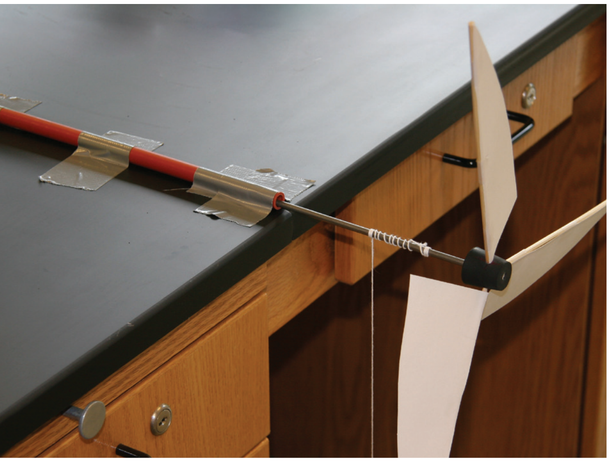
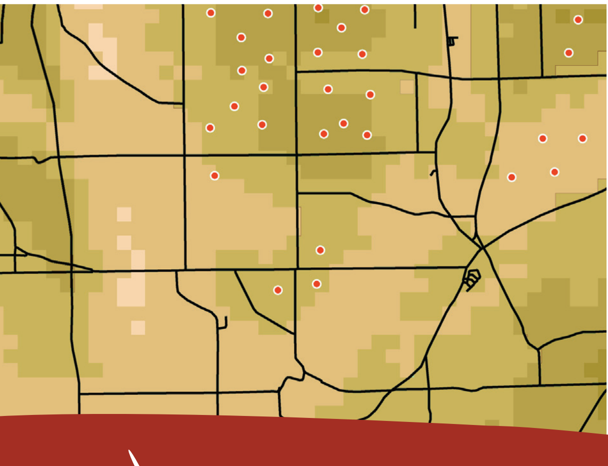
WindWise Education

Transforming the Energy of Wind into Powerful Minds





A Curriculum for Grades 6–12

2nd edition

windwise education

www.WindWiseEducation.org

NYSERDA
New York State
Energy Research and
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NREL
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WHEN IS A WIND FARM A GOOD INVESTMENT?

LESSON 18

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

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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 worksheets*
  *included with this activity

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 17: Where Do You Put a Wind Farm?

ADDITIONAL RESOURCES

The following fact sheets provide useful background information on wind farm economics.

AMERICAN WIND ENERGY ASSOCIATION—http://kwind.me/u8i—The Economics of Wind Energy fact sheet (PDF)

RENEWABLE ENERGY RESEARCH LABORATORY—http://kwind.me/r5t—The Effect of Wind Speed and Electric Rates on Wind Turbine Economics fact sheet (PDF)

RENEWABLE ENERGY RESEARCH LABORATORY—http://kwind.me/g9j—Wind Power: Capacity Factor, Intermittency, and What Happens When the Wind Doesn't Blow? fact sheet (PDF)

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.

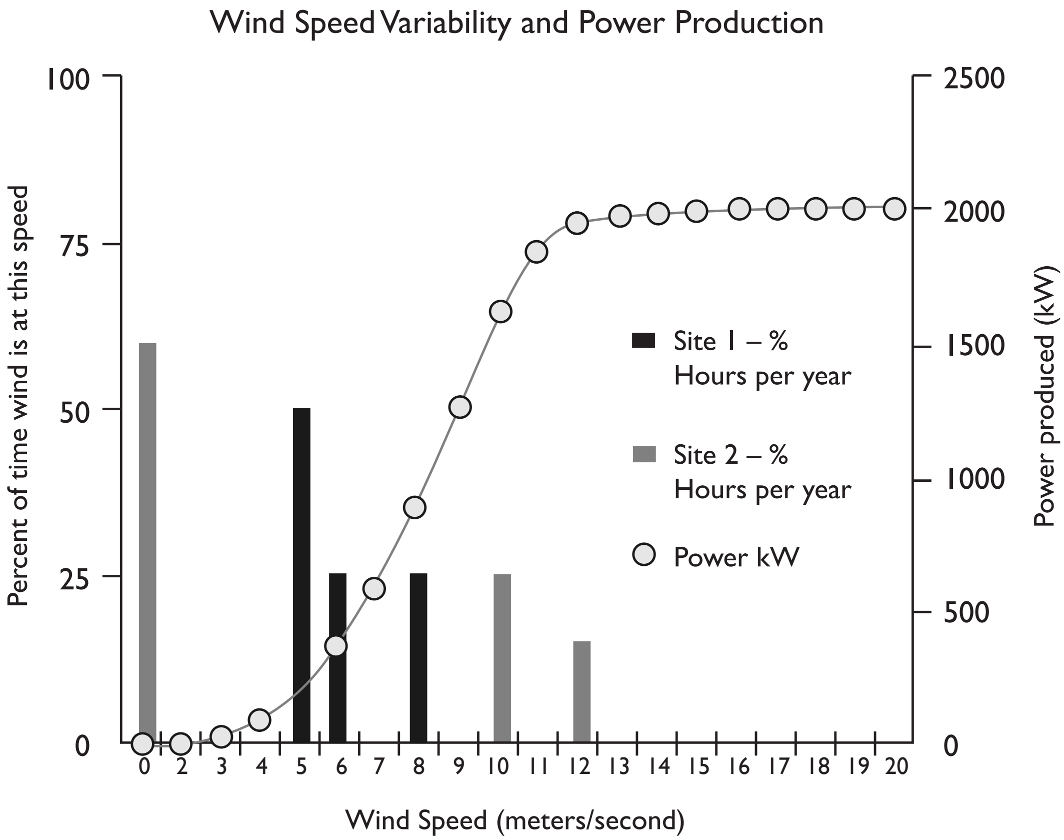
1. Based only on the information above, which site do you predict will be the better investment (have the shortest payback period)?
2. Using the wind speed variability and power production graph (page 359), estimate the energy production for one turbine for a day and then for a year. Calculate the annual 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 359), 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.