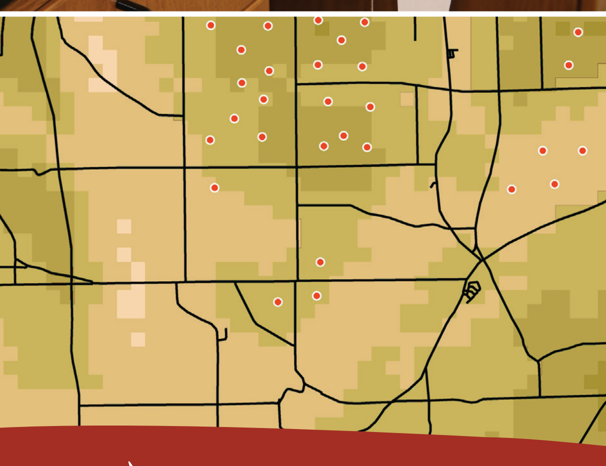
WindWise Education

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
Development Authority

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

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Updates to Lessons 3 & 5 and the addition of
Lesson 16 were funded by the Department
of Energy: subcontract No. AFT-1-40657-01

V2.0

WHAT FACTORS INFLUENCE OFFSHORE WIND?

LESSON 16

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

windwise education
www.WindWiseEducation.org

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 (KidWind model turbine)
- ❑ 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 Worksheets*

*included with this activity

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?

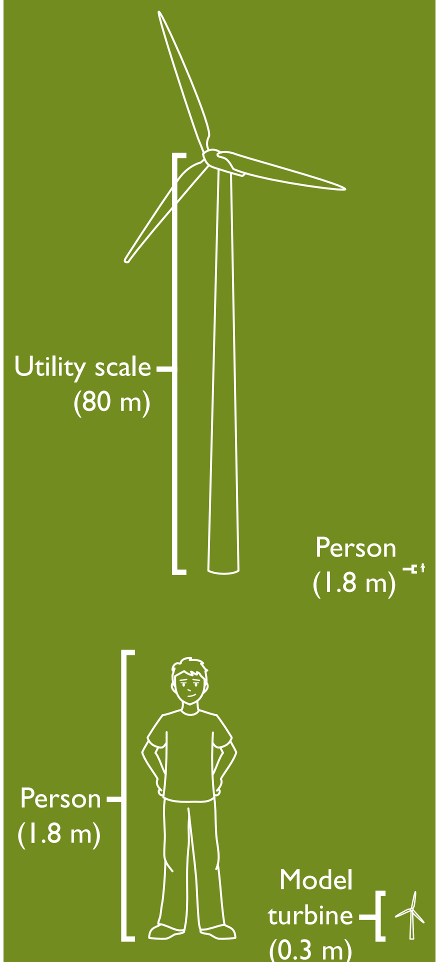
Step 3: Discussion
Use the following questions to discuss offshore wind farm development in the US:

- 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!

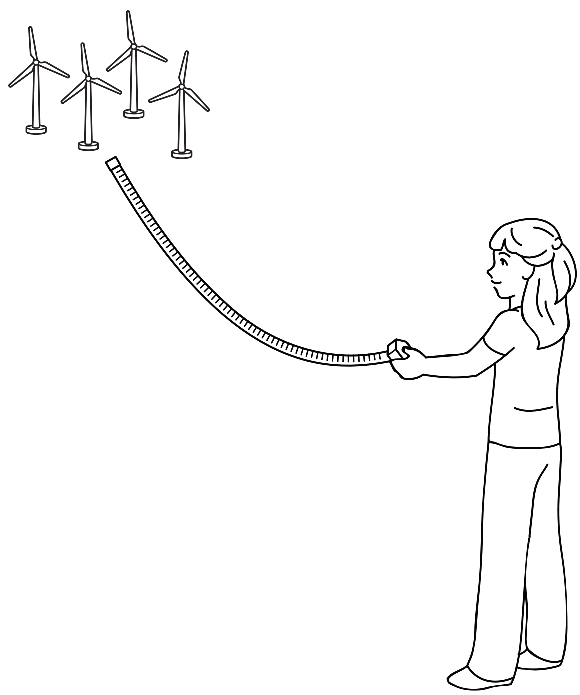
Step 2: Building the scale model wind farm

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 17 (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://kwind.me/q2n

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 17: Where Do You Put a Wind Farm?

ADDITIONAL RESOURCES

CAPE WIND—http://kwind.me/i9b—Project website for Cape Wind.

NATIONAL MARINE SANCTUARIES— http://kwind.me/q2n—National Marine Sanctuary Maps

OFFSHOREWIND.NET—http://kwind.me/k9v—Site aggregating information about proposed offshore wind.

SAVE OUR SOUND—http://kwind.me/p8b—Group opposed to wind development in Nantucket Sound.

UNIVERSITY OF DELAWARE—http://kwind.me/c3n—Research and information on offshore wind energy.

UNIVERSITY OF DELAWARE—http://kwind.me/s0n—Examination of locations both windy and shallow in the North East US.

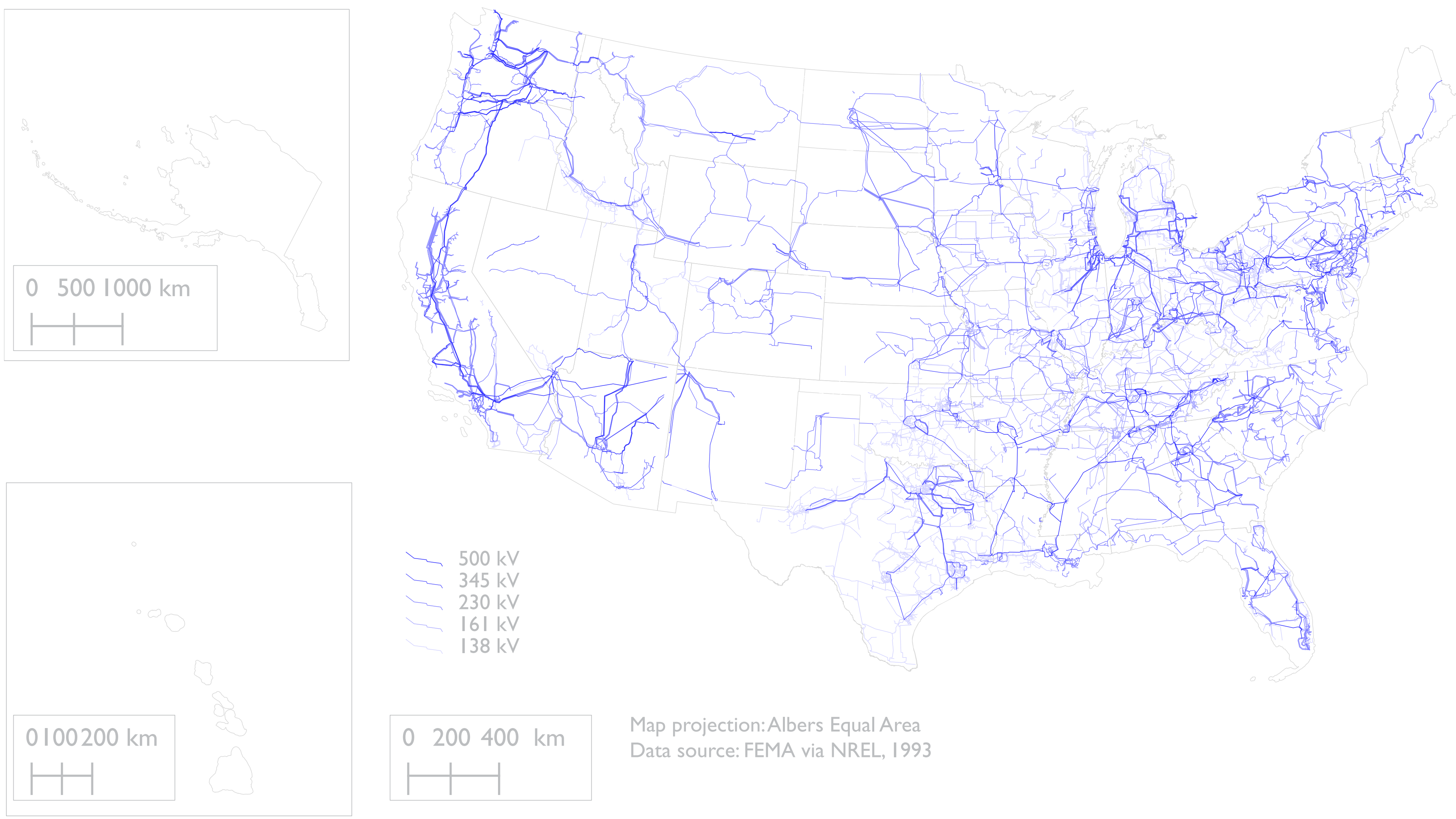
US OFFSHORE WIND COLLABORATIVE—http://kwind.me/s5v—Organization devoted to developing offshore wind in the US.

WINDPOWER ENGINEERING & DEVELOPMENT— http://kwind.me/w0h—Info on planned offshore transmission projects.

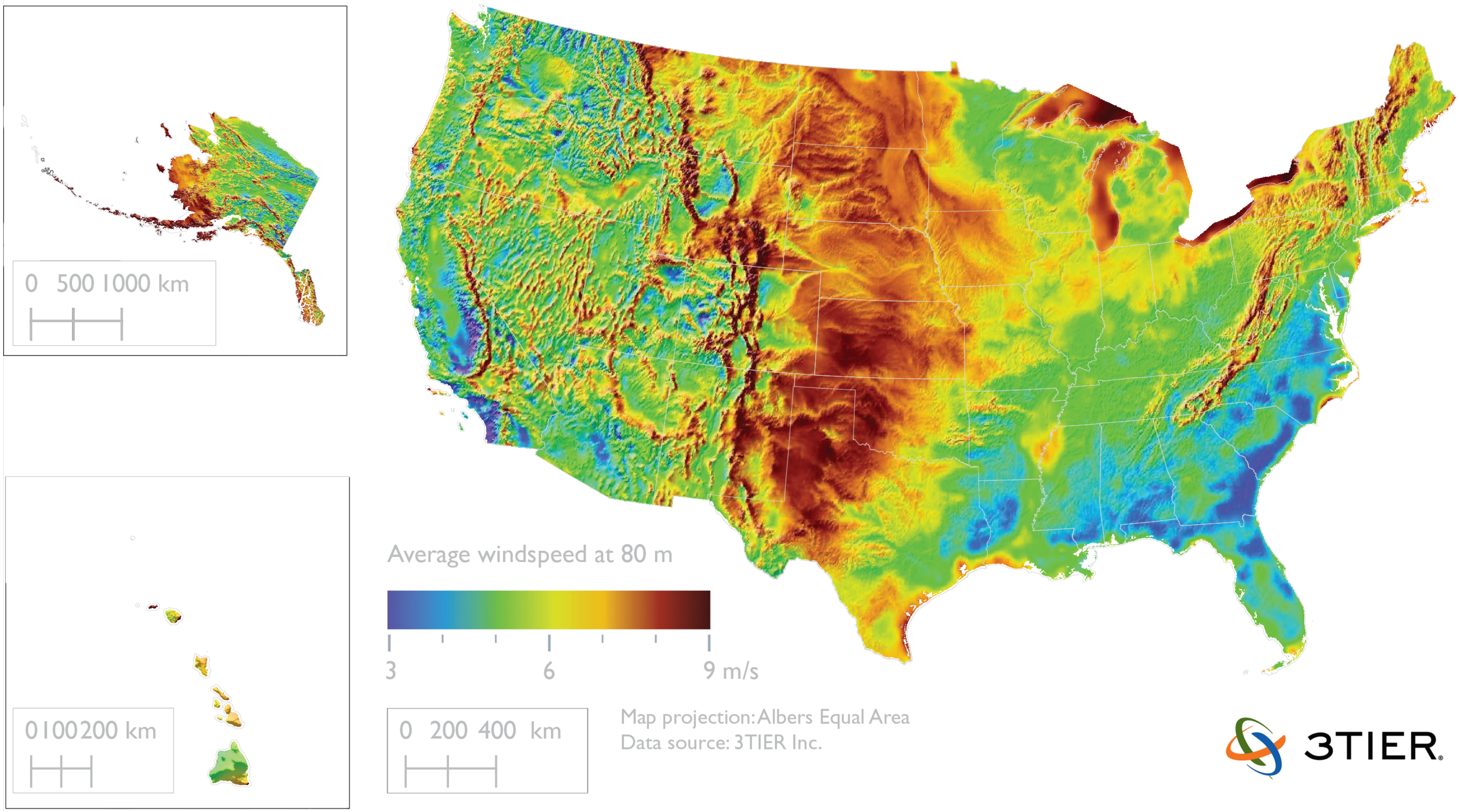
MAP SHOWING US LIGHTS AT NIGHT

Map projection: Albers Equal Area
Data source: NOAA's National Geophysical Data Center. DMSP data collected by US Air Force Weather Agency

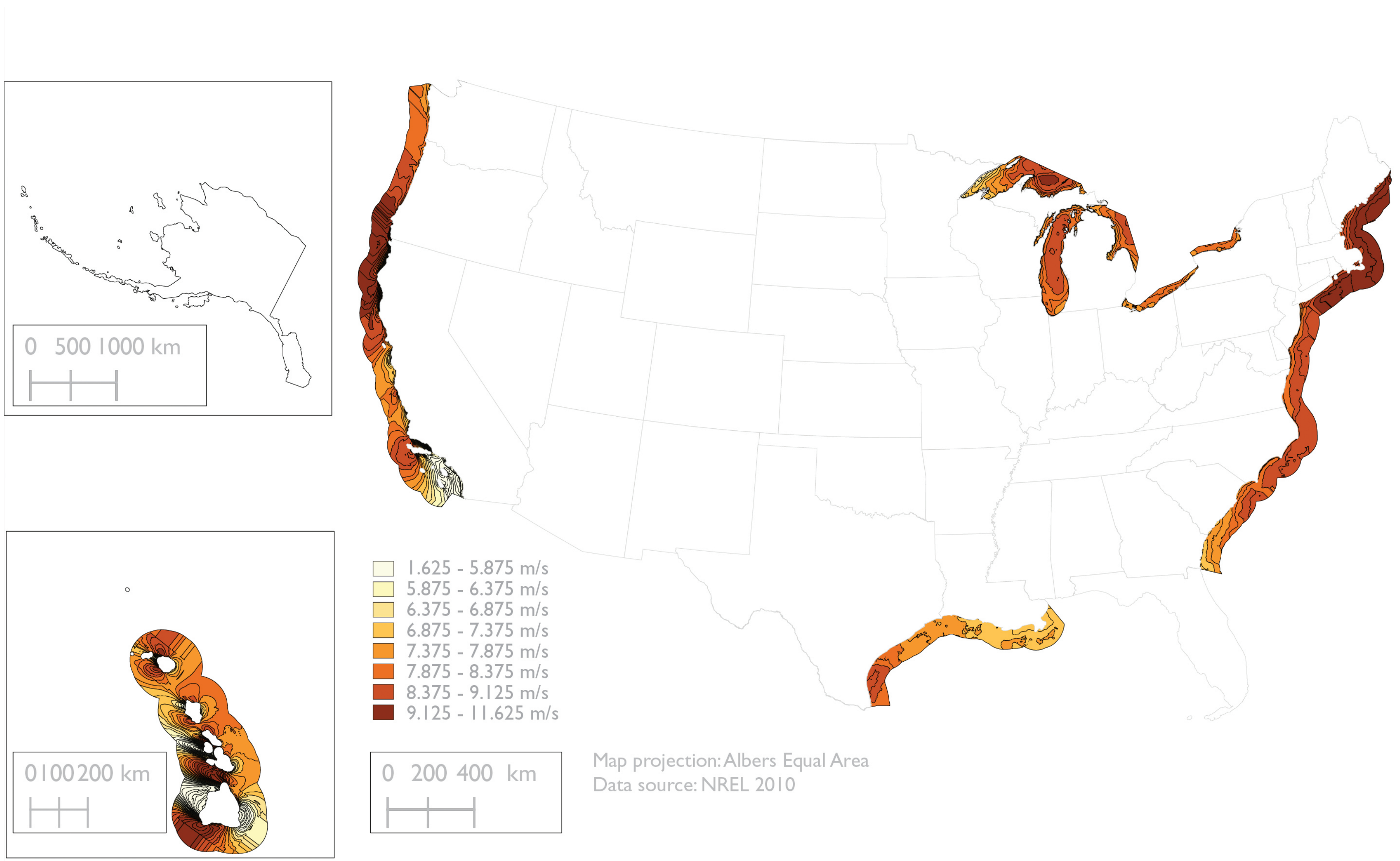
MAJOR ELECTRIC TRANSMISSION LINES IN US



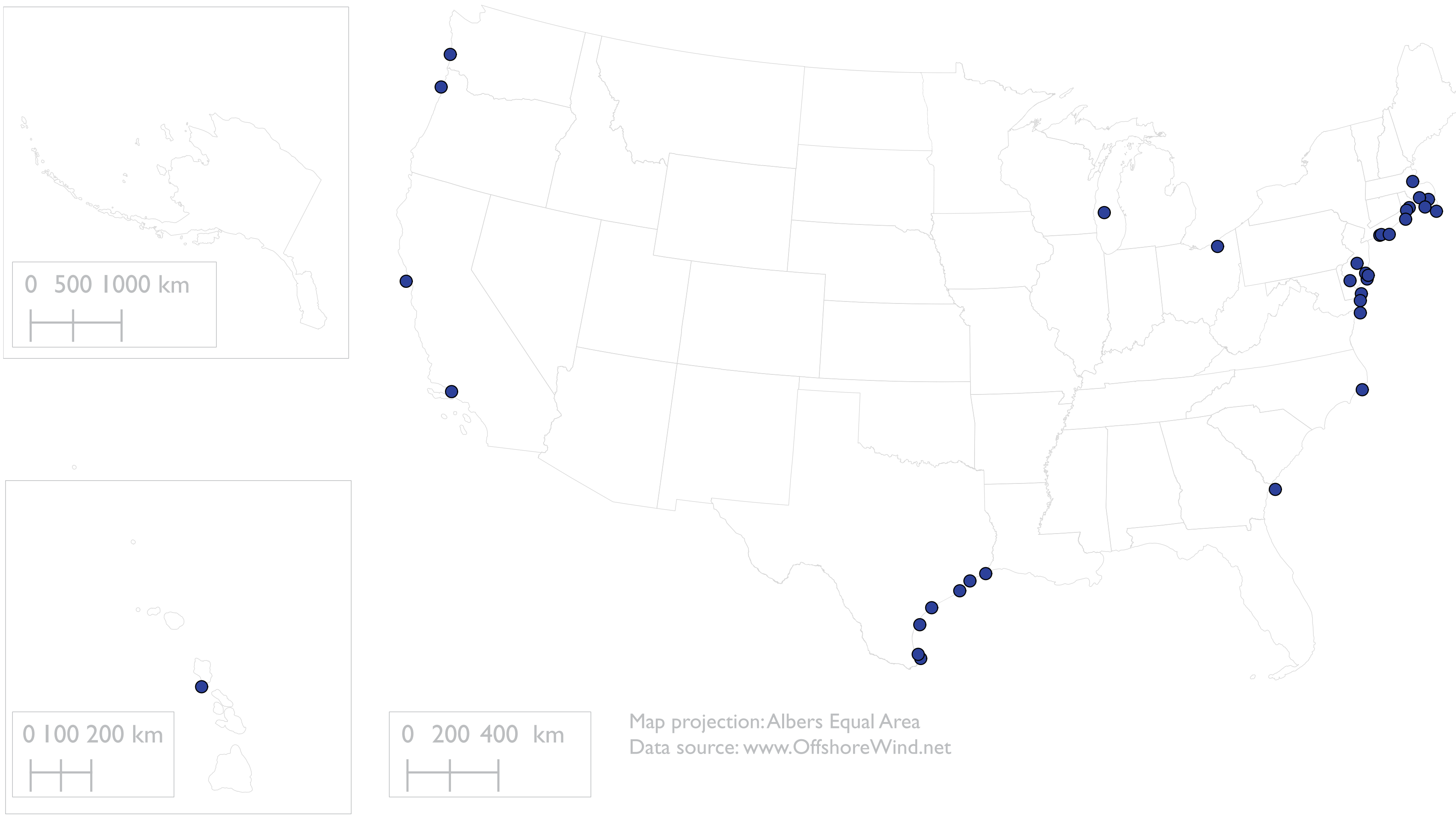
UNITED STATES WIND RESOURCE



UNITED STATES OFFSHORE WIND RESOURCE

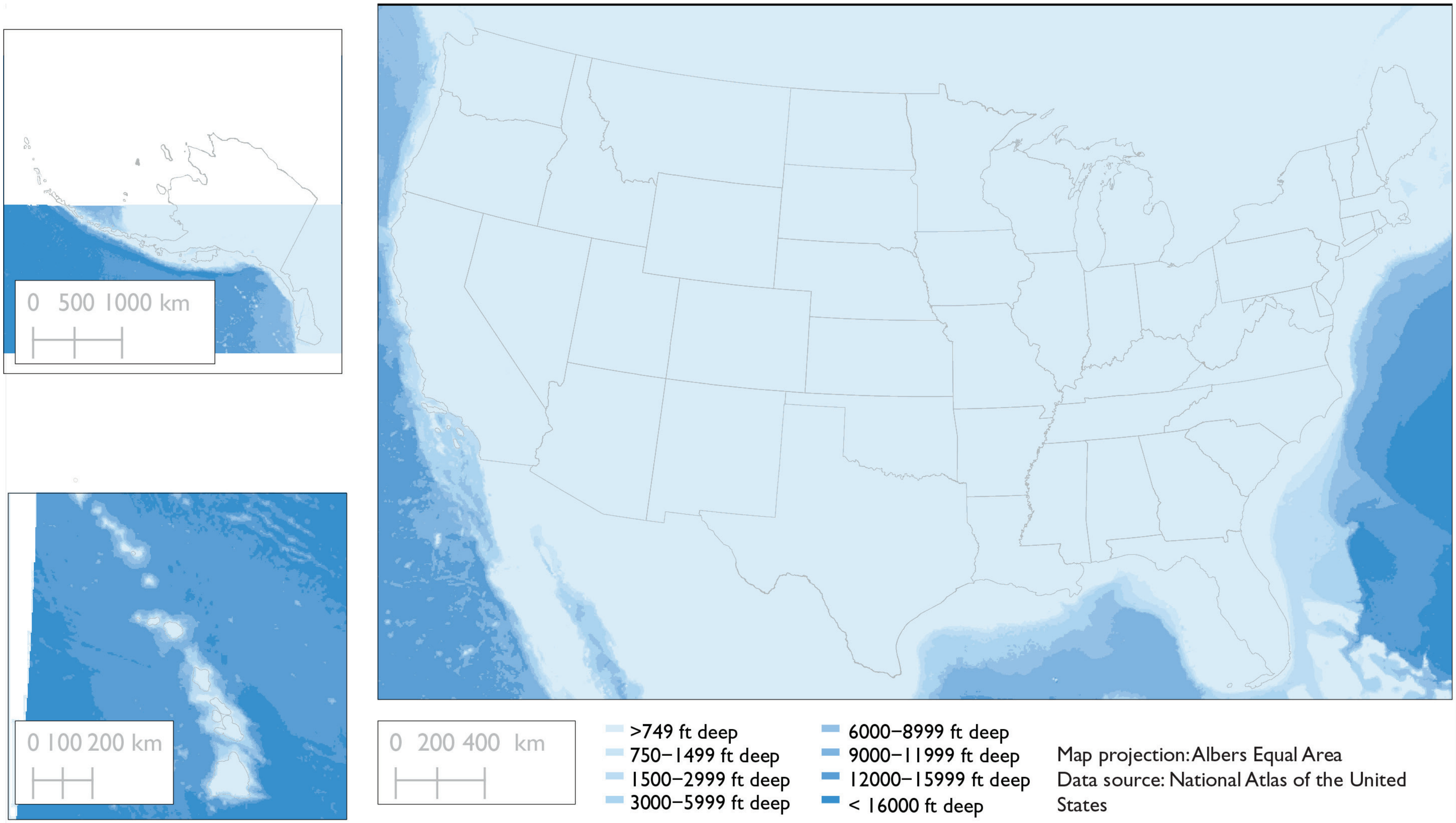


CURRENT PROPOSED OFFSHORE WIND PROJECTS



Map projection: Albers Equal Area
Data source: www.OffshoreWind.net

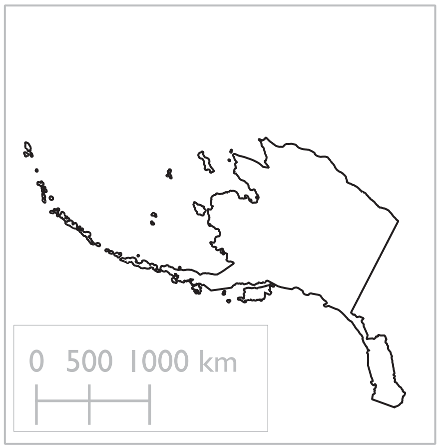
US BATHYMETRY (SEA DEPTH MAP)

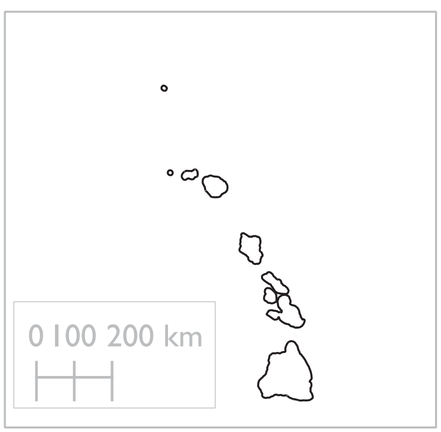


Map projection: Albers Equal Area
Data source: National Atlas of the United States

BASE MAP OF US STATES

Pick three "Best" and "Worst" locations for offshore wind development



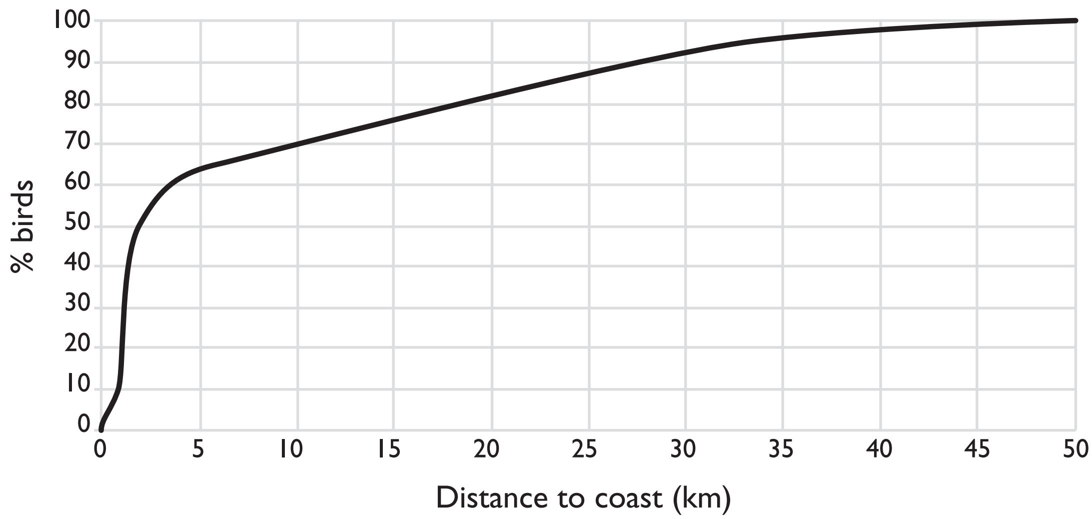


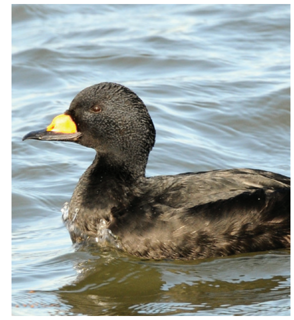
Map projection: Albers Equal Area
Data source: National Atlas of the United States

PHOTOGRAPH FOR VISUAL IMPACT SIMULATION

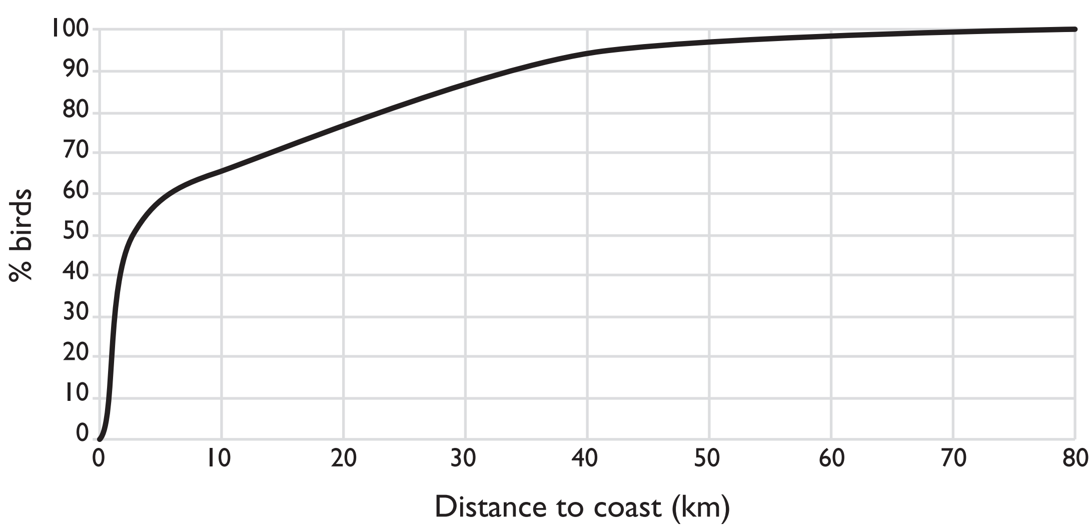
GRAPHS OF SEABIRD FORAGING RANGES

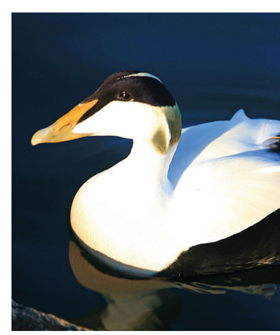
Black Scoter Foraging Range





Common Eider Foraging Range





Common Tern Foraging Range

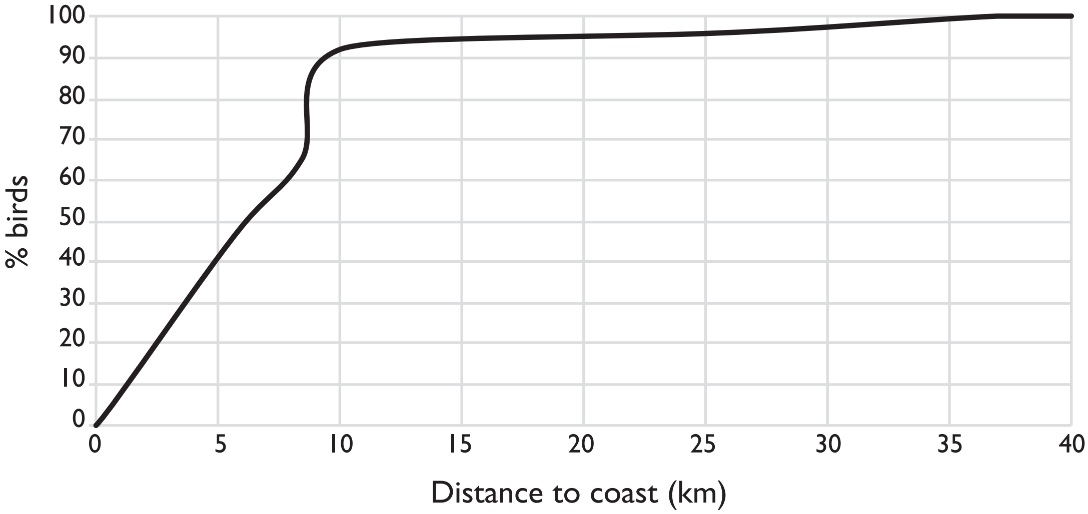


Photo: Tony Hisgett, CC BY 2.0

Roseate Tern Foraging Range

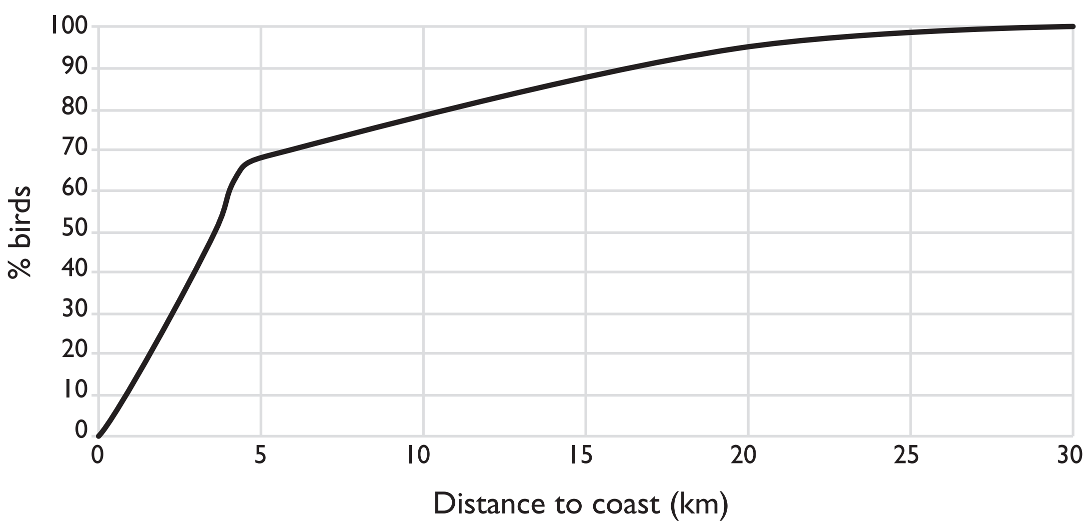


Photo: Sarah Nystrom, CC BY 2.0

Graph data from: Birdlife International. http://seabird.wikispaces.com/ Creative Commons (CC BY-SA 3.0)

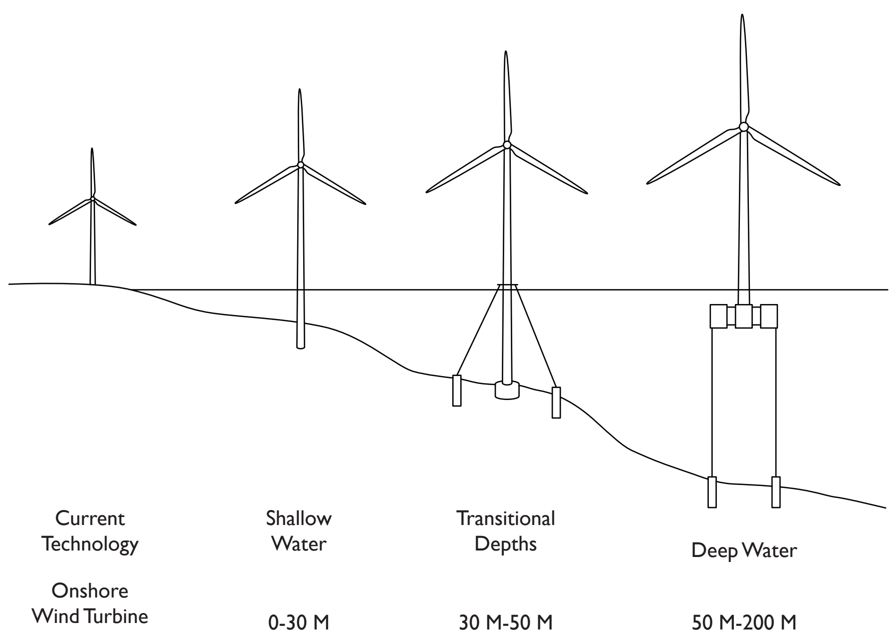
READING PASSAGE

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://kwind.me/o0p

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.

$$\frac{80 \text{ m} \times 100 \text{ cm}}{1 \text{ m}} = \underline{\hspace{4cm}} \text{ cm}$$

2. Calculate the scale by dividing the model height by the real turbine height.

$$\frac{\text{Model Height (cm)}}{\text{Real turbine height (cm)}} = \frac{\underline{\hspace{4cm}}\text{ cm}}{\text{cm}}$$

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. $9 \text{ km} \times \frac{1000\text{m}}{1\text{km}} \times \frac{100\text{cm}}{1\text{m}} =$ __________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. $9 \text{ km} \times \frac{1000\text{m}}{1\text{km}} \times \frac{100\text{cm}}{1\text{m}} =$ *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.