Scale Models and Wind Turbines

Grades: 5-8, 9-12

Topics: Wind Energy

Owner: Kidwind Project

This educational material is brought to you by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy.

Visual simulations of a wind turbine installations compared to what they actually look like in real life. These are computer generated scale models similar to what we will can do with physical scale models.
Photos from http://www.capewind.org

Scale Models & Wind Turbines

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The production of the kits and other materials related to wind energy have been generously supported by these agencies.

We would like to thank the *Wright Center for Science Education* at Tufts University for giving us the time and space to develop a nugget of an idea into something that has proven to be useful to hundreds of teachers.

We would also like to thank Trudy Forsyth at *National Wind Technology Center* and Richard Michaud at the *Boston Office of the Department of Energy* for having the vision and foresight to help to keep the Kidwind Project going! Lastly we would like to thank all the teachers for their keen insights and feedback on making these wind turbine kits and materials first rate!

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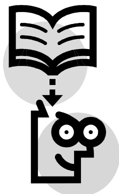
Lesson Zap! - Scale Model Wind Turbines



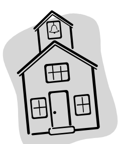
Background

As wind turbines and wind farms become larger and larger to take advantage of the economies of scale and increased wind speeds at higher altitudes, their impact in the locales where they are sited becomes more dramatic. One place this is especially contentious is the offshore environment of the Northeast. This lesson explores scale models and issues surrounding models and their accuracy when developing a large wind farm.

Objectives:

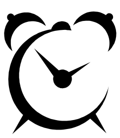
Students will learn:

- How to determine scale
- Importance of scale models
- One method used to determine the visual impact of wind turbines



Suggested Level

Middle & High School



Time Required

1-2 Class Periods

Materials Required

- 5-10 Model Scale Turbines (For this lesson we are using a train set scale model sold by Walthers H/O)
- Cardboard green blue and brown paint
- Meter Sticks
- 100m Tape Measure (can make measuring easier)
- Images of Turbines
- Readings about Cape Wind and other offshore and onshore siting debates for wind farms
- Student Worksheet
- A number of scale model items: Ken, Barbie or other dolls of varying size, model airplanes, matchbox cars and model cars of maps at different scale

Doing the Activity

Preparation

The day before the lesson have the students read a few articles related to offshore or onshore wind energy development—a few links to articles are found in the resources section and on the KidWind Website. These should be from both sides of the issue to give students a balanced perspective about wind farm development.

The day of class distribute your model turbines around the classroom so that the kids can look at them. Keep the meter sticks and the handouts close by.

If you think that students can work through the math in one period you might want to have the scale model area set up. It can help to have an area demarcated for land and ocean to orient the students.

Class Time

Introduction

If students were able to read some of the articles you can ask the questions about what they read to get the ball rolling.

Some possibilities…

- What is the controversy concerning some wind farms?
- Why are some people angry about their construction?
- How do you feel about this?
- What is a viewshed?
- How could we get a better idea of what a proposed wind farm might look like?
- Are there other man made things in the world that impose on our landscape?
- What are some of the negative impacts of wind turbines?
- What are some positive impacts of wind turbines?

You can let this go on for 5-10 minutes. This can be pretty open as you are just trying to assess how well they read the article and how much they are bringing to the class.

Working with Scale Turbines

One way we can get a better idea of what a large wind farm will look like is to build a scale model. What is a scale model? Give students a few minutes to describe. Push and probe them to think about what this really means.

You are bound to get lots of answers, but listen for ones that link up an idea that these are miniature versions of real things **that are in correct proportion**. While

> **Note:** Teaching kids about scale is very challenging. You might ask them if they have done fractions/ratios before you begin a lesson like this.
>
> Doing conversions and ratios is also very challenging for middle school students so be careful. It is always a good idea to talk to the math teacher before you start a lesson like this or else it can go very, very badly!

kids will not use these words but look for descriptions that have this general meaning. Try to make sure that students understand that there is a mathematical relationship between the model and object that exists in real life. These miniaturizations are meant to exactly mimic the real thing just in smaller size.

Some things they may talk about during the discussion:

- Models Airplanes/Cars many are built at ¼, 1/8, 1/25 scale.
- Scale Maps
- Matchbox Cars

After some discussion many will say they get the idea. In theory they might and will nod that they understand. Some probably do, but once you try the math things will get challenging, believe me I have been there!

Determining Scale
Let's practice determining scale. Here is where the Ken doll, the Matchbox cars, the airplanes or the maps can come in handy as examples. It is also helpful to have the same item (car, map, doll) in different sizes so you can show them how the scale changes as the size of the model changes.

Ken Doll Example
We can determine the scale of something if we know the size of the model and the size of the original.

We'll practice using a couple of dolls and the presenter.

Let's determine the scale between doll and the presenter. Have a student measure the doll and you in centimeters.

Ken/Barbie Doll	**Height ~ 25 cm**
Teacher	**Height ~ 170 cm**

Let's pretend that the doll is a scale model of the teacher. What is the ratio or the scale between the ken doll and the teacher? Here's where we get to the math so go SLOW!!

Ken Doll	**25cm**
Teacher	**170cm**

That is the scale of the Doll/Presenter model…but it is hard to understand. Why?

When we talk about scale we like to get the top number to be a one (refer to the scales on maps) The students will ask you why? Just tell them it makes our life easier when comparing things of different scale.

To get a one on the top we divide the top number by itself. But to keep everything equal we also have to divide the bottom number by the top number.

> **What does ¼ scale mean?**
>
> Well to keep it simple for students you might tell them that this means 1" on the model equals 4" in real life. Or 1 foot on the model equals 4 feet in real life. The units really don't matter it's the relationship that is key.
>
> Depending on the size of the model the scale will change. A 1/8 scale model will be much smaller than a ½ scale model. This is because on 1/8 scale model 1" on the model is equal to 8" in real life.

Ken Doll	**25/25**	**=**	**1**
Presenter	**170/25**	**=**	**6.8**

So the scale of this model is about 1/7. For every 1 cm on the doll it is 7 cm on the teacher.

Repeat this for a doll that it is of smaller size say 10-12cm tall. If done correctly then the scale should come out to around 1/15. This helps them see in a hands on fashion how the scale changes when you change the size of the model.

For more practice you can have them compare some model cars, planes, maps.

Scale Model Wind Farm

Before you start this part of the activity make sure you have a place where the students can set up their model wind farm. A long hallway works well, or a gym, auditorium. If the weather is nice a field works great!

Now that you are experts in scale models we need to make a scale model of an offshore wind farm like Cape Wind or one of the other wind farms you have read about. The model turbines we are going to use are sitting at the lab tables.

These windmills are scale models of the larger ones that really exist in real life they are in correct proportion to those really big ones (If may be helpful here to show them some PowerPoint images or pictures of real turbines around the world). Actual documentation from a Vestas, GE or Enercon wind turbine can be interesting as well so they can see the specifications for a real one.

There are some things we need to figure out before we can build a scale model and determine the scale. Do you remember what were they? Hopefully you can get a couple to say the **height of the model turbine** and the **height of an actual turbine**. Once we have those we can determine the scale and start building a scale model of the wind farm.

Let the Try the Worksheets

At this point let the students start working on the worksheet to determine the scale. Some kids will do this very fast and others will struggle. It sometimes helps to match these kids together. Depending on how much math they have had converting to get the same units for the model and the real live turbine can be very, very difficult. You can give them the tower in cm if it makes your life easier.

Give them 5-10 minutes to work on the first side of the sheet and then bring them all together. Compare what they have calculated and if it matches what you got. For groups that have incorrect answers have them come up and show what they did. Others surely made the same mistake and it is good practice.

When you feel good about their understanding of this topic take them out to where the scale model will be constructed. It is useful to have some brown construction paper or painted cardboard on the ground to signify shore. You can put some blue to show the ocean and have a sky backdrop for a dramatic effect. Show them where the shore and the ocean are located, and tell them that we need to find out where to put the turbines in this model. Do not give them any idea where the models will be placed. You might even ask them to hazard a guess about where they might be placed without doing the calculations. Have them return to their seats and finish the calculations.

These calculations will be very tricky for middle school students. If they are having trouble try working through them on the board together and then let them try to figure out how many strides they must take to put it in the right place.

Once they have placed the model turbines make sure they lay down on "shore" to see what they look like. Also have them draw a picture to get an idea of how "small" they are on the horizon.

Follow Up

One of the major conflicts with large offshore wind farms in US today is people want to know what it is going to look like. As large wind farms do not exist in many parts of the US we have to make scale models to help get a better idea of what these might look like. Building a scale model like you did in class today is one way to accomplish this task.

Another way is to visualize a wind farm is to use computers to create simulations of what a project might look like. Computer simulations are very useful as we can change a variety of factors very quickly and see what it might happen. For example what would the turbines look like if the sun is high in the sky or if we paint the tower grey instead of white. The computer does all the calculations and we do not have to. If you recall from the lesson these calculations can get quite challenging so we are happy to let the computer give it a try.

One problem with these new types of simulations and models is that sometimes the models and images for the same project do not look the same. One of the major complaints in one offshore wind project is that the scale simulations are not accurate or they are doctored. Each side uses scale images that that make their arguments look better. Some of these images are not to "scale" which can be very misleading to the general public.

If you would like to go deeper you can also read some articles about the conflict surrounding these visualizations.

More Questions to Explore

- Based on the model do they think wind turbine can be an eyesore?
- Could you live with this visual intrusion?
- Why might people be disappointed to see a wind farm near their house?
- What if you were a sailor, boater or fisherperson how would you feel?
- Why are scale models important? How are they helpful?
- What are there limitations of a scale model?
- Have you ever seen a fossil fuel power plant? Are they an eyesore as well?
- How can we balance the visual and physical intrusions with our need to generate power in the United States.

Additional Resources

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

Resources
For some information on wind farm development information visit:
http://www.capewind.org
http://www.lioffshorewindenergy.org/
http://www.endlessenergy.com/photogallery.shtml

For a different point of view on wind farm development visit:
http://www.saveoursound.org/

For a wide variety of balanced information and a more in-depth project:
http://www.web-and-flow.com/members/polson/webquest/webquest.htm

These manufacturers produce large turbines. Check their websites for spec sheets on their turbines.

GE Windpower
http://www.gepower.com/businesses/ge_wind_energy/en/index.htm

Vestas
http://www.vestas.com/uk/Home/index.asp

Suzlon
http://www.suzlon.com/

Gamesa
http://www.gamesa.es/gamesa/index.html

Research Project WindNRG Corporation – Wind Farm Model

The WindNRG corporation has decided to build a 20 turbine wind farm 6km (3.3mi) off the coast of the United States. As this will be the first project of this kind we would like to construct a scale model to see what it will look like in miniature. We need you to crunch the numbers and help build a scale model.

Here is some data that may be useful.
1 km = 1000 m
1 m = 100 cm

VESTAS 52-850KW

Blade Diameter:	52 m
Swept Area:	2,100 m^2
Revolutions Speed:	25/min
Tower Height:	**55 m**
Cut In Speed:	4 m/s
Max Speed:	25 m/s
Power Output;	850kW

Model Vestas

Blade Diameter: __________ cm

Tower Height: __________ cm

We need to get the units for the real tower and model to be the same or else things will get very messy. Convert the real life tower height from meters to cm.

$55\text{ m} \times \frac{100\text{ cm}}{1\text{m}} = $ ___________ cm

	Above #s	Divide by smaller #		Model Scale
Model Height (cm)	(cm)			
	--------------------- /	-------------------	=	
Tower Height (cm)	(cm)			

Building the Scale Model of the Farm

The plan is for 10 turbines to be 6 km offshore. The water is shallow here and the winds are very favorable. In order to help us see what this will look like we need to build the scale model.

You need to determine how far 6 km is on our model. Because if we had to put these turbines 6 km away we would be walking for a very long time.

The scale of your model turbine is [ ]

This means that ____________ cm in the model is equal to ___________ cm in real life.

We need to get the same units for our model and reality. How far is 6km in cm? Recall the conversions on the first page and try the following calculation.

$$6 \text{ km} \times \frac{1000\text{m}}{1\text{km}} \times \frac{100 \text{ cm}}{1\text{m}} = \underline{\hspace{6cm}} \text{ cm}$$

To determine the scale distance we need the actual distance in cm and our scale calculations.

Distance _____________ cm x [ ] = [ ]

Model Scale | Distance From Shore in cm

Measure the length of your stride in cm _____________________

Knowing this, and the distance it should be from shore, place your turbines in the appropriate place to make this a scale model. Once you have placed the turbine head back to land lay down and see what it looks like.

How many strides from shore should you place your turbine? ___________

Do the turbines look **large, small or very small, or very, very small?**

On a separate piece of paper draw a picture to show how big these windmills could possibly look on the horizon.

Research Project WindNRG Corporation – Wind Farm Model
ANSWER KEY!!!

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Max Speed:	25 m/s
Power Out-	put;

Model Vestas

Blade Diameter: __________ cm

Tower Height: __________ cm

We need to get the units for the real tower and model to be the same or else things will get very messy. Convert the real life tower height from meters to cm.

$$55\ m \times \frac{100\ cm}{1 m} = \mathbf{5500\ cm}$$

	Above #s		Divide by smaller #		Model Scale
Model Height (cm)	~ 28 (cm)	/	~ 28 (cm)	=	1
Tower Height (cm)	~5500 (cm)		~ 28 (cm)		196

IMPOORTANT NOTE: The model scale depends on the measured height of the model that you use! You can use any model...but the numbers might not match

Building the Scale Model of the Farm

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You need to determine how far 6 km is on our model. Because if we had to put these turbines 6 km away we would be walking for a very long time.

The scale of your model turbine is $\frac{1}{196}$

This means that **1 cm** in the model is equal to **196 cm** in real life.

We need to get the same units for our model and reality. How far is 6km in cm? Recall the conversions on the first page and try the following calculation.

$6 \text{ km} \times \frac{1000\text{m}}{1\text{km}} \times \frac{100 \text{ cm}}{1\text{m}} =$ **600,000 cm**

To determine the scale distance we need the actual distance in cm and our scale calculations.

Distance **600,000 cm** **x** $\frac{1}{196}$ **=** **3061 cm**

Model Scale Distance From Shore in cm

Measure the length of your stride in cm **~ 60-100 cm**

Knowing this, and the distance it should be from shore, place your turbines in the appropriate place to make this a scale model. Once you have placed the turbine head back to land lay down and see what it looks like.

How many strides from shore should you place your turbine? **30—60 strides**

Do the turbines look **large, small or very small, or very, very small?**

On a separate piece of paper draw a picture to show how big these windmills could possibly look on the horizon.