Floating Offshore Wind Turbines

(Elementary Grades 3-5)

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

WHYMAKER
EDUCATION THROUGH MAKING

Stony Brook University

Lesson Objectives:

- Students will be able to discuss how wind turbines produce renewable energy.
- Students will be able to identify and describe types of wind turbines; particularly how floating offshore wind turbines differ from fixed wind turbines.
- Students will be to describe the many stakeholders involved in determining the location of wind farms, especially offshore wind farms.
- Students will be able to discuss the challenges of building offshore floating wind turbines.
- In a small group, students will demonstrate problem-solving skills as they build their floating offshore wind turbines.
- After completing a hands-on activity, students will be able to explain how a floating offshore turbine works.

Activity Preparation:

The following should be done prior to the start of the class. You should plan for at least 30 minutes to complete the set-up.

- Fill all the buckets with water. There is a hose and a funnel to assist if a suitable faucet is not available. Fill the buckets to the line inside each bucket.
- Place the tarp on the floor, then put four filled buckets on each tarp.
- Place a group kit next to each bucket.
- Place one laminated Student Placement Guide next to each bucket. Students should refer to them throughout the activity.
- **At the end of the class,** you will need to collect all the material and Student Placement Guides for use in future lessons.

  Group Kits include:
  - 1 Small wind turbine model
  - 3 Test tubes
  - Weights-
    - 20 Marbles
    - 30 Pennies
  - 1 Roll of masking tape
  - 2 Adhesive squares to anchor the wind turbine to the test tubes
  - 4 student handouts

- Student groups of three or four students can be formed either before the lesson or before the activity. You can have a maximum of eight groups.

Demonstration Preparation:

- There are three separate test tubes for the demonstration of buoyancy in the lesson. These are for your use.
- The demonstration of buoyancy will occur on Slide 9.

Teacher Strategies and General Information:

- Be mindful of student airtime during whole group discussions. It is always important that we diversify the voices in the room and encourage those who would otherwise be quiet so they have an opportunity to be heard, especially when a conversation could be moving quickly. Offer a time for everyone who wants to share a comment or connection before calling on the same student for a second share. Once everyone has been given ample opportunity to contribute at their comfort level, then open the floor for more discussion as time permits!

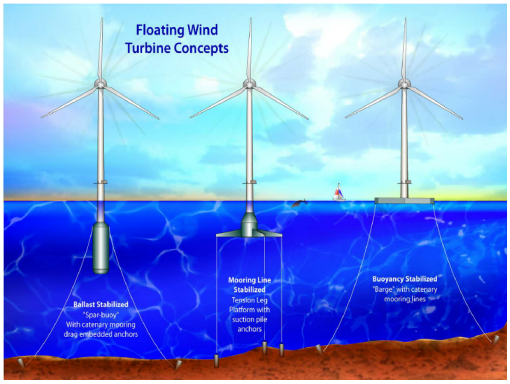
- Explicitly teaching and then using content vocabulary will support knowledge development for students – especially those whose English is not their first language and those who potentially struggle with "language-heavy" activities. Front-loading content-specific vocabulary will encourage all students to participate in the conversation. Be intentional and consistent with your use of vocabulary.

Vocabulary Overview

- **Ballast** is a material that is used to provide stability.
- **Buoyancy** is the upward force that keeps things afloat in liquids. Water exerts a force on the contacting surface. Buoyancy is the force pushing you up.
- **Destructive Force** is an element that causes negative buoyancy, therefore tipping the floating object.
- **Displacement** is defined to be the change in position of an object.
- **Equilibrium** is the state of physical balance.
- **Fixed Foundation Wind Turbines** have fixed foundations and can be installed on either land or shallow waters up to 160 to 200 ft.
- **Floating Offshore Wind Turbines** are offshore wind turbines mounted on floating structures in water depths ranging from 60 meters to 300 meters.
- **Gravity** is a force pulling together all matter (which is anything you can touch). The more matter, the more gravity. Gravity is the force pulling you down.
- **Lift** occurs when wind flows across the blade, the air pressure on one side of the blade decreases. The difference in air pressure across the two sides of the blade causes the rotor to spin.
- **Restorative Force** is defined as the force or element that causes an object back to its upright position.
- **Moorings** are the anchors that go into the water to stabilize the floating turbine.
- **Renewable Energy** is energy that comes from natural sources. It includes sources such as sunlight, wind, water movement, and geothermal heat (earth's heat).
- **Wind Turbines** are devices that convert the kinetic energy of wind into electrical energy.

There are three main types of floating turbines:

- **Tension Leg Platform (TLP)** This type uses the buoyancy of its floater to tension mooring lines between the floater and the anchor points in order to stay stable.
- **Spar buoy** This type of floating wind turbine gains its stability from having the center of gravity below the center of buoyancy, meaning that the upper part is lighter than the lower part.
- **Buoyancy Stabilized Turbine** This is like a shipping barge in terms of dimensions. The beam and length (length and width) are significantly larger than the draught (height).

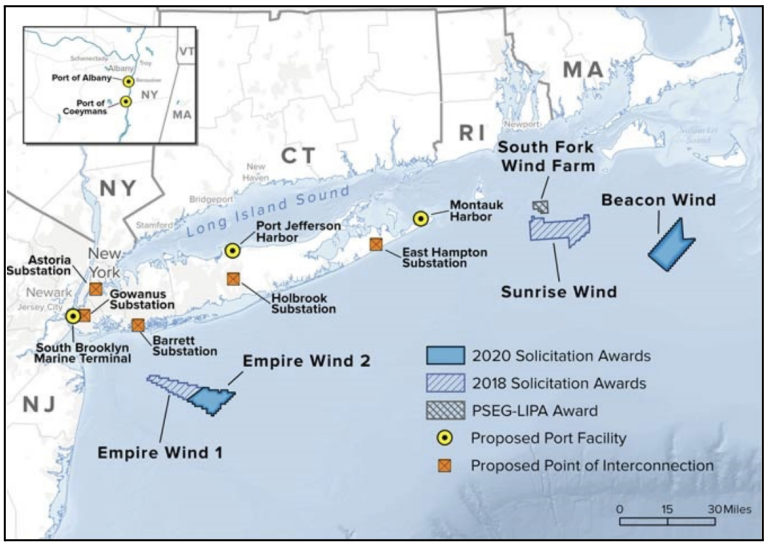


General Information for Teachers

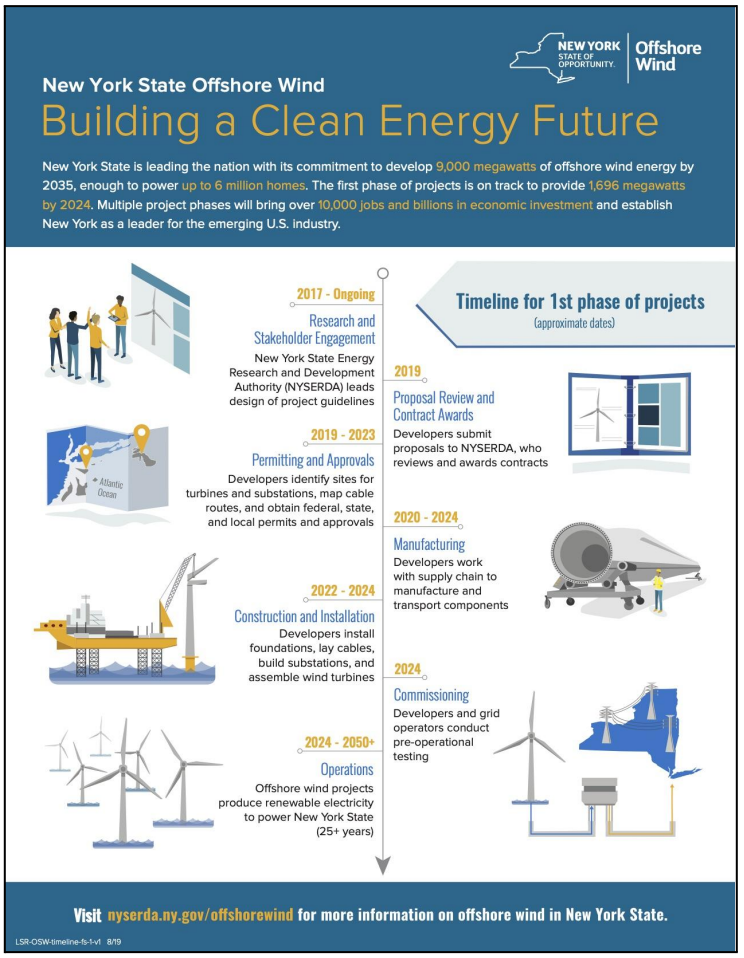
The following section is composed of several documents that will give you an understanding of what is currently happening in NY in terms of offshore wind energy projects.

Quick Facts

Empire Wind 2 and Beacon Wind will bring tremendous economic benefits to New Yorkers. Together with Empire Wind 1 and Sunrise Wind, the awarded projects from NYSERDA's inaugural solicitation will:



- Power more than 2.4 million New York homes.
- Bring a combined economic impact of $12.1 billion to upstate, downstate, and Long Island.
- Invest approximately $730 million in combined private and public funds in long-term port facilities and cutting-edge technologies, including the nation's first offshore wind tower manufacturing plant at the Port of Albany.
- Support more than 6,800 jobs in project development, component manufacturing, installation, and operations and maintenance.
- Directly offer well-paying careers with salaries averaging approximately $100,000 per year.
- Deliver significant economic benefits to disadvantaged communities and support the responsible retirement of aging fossil-fuel power plants near key environmental communities.



Lesson & Slide Deck Guide

➔ NYPA team Introduction and Get to Know students (Slide 2)

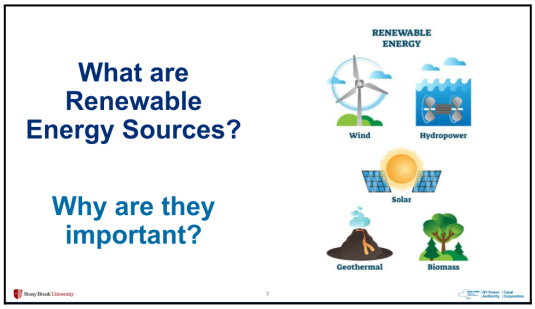
<*Narrative*> NYPA is the largest state-owned power facility in the nation, with 16 generating facilities in New York State producing approximately 5826 MWs of electricity. They are a national leader in promoting energy efficiency, the development of clean energy technologies and electric vehicles.

Their energy services projects can be found throughout New York State, saving money and megawatts while helping reduce greenhouse gas emissions. Over 80% of NYPA's electricity is produced through hydroelectric power.

Recently, NYPA has become involved in another type of renewable energy, wind. Once the wind turbine produces electricity, it has to be distributed throughout NYS through transmission lines. NYPA will be building these transmission lines that will connect the wind turbines, located offshore, to communities on shore.

Why is this important? The Climate Leadership and Community Protection Act (CLCPA) is legislation that addresses the climate crisis and sets ambitious goals for NYS to achieve, such as having zero-emission electricity by 2040 and an 85% reduction in greenhouse gas emissions by 2050, which will be achieved by using renewables such as hydropower, wind, and solar. NYS goal is to add 9000 MW of Wind energy by 2035!!

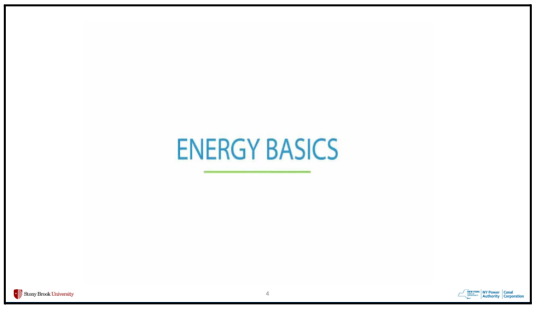
➔ Renewable Energy Sources (Slide 3)



<*Narrative*> *Ask students the answer questions on the screen. Students will have a variety of answers. Validate their responses and focus on renewable sources.* There are 3 major categories for electricity generation - fossil fuels (coal, natural gas, and petroleum), nuclear energy, and renewable energy sources.

Today we are going to focus on learning more about one specific renewable Wind Energy. Our goal is to use what we learn today to do a hands-on activity soon.

➔ Energy Basics (Slide 4)

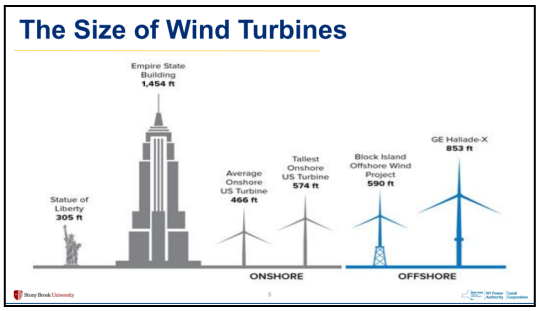


<*Narrative*> How does wind energy work? Let's watch a video about a young boy and his mom talking about wind turbines. *Ask students: What* did you learn from this video?

<Teacher Notes> Check for understanding before moving on to the next slide by asking students to share facts about wind turbines that they learned from the video.

<Video Credit> Video- Energy Basic 1:37

➔ Types of Wind Turbine Structures (Slide 5)



<*Narrative*> Wind Turbines are used throughout New York, both on land and close to the shore. Based on their location they use different foundational structures. If they are on land or shallow waters, they are fixed foundation turbines. Wind turbines built far offshore or in deeper water are referred to as Offshore Floating Wind Turbines.

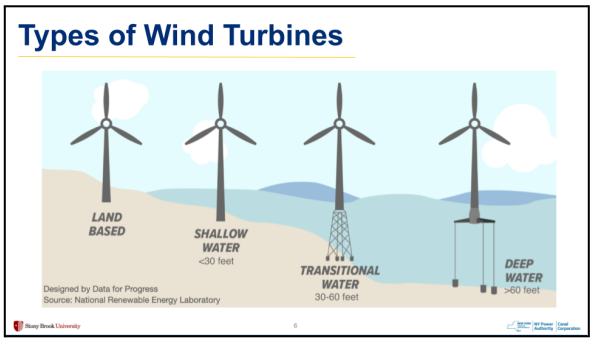
Can you think of why offshore floating wind turbines are a better idea than those on land or in shallow waters?
Ask students for answers, Validate student answers and make sure the following points have been mentioned:

- reduce visibility from the shore
- less impact on marine life and the fishing industry
- the impact on birds and the environment is less
- helps by not competing for land
- results in lower construction costs
- higher and steadier wind

There is nothing blocking or slowing the wind down on the ocean, which allows for stronger, more reliable wind conditions. Therefore they allow for more opportunities for the wind turbines to capture the potential energy.

<Picture credit>
https://www.nyserda.ny.gov/-/media/Project/Nyserda/Images/Programs/Offshore-Wind/1-2_Turbine-Size_539x344.jpg

➔ Harnessing Offshore Wind is a game changer (Slide 6)



<*Narrative*> As we just learned, wind turbines are complex and big machines with a lot of moving parts. In addition to the mechanics of the turbines, the turbines need to be built to withstand all sorts of weather and other natural forces. Wind Turbines are used throughout New York, both on land and close to the shore. based on their location they use different foundational structures.

If they are on land or shallow waters, they are fixed foundation turbines. Wind turbines built far offshore or in deeper water are referred to as Offshore Floating Wind Turbines. Over the last decade there has been a push to build wind turbines offshore - far offshore in deep waters.
Why do you think there is a push for offshore wind turbines?

Take a look at this image, what do you notice about the foundations?

- Wind turbines on land or in shallow water are fixed into grounds
- Wind turbines in medium depth water have a structure that is fixed into the ground
- Wind turbine in deep water are floating with anchors

<*Teacher Note*> Students will give various answers, validate answers and point out the tan in land, and the blue is water and the structures that are holding each up. Show how the deep water turbine base is floating in the water.

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➔ Why things Float or Sink (Slide 7)

<*Narrative*> How can such huge structures float and not "fall to one side or the other or sink." Let's watch this short video to learn more. *After the video ask students* what did you learn about what things float?

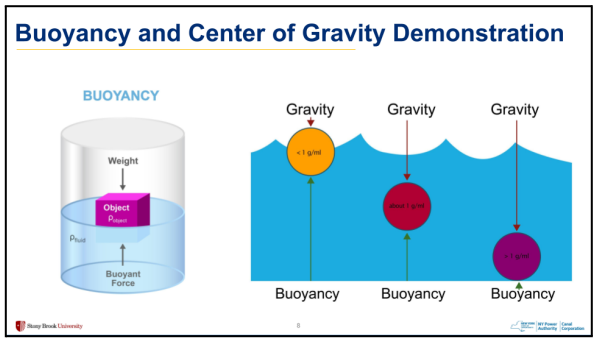
<*Teacher Note*> There are two important forces: gravity and buoyancy that make it possible for the floating turbine to stay vertical.

Gravity is a force pulling together all matter (which is anything you can physically touch). The more matter, the more gravity. Gravity is the force pulling you down.

Buoyancy is the upward force that keeps things afloat in liquids. Water exerts a force on the contacting surface of the board. Buoyancy is the force pushing you up.

<Video credit> Discover why an object will float or sink 1:49 min of video

➔ Buoyancy and Center of Gravity Demonstration (Slide 8)



<*Narrative*> Let's discuss what makes things float or sink or stay in between. I have 3 test tubes that I will use to demonstrate positive, negative, and neutral buoyancy and gravity in action.

<*Teacher Demonstration*> Demonstrate positive, negative, and neutral buoyancy using the labeled test tubes provided and a bucket of water. Focus on showing students about buoyancy and how having a lower center of gravity creates balance and stability.

1) The empty test tube labeled Positive Buoyancy will float.
2) The filled test tube labeled Negative Buoyancy will sink.
3) The test tube filled half way, is labeled Neutral Buoyancy and will float vertically.

<*Teacher Note*> *With so many variables continually knocking the turbine out of its equilibrium there needs to be a way that the foundation is able to continually correct itself and not tip over. Returning to equilibrium may be referred to as a restorative force (pulling it back into place) versus a destructive force (when pushed to a certain angle the object tips/falls over).*

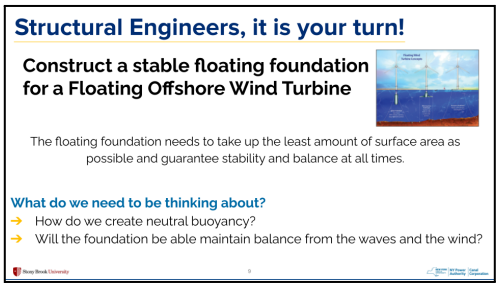
<*Narrative*>
Positive buoyancy is created when there is less gravity pushing down and more buoyancy pushing up
Negative buoyancy is created when there is more gravity than buoyancy
Neutral buoyancy which enables something to neither completely float or completely sink. This happens when there is an equal amount of buoyancy and gravity.
Ask students: What do they notice about the different test tubes, what makes one float, one sink and one stay in the middle?

<*Teacher Note*> Don't tell the students how this is connected to wind turbines. They will explore these concepts as they build their floating wind turbines.

Activity: Building a Floating Foundation for a Wind Turbine

➔ NYPA Structural Engineers, it is your turn! (Slide 9)

<*Narrative*> You are now NYPA Engineers working on constructing an offshore floating wind turbine - focusing on creating a stable floating foundation. Construct a stable floating foundation for a floating offshore wind turbine. Your floating foundation needs to take up the least amount of surface area on the water as possible and guarantee stability and balance of a wind turbine above the water at all times. Working with your team, you have a set of materials you can use: test tubes, weights, masking tape to build your floating foundation. Then balance the wind turbine on top of the floating foundation and make it permanent using double sided tape. As you plan out your build ask yourselves:



- What do you need to be thinking about when you are building a floating foundation?
    - Creating neutral buoyancy so the test tubes can float
    - Foundation stability and balance, while having the smallest possible footprint.

<*Teacher Notes*> Group students into groups of three or four depending on the total number of students. Each group will have their own materials kit and share buckets of water. Student handout guides tell students exactly what to do in building the structure - feel free to work through the test tube part together. Even if you build the structure together, the students still need to figure out how many marbles in each tube will be needed to make the test tubes stable and vertical in the water. State how much time they will have and give them a signal when there is 5 minutes left. Circulating around the room while students work. Encourage students to test and then modify one part at a time.

Walk around throughout the activity. Try not to "give the answer" to questions but rephrase the questions so they do the "thinking."
Examples of pointed questions, you might ask:

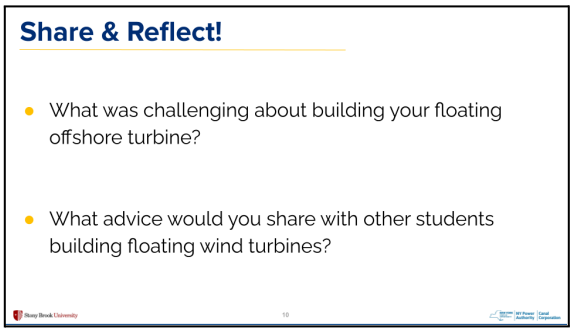
- Why is the turbine not stable? Or standing upright?
- What adjustments have you made? What adjustment might you try?
- What role do the marbles play? How do they contribute to the buoyancy of the wind turbine?

Examples of general questions, you might ask:

- What do you think will happen if we change this variable?
- How do you think this will affect the outcome of the experiment?
- What do you predict will happen next?
- What do you think will happen if we do this differently?
- How can we test your prediction?

Activity Reflection- Debrief/Discussion

➔ Reflection Slide (Slide 10)



<*Teacher Note*> Allocate at least 10 minutes. Make sure to leave enough time at the end for students to reflect and discuss. This is when the real learning happens. The structures that the students built should be floating in containers at this time.

- If a group didn't finish, that is OKAY. Focus on the reflection and process. Remind students that engineers do not always succeed and most learning happens when things do not work out the way they want.

<*Narrative*> Before having students reflect on the questions, have groups share their builds.

Ask students these reflection questions:

- What was challenging about building your floating offshore turbine?
  Possible student answers: unable to keep it from tipping, not enough marbles.
- What advice would you share with other students building floating wind turbines?
  Possible student answers: use more marbles/weights, experiment and record the information.

➔ Closing Slide (Slide 11)

<*Narrative*> Today you were NYPA engineers, you helped us explore the feasibility of offshore wind turbine farms. Offshore wind has opened the door to many new careers, and NYPA renewable and non-renewable energy to solve a problem and transmit electricity to a city building. NYPA has thousands of electricians, engineers and others that keep all of our lights on day to day. Everyday the citizens of New York State use more and more electricity in different ways, we need your great minds to keep the lights on and design solutions for our communities now and in the future.

- What careers do you think you could have with NYPA in the future?
- What problems do you want to solve?

THANK YOU!!