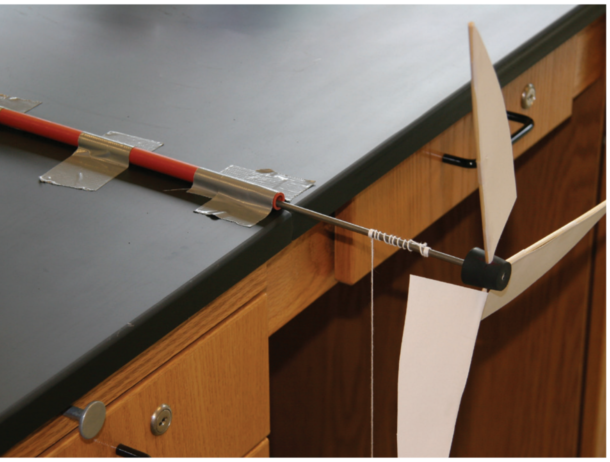
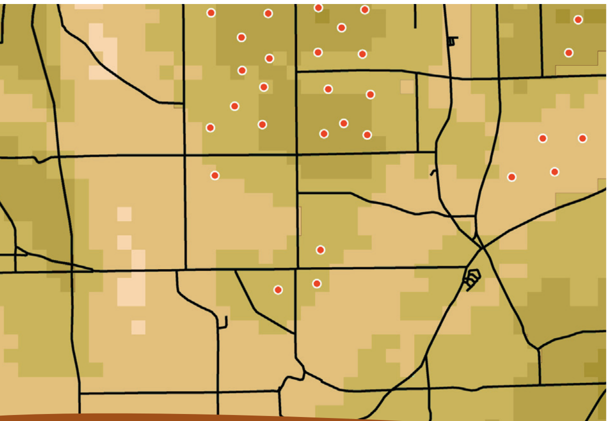
WindWise Education

Transforming the Energy of Wind into Powerful Minds





A Curriculum for Grades 6-12

windwise education

www.WindWiseEducation.org

NYSERDA

WindWise Education was developed with
funding from the New York State Energy
Research & Development Authority.

V1.0

CAN WIND POWER YOUR CLASSROOM?

LESSON 5

KEY CONCEPT

Students will 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

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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 and/or supplied data sheets)
- ❑ Computer with Internet access
- ❑ LCD projector (recommended for displaying live data sites)
- ❑ Student Worksheets*

Optional:

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

*included in this activity

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 for 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/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

Have the students look around the room and name all the things currently using electricity—lights, computers, projector, fans, clock, etc. List all of these electric devices.

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 Worksheet #1.

Difference Between Energy and Power

	ENERGY	POWER
	Quantity	**Rate**
Unit	Kilowatt-Hour (kWh)	Watt, kW, MW
Water Analogy	Gallons	Gal/Min
Car Analogy	How many gallons of gas in the tank?	Engine HP
Cost Example	12 cents/kWh	$1,500/kW
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?

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, log onto this site and type in your zip code to find current local wind speed: http://www.wunderground.com/

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?

Step 5: Analyzing Sample Wind Turbine Data
Using the sample wind turbine data sheets included in this lesson, complete Worksheet #2.

Step 6: Analyzing Live Wind Turbine Data
Log onto one of the wind turbine data websites and complete Worksheet #3.

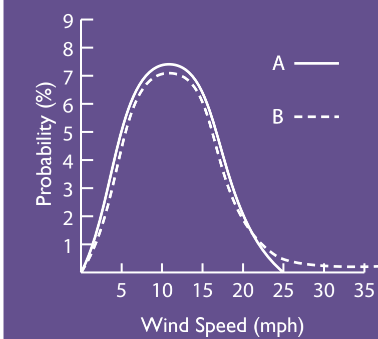
Step 7: Wrap Up
- How much electricity does your classroom draw?
- Estimate how much power your whole school might consume on average.
- Is the wind around your school adequate for a wind turbine?
- What are some ways you could use less electricity in your classroom?
- Should your school buy a wind turbine?

EXTENSION

Using Data to Understand Residential Wind Energy Economics
In many states, wind turbine owners can sell excess energy to the utility. 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



VOCABULARY

Cut-In Speed – The minimum wind speed at which a wind turbine will generate usable power; for most turbines, this is typically between 7 and 10 mph.

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.   1MWh = 1000kWh

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 measure for power, or how fast energy is used. One watt of power is equal to one ampere (a measure of electric current) moving at one volt (a measure of electrical force). One watt is equivalent to one joule of electrical energy per 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 given location.

ADDITIONAL RESOURCES

ABS ALASKAN POWER CONSUMPTION TABLE—http://www.absak.com/library/power-consumption-table —This table lists the average power consumption of many typical household appliances.

ENERGY INFORMATION ADMINISTRATION—Average Retail Price of Electricity by State—http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html —This table lists the average price of electricity for every state and by region.

ENERGY INFORMATION ADMINISTRATION—Average Monthly Electric Consumption & Cost by State—http://www.eia.doe.gov/cneaf/electricity/esr/table5.html —This table shows how much electricity is consumed each month in every state.

UNIVERSITY OF ILLINOIS—The Power Grid—http://tcip.mste.illinois.edu/applet2.php —Interactive web applet showing how the power grid works. Think like a grid system operator!

Wind Turbine Live Data Sites:

https://smartview.northernpower.com/public/medford

https://smartview.northernpower.com/public/kensington

http://windturbine.sctc.edu

http://www.mge.com/Environment/Innovative/urban.htm

http://www.solaroneveryrooftop.com/data.html

http://view2.fatspaniel.net/FST/Portal/ThirdSunSolar/indian/HostedAdminView.html

http://view2.fatspaniel.net/PV2Web/merge?&view=PV/standard/Simple&eid=155512

http://www.coe.montana.edu/wind/skystream/main.html

http://www.glsc.org/energy/flash/live_data.swf

http://www.greenbush.org/wind_turbine.cfm

http://www.ceas.wmich.edu/WindData/index.php

http://view2.fatspaniel.net/MissouriUniversity/highwaypatrol/HostedEndUserView.html

http://view2.fatspaniel.net/FST/Portal/SouthWestWindPower/siteD/HostedEndUserView.html

NY STATE STANDARDS

Intermediate Level Science–Standard 1: Analysis, Inquiry, and Design
Mathematical Analysis

Key Idea 3:
Critical thinking skills are used in the solution of mathematical problems.

Major Understandings:
M3.1 Apply mathematical knowledge to solve real-world problems and problems that arise from the investigation of mathematical ideas, using representations such as pictures, charts, and tables.

Intermediate Level Science–Standard 4: The Physical Setting
Key Idea 4:
Energy exists in many forms and when these forms change, energy is conserved.

Performance Indicator 4.1:
Describe the sources and identify the transformation of energy observed in everyday life.

Major Understandings:
4.1c Most activities in everyday life involve one form of energy being transformed into another.

Mathematics–Standard 3
Key Idea 4:
Students use mathematical modeling/multiple representation to provide a means of presenting, interpreting, communicating, and connecting mathematical information and relationships.

Major Understandings:
Students construct tables, charts, and graphs to display and analyze real-world data.

Key Idea 5:
Students use measurement in both metric and English systems to provide a major link between the abstractions of mathematics and the real world in order to describe and compare objects and data.

Major Understandings:
Students use statistical methods such as graphs, tables, and charts to interpret data.

Economics–Standard 4
Key Idea 1:
The study of economics requires an understanding of major economic

concepts and systems, the principles of economic decision making, and the interdependence of economies and economic systems throughout the world.

Major Understandings:
Students understand how people in the United States and throughout the world are both producers and consumers of goods and services.

Intermediate Level Science–Standard 4: The Physical Setting
Key Idea 4:
Energy exists in many forms and when these forms change, energy is conserved.

Performance Indicator 4.1:
Describe the sources and identify the transformation of energy observed in everyday life.

Major Understandings:
4.1c Most activities in everyday life involve one form of energy being transformed into another. For example, the chemical energy in gasoline is transformed into mechanical energy in an automobile engine. Heat energy is almost always one of the products of energy transformations.

4.1d Different forms of energy include heat, light, electrical, mechanical, sound, nuclear, and chemical. Energy is transformed in many ways.

Performance Indicator 4.4:
Observe and describe the properties of sound, light, magnetism and electricity.

4.4d Electrical energy can be produced from a variety of energy sources and can be transformed into almost any other form of energy.

4.4e Electrical circuits provide a means of transferring electrical energy.

4.4g Without direct contact, a magnet attracts certain materials and either attracts or repels other magnets. The attractive force of a magnet is greatest at its poles.

Intermediate Level – Standard 4: The Physical Setting
Key Idea 5:
Energy and matter interact through forces that result in changes in motion.

Performance Indicator 5.2:
Observe, describe and compare effects of forces on the motion of objects.

Major Understandings:
5.2b Electric currents and magnets can exert a force on each other.

5.2c Machines transfer mechanical energy from one object to another.

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://tcip.mste.illinois.edu/applet2.php. After you become familiar with the system, try the 5 challenges on the left sidebar.

Name________________________________ Date______________ Class_________

CAN WIND POWER YOUR CLASSROOM?

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

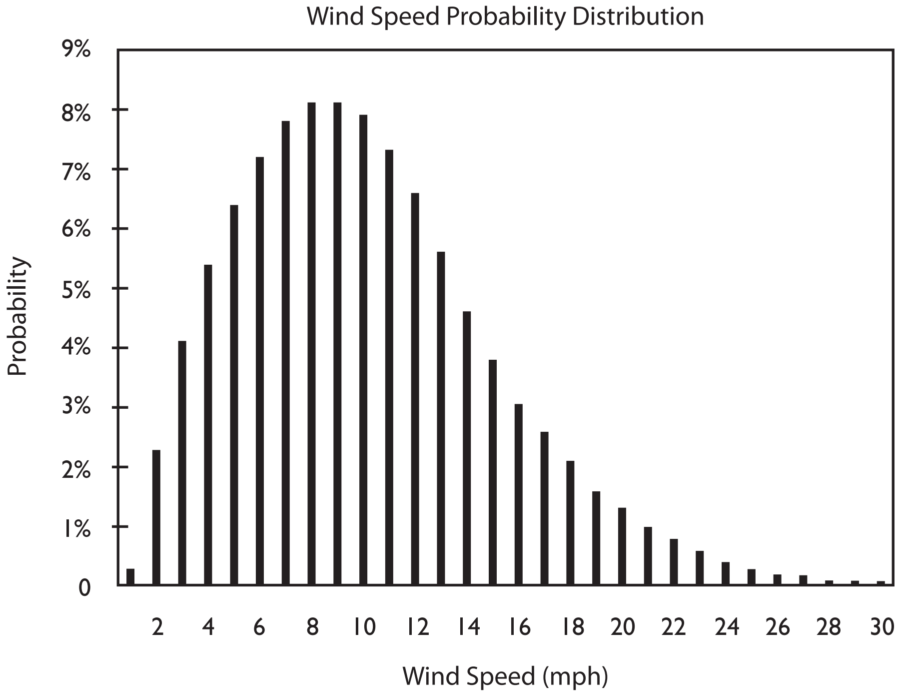
Do an Energy Audit for your classroom

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). Use this website to help you estimate: www.absak.com/library/power-consumption-table

DEVICE	WATTS
TOTAL POWER	Watts
	kilowatts (W/1000)

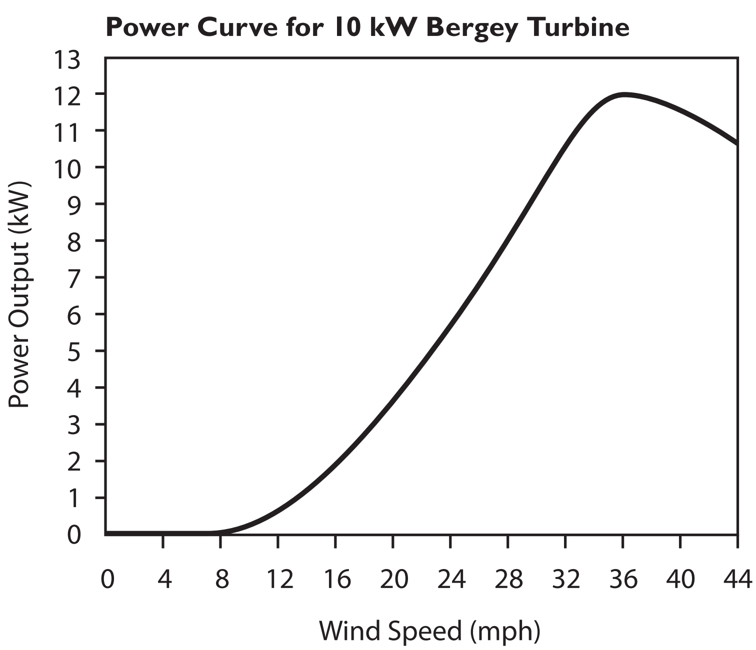
2. Look at the wind turbine power curve. Could this wind turbine make enough power for your classroom? (Remember: 1 kW = 1,000 watts) If so, how fast does the wind have to be blowing to make enough electricity for your classroom?

3. Look at the “Wind Speed Probability” graph. What percentage of the time does the wind blow at the wind speed that you answered in 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 probability 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.weather.gov) Is this 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

Find a turbine on the Internet producing live data to answer these questions.

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 the 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 (# 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 U.S. today is about 11.4 cents per kWh. The average U.S. 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. Knowing 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 U.S. 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?

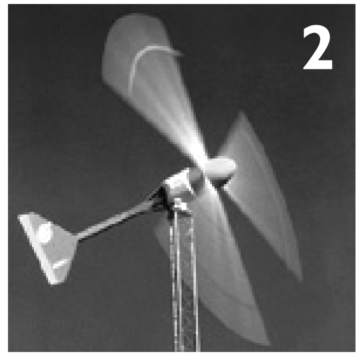
WIND TURBINE DATA SHEETS FOR WINDWISE LESSON

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" graph. What percentage of the time does the wind blow at the wind speed that you answered in Question 2? Is the wind normally faster or slower than this?

   Answers will vary. Should be between 1% and 6%. 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% of the time.

5. How fast is the wind currently blowing? (Use an anemometer or check here: www.weather.gov) 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

Find a turbine on the Internet producing live data to answer these questions.

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 (# 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 U.S. today is about 11.4 cents per kWh. The average U.S. 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. Knowing 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 U.S. 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.