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| **Title** | Using Model Turbines to Explore Energy |
| **Introduction** | What do wind, hydroelectric, nuclear, and coal have in common? They all require a turbine to generate electricity. In this lesson, students will experiment with a model turbine (foam pinwheel) to determine the ideal conditions for placing a hydroelectric or wind power plant. Having a concrete understanding of how turbines work will also aid students’ understanding of how nuclear and coal power are generated. |
| **Curriculum Alignment** | North Carolina New Essential Standards:  High School Earth & Environmental Science:  EEn.2.8.1: Evaluate alternative energy technologies for use in North Carolina  8th Grade Science:  8.P.2.1: Explain the environmental consequences of the various methods of obtaining, transforming, and distributing energy. |
| **Learning Outcomes** | Students will describe the ideal conditions for turbine rotation and identify key characteristics to consider when placing a turbine.  Students will analyze a topographic map and suggest ideal locations for building a hydroelectric power plant. |
| **Time Required and Location** | * Explore and Model System: 30 minutes * Content wrap-up: 20 minutes * Guided Practice: 50 minutes * Extension and Assessment: 45 minutes |
| **Materials Needed** | In addition to the foam pinwheel, gather the materials needed for each lab station (see below).Materials needed To make the foam pinwheel:   * 15x15cm square of craft foam sheet * A pencil * A straight pin * Scissors   Each lab group should have:   * A 2-liter bottle * A foam pinwheel * A meter stick * A lab sink or catch basin * A stopwatch (optional) * Water   For demonstration:   * An empty 2 liter bottle with three holes poked in it, at differing heights * A long strip of masking tape that covers all three holes.   Make a class set of copies of (1 for each group):   * Elevation map of North Carolina (<http://geology.com/state-map/north-carolina.shtml>) * North Carolina Rivers Map (<http://geology.com/state-map/north-carolina.shtml>) * Wind map of North Carolina (<http://www.windpoweringamerica.gov/pdfs/wind_maps/nc_80m.pdf>)   If you print color copies, you should laminate them or put them in sheet protectors to aid re-use.  **Technology resources**   * A computer and projector to show PowerPoint slides. |
| **Safety** | Make sure students are careful with electricity. |
| **Participant Prior Knowledge** | This lesson is designed to follow “Using Model Generators to Explore Energy.” However, if there is not enough time for a full lesson on how generators work, a demonstration of how a generator works would suffice. Students should see how the rotation of the magnets is required to create a current, and should be comfortable with the terms “generator” and “turbine.” They should understand that a turbine is something that translates the motion of a fluid (air, water, or steam) into rotational motion in order to generate electricity. |
| **Facilitator Preparations** | In this lesson, the model used to represent a turbine is a simple foam-board pinwheel. These are very simple to assemble, and can either be made ahead of time, or the first class of the day may assemble them:Start with a 15x15cm square of craft foam sheet (does not need to be exact; this dimension yielded six squares from one large sheet). Cut diagonal slits from the corners towards the center, as shown in the pinwheel pattern. Pin the corners to the center with a straight pin (align the dots on the pattern vertically), and then insert the end of the pin into the eraser of a new pencil.http://0.tqn.com/d/familycrafts/1/0/W/s/1/pinwheel-step3.jpgPinwheel pattern |
| **Activities** | Students will be working in groups of four, with the following roles:   * 1. Water-pourer: pours water from the bottle over the turbine   2. Turbine-holder: holds the end of the pencil so the turbine stays over the sink or catch basin   3. Timer/counter: Estimates the speed of the spinning turbine (either by counting number of turns or putting speeds in relative order: slowest, slow, fast, fastest)   4. Measurer: Measures the distance between the turbine and the water source   If necessary, a fifth student could be data recorder, or all students can record their own data  between trials.  **Exploration:**  Invite a student to volunteer with the demonstration. Have the student hold the pencil horizontally so that the turbine (pinwheel) is over a sink or catch basin. Demonstrate how to pour the water over the pinwheel to make it spin. Ask for another student volunteer; have them pour while you demonstrate how to measure the distance between the turbine and the bottle of water (pencil to spout). This height should be rounded to the nearest centimeter.  Assign students groups.  In groups, students will choose roles, and find the highest height from which they can make the turbine turn smoothly.  **Model System:**  Student will investigate how the height above the turbine affects the spinning rate. They will measure the speed of the turbine when pouring water from four different heights (25%, 50%, 75%, and 100% of their maximum height works well). Students will record and graph their results; they may use the student sheet “Elevation vs. Turbine Speed” for reference and to record their results.  **Content Wrap-Up:**  In nature, the speed of rivers is variable. However, we want the output from power plants to be very even and predictable. So to control the flow of the river, we build dams. As we learned when we explored generators, the faster the turbine turns, the more electricity is produced. In today’s experiment, we found that water moves faster (and turns turbines faster) when it goes through a greater elevation change. In order to maximize the elevation change at a hydroelectric dam, engineers either choose a site with natural elevation change, build a high dam to create an elevation difference, or both.  Demonstration:  2 liter bottle with vertically aligned holes: Fill with water, and remove tape, allowing water to flow into sink or catch basin. (Water from bottom hole should flow out the farthest, because it has the largest difference in elevation between the hole and the surface of the water.) Students watch and complete a quick-write.  Quick write:  What did you observe?  *The water flows fastest and farthest out of the bottom hole.*  Why are some of the streams of water moving faster than the others?  *The elevation difference is larger.*  If you were going to place a turbine on one of these streams to generate electricity, which would you choose and why?  *The bottom stream of water, because it is flowing fastest and would turn a turbine more quickly*  What other factors will affect the speed of water?  *pressure smoothness of channel*  *slope volume of water*  **Guided Practice**  Using [Hydroelectric PowerPoint](file:///C:\Users\Pamela\Documents\Kenan%20Fellowship\Lesson%20Plans\Turbine\Hydroelectric_Sites.pptx), show series of (pairs) of images, ask students:  Which would be the better location for a hydroelectric dam? Why?  (The answer for each slide is included in the slide notes)  Ask students: Using maps of elevation and river basins, choose three potential sites for a hydroelectric dam, and explain why you chose them. (It may be helpful to print the river map on a transparency, so that students can lay it over the elevation map).  Project the North Carolina River Map on the white board, and have students take turns marking the location they chose. Once all locations are marked, compare map to the map of hydroelectric dams in North Carolina. Discuss as a class how well the maps matched or did not match. Also discuss how hydroelectric power is the power source with the least capacity for expansion; using the types of dams we have now, the best sites already have power plants built on them!  **Extension**  Next, expand the idea of getting the turbine to spin the fastest to other types of power generation, beginning with wind.  Have the students think, pair, and share:  What factors affect the speed of wind?  *-pressure differences*  *-temperature contrast*  *-open space without trees to slow it down*  Again, show the students a map (Wind Potential for North Carolina), and have students choose one potential site for a wind farm, and explain why.  Next, relate to generators that use steam to turn the turbine:  What are some sources of heat/steam that could spin a turbine?  *-underground/earth’s internal heat*  *-burning things (manure, wood, garbage, etc.)*  *-nuclear reactions*  What type of information would you want in order to decide where to place a geothermal power plant?  *How the temperature of the ground varies with depth; the deeper you must drill, the more expensive the energy is to produce.*  Burning things can be divided into two categories: Biomass and waste-to-energy incinerators  Show pictures of biomass including manure, untreated wood, corn stalks, and leaves, and ask students:  What do these things have in common?  *Found on farms and rural areas*  Where would you put biomass generation?  *In agricultural regions; in North Carolina these could be places in the Piedmont and Coastal Plain with low population density*  Show picture of waste/garbage that could be burnt in a waste-to-energy facility  Where would you place one of these?  *-near landfills*  *-away from people*  Lastly, nuclear reactors also run on steam, but from heat generated from nuclear fission. They are sometimes placed near water for cooling, but can also use cooling towers when not sited near a body of water. Sites chosen for nuclear reactors should be as stable as possible. One would want to minimize risk of natural disasters such as earthquakes and floods when building a nuclear power plant. |
| **Assessment** | Give students a blank map of North Carolina. Have them mark a location to place a hydroelectric dam, a wind farm, a biomass energy plant and a waste-to-energy power plant.  For each, the students should give a reason to justify why they placed a power plant there.  One point is earned for each of the following criteria:  Hydroelectric Dam:  \_\_\_ Placed on a river  \_\_\_ River has significant elevation change  \_\_\_ River is in western North Carolina/the mountains  \_\_\_ Justification logically suits the placement of the dam  Wind Farm:  \_\_\_ Placed on the coast (either onshore or offshore) or on a mountain ridge  \_\_\_ Justification logically suits the placement of the wind farm  Biomass Energy Plant:  \_\_\_ Placed in an agricultural or wooded area  \_\_\_ Justification logically suits the placement of the biomass energy plant  Waste-to-energy  \_\_\_ Location not near major parks or recreation areas  \_\_\_ Justification logically suits the placement of the waste-to-energy plant (if near a city, the short transportation distance required for the garbage; if far from a city, minimizing the population’s exposure to pollutants from incinerating waste) |
| **Critical Vocabulary** | Turbine: a device that rotates as a fluid (steam, gas, air, or liquid) flows through  Generator: a device that uses the motion of a magnetic field to create electricity  Hydroelectric dam: a structure built across a river to maximize the difference in elevation between water on either side; water is released at the bottom to maximize flow and keep flow rates predictable. This flow of water is used to turn turbines and generate electricity.  Biomass: wood, corn husks, leaves, sticks, manure, sugar cane stalks, and other organic material that can be burned so that the heat will turn a turbine. |
| **References** | Maps of North Carolina (Elevation, River): <http://geology.com/state-map/north-carolina.shtml>  Wind Maps for North Carolina:   * U.S. Department of Energy: <http://www.windpoweringamerica.gov/pdfs/wind_maps/nc_80m.pdf> * Appalachian State University: <http://www.wind.appstate.edu/sites/default/files/NC_50M_windmap_11x17.pdf>   <http://www.wind.appstate.edu/wind-power/wind-power-factsheets> |
| **Author Info** | Pamela Weghorst teaches Earth and Environmental Science and AP Environmental Science at Ardrey Kell High School in Charlotte, North Carolina. She has been teaching since completing her Master of Science in Geology at Kent State University in 2008. |