATIONS ■ When you look at the existing and simulated photos, do you think residents will be for or against the turbines? ■ Are there attractive views that will be altered (positively or negatively) by the wind turbines?			
LOCAL TOWN LAWS ■ Are there any town codes that may make the wind facility easier or more difficult to build?			
COMMUNITY OPINION ■ What is public opinion of the wind facility?			
PROPERTY VALUES ■ Based on the projected property values, do you think residents will support or oppose the wind facility?			
TOTAL SCORE			

Step 2: Small group discussion
As a group, take a few minutes to discuss the two sites.

1. What are the biggest advantages of each site?
2. What are the biggest challenges with each site?
3. Are there compromises that you have to make with either site?

Step 3: Write a proposal
Based on the scores for each site and your analysis of which factors are most important, which site will your company recommend to the developer? Consider that you do not need to select the site with the highest score if there are certain factors that may outweigh that choice. Write a paragraph describing why you have selected this site.

Step 1: Compare and contrast the sites

To help compare and contrast the two sites, use a scale to rank each feature. If the feature provides an advantage to the site, give it a positive score (+1 to +3), with +3 being the most positive. If the feature appears to put the site at a disadvantage, give it a negative score (-1 to -3), with -3 being the most negative. Think about the questions to help you decide how positive or negative the feature is. After evaluating each site, total the score for each site.

Students' responses will vary depending on how they interpret the information and should be used as a basis for class discussion.

Step 2: Small group discussion

As a group, take a few minutes to discuss the two sites.

Students' responses will vary depending on how they interpret the information and should be used as a basis for class discussion.

Step 3: Write a proposal

Based on the scores for each site and your analysis of which factors are most important, which site will your company recommend to the developer? Consider that you do not need to select the site with the highest score if there are certain factors that may outweigh that choice. Write a paragraph describing why you have selected this site.

WHERE DO YOU PUT A WIND FARM?

PROJECT DESCRIPTION

Questions to consider:

- How many turbines will the site have? How many megawatts? How many homes would the wind farm theoretically provide power to?
- How many individuals does the wind farm need to obtain leases from?
- Are there any towns near the project site?
- Are there local laws that will impact the wind farm?
- Will the topography make it potentially easier or more difficult to develop the wind farm? Why?

Windy Hills, LLC, is proposing to develop a wind powered generating facility with 62 turbines and a capacity of approximately 100 megawatts (MW). Each turbine has a maximum height of 410 feet. The proposed Windy Hills Wind Project would meet the electrical needs of over 40,000 homes. The project will employ approximately 10 to 20 administrative and other personnel.

The project will be developed on fifty separately owned parcels of land. Land use within the project area is dominated by agriculture with farms and single-family rural residences generally along the road frontage.

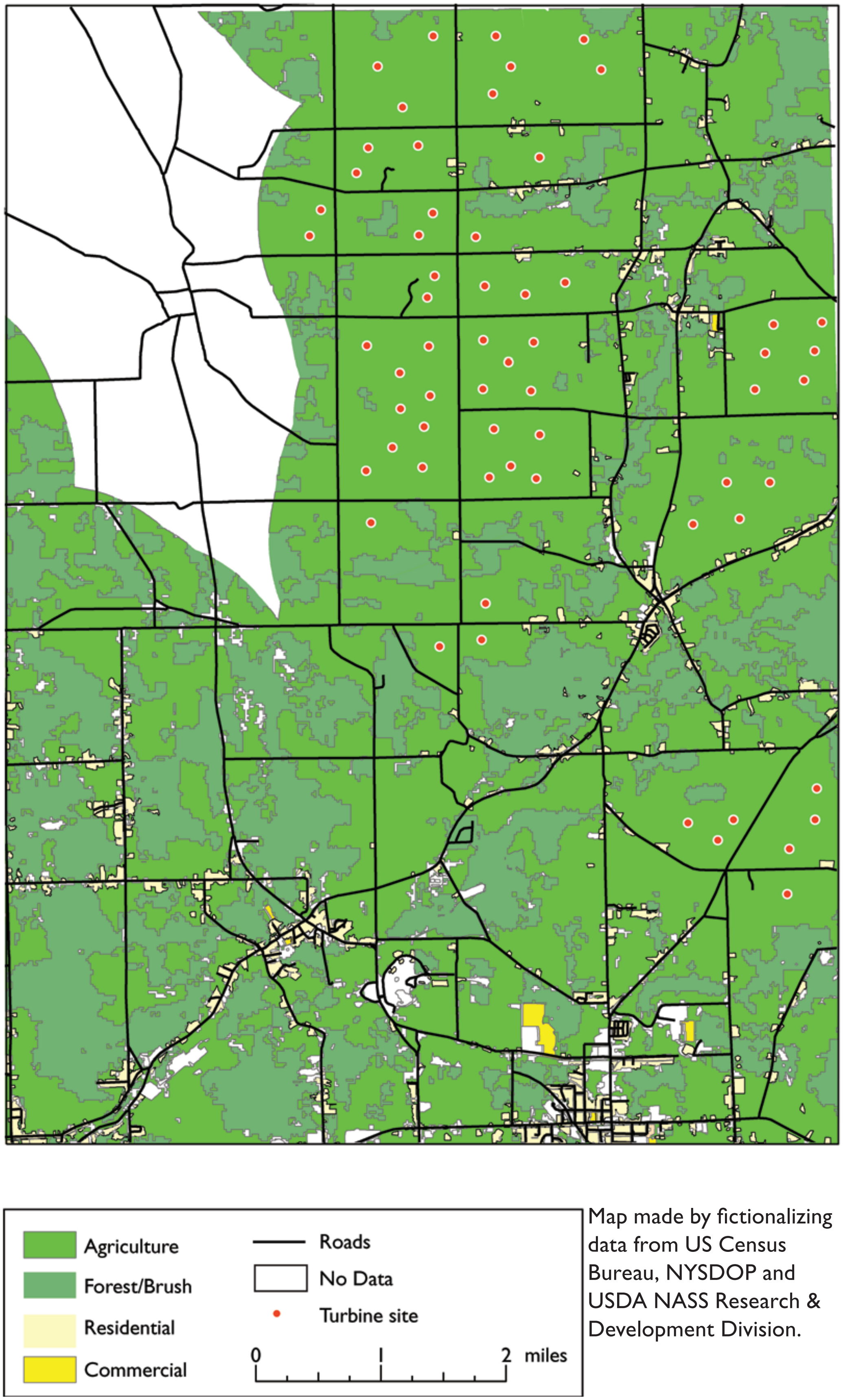
The closest town is 2 miles away. The wind farm is not located within town boundaries and would, therefore, not be subject to any town laws. The proposed 62 turbines would be located at least 2,500 feet from most nearby residences in order to minimize visual and sound effects.

This area has a hilly topography with valleys and ridges where elevations and slope increase. The majority of the turbines will be placed near hill- and ridge-tops.

LAND USE MAP

Questions to consider:

- What are the 2–3 primary land uses in the wind farm site?
- Do you think these land uses will make it easier or harder to introduce turbines?
- For agricultural areas, how do you think the turbines will impact farming operations?
- How do you think the turbines will impact residences in the area?



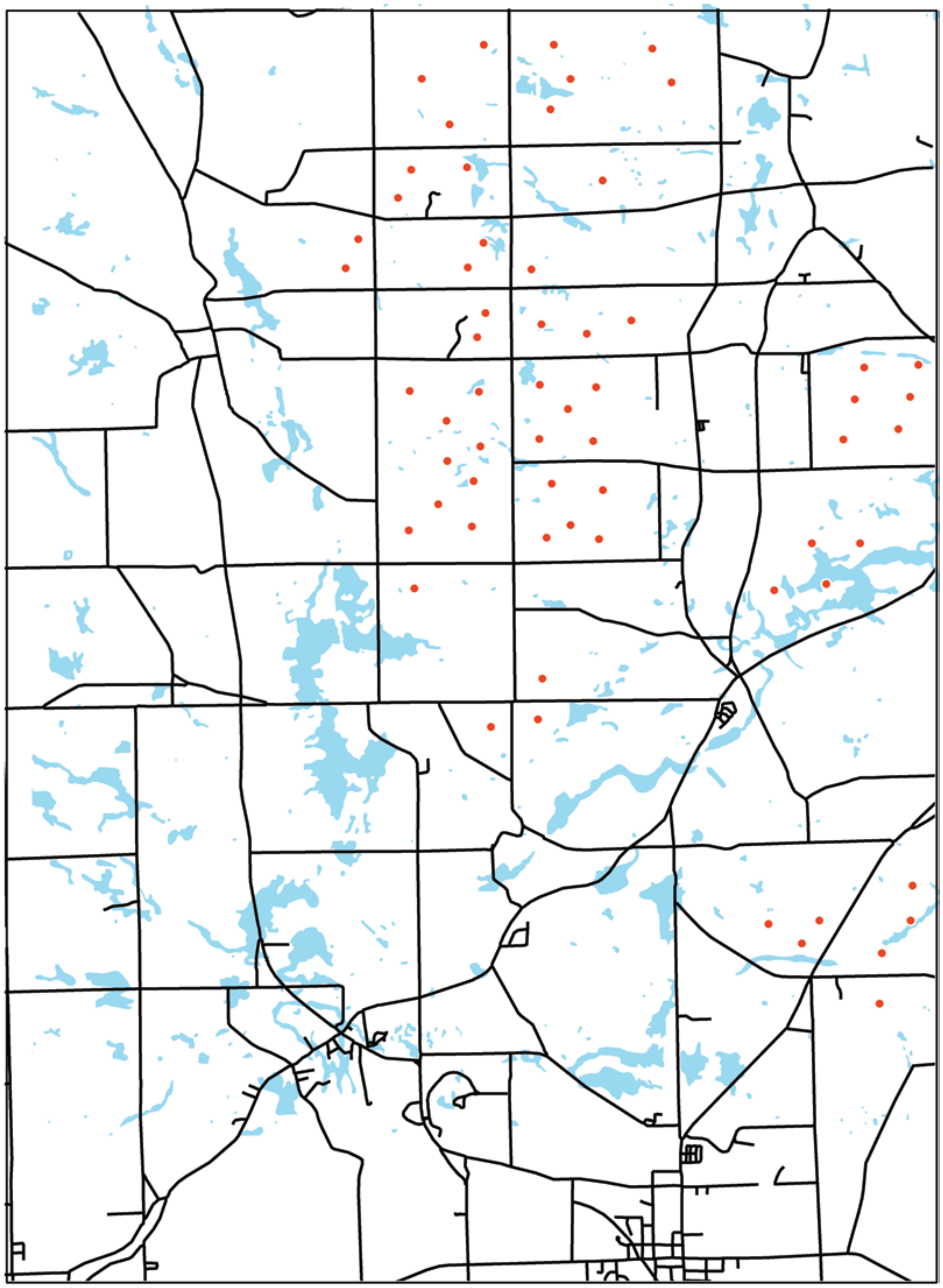
Map made by fictionalizing data from US Census Bureau, NYSDOP and USDA NASS Research & Development Division.

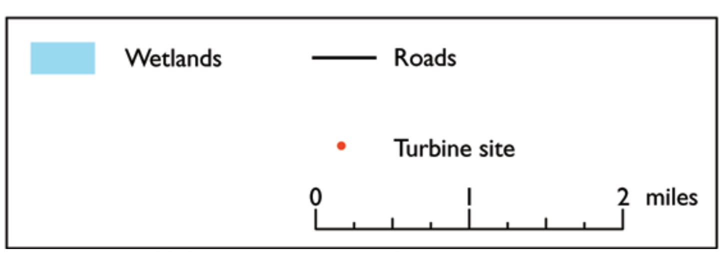
WETLANDS

There is no local town law that stipulates the distance wind turbines need to be from wetlands. A few of the proposed turbines would stand within 150 feet of wetlands. These wetlands are seen as valuable habitat.

Questions to consider:

- Based on the map, how much wetland area do you believe will be impacted?
- Can you think of any way the wind farm can ensure protection of these wetlands?





Map made by fictionalizing data from US Census Bureau and New York State Department of Environmental Conservation.

BIRD SPECIES OBSERVED

Questions to consider:

- Are there any threatened or endangered bird species within the project site or nearby?
- Have any members of threatened or endangered species been seen at the project site during surveys? If so, are they thought to live on the site, breed at the site, or migrate through the site?

Table 1: Number of individual birds and groups in surveys, 2005–2007.

SPECIES	SPRING	FALL	TOTAL
Water birds			
Great blue heron	4	0	4
Herring gull	0	0	0
Ring-billed gull	4	1	5
Waterfowl			
Canada goose	16	145	161
Mallard duck	3	12	15
Raptors			
Cooper's hawk*	0	0	0
Sharp shinned hawk*	1	0	0
Red-tailed hawk	13	7	20
Red-shouldered hawk*	1	1	2
Northern harrier**	4	6	10
American kestrel	1	1	2
Turkey vulture	30	34	64
Osprey*	0	1	1
Passerines			
American crow	9	35	44
European starling	0	92	92
Red-winged blackbird	0	85	85
Blue jay	0	25	25
American goldfinch	0	8	8
American redstart	0	7	7
Tree swallow	0	3	3
Other birds			
Pileated woodpecker	2	2	2

*New York State Species of Special Concern

**New York State Threatened Status

THREATENED OR ENDANGERED SPECIES

Sensitive species were observed throughout the project area and nearby areas. One New York state threatened avian species, northern harrier, was documented during surveys. This species is common in agricultural settings and is probably a breeding resident in or near the wind farm site.

Three species of concern—the sharp-shinned hawk, Cooper's hawk, and red-shouldered hawk—were recorded during migratory raptor surveys at the wind farm site. One sharp-shinned hawk was also documented during breeding bird surveys.

Listed species seen in the area were often represented by one or two individuals passing through during migration. In some cases, individuals were seen in one season or year, but not another season or year. Based on the low occurrence of these raptors, the project is not expected to have any adverse effects on eagles or falcons migrating through the area or to substantially increase risk of eagle/falcon collisions with turbines.

BAT SPECIES OBSERVED

Questions to consider

- Are there any threatened or endangered bat species within the project site or nearby? Have any of these been sited at the project side during survey nights?
- Of the species detected at the site, are there any that may be of special concern?

Table 2: Summary of detected bat species during summer night surveys

SPECIES	THREATENED/ ENDANGERED	DATE SAMPLED								
		6/25	6/26	6/27	7/08	7/09	7/10	7/23	7/24	7/25
Big brown bat *Eptescus fuscus*	No	51	85	8	0	1	2	0	29	0
Eastern red bat *Lasiurus borealis*	No	6	6	15	1	2	64	8	9	1
Hoary bat *Lasiurus cinureus*	No	6	3	5	9	0	5	3	8	0
Tri-colored bat *Perimyotis subflavus*	No	0	1	0	0	0	0	0	0	0
Little brown bat *Myotis lucifugus*	No	3	21	12	11	1	20	24	23	1
Northern myotis *Myotis septentrionalis*	No	6	4	5	0	0	0	0	5	0
Myotis species (This category includes any bat in the genus *myotis* whose species is not identified.)	One species, the *Myotis sodalis* (Indiana bat) is endangered.	4	39	4	13	2	5	11	16	3
No species ID		15	64	24	25	43	296	34	55	21
Total detections per night		91	223	73	59	49	392	80	145	26

Myotis sodalis (Indiana Bat)

The Indiana myotis, federally identified as endangered, is a small gray bat that roosts in crevices or under the loose bark of trees during the summer. Indiana myotis hibernate in caves during the winter, and the majority of them found in Indiana, Kentucky, and Missouri. While no Indiana bat fatalities have been confirmed at active wind energy facilities, other *Myotis* species (*Myotis* spp.) that exhibit similar life history characteristics and behaviors have been killed; therefore, there some risk may be associated with this species.

TRANSMISSION CONSIDERATIONS

Questions to consider:

- How difficult will it be to create a transmission connection? How much will it cost?
- Are there any issues that make the transmission connection easier or more difficult?

The closest transmission connection is 10 miles away and will cost $2 million per mile. Most of the distance can follow a major state road so would require very limited clearing of vegetation. There are no critical habitats along this corridor. This connection has a very high likelihood of approval.

PROPERTY VALUES

Questions to consider:

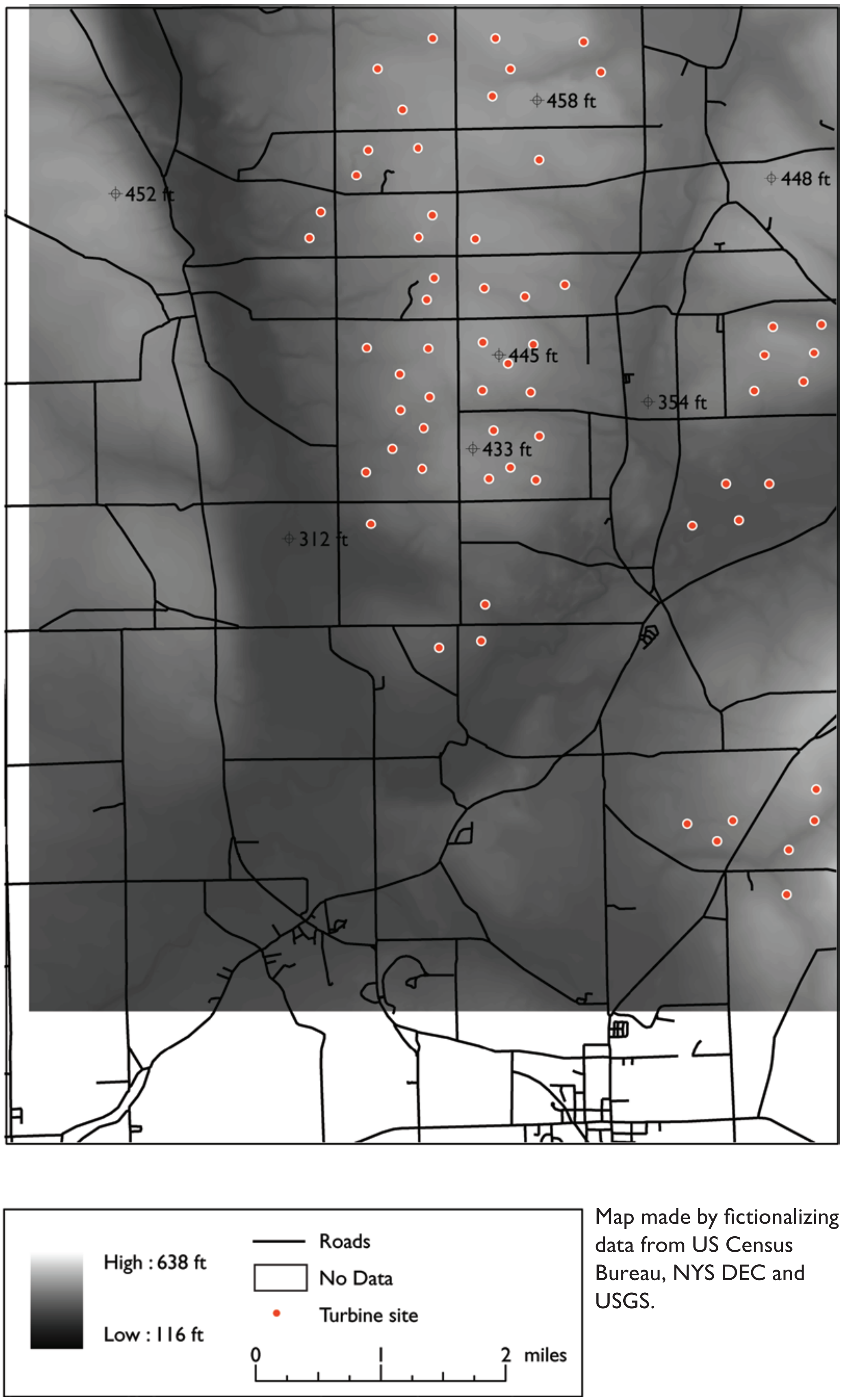
- Are property values predicted to go up or down with the installation of the wind farm?
- What are the pros and cons of the wind farm for specific groups of people such as farmers, non-farming residents, and business owners?
- Are there any significant issues that would delay or prevent the installation of the wind farm?

Impacts of the Windy Hills Wind Farm on local property values
An evaluation of area properties and existing conditions suggests that the economic impact of the wind farm will be positive. The construction and ongoing maintenance and operation of the Windy Hills Wind Farm will generate revenue for local contractors and good paying, permanent jobs. Licensing fees and other payments to the host communities will possibly facilitate investment in local infrastructure needed to attract new business to the area.

Most of the project will be situated on large tracts of agricultural acreage where turbine placement will be designed to minimize interference with ongoing farming activities, whether it be row crops or dairy stock. The rental income from the land leases will provide farmers with additional revenue streams.

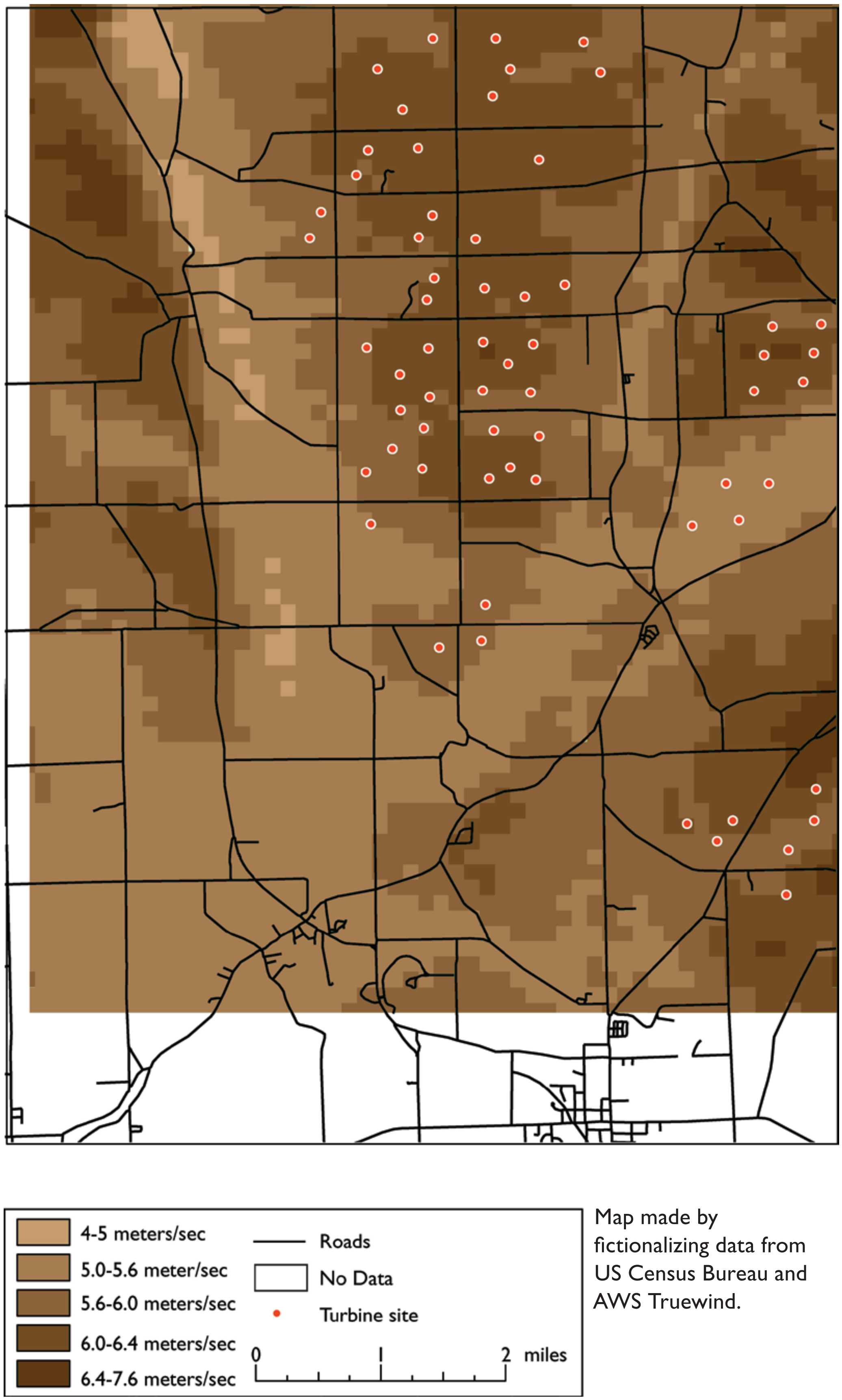
The main area of concern regarding turbine placement is the viewshed for residential properties in the vicinity. In assessing other communities where wind farms have been built, surveys found that wind farms have no demonstrable impact on property values, even near high-end or executive home development.

ELEVATION MAP



Map made by fictionalizing data from US Census Bureau, NYS DEC and USGS.

WIND SPEED MAP



Map made by fictionalizing data from US Census Bureau and AWS Truewind.

VISUAL IMPACT

Questions to consider:

- How would you describe the before and simulated after pictures?
- Do the turbines look attractive or unattractive? Do they significantly impact any "views?"
- Do you think people living in this area would be supportive of, or opposed to the turbines?

Photo of existing conditions

Photosimulation showing new wind turbines

Photo of existing conditions

Photosimulation showing new wind turbines

Photo of existing conditions

Photosimulation showing new wind turbines

COMMUNITY OPINION

Questions to consider:

- Do community members tend to support or oppose the wind farm?
- What are the pros and cons of the wind farm as identified by the community?
- Are there any issues that you think would make it very difficult for this wind farm to gain approval?

LETTERS TO THE EDITOR

Dear Editor:

I am writing in support of the proposed Windy Hills Wind Farm.

Over the past few months, a group of citizens have collected over 300 signatures in support of the wind farm. As one of those supporters, I believe that a new wind farm is the beginning of a wonderful opportunity for residents and will benefit our grandchildren.

In addition to providing a clean energy source to our state, the Windy Hills Wind Farm would provide over $700,000 annually to our town, county, school districts, and fire departments. Those farmers who lease the use of their land will also benefit, enabling them to increase the viability of their farms. The wind farm would also bring 13 full-time jobs and over 100 construction jobs. Windy Hills would be a great asset to our community.

I hope that the Board will approve this project.

Ronald Davies

Dear Editor,

I hope the Town Board will realize what a boondoggle Windy Hills is before it's too late.

The proposed panacea of green energy and jobs will forever change the face of our community. Our rolling green hills and expansive skies will be marred by enormous rotating metal blades that equal the span of a 747. As for jobs, what happens after the turbines are constructed? And where are the guarantees that local people will be hired over outside contractors? If you take a good look at Windy Hills' proposal, it just doesn't add up.

I urge the board to vote no on Windy Hills.

Debbie McGriff

WHERE DO YOU PUT A WIND FARM?

Questions to consider:

- How many turbines will the site have? How many megawatts? How many homes would the wind farm theoretically provide power to?
- How many individuals does the wind farm need to obtain leases from?
- Are there any issues that may make it easier or more difficult for the wind farm to gain approval?
- Are there local laws that will impact the wind farm?
- Will the topography make it potentially easier or more difficult to develop the wind farm? Why?

The Clean Horizons Wind Farm LLC proposes to construct a wind-powered generating facility with 46 turbines with a total capacity of 75 megawatts (MW). Each turbine has a maximum height of 375 feet. The proposed project would meet the electrical needs of over 30,000 homes. The project will employ 7–12 administrative and other personnel.

Eighty landowners own the 110 land parcels that make up the project site. The land used in the project site is predominately forested and would require clearings for the turbines and access roads.

The topography of this area is hilly, with valleys and ridges where elevations and slope increase. Located to the southeast of the windfarm is a large park that is protected from future development. The park has a number of points from which visitors can look out onto the surrounding area where the wind farm will be visible.

The proposed turbines would be adjacent to two nearby towns and would be located partially within the boundaries of one of these towns, where there is a town law related to wind farms. There are many single-family residences and commercial areas nearby. All turbines are located so that there is a distance of 1,200 feet between the center of any tower foundation and the nearest off-site residence. When it is possible, trees will be planted to minimize the visual and auditory effects of the turbines.

TOWN LAW

(9) Location of the residential structures within 1,200 feet of each proposed tower to any off-site residence within one-hundred feet shall be noted.

a. Wind turbines shall be designed to minimize the impacts of land clearing and the loss of open space areas. Land protected by conservation easements shall be avoided when feasible. The use of previously developed areas will be given priority wherever possible.

b. Wind turbines shall be located in a manner that minimizes significant negative impacts on rare animal species in the vicinity, particularly bird and bat species.

c. Wind energy conversion facilities shall be located in a manner consistent with all applicable state and Federal wetlands laws and regulations

d. Storm-water run-off and erosion control shall be managed in a manner consistent with all applicable state and Federal laws and regulations

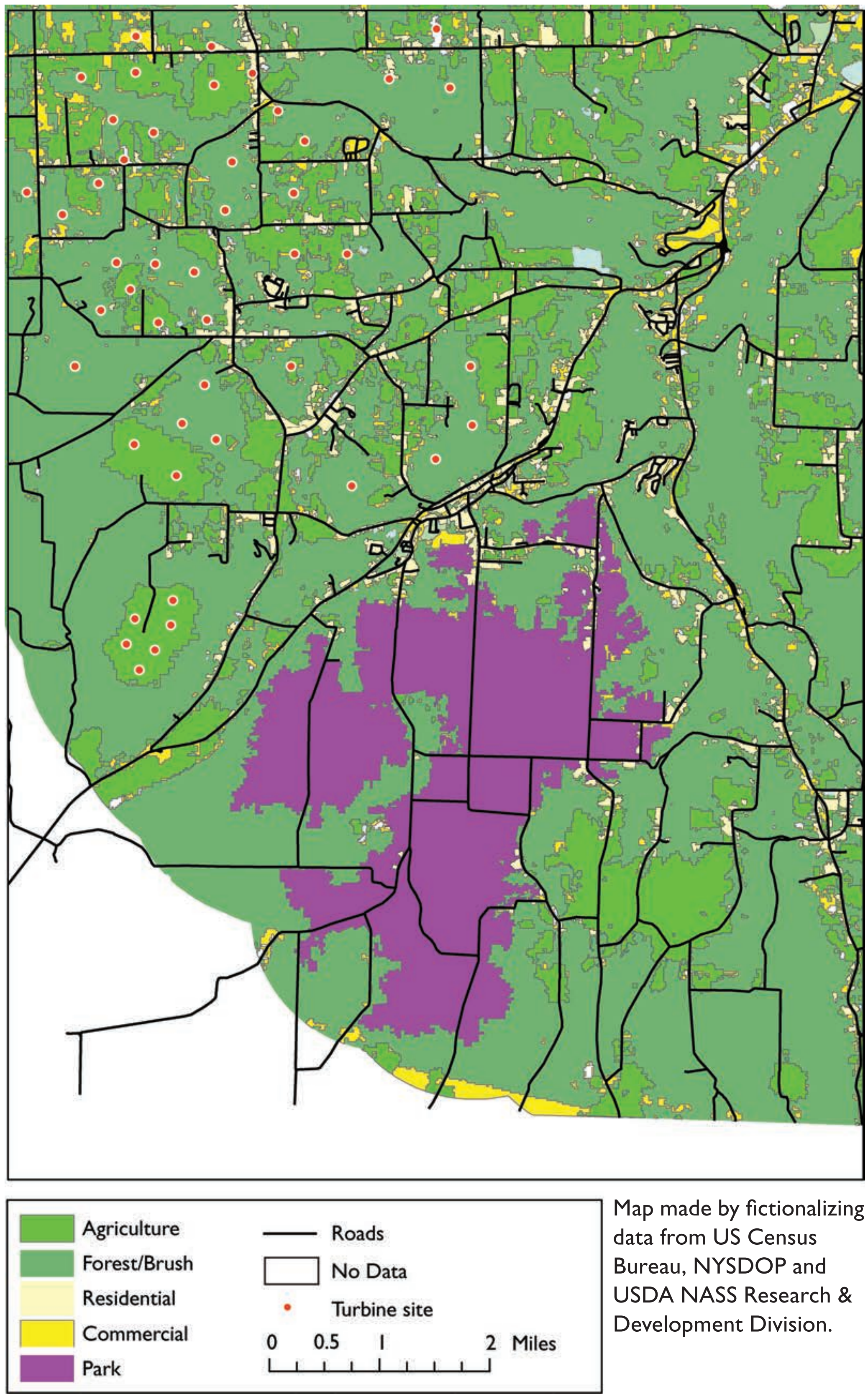
e. The maximum Total Height of any wind turbines shall be 420 feet.

(10) Turbines shall be 100 feet from state-identified wetlands. This distance may be adjusted to be greater or lesser at the discretion of the reviewing body, based on topography, land cover, land uses and other factors that influence the flight patterns of resident birds.

LAND USE MAP

Questions to consider:

- What are the 2–3 primary land uses in the wind farm site?
- Do you think these land uses will make it easier or harder to introduce turbines?
- How do you think the turbines will impact farming operations in agricultural areas?
- How do you think the turbines will impact residences in the area?



Map made by fictionalizing data from US Census Bureau, NYSDOP and USDA NASS Research & Development Division.

THREATENED OR ENDANGERED SPECIES OR HABITAT

The following is a table of species about special concern that have been sited either on or near the wind farm project site.

Questions to consider:

- Compare the table below with the table on the next page that shows which birds are present at the site. Are there any threatened or endangered birds found on or near this site?
- How many of these birds are found on the site? Should the presence of these birds be of concern in the development of the wind farm?

Table 1

SPECIES	TYPE OF SPECIES	DISTANCE FROM SITE	NY LEGAL STATUS
Ammodramus heslowii Henslow's sparrow	Bird	Within 10 miles of site	Threatened
Bartramia longicauda Upland sandpiper	Bird	Within 10 miles of site	Threatened
Podilymbus podiceps Pied-billed grebe	Bird	Within 10 miles of site	Threatened
Asio flammeus Short-eared owl	Bird	Within site boundary	Endangered
Circus cyaneus Northern harrier	Bird	Within 10 miles of site	Threatened

BIRD SPECIES OBSERVED

Questions to consider:

- Are there any threatened or endangered bird species within the project site or nearby?
- Have any of threatened or endangered species been observed at the project site during survey nights? Are these thought to live on the site, breed at the site, or migrate through the site?

Table 2: Raptors and other large birds observed in surveys at the Clean Horizons Site.

SPECIES	SPRING	FALL	TOTAL
Water birds			
Great blue heron	0	0	0
Herring gull	0	2	2
Ring-billed gull	8	3	11
Waterfowl			
Canada goose	24	0	24
Mallard	5	0	5
Raptors			
Cooper's hawk*	3	2	5
Sharp shinned hawk*	6	4	10
Red-tailed hawk	23	32	55
Red-shouldered hawk*	2	2	4
Northern harrier**	8	9	17
American kestrel	0	6	6
Turkey vulture	50	157	207
Osprey*	0	0	0
Passerines			
American crow	22	60	82
European starling	45	55	100
Red-winged blackbird	0	82	82
Blue jay	0	10	10
American goldfinch	0	11	11
American redstart	0	2	2
Tree swallow	0	5	5
Other birds			
Pileated woodpecker	1	0	1

*New York State Species of Special Concern

**New York State Threatened Status

NORTHERN HARRIERS

Northern harriers, which are considered threatened in New York, were documented in the Clean Horizons study area during both seasons of study.

One area close to a nearby lake is considered a potential breeding habitat. It is likely that many of the harriers observed were migrants or transients through the area. It is also possible, however, that harriers were breeding residents in the Clean Horizons area.

Based on the current project layout, no turbines are proposed for the potential northern harrier breeding habitat in the Clean Horizons project. No direct habitat loss impacts are expected. Northern harriers could be at risk of collision with turbines and they have been recorded as fatalities at other wind farms, primarily in the western US. Northern harrier behavior, which generally includes low level flights and very little soaring, is not likely to put them at great risk from turbines while they are on the breeding grounds.

BAT SPECIES OBSERVED

Questions to consider:

- Are any threatened or endangered bat species within the project site or nearby? Have any of these observed at the project site during survey nights?
- Of the species detected at the site, are there any that may be of special concern?

Table 3: Summary of detected bat species during summer night surveys.

COMMON NAME (*Scientific Name*)	THREATENED/ ENDANGERED?	NUMBER
Big brown bat (*Eptescus fuscus*)	No	100
Eastern red bat (*Lasiurus borealis*)	No	90
Hoary bat (*Lasiurus cinureus*)	No	65
Myotis spp. (This category includes any bat in the genus *myotis* whose species is not identified.)	One species, the *Myotis sodalis* (Indiana bat), is endangered.	72
No identification		325

Myotis sodalis (Indiana myotis)

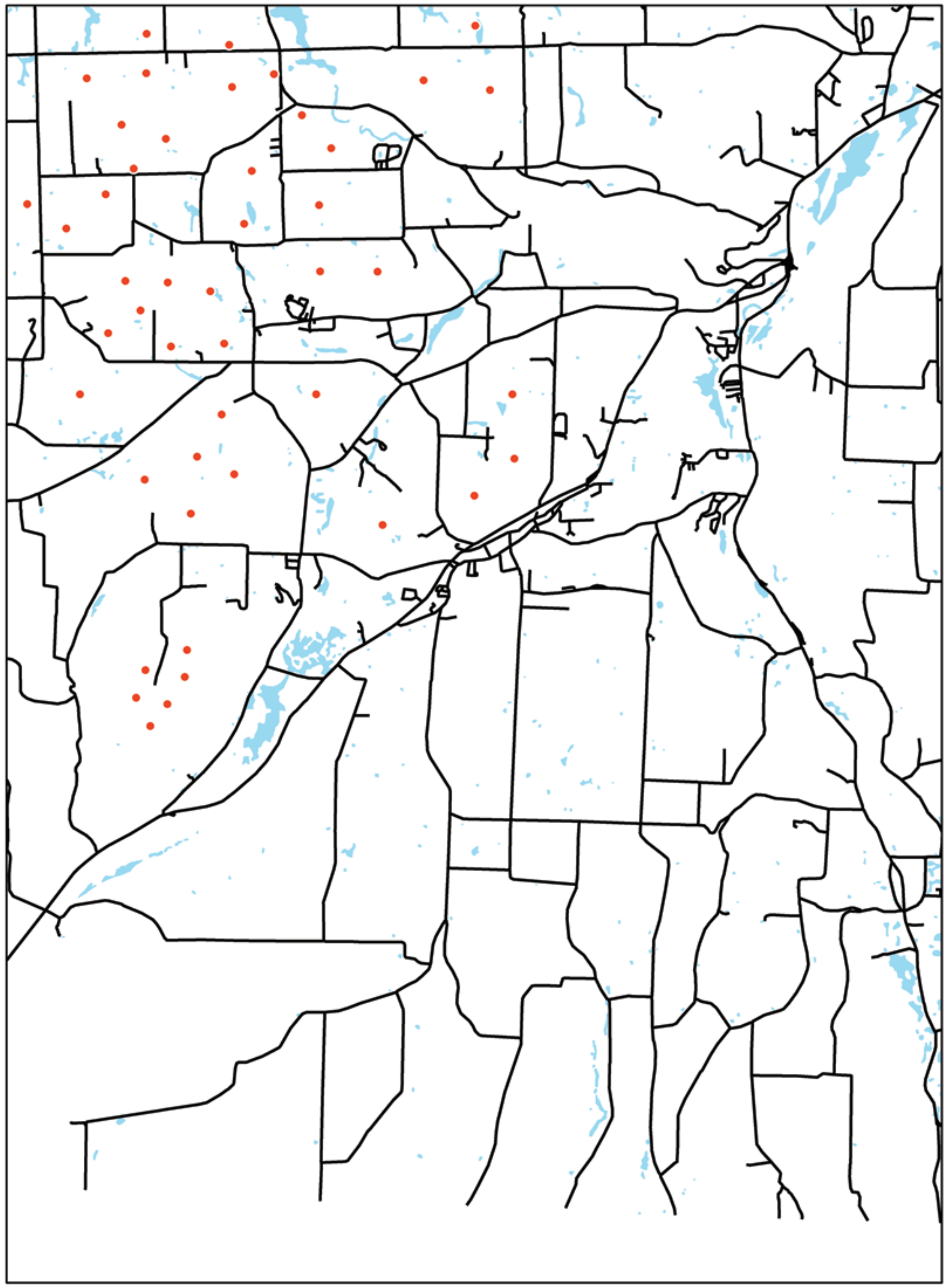
The Indiana myotis, federally identified as endangered, is a small gray bat that roosts in crevices or under the loose bark of trees during the summer. Indiana myotis hibernate in caves during the winter, the majority of them found in Indiana, Kentucky, and Missouri. While no Indiana bat fatalities have been confirmed at active wind energy facilities, other *Myotis* species (*Myotis* spp.) that exhibit similar life history characteristics and behaviors have been killed; therefore, there some risk may be associated with this species.

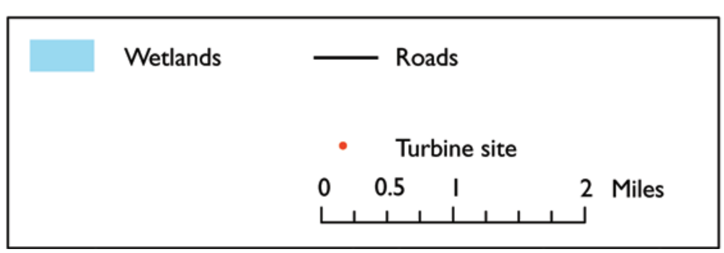
WETLANDS AND PROTECTED AREAS

Town law recommends that turbines be placed at least 100 feet from state protected wetlands. While all proposed turbines are at least 100 feet from wetlands on the site, a few turbines are within 200 feet of the wetlands and will have access roads also near the wetlands. The wetlands in this area serve as valuable habitat.

Questions to consider:

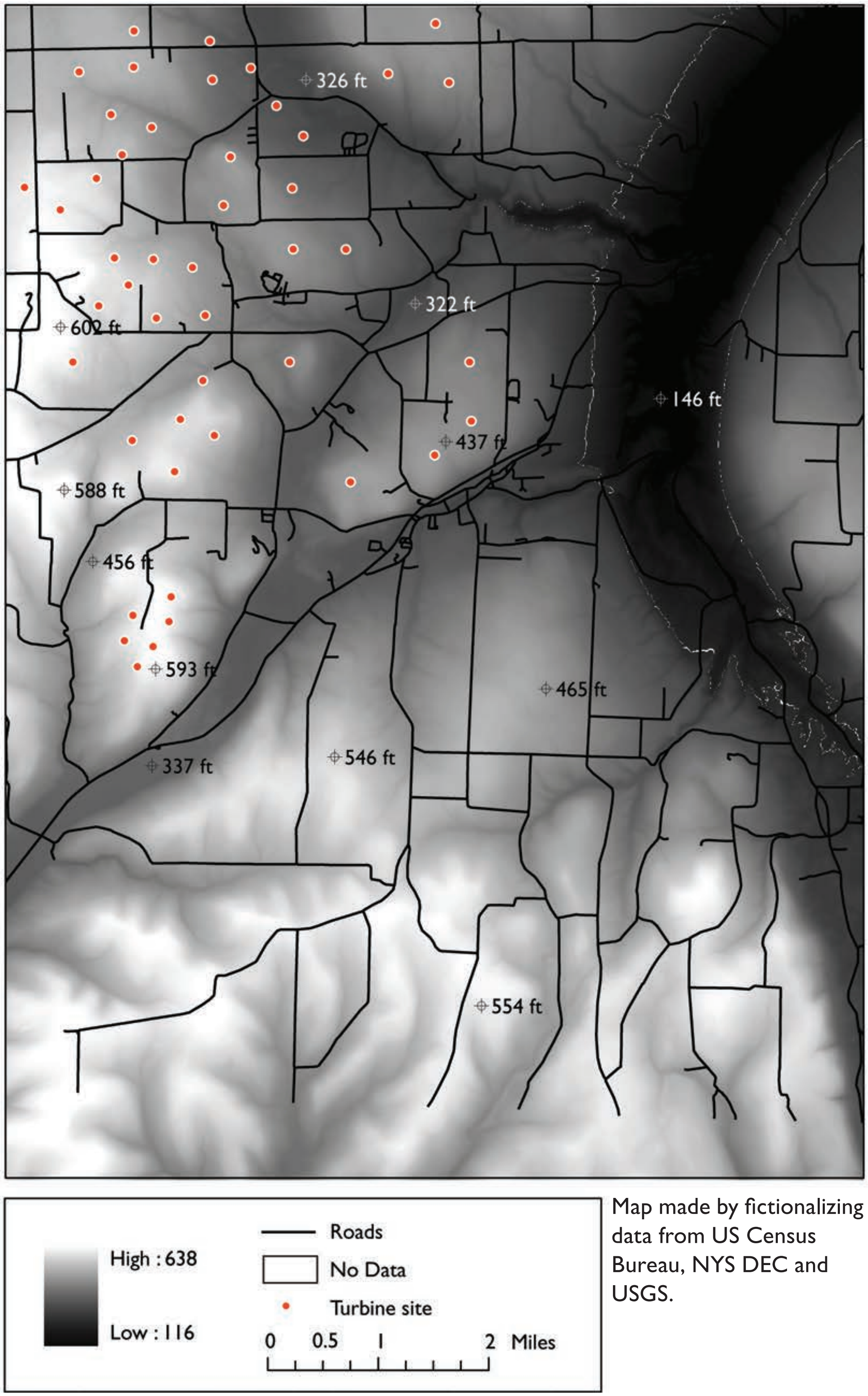
- Based on the map, how much wetland area do you believe will be impacted?
- Can you think of any way the wind farm can ensure protection of these wetlands?





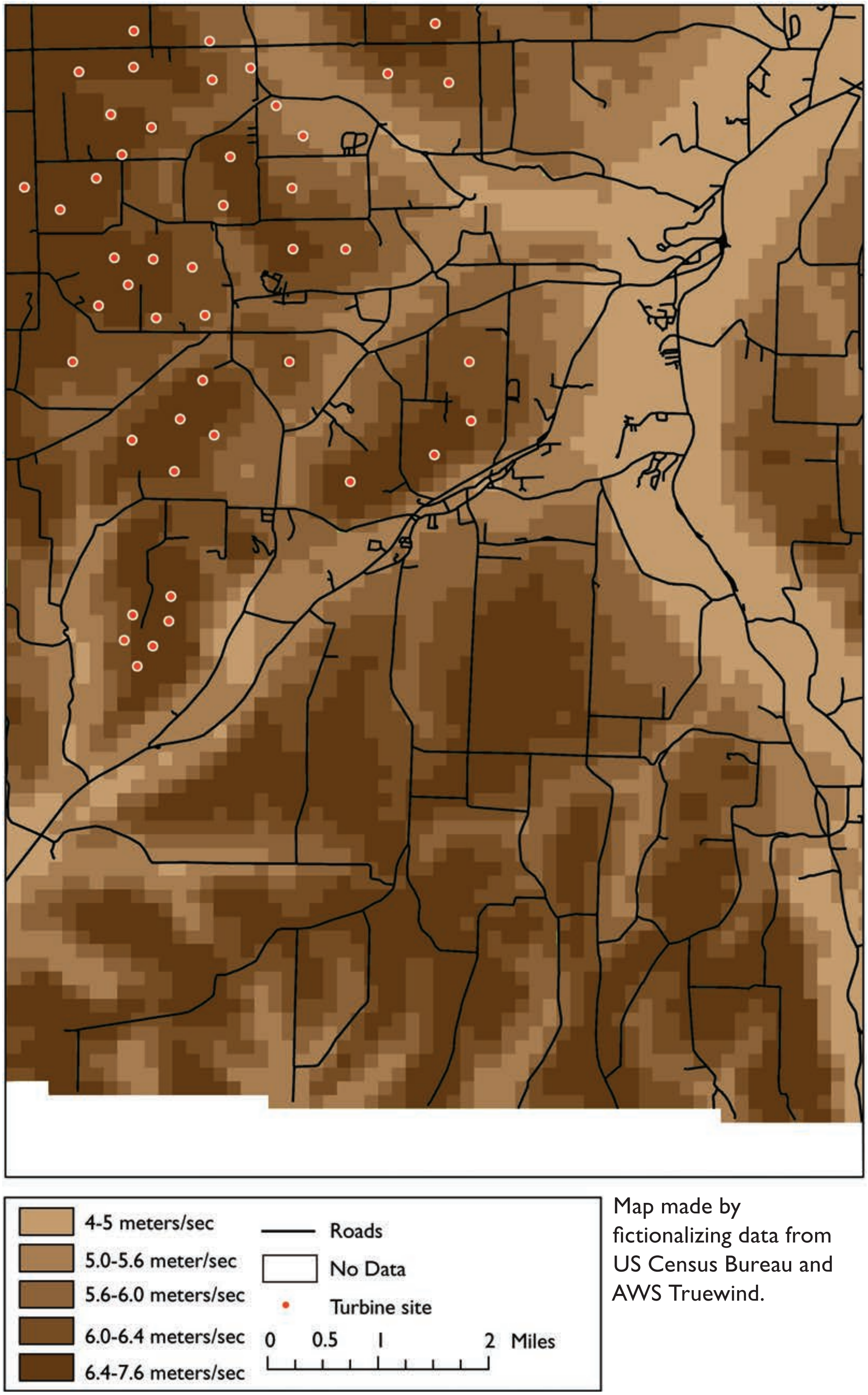
Map made by fictionalizing data from US Census Bureau and New York State Department of Environmental Conservation.

ELEVATION MAP



Map made by fictionalizing data from US Census Bureau, NYS DEC and USGS.

WIND SPEED MAP



Map made by fictionalizing data from US Census Bureau and AWS Truewind.

TRANSMISSION CONSIDERATIONS

Questions to consider:

- How difficult will it be to create a transmission connection? How much will it cost?
- Are there any issues that make the transmission connection easier or more difficult?

The closest transmission connection is 1 mile away and would cost $2 million per mile. Along the one-mile stretch is a wetland that has been identified as an important habitat. To go through the wetland would cost an additional $5 million in mitigation. To avoid the wetland would take an additional 2 miles of transmission that would be adjacent to residential areas.

PROPERTY VALUES

Questions to consider:

- Are property values predicted to go up or down with the installation of the wind farm?
- What are the pros and cons of the wind farm for specific groups of people such as farmers, non-farming residents, and business owners?
- Are there any significant issues that would delay or prevent the installation of the wind farm?

Properties that are near the Clean Horizons Wind Farm include a mix of forested land, residential and commercial areas and some small farms.

The existing homes are of lower value and do not rely on the viewshed as the more expensive, executive homes would. Because there are no executive-type homes in the area, the impact to the viewshed would have little to no impact on the property values. However, some of the wind turbines are relatively close to residential structures (1,200 feet), which may create some visual or auditory effects from the turbines and could negatively impact the values of these homes.

A large park is located less than a mile southeast of the southern edge of the wind farm. This park is seen as an important amenity because it draws visitors from a wide area. Visitors often frequent local businesses in the town while in the area. The viewshed from this park will include the wind farm. It is unknown if the wind farm will change the number of visitors to the park.

VISUAL IMPACT

Questions to consider:

- How would you describe the before and simulated after pictures?
- Do the turbines look attractive or unattractive? Do they significantly impact any "views."
- Do you think people living in this area would be supportive of, or opposed to the turbines?

Photo of existing conditions

Photosimulation showing new wind turbines

Photo of existing conditions

Photosimulation showing new wind turbines

Photo of existing conditions

Photosimulation showing new wind turbines

COMMUNITY OPINION

Questions to consider:

- Do community members tend to support or oppose the wind farm?
- What are the pros and cons of the wind farm as identified by the community?
- Are there any issues that you think would make it very difficult for this wind farm to gain approval?

LETTERS TO THE EDITOR

Wind Power May Forever Change Our Rural Community
Dear Editor:

The beauty of our rural community is rapidly being threatened by the proposed Clean Horizons Wind Farm. The heart of our community is being wrenched before our very eyes as 400 foot turbines are ready to march across our countryside.

Clean Horizons has promised our community jobs and economic incentives, but at what cost? I am gravely concerned about the impacts these turbines will have to our health, our views, and property values.

Clean Horizons recommends the turbines be set back 1,000 to 1,500 feet from residences. Will this be enough to protect residents from flickering blade shadows that can travel up to a mile? Imagine your kids playing in the backyard with giant shadows flying past. Residents in other wind communities are claiming the shadows cause dizziness and nausea. In Europe some communities are recommending setbacks of over 4,000 feet. Will we wait until our children are sick to protest?

How about the impact these towers will have on our property values? For many of us, our home and land is our main financial asset. Destroy our property values and what have we? Already, one owner lost a sale because of the proposed turbines. The town board has shown no concern for the impacts that all of us will feel as our town is transformed from rolling hills and bucolic farms to stark, whirling towers of doom.

Should we be forced to bear the health and safety impacts of these turbines for the sake of corporate profits? I think not. Join me in fighting Clean Horizons' proposal at the next town meeting.

Bertrand Phillips

Scaled-down Clean Horizons Project Addresses Resident's Concerns
Dear Editor:

The latest proposal from Clear Horizons, LLC would include significant reductions in noise, land conversion, and other issues. The project would include 46 turbines instead of the originally proposed 75, therefore, reducing the overall impact to surrounding townships.

The new proposal also significantly reduces the amount of forested areas that will need to be cleared for turbines and access roads.

Shadow flicker would also be reduced, and Clear Horizons indicates no projected situations with more than 30 hours per year at any residence. Significant reductions would also include noise, which likewise wouldn't exceed 50 decibels, meeting town requirements.

A total of 10 miles of access roads would be required, compared to the original 17 miles meaning less forested area will be disturbed. Perhaps even more important to our town is that it will bring an estimated $600,000 annually to our local economy.

I think Clear Horizons has met the residents' concerns and deserves a place in our community.

Brenda Scout

WHEN IS A WIND FARM A GOOD INVESTMENT?

LESSON 19

KEY CONCEPT

Students learn what factors impact the economics of a wind farm and compare and contrast two potential sites.

TIME REQUIRED

1–2 class periods

GRADES

6–8
9–12

SUBJECTS

Economics
Social Studies
Earth Science
Mathematics

BACKGROUND

Investors and banks decide whether or not to invest in a wind farm based on how long it takes to recoup the initial costs through revenue generated by the wind farm. This is called the payback period. Students will calculate and compare the payback period for two potential wind farm sites to determine which wind project is the better investment.

OBJECTIVES

At the end of the lesson, students will:

- be able to calculate the costs, revenue, and payback period of a wind farm
- understand how wind speed variations impact power generation and revenue

METHOD

Students will calculate the costs and potential revenue of two potential wind farm sites. Using these figures, they will determine the current payback period of each site. Students will discuss which site is a better investment and the factors that influence the payback period.

MATERIALS

- ❑ Calculator
- ❑ Student reading passages and student worksheets*
  *included with this activity

Additional Resources for every lesson can be found at http://learn.kidwind.org/windwise/. Resources include presentations, videos, extension activities, and other materials.

GETTING READY

- Provide students with a review of capital costs and revenue.
- Make copies of the worksheets.
- Teachers may review the fact sheets listed under Additional Resources for more information on wind farm economics.

ACTIVITY

Step 1: Beginning questions for students

- How much do you think a turbine costs?
- How much do you think a wind farm developer has to spend to build a wind farm?
- How many years do you think it takes to install a wind farm?
- How many years do you think it takes to pay off a wind farm?
- What are some of the costs of installing a wind farm?
- How does a wind farm generate revenue?
- Does the speed of the wind impact how much revenue a wind farm can generate?

Introduce the concept of a payback period and, if needed, give students a basic "lemonade stand" example with some general numbers to show how the payback period is calculated. The capital costs of a lemonade stand would be the stand itself, the lemon squeezer, and signage. Operational costs include the lemons, sugar, water, cups, and advertising. Revenue is generated from the sale of the lemonade. The payback period is how long it takes for the lemonade stand to earn enough revenue to pay for the capital costs.

Step 2: Calculating the Payback Period

Present students with the following scenario:

Windy Valley, LLC, is developing a wind farm that will have 60 turbines. Each turbine will have a nameplate capacity of 2.0 megawatts (MW). The company has been measuring wind speeds at two different locations and wants to determine which site will be a better investment. Your job will be to compare the payback period of the two sites.

Ask each student to complete the activity worksheets to calculate the payback period.

Step 3: Wrap up

After students have completed the worksheets, lead a class discussion. Consider some of the questions and scenarios below:

- Which wind farm is a better investment? Why?
- How much do the wind speeds impact the payback period?
- If you kept everything the same and only changed the number of turbines (e.g., from 60 to 50), would that change the payback period?
- If in 10 years, the wind speeds slowed by 5 percent, how would it affect return?
- Are you surprised by how long it takes to "pay back" the initial investment?

EXTENSION

Over 50 percent of the electricity in the US is produced with coal-fired power plants, and about 20 percent is produced from nuclear power plants. Ask students to determine how many MW an average coal and/or nuclear plant produces. Ask them to calculate how many 2 MW turbines would be necessary at each site to produce the same amount of power.

VOCABULARY

capital cost – The money spent in the years leading up to and during construction to plan and build a project.

gross revenue – The amount generated from the sale of goods or services before any costs are deducted.

nameplate capacity – The amount of power (MW) a wind turbine is capable of producing.

net revenue – The amount generated from the sale of goods or services after the costs are deducted.

operational costs – Recurring costs that are required to continue operating the project.

payback period – The time required to break even on an investment.

RELATED ACTIVITIES

- Lesson 5: Where Is It Windy?
- Lesson 18: Where Do You Put a Wind Farm?

Name______________________________________ Date________________ Class_________

WHEN IS A WIND FARM A GOOD INVESTMENT?

Windy Valley, LLC, is developing a wind farm that will have 60 turbines. Each turbine is designed to produce 2.0 megawatts (MW). This is referred to as the turbine's nameplate capacity. The company has been measuring wind speeds at two different locations and wants to determine which site will be a better investment. Your job will be to compare the payback period of the two sites.

Calculate capital costs

The average cost of installing a wind farm is $2 million per MW. Determine how many MW the wind farm will install and then calculate the total capital costs.

______________ × _________________ = ___________________
MW per turbine # turbines MW for wind farm

______________ × _________________ = ___________________
MW for wind farm cost per MW Total capital costs for wind farm

Calculate Annual Energy Production

Before a wind farm is built, wind speed is measured at each potential location for two years or more. Both of the sites have an average wind speed of 6 meters/second (m/s). However, during a 24-hour period, the wind speeds vary between sites.

For Site 1, the wind speed is 8 m/s for 6 hours a day, 6 m/s for 6 hours a day, and 5 m/s for 12 hours a day.

For Site 2, the wind speed is 12 m/s for 4 hours a day, 10 m/s for 6 hours a day, and 2.6 m/s for 14 hours a day.

1. Based only on the information above, which site do you predict will be the better investment (have the shortest payback period)?

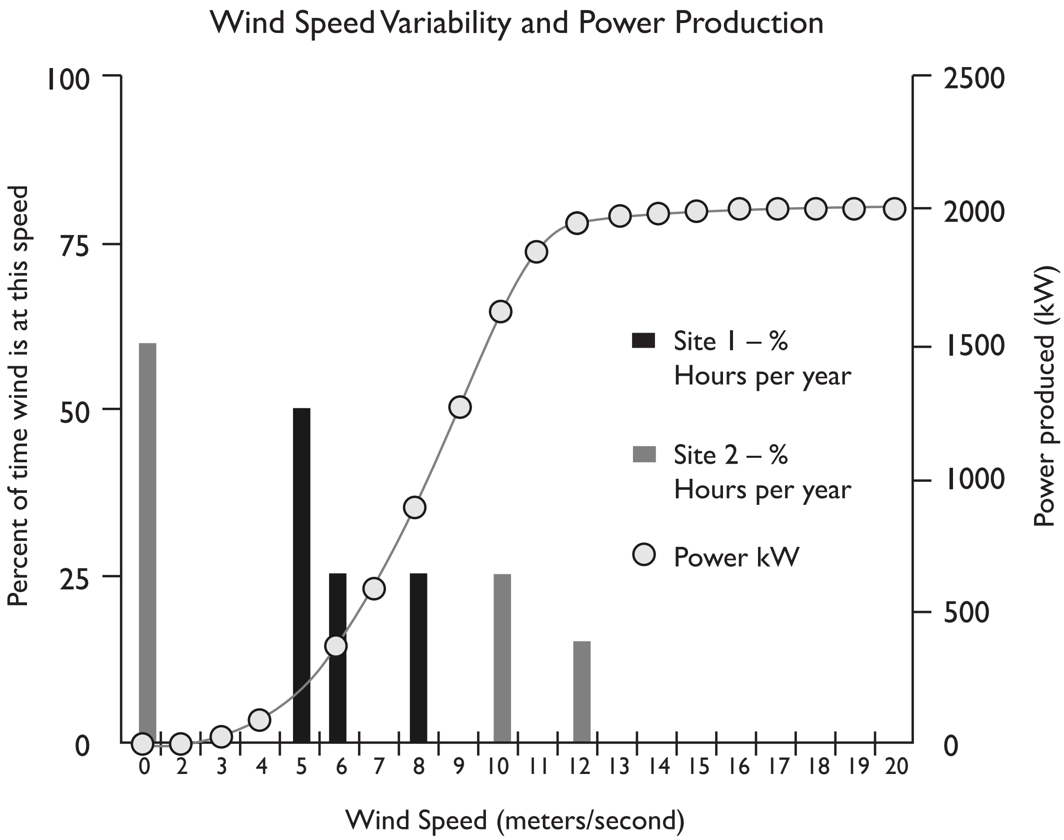
2. Using the wind speed variability and power production graph (page 369), estimate the energy production for one turbine for a day and then for a year. Calculate the annual energy production for the entire farm. Record the answers in the following tables.

Site 1

Speed	Power (kW) produced at this speed	Energy (kWh) produced in one day (How many hours a day is the wind at this speed?)	Energy (kWh) produced in one year (365 days in a year)
8 m/s	900 kW	900 × 6 = 5400 kWh	5400 × 365 = 1,971,000 kWh
6 m/s			
5 m/s			
		Total kWh produced per turbine	
		Total kWh produced for entire wind farm	

Site 2

Speed	Power (kW) produced at this speed	Energy (kWh) produced in 1 day (How many hours a day is the wind at this speed?)	Energy (kWh) produced in 1 year (365 days in a year)
12 m/s	1950 kWh	1950 × 4 = 7800 kWh	7800 × 365 = 2,847,000 kWh
10 m/s			
2.6 m/s			
		Total kWh produced per turbine	
		Total kWh produced for entire wind farm	



Calculate annual net revenue

The gross revenue is based on how much money can be made by selling energy per kWh. There are three main sources of revenue:

SOURCE	RATE
Sale of energy	\$.05 / kWh
Tax credit	\$.02 / kWh
Green credit	\$.01 / kWh

3. Use the following formula to calculate the estimated annual gross revenue from each source. Enter your answers in the table on the next page.

   Annual Gross Revenue = Annual Energy (kWh) Production × Rate

4. Each year, wind farms lose potential revenue for a variety of reasons: turbine availability, blade icing and soiling, and shutdown due to extreme temperatures or winds. Annual losses average \$50,000 per turbine. Determine the annual loss by multiplying the number of turbines in your wind farm times \$50,000/turbine. This will allow you to calculate the Annual Net Revenue. Enter your answers in the table below.

   Annual Net Revenue = Gross Annual Revenue − Annual Losses

Name______________________________________ Date________________ Class__________

Calculated annual net revenue

	Site 1	Site 2
Revenue from sale of energy		
Revenue from tax credit		
Revenue from green credit		
Gross annual revenue		
Annual losses		
Net revenue		

5. Which site will generate more revenue?

6. Calculate the payback period of the wind farm using the formula below. The payback period is measured in years.

$$\textbf{payback period (years)} = \frac{\textbf{capital costs}}{\textbf{annual net revenue}}$$

7. Enter the data from the previous questions in the summary table below.

Summary table

	Site 1	Site 2
Annual energy production for wind farm (kWh)—Question 2		
Expected net revenue—Question 4		
Expected payback period—Question 6		

8. Which site is a better investment? Does this match your prediction?

9. Both sites have the same average daily wind speed. One site, however, would produce a lot more energy and generate a lot more revenue. Describe why this is the case.

The average cost of installing a wind farm is $2 million per MW. Determine how many MW the wind farm will install and then calculate the total capital costs.

60 turbines × 2.0 MW = 120 MW

120 MW × $2 million = $240,000,000

1. Based on this information, which site do you predict will be the better investment (have the shortest payback period)?

   Student prediction

2. Using the wind speed variability and power production graph (page 369), estimate the energy production for one turbine for a day and then for a year. Calculate the Annual Energy Production for the entire farm. Record the answers in the following tables.

Site 1

	Power (kW) produced at this speed	Energy (kWh) produced in one day (How many hours a day is the wind at this speed?)	Energy (kWh) produced in one year (365 days in a year)
8 m/s	900 kW	900 × 6 = *5400 kWh*	5400 × 365 *= 1,971,000 kWh*
6 m/s	*450 kW*	*450 kW × 6 hrs/day = 2700 kWh/day*	*2700 kWh/day × 365 days/yr = 985,500 kWh/yr*
5 m/s	*200 kW*	*100 kW × 12 hrs/day = 2400 kWh/day*	*2400 kWh/day × 365 days/yr = 876,000 kWh/yr*
Total kWh produced per turbine			3,832,500 kW
Total kWh produced for entire wind farm			229,950,000 kW

Site 2

	Power (kW) produced at this speed	Energy (kWh) produced in 1 day (How many hours a day is the wind at this speed?)	Energy (kWh) produced in 1 year (365 days in a year)
12 m/s	1950 kWh	1950 × 4 = *7800 kWh*	7800 × 365 *= 2,847,000 kWh*
10 m/s	*1625 kW*	*1625 kW × 6 hrs/day = 9750 kWh/day*	*9750 kWh/day × 365 days/yr = 3,558,750 kWh/yr*
2.6 m/s	*25 kW*	*25 kW × 14 hrs/day = 350 kWh/day*	*350 kWh/day × 365 days/yr = 127,750 kWh/yr*
		Total kWh produced per turbine	6,533,500 kW
		Total kWh produced for entire wind farm	392,010,000 kW

3. & 4.

	Site 1	Site 2
Revenue from sale of energy	*$ 11,497,500*	*$ 19,600,500*
Revenue from tax credit	*$ 4,599,000*	*$ 7,840,200*
Revenue from green credit	*$ 2,299,500*	*$ 3,920,100*
Gross annual revenue	*$ 18,396,000*	*$ 31,360,800*
Annual losses	*$ 3,000,000*	*$ 3,000,000*
Net revenue	*$ 15,396,000*	*$ 28,360,800*

5. Which site will generate the most revenue?

   Site 2

6. Calculate the payback period of the wind farm using the formula below. The payback period is measured in years.

   Site 1:
   240,000,000/15,396,000 = 15.6 years
   Site 2:
   240,000,000/28,360,800 = 8.5 years

7. Enter the data from the previous questions in the summary table below.

	Site 1	Site 2
Annual Energy Production for wind farm (kWh)—Question 2	229,950,000 kW	392,010,000 kW
Expected net revenue—Question 4	$ 15,396,000	$ 28,360,800
Expected payback period—Question 6	15.6 years	8.5 years

8. Which site is a better investment? Does this match your prediction?

   Site 2 is a better investment.

9. Both sites have the same average daily wind speed. One site, however, would produce a lot more energy and generate a lot more revenue. Describe why this is the case.

   Higher wind speeds produce more power and, thus, generate greater revenue. It is advantageous to have very high wind speeds, even if they are only for short periods of time during the day. Short bursts of very high wind speeds can generate exponentially more power than slower wind speeds can during the same amount of time.

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