Wind turbines of the Southwest Mesa Project in Texas
This project has a total of 107 units producing 74.9 MW

Siting a Wind Farm

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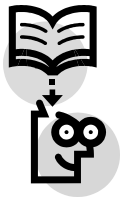
Lesson Zap! - Wind Farm Siting



Background

The goal of this lesson is for students to pick the site for a wind farm in Massachusetts. Students will examine and synthesize a variety of variables related to four different sites and then select one of these site for the development of the wind farm. No site is perfect, so students will need to make an argument as to why they chose their location. Hopefully they will learn more about the complexities that arise when making decisions related to power generation.

Objectives:

Students will learn:

- How to analyze and interpret maps
- How to synthesize data from a variety of sources and develop
- The major variables considered when siting a large wind farm

Suggested Level

High School

Time Required

2-3 Class Periods

Materials Required

Download Packets for 4 Proposed Sites in Massachusetts
Student Analysis Sheet
Small colored dot stickers
Readings & Materials from Resource Websites (Optional)

Doing the Activity

Preparation

You will need to download and print site packets for each location. These packets include maps, data and descriptions of the proposed locations for a large scale wind farm (Provincetown, Princeton, Florida and Somerville).

It is recommended that you print these documents in color as they include a great deal of information that is hard to decipher in black and white. You should make a duplicate map of the aerial photo or one of the easier to read maps. On this map students can draw dots or place small round adhesives to show where they are going to place their 10 turbines. Another option is to laminate the sheets in each packet so that students can use overhead markers or stickers to document where they are planning to develop their wind farm.

One thing you will need to help your student understand is that the maps are showing different "layers" of data for the same location. To get a better understanding of what is going on they will need to orient them correctly. You may need to help them understand this. One way to help would be to print these maps on overhead paper so students could lay them on top of one another to compare and synthesize a variety of data sets simultaneously.

This is what wind farm developers do digitally on computers using GIS software to help them select locations for wind farms more quickly.

Each packet includes:

- Description of the Locale
- Wind Speed Maps (30m, 50m, 100m)
- Surface Roughness
- Wind Rose
- Topography Map
- Local Land Use
- Aerial Photo
- Pictures of Selected Areas in the Area

Each of these maps provides a piece of the puzzle to selecting the "best" location for the wind farm. Some variables are more important than others but they will all have bearing on where the farm is sited.

To make it easier on students you might have a small group, say 2-4 students, analyze one location and make an argument for the best spot within that locale. This means that they will only have to analyze one packet and that will take less time an be much easier.

You could have them examine all the locations and then choose where to put the wind farm. But then each group will have to analyze a great deal of data from four different sites which can be daunting.

Map & Data Descriptions

Description of the Locale

The short descriptions are designed to give you a feel of the suggested location. Citizens of the local town can block the construction of a wind farm if they are opposed to it. Steps will have to be taken to be sure as many people as possible will support your plans. The locations we have selected have all had wind farms proposed so you may be able to find newspaper articles to help you better understand how the community is thinking about the construction of a wind farm.

Wind Speed Maps (30m, 50m, 100m)

As the power we can extract from the wind heavily relies on wind velocity it is important to find a site that has strong winds that occur most of the time so we can efficiently produce the most electricity possible

Surface Roughness

The surface over which the wind blows will affect its speed. Rough surfaces, such as areas with trees and buildings, produce more friction and turbulence than smooth surfaces such as lakes or cropland. The increased friction means the wind speeds near the ground are also reduced.

Wind Rose & Topography Maps

A diagram showing the distribution of wind direction and speed at a location over time. Ideally you would like to place wind farms in lines perpendicular to oncoming winds. Turbines that "shadow" one another from oncoming winds will creating turbulence and reduce your output.

Local Land Use & Aerial Photo

Townspeople will not want to see existing structures destroyed and turbines cannot be closer than 500 feet from existing houses/structures. Open areas also tend to have higher winds than areas with many surrounding trees or tall structures.

Pictures of Selected Areas in the Area

The pictures are included to show you what the area looks like from a variety of vantage points. One major issues in siting wind farms is will they be visible from area of the town are historic or scenic.

Massachusetts Major Transmission Lines

Building high-voltage lines is costly and very unpopular with local populations. Placing wind farms next to high voltage transmission lines allow you to get your power onto the grid more easily and will reduce your over all installation costs.

Class Time

You will need to introduce the problem to the students. The more you turn this into a scenario the more interested the students will be. The other great thing is that there is no right answer. All of the locations have good things and bad things about them. They need to select a spot and then support it with the data that they have.

This lesson is nice way to show students the complexity of siting large projects. Whether it is related to energy or some other development that will affect the local the environment.

You should give students a copy if the **Maps & Data Descriptions** and go over them with the students. They need to have a decent understanding of the variables involved with siting a wind farm to evaluate and synthesize all of the data that you give to them. Kidwind also has provided a basic PowerPoint show to help you present this data to the students. You can down load this at www.kidwind.org.

The student handout will guide them through the process of deciding where to put their wind farm. Doing some additional research on the web will also help them have a better understanding as well.

After you have given them some background on how to interpret the maps paint them a picture. We provide one below and feel free to embellish.

> *A large wind developer is interested in building a wind farm in Massachusetts. They are looking to build a 25 MW farm which will have 10 2.5MW turbines. They have a few locations in mind. Provincetown, Princeton, Florida and Somerville. As siting analysts we would like you to examine the data we have collected (and add more if you like from the web or other sources) and pick the best location for our wind farm. As there is a great deal of data we would like each group to select a site and make the best case they can for a particular place on that site.*
>
> *In a few days we would like you present your case to the class for the site you have selected in your locale.*

Once again you want to stress to your students that each site has good and bad. They need to find the best arguments for their site as possible. They should also be aware of any problems that the site may have as they may need to answer complaints from local people or competing sites.

Give students 1-2 class periods to analyze the data and fill out their sheets. Once you think they are getting close to done….tell them to be prepared to present to

the class. Students can present using pen and paper, chalk boards or technology. Persuasive presenting is an important skill to learn and tell the students they are looking to convince their peers that their site is really the best.

Additional Maps/Data:

The packet for each location contains a decent amount of data to get started. If your students want to do more research that is fine but you will have to give them more time. Other ideas for analysis include:

Bird/Bat Migration Pathways or Endangered Species

One major concern with wind farms is impacts to flora and fauna. Birds and bats that migrate through the area may come in contact with a proposed wind farm. Wind developers often spend years documenting the species that move through the area to get a better idea of what these impacts might be.

Students can do research on the web related to bird migrations to see if there is any data for their site.

Local Perceptions of Wind Energy in the Communities

Some of the communities used in these lesson plan have had wind farms proposed for their region. This means that local newspapers will have articles on the subject. A little searching can find these articles and give your students a better understanding of how the community feels about this development.

USGS Topographic Maps & Aerial Imagery

We have included some basic topographic maps and aerial photos. You can head to this great USGS website (http://nationalmap.gov/gio/viewonline.html) and find lots of other sites to get more detailed data. Some great sites include http://terraserver-usa.com/ & http://www.topozone.com.

With these maps students can produce much more detailed imagery on the exact location of their farm. One way to use this data is for students to first narrow their site down on the large maps and then do a more detailed study using these resources.

Additional Resources

Additional resources for this lesson can be found on the KidWind website.
http://www.kidwind.org/materials/Lessons/siting/SitingWind.html

Map Resources

http://www.topozone.com/
http://maps.google.com
http://terraserver.microsoft.com/

http://www.bp.com/sectiongenericarticle.do?categoryId=9000089&contentId=7004093

This is a link to BP Wind Developer Software for Kids. It is a neat game which simplifies wind siting quite a bit, but can give students a quick idea of what is going on.

http://www.web-and-flow.com/members/polson/webquest/webquest.htm

Neat webquest about siting wind farms offshore. Lots of good questions and links. Plenty for students to think about when siting a wind farm.

Please keep in mind that sites below promoting and questioning wind farm development have an agenda. Read both side of the issue and then try to figure out who you believe. Some of the data on these site can be misleading or incorrect.

Promoting/Researching Wind Farm Development

http://www.windustry.com/
http://www.eere.energy.gov/windandhydro/windpoweringamerica/
http://windeis.anl.gov/guide/index.cfm
http://www.ceere.org/rerl/

Questioning Wind Farm Development

http://www.windwatch.org/
http://www.protecttheflinthills.org/
http://www.wvmcre.org/
http://www.saveoursound.org/home.aspx
http://www.windcows.com/
http://www.saveupstateny.org/
http://www.vawind.org

Wind Farm Developers

http://www.endlessenergy.com/
http://www.noblepower.com/
http://www.windpower.com/
http://www.horizonwind.com/home2.asp
http://www.globalwinds.com/

Wind Farm Analysis Worksheet **Team Name _____**

This sheet is to be completed after you have done your analysis and selected the "best" on your map. Make sure use all of your maps to make a selection and remember you may have to make compromises. Sites rarely have ideal situations for all parameters.

Describe where are you planning to site the 10 wind turbines in your region? Please place your 10 dots on the student map so we can see where these will be located.

Wind Speed & Direction Maps

Based your analysis where do the highest wind speeds tend to be located? (On hills, near shore, in valleys)?

What is the average wind speed for the location of your farm? _____

Did you site your farm in the area with the highest wind speeds? If not, what was the problem with siting the wind farm there?

Why do we want to site our wind farm in the areas with the highest wind speed?

From which direction does the wind come from most of the time at your site?

Are your turbines aligned so that they will not "shadow" one another from the primary wind direction?

Surface Roughness
For your primary location what is the surface roughness?

What does this number tell you about the wind in your location? Why can this be a problem?

Land Use and Aerial Photo Maps
What types of land use are near your proposed wind farm?

On the aerial photo maps can you see any signs of houses or other structure nearby?

Is your farm located near a major electrical transmission line? Can you tell?

How you made your decision
What compromises did you have to make when siting your wind farm?

What was the biggest challenging in siting your farm?

What are some other map resources that would have been helpful in making your decision?

Did you have any alternative locations in mind? If so mark them on your map and describe why you chose this one.

Where problems do you think you will face when siting this wind farm?

Power in the Wind — A simple look

If a large truck or a 250lb linebacker was moving towards you at a high rate of speed you would move out of the way right?

Why do you move? You move because in your mind you know that this moving object has a great deal of ENERGY as a result of its **mass** and its **motion** and you do not want to be on the receiving end of that energy.

Just as those large moving objects have energy so does the wind. Wind is the movement of air from one place on earth to another. That's the motion part.

What is air though? Air is a mixture of gas molecules. It turns out that if you get lots of them (and I mean lots of them) together in a gang and they start moving pretty fast they can definitely give you, a sailboat or a windmill a serious push. Just think about hurricanes, tornadoes or a very windy day!

Why aren't we scared of light winds while we stay inside during a hurricane or wind storm? The velocity of those gangs of gas molecules have a dramatic impact on whether or not we will be able to stay standing on our feet. In fact, in just a 30 mph gust you can feel those gas molecules pushing you around.

Humans have been taking advantage of the energy in the wind for ages. Sailboats, ancient wind mills and their newer cousins the electrical wind turbines, have all captured the energy in the wind with varying degrees of effectiveness. What they all do is use a device such as a sail, blade or fabric to "catch" the wind. Sailboats use energy to propel them through the water. Wind mills use this energy to turn a rod or shaft.

A simple equation for the ***Power in the Wind*** is described below. This is instantaneous and does not take time generating power into consideration.

$$P = 1/2\ \rho\ \pi\ r^2\ V^3$$

ρ = Density of the Air
r = Radius of your swept area
V = Wind Velocity

From this formula you can see that the size of your turbine and the velocity of the wind are very strong drivers when it comes to power production. If we increase the velocity of the wind or the area of our blades we increase power output. The density of the air has some impact as well. Cold air is more dense than warm air so you can produce more energy in colder climates (as long as the air is not too thin!).

You could calculate the peak power production of your wind turbine using this equation. It will be way off as it leaves out a number of variables that impact the actual power output of your turbine. This includes things like how well your blades transform the energy in the wind and the efficiency and type of generator that you are using. It might be fun to calculate the hypothetical and compare it to how much you are producing and generate some efficiency numbers. Be prepared to be shocked at how low your efficiency is.

We recommend you check out the Kidwind website for more links that explore this equation and its variants in more complexity.