Solar vs. Wind Energy

Lesson 5: Variables Affecting Wind Turbine Power

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GRADE LEVEL: 7-8

LESSON DURATION: 3-5 days

SUBJECT AREA(S): science, energy, energy transformation, energy generation, wind turbine, voltage, current, power, investigation, generator, variables

LESSON OVERVIEW:

Now that students are familiar with how mechanical electricity generation works, they will build a wind turbine powered by a box fan. Different teams will test different turbine variables to see how the amount of electrical power is affected. After each team completes testing their chosen variable, the highest wind turbine configurations from each team will tested against one another. The turbine that generates the most power from this lesson will then compete with a photovoltaic cell of approximately equivalent cost to see whether wind or solar is the most economical (in the next lesson).

OBJECTIVES:

- Students will be able to identify and explain at least three variables that affect the efficiency of wind turbines
- Students will conduct a scientific investigation to determine which wind turbine configuration will generate the most power

NEXT GENERATION SCIENCE STANDARDS:

MS-PS3-4 (Science and Engineering Practices)

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

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MS-PS3-1 (Science and Engineering Practices)

- Construct and interpret graphical displays of data to identify linear and nonlinear relationships

MS-ETS1-2

- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

COMMON CORE STANDARDS:

CCSS.ELA-Literacy.RST.6-8.3

- Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

STUDENT BACKGROUND: This lesson assumes some knowledge of circuits and understanding about how electricity can be generated using magnets.

EDUCATOR BACKGROUND: It will be helpful if you have a basic understanding about how generators create electricity using magnets and coiled wire. The following video does a nice job of explaining how a DC motor works. Although we are testing electricity generation, not motors, the two are very closely related. "DC Motors, How it Works?": https://www.youtube.com/watch?v=LAtPHANEfQo

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KEY VOCABULARY:

- Alligator clips
- Multimeter
- Wind Turbine
- Generator
- Volts
- Current

MATERIALS NEEDED FOR WIND TURBINE:

- (1 per 2 groups) "DIY" Basic Turbine Kit
  - *(5) 1" PVC 90° Fittings*
  - *(3) 1" PVC T Fittings*
  - *(1) 5 ft length, 1" gauge PVC Pipe*
  - *(1) 1" PVC Coupler*
  - *(1) Electric Motor – "Motor 500 (Pitsco)"*
  - *(2) Clips (Alligator or Banana)*
  - *(1) Hub – buy a set of 10 from Vernier (website below)***
  - *(1) Box of blade materials (balsa wood, cardboard, and wooden dowels) from Vernier****
- (1 per student) Copies of "Wind Assessment: How windy is it where you live?"
- (1 computer per 2 students) Colored copies of national and state wind maps from your area OR computer access. See step #6 under "prep" below for details.
- (1 per person) Copies of "Student Sheet 5: Measuring Power Generation in Wind Turbines"
- Copies of how to make wind turbine – simply make copies of pg. 4-7 from the PDF link below: http://www1.eere.energy.gov/education/pdfs/wind_basicpvcwindturbine.pdf
- Computer with Internet and LCD projector

- (1 per group) Multimeter
- Duct Tape (to secure motor in PVC shaft)
- Razor blades or scissors (tool for groups to change the shape/size of their turbine blades)
- (1 per 2 groups) Box fans***
- *Optional*: Anemometer (useful if testing at the average wind speed for your region)
- *Optional*: Hack saw (If you build "DIY" wind turbine)
- *Optional*: "Blade Pitch Protractor" from Vernier (search by title or "KW-BPP" – it helps set the blade angles)
- *Optional*: 1.5 AA battery, small light bulb (for learning how to find current and voltage)

Notes:

- *You can make the "DIY" wind turbine prototype from KidWind.org for approximately $20-30 using the following link, or you can access an electronic copy in the included materials for this lesson called "windbasicpvcwindturbine.pdf": http://www1.eere.energy.gov/education/pdfs/wind_basicpvcwindturbine.pdf
  - The purchased version can be obtained from Carolina Biological Supply Item # 183251 or from Vernier (KW-BWX – KidWind Basic Wind Turbine):
  - One disadvantage of "DIY" kit is there are fewer options such as LED lights, gears, and directions but the DIY kit still works well for basic applications.
- ** Purchasing a set of 10 quick release hubs allows you to quickly change out hubs from the different groups to the motor/generator so you don't have to build/purchase as many complete wind turbine towers/setups. (Vernier KW-WTH10 – KidWind Wind Turbine Hub, 10 pack). *Note that this 10-pack comes with one blade pitch protractor*
- ***Box of blades materials from Vernier – this comes with 75 precut balsa wood sheets and 150 precut chipboard sheets. (KW-BDC – KidWind Blade Design Consumables)
- ****It is helpful to have 1 box fan per two groups (relatively easy to borrow from parents/teachers – don't worry if they are not all exactly the same). Here is an example of one of the fans that can be used: http://www.amazon.com/Lasko-3733-20-Fan-Box/dp/B00002ND67

PREP:

1. Purchase Pre-made Wind Kit (see materials above) or purchase the materials to build "DIY" wind kit.
2. Put materials for constructing or assembling wind turbines in bins or in location within the room. If you decide to buy the materials to make your own "DIY" wind turbine, you can buy 5' PVC pipes and then cut them to correct lengths (You can also have students do this but it takes about 45 min for them to cut and construct them. You will also need one hacksaw per group or the kids end up waiting).
3. Decide how to divide the labor between the two groups for each wind turbine (2 groups will be sharing 1 wind turbine).
4. Make copies of "windbasicpvcwindturbine.pdf" so students have the directions to build their wind turbines (1 or 2 copies per group works well - students can share directions).

5. Make copies of "Student Sheet 5: Measuring Power Generation in Wind Turbines" – 1 copy per student.
6. Colored copies of national and state wind maps from your area or computer access (1 computer per 2 students). An example is provided in lesson 5 materials "National and State Wind Rating Maps.pptx" See website below: http://apps2.eere.energy.gov/wind/windexchange/windmaps/residential_scale.asp

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LESSON 5:

Build/Set Up Turbine and Box Fan (20-30 minutes)

- Hand out: "Student Sheet 5: Measuring Power Generation in Wind Turbines" to each student.
- Next, have students get the materials necessary to build one wind turbine (note: there is one wind turbine for two groups of students). Also, have students collect the box fan. Show students the video for putting together their wind turbine set up (just over a minute long). The video is not exactly the same as building the "DIY" turbine, but the ideas are the same. http://vimeo.com/23002291 or http://www.popularmechanics.com/science/environment/how-to/g118/make-your-own-miniature-wind-turbine/ Once each group has set up their wind turbine, give them time to set up and play with their turbine and box fan set up.

  Teacher Notes:
  - If you plan on students cutting the PVC themselves, show them how to cut safely and plan on using almost an hour to construct their wind turbines.
  - Make sure wind turbines are labeled by group number so that you can redistribute the same wind turbines to each group the following day so students are able to finish collecting data. Also, If you opted for the "home made" version, yours will be different, but the idea is the same.

Brainstorming Variables that Affect Voltage in Wind Turbines (10-15 minutes)

- After each group has had an opportunity to investigate the turbines in action, have elbow partners brainstorm as many variables as they can that will affect the speed of the wind turbine and write them on Part 1 of "Student Sheet 5: Measuring Power Generation in Wind Turbines". Have groups share out possible variables and then teacher may write them on the board. Finally, assign (or allow each group to choose) a particular variable to test.

  Teacher Note: It is helpful if different groups are investigating different variables so students can communicate their results and learn from each other. Examples of

variables students may choose include: Number of turbine blades, turbine material, turbine angle, distance between fan and turbine, and speed of fan, to name a few.

Research Wind Patterns in the Entire Country, your State, and Your town (15-20 minutes)

- Hand out student sheet "Copies of "Wind Assessment: How windy is it where you live?" (1 copy per student). Have students work in groups of two to examine the colored wind maps you photocopied from both the entire country and the state you live in. If you have computer access, students will not need the colored wind maps and may find the wind map resources at: http://apps2.eere.energy.gov/wind/windexchange/windmaps/residential_scale.asp Have students answer the questions on their student sheet and then review them as a class.

  Teacher Note: If you have access to an anemometer and are able to take readings from your fan, you can decide whether or not you want to duplicate the average wind speed conditions of your region while actually performing your investigation in the next section. This way, students can find the fan speed and distance from the fan that most closely approximates the average wind speed in their area.

Optional but Helpful: Teaching Students how to find Voltage and Amperage using Multimeters (15-20 minutes)

- **Special Materials:** For this section, make sure each group of students has access to a multimeter, 1.5 V AA battery, two alligator clips, and small load such as a light, or motor. Then show them the following video clips:
- **Finding Voltage:** You can have students try this using their multimeters and a small battery (1.5 V AA battery works) - https://www.youtube.com/watch?v=GZX3MyBkMvA
- **Finding Current:** Once again, have students try what they see in the video with their multimeters and batteries. However, finding current is a little more difficult than finding voltage because you need to have the battery and a load (light, resistor, or something that is using electricity). You will need to have students attach their multimeter in series from the battery to the load to find the current.
  - https://www.youtube.com/watch?v=7IwZkI0yBqA
  - https://www.youtube.com/watch?v=bF3OyQ3HwfU (start this video at 3:30 to see an explanation and then a diagram and example of how to measure current)
- **Teacher Resource:** Here is a short video clip that might be helpful if current and voltage is confusing but it may be too confusing for students:
  - https://www.youtube.com/watch?v=lYZUXV-v71Y

Write Question, Hypothesis, and Procedure for Tested Variable (15-20 minutes)

- Have students work in their groups to fill out Part 2: "Write Question, Hypothesis, and Procedure for Tested Variable" for "Student Sheet 5: Measuring Power Generation in Wind Turbines".

Teacher Note: It is highly advisable to check procedures from groups as they finish and check them off to be sure they are complete and specific. Also, some teachers like to have everyone in a group write the same procedure exactly OR you can have individual students write their own.

Work in Groups to Make Turbine Blades (25-35 minutes)

- Quickly review with each group what variable they will be testing. Also, show students how to attach the turbine blades to the balsa wood using duct tape and then how to attach the dowels to the black plastic hub. If you need a refresher, see the following link: http://www.popularmechanics.com/science/environment/how-to/g118/make-your-own-miniature-wind-turbine/

  Teacher Notes:
  - Make sure students have access to balsa wood blades, chipboard blades (basically cardboard), duct tape, a black hub for each group, wooden dowels, razor blades and scissors, etc.
  - You will need to show students how to use the "Blade Pitch Protractor" to set all the blades at the same angle
  - Students will struggle to figure out that the blades need to have an angle on them to actually rotate and the angle needs to be in the same direction for each blade.

Collect Data (25-35 minutes)

- Once students have finished their blade set-up, have them attach their hubs to a wind tower and begin testing for voltage and current. Make sure and record your data in the data table from Part 3 "Collecting Data" of "Student Sheet 5: Measuring Power Generation in Wind Turbines". It is possible students will struggle to work out "issues" in their experimental setup and not actually collect "real" data the first day. That is normal!

  Teacher Notes:
  - If you have an anemometer, you can collect data at the "average wind speed" of your region. You will need to visit each station to find out how far away the wind turbine has to be from the fan in order for the wind speed to be correct. This is not necessary but it does help recreate more "real" life conditions.
  - If you feel overwhelmed trying to find both voltage (potential in volts) and current (amps), it is ok to simply have your students do all their measurements in volts in the data table and skip finding the power (finding power is: Volts X Amps = Watts)
  - Make sure wind turbines are labeled by group number for easy retrieval tomorrow.
  - You can have students write/type their results using a document camera, chart on the board, Excel spreadsheet, or poster. The graph provided can be used in

any number of ways as well. Feel free to substitute any graphing method applicable to your students' level of understanding.

Communicate Data with Others (10-15 minutes)

- Have each group quickly share their question and the results they obtained. Examples of data shared could include: number of turbine blades, distance from fan to wind turbine, speed setting of fan (wind speed), angle of blade, weight/density of blades, total surface area of blades (solidity).

Which Wind Turbine Configuration Generates the Most Power? (10-15 minutes)

- Choose one wind turbine tower and fan as the test set up. Then, have each group test their wind turbine blade configuration that generated the most power using the test set up (to make sure all the variables are the same). Keep track of the amount of power generated (or just voltage if you wanted to keep it simple) and write your data on the board.
- **Option #1:** Keep track of which configuration generated the most power. Save this turbine blade configuration and test this model against the winning solar power configuration in the upcoming lesson.
- **Option #2:** Alternatively, you could also take the best configuration, distance, wind speed, etc. and combine it all into one configuration and use this set up to compete against solar power.

SOURCES AND WEBSITES USED:

How a DC Motor Works
https://www.youtube.com/watch?v=LAtPHANEfQo

Directions and Materials for "DIY" PVC Wind Turbine used by permission from KindWind.org
http://www1.eere.energy.gov/education/pdfs/wind_basicpvcwindturbine.pdf

Setting up Wind Turbine:
http://vimeo.com/23002291
http://www.popularmechanics.com/science/environment/how-to/g118/make-your-own-miniature-wind-turbine/

Resources to Examine Wind Resources in Your Area:
http://apps2.eere.energy.gov/wind/windexchange/windmaps/residential_scale.asp

Finding Voltage:
https://www.youtube.com/watch?v=GZX3MyBkMvA

Finding Current:
https://www.youtube.com/watch?v=7lwZkl0yBqA

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https://www.youtube.com/watch?v=bF3OyQ3HwfU

Understanding the Difference Between Voltage and Current
https://www.youtube.com/watch?v=lYZUXV-v71Y

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