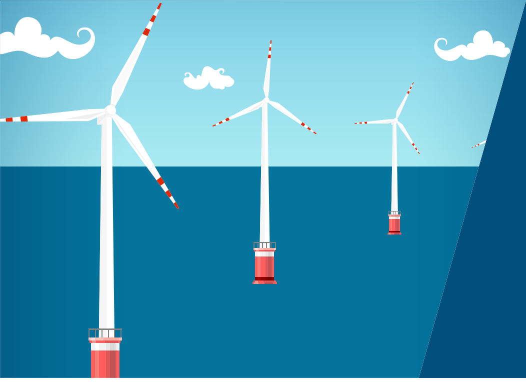


GRADES 6-8

Floating Offshore Wind Turbine

Key Concepts

Students understand and participate in the science and engineering that goes into building offshore wind turbines.

Time Required

70-200 minutes

Standards

Disciplinary Core Ideas

- MS-PS3.A
  Definitions of Energy
- MS-PS3.C
  Relationships Between Energy and Forces
- MS-ETS1.A
  Defining and Delimiting Engineering Problems
- MS-ETS1.B
  Developing Possible Solutions

Cross Cutting Concepts

- Cause and Effect
- Systems and System Models
- Stability and Change

Science and Engineering Practices

- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions

OVERVIEW

The goal of this activity is to construct a floating wind turbine that generates power in a simulated wave and wind environment. Students will learn about engineering and design solutions to offshore wind turbine problems.

LEARNING OBJECTIVES

At the end of the lesson, students will be able to:

- Understand types of offshore wind turbines and how they are relevant to offshore wind turbines and energy production.
- Create a design solution for a model offshore wind turbine.

BACKGROUND

As we look to increase renewable energy production around the globe, many regions are turning to offshore wind energy. Most of these turbines will be anchored to the ocean floor with a fixed bottom foundation, which limits construction to shallow areas off of coastlines. However, there is far more ocean than just the shallow coast! Floating offshore wind offers new possibilities for harnessing wind power over open water.

ADDITIONAL RESOURCES

Additional resources for this lesson can be found at https://kidwind.org/activity/MSFloatingTurbine

MATERIALS

- [ ] Large plastic container able to be filled with water (i.e., 64 quart plastic tub) – see note in Getting Ready for more details.
- [ ] Box fan
- [ ] Bench or table to put under box fan to bring fan to water level
- [ ] Firefly Classpack
- [ ] Rubber bands
- [ ] Duct tape
- [ ] Corks
- [ ] Foam cube or pool noodle section
- [ ] Plastic bottles
- [ ] Paper clips
- [ ] Balloons
- [ ] Washers
- [ ] Popsicle sticks
- [ ] Straws
- [ ] Skewers
- [ ] String
- [ ] Zip ties
- [ ] Floating Offshore Wind Turbine Design Evaluation Tool
- [ ] Jigsaw Activity Worksheet

KidWind® PROJECT

Click here to check out the NGSS Website, Full NGSS Standards, or Science and Engineering Practices in the NGSS.

GETTING READY (30-60 MINUTES)

Prepare material kits for each group: Each materials kit should include the following, though you should adjust depending on your class size and needs:

- 4 rubber bands
- 3 corks (like from wine bottles)
- 1 plastic bottle (like soda or water bottle)
- 4 paper clips
- 1 balloon (not inflated)
- 8 washers
- 8 popsicle sticks
- 4 skewers
- 4 zip ties
- 4 plastic straws
- 1 – 6" piece of duct tape
- 1 – 6" piece of string
- 1 Firefly mini turbine
- Scissors

Set-up your testing area: Fill a large plastic tub with water to the top. Position your box fan so that the bottom of the fan is at the water level in your tub. You may need to place the box fan on a bench or table to get to the right height. Each design will need to be tested the same distance from the fan so you can use tape to create an x on the bottom or side as an indicator of where to place the turbine so all designs are tested equally.

Selecting your "ocean": Anything from a kiddy pool or underbed plastic storage box to a large 60+ quart plastic box can work for this activity. A shallower bin will be easier to fill and requires less water, but a deeper bin will allow the students to play with buoyant force by tethering their turbine to rocks or even washers to help with stability (rocks are not included in the student supplies, but you can add them to the bottom of your testing area). If your students are thinking about buoyancy, a clear container allows them to see what's happening.

Print:

- Jigsaw Activity Worksheet (1 per student)
- Floating Offshore Wind Turbine Evaluation Tool (1 per team, if using)

While you may want to show students examples of floating wind turbine design before the design and construction phase, we suggest waiting until the end of the activity so that you do not limit their ideas!

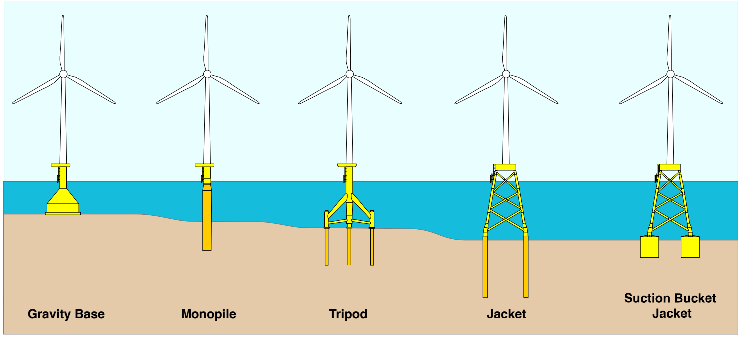
Alternative Materials Extension: Rather than providing a set amount of materials to each group, you could also give student teams a limited amount of play money to use to actually "buy" these items from a "store".

PART 1: EXPLORE OFFSHORE WIND

Step 1: Introduce Offshore Wind (15-30 minutes)

Building wind farms offshore—several kilometers out at sea—is becoming more common globally. 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.

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. While a 60 meter blade is difficult to transport on roads, it can be moved with relative ease on the water. Additionally, the cost of installing a turbine offshore does not change greatly based on the size of the turbine, so it is cost-effective to install a larger turbine that will produce more energy.



Different types of wind turbine anchors, or "moorings."

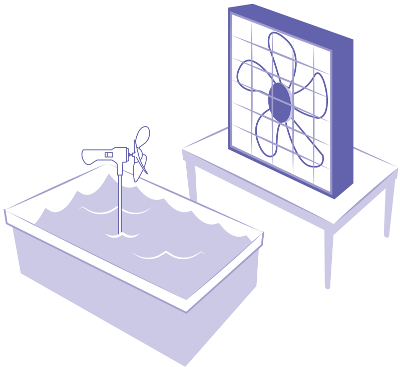
An offshore wind farm must be sited where the water is relatively shallow so that the turbine foundations can be secured to the ocean floor. While advances are ongoing, we can currently only safely anchor wind turbines in water that is less than about 60 meters deep.

Nearly two-thirds of possible offshore wind sites in the US, however, are in water too deep for these fixed bottom turbines.[1] If we could design a wind turbine for these deep waters, we could harness a tremendous amount of wind power. Floating offshore wind turbines are one possibility for this deep water construction.

In this activity, students will use the engineering design process to design, build, and test a working floating wind turbine.

[1] "Floating Offshore Wind Shot: Unlocking the Power of Floating Offshore Wind Energy." (2022). Energy Earth Shots. U.S. Department of Energy.

Visual representation of the different ways to design floating offshore wind turbines.
Illustration by National Renewable Energy Lab / Josh Bauer.



Step 2: Introduce the Challenge (~10 minutes)

Tell students that they will work in a team to construct a mini floating wind turbine that must work in a simulated ocean environment. Show the class your simulated ocean testing environment so that they will understand the scale of this activity.

Each team will be provided with the same set of materials. You can only use these provided materials to build your turbine. And there is a catch – every material you use costs something. Building offshore wind turbines is very expensive. Engineers must think very carefully about the costs of materials when designing their turbines.

Here is a suggested material cost list per item used:

- Rubber band – $1
- Paper clip – $1
- Washer– $2
- Popsicle stick – $2
- Straw – $2
- Skewer –$2
- Zip tie – $2
- Balloon – $3
- Cork – $3
- 6" string – $4
- Plastic bottle – $5
- 6" duct tape – $5
- Foam cube or pool noodle section – $10

Alternatively, you could give student teams a limited amount of play money to use to "buy" construction materials from a "store."

At the end, total the cost of the materials used. The cost effectiveness of the design and construction should impact the overall determination of turbine performance (or score if you are assigning point values to each element of this activity).

We suggest doing this by first calculating how much the full material set "costs" when you distribute the materials. Then at the end of the design phase, deduct the costs of any materials left unused from the total cost. For example, if the total materials set is calculated to cost $50 and the only items left after the build are 1 balloon and 3 paper clips, then (according to the suggested cost list) the design cost would be: $50 – $3 (balloon) – $3 (3 $1 paper clips) = $44. That would be a pretty expensive turbine!

Once you've answered any student questions, it's time to get to work!

PART 2: ENGAGING IN THE ENGINEERING DESIGN CYCLE

This design and build stage could last anywhere from 20 minutes to multiple class periods, depending on your students' interest, the parameters and expectations you have set and your available time.

Step 1: Getting Organized

Remind students to use the scientific method as they design and test their models. This iterative process, the engineering design process, can be recorded in an engineering or lab notebook.

Divide your students into teams. While you may want to base this on your class size or the number of Fireflies and materials sets you have on hand, we have found that teams of 3-4 students are usually best.

Give each team 1 Firefly mini turbine and access to their construction materials. You will also want to give each group (at least) 1 set of scissors.

Step 2: Design

Set a timer (5-10 mins.) and have teams draw out as many design ideas as possible. They are NOT building during this time; they are thinking through and drawing possible designs. It is important for them to have their construction materials while they design so that they can see what they are working with.

Step 3: Build & Test

Once they have had some time to prepare basic designs and before students begin building, discuss the process for testing their turbines. Ideally, the teacher can be near the testing station. During testing, the variables of fan setting (speed) and distance from the windmill should be kept constant. There should be an agreed upon process (how many groups can test at a time, who is turning on the fan, how long is each test?) so that all groups have an opportunity to test a few times with different models/design iterations.

Once groups know the protocols, they are set free to build, test, and rebuild their models. Teams should draw their designs and track their testing in an engineering or lab notebook so that they can systematically improve their design.

As students test their floating offshore wind turbines, give them guidance and tips on how to improve their designs. Encourage them to focus on one concern at a time. For example, the teams likely need to begin with making a turbine that can float, and then can turn to the question of stability.

Some groups may struggle to get the turbine to float. Urge them to look at other groups that have been successful. What techniques work well and what does not seem to work? Remind students that this activity is not a competition, but rather a collective effort. Students can learn from and support each other.

PART 3: EVALUATING OUR DESIGNS (30-45 MINUTES)

Bring the class back together halfway through the allotted Built & Test time and pause to observe and discuss each team's design process and testing outcomes in a jigsaw activity.

Step 1: Presenting Designs

Ask each team to present their design to the class. After a team presents their design, allow time for the class to ask the team questions to clarify aspects of the design.

Step 2: Defining Challenges

Once each team presents their design, pass out the Jigsaw Activity Worksheet. Have each team discuss the most significant challenge that they are facing in testing their turbine (i.e. instability, sinking, not balanced). Each group member should then write this down on their worksheet.

Step 3: Jigsaw

Move the class into new groups so that each new group has at least one representative from each of the teams (jigsaw).

In these new groups, each representative should take turns sharing their design challenges and receiving feedback from the other group members on possible solutions. The representative should track the suggested solutions in the table on the Jigsaw Activity worksheet.

Step 4: Evaluating Solutions

After all group members share their greatest challenge and receive suggested solutions, move the students back into their teams.

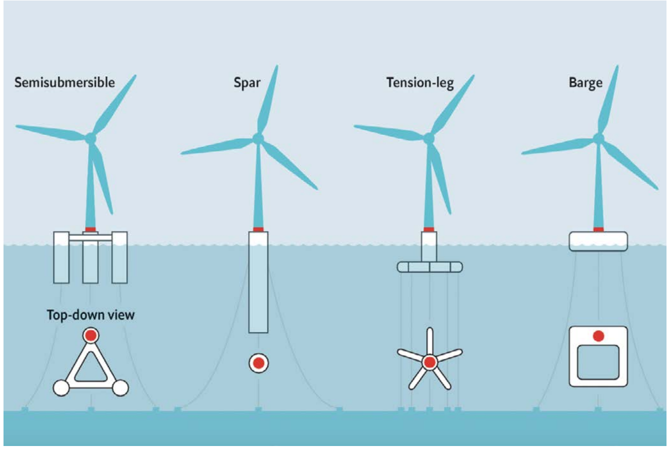
Finally, ask each team to discuss the suggested solutions they received during the Jigsaw. They should then evaluate each solution, determine their best pathway to improve their design and then return to the Build and Test process.

PART 4: DISCUSSION (15-20 MINUTES)

At the end of the testing and revision phase, bring the class together to discuss what they learned.

Possible points of discussion:

- What designs were most successful? Why do you think these were successful? (students use evidence based reasoning)
- If you were to give suggestions to other students doing this, what materials would you suggest/not suggest? (students use evidence based reasoning)
- If you were to try this again, what modifications might you use knowing what designs have been created?
- These are the models of floating offshore wind turbines that have been designed. Did your model look similar to one of these?



Floating offshore anchoring designs

VOCABULARY

Energy

Energy is the ability to do work. We need energy to do many things in our daily life: heat our homes, move our cars, light our rooms, and make our bodies move. The primary unit of energy is the joule (J), defined as the work required to move an object one meter against a force of one Newton. This is approximately the energy required to lift a 12 oz soda can one foot straight up.

Engineering Design Process

An iterative set of steps that engineers use to solve a defined problem. Examples of steps may include imagining multiple solutions, building, testing, and evaluating.

ADDITIONAL RESOURCES

- Floating Offshore Wind: What it is and how it works (reading)
- Overview of floating offshore wind (video)
- Floating offshore wind: the next five years (reading)
- Offshore Wind Siting comprehensive video by Cheddar

FLOATING OFFSHORE WIND TURBINE

Did the Team Work Well Together? ▢ Yes (__ pts) ▢ No (__ pts)

Does it Float? ▢ Yes (__ pts) ▢ Sort of (__ pts) ▢ No (__ pts)

Was it Stable? ▢ Very (__ pts) ▢ Sort of (__ pts) ▢ Fell Over (__ pts)

Material	Cost Per Item
Rubber Band	$1
Paper Clip	$1
Washer	$2
Popsicle Stick	$2
Straw	$2
Skewer	$2
Zip Tie	$2
Balloon	$3
Cork	$3
6” String	$4
Plastic Bottle	$5
6” Duct Tape	$5
Foam Cube or Pool Noodle Section	$10

Total Construction Cost __________

▢ <$_____ (__ pts)

▢ $_____ – $_____ (__ pts)

▢ >$_____ (__ pts)

Overall Design

▢ Excellent Design

▢ Good Design BUT Construction Issues

▢ Significant Design Flaws

COMMENTS

TOTAL POINTS: ________ pts

This simple assessment can be adapted to meet the needs of your students. You may want to remove the “points” or adjust the material list. You may also want to provide more criteria for collaboration, stability, and whether or not the turbine floats!

JIGSAW ACTIVITY WORKSHEET

Team Members ____

____

What is the greatest design challenge that you are currently facing?

Track the suggested solutions to this challenge offered by your Jigsaw Group. Be prepared to present these suggestions back to your team.

Solution 1	
Solution 2	
Solution 3	
Solution 4	
Solution 5	