**STEM Activity: Building Wind Turbines to Provide Alternative Energy for Puerto Rico**

Hurricane Maria hit Puerto Rico in September 2017, and over half the island still did not have power even six months later. In one day, people’s lives changed: Schools had to meet outside because their classrooms did not have power, and hospitals and clinics need to find ways to power medical devices. Sergio, a five year-old with asthma, visited a local restaurant several times a day because they had a generator that could power the machine that helped him breathe.

A storm like Hurricane Maria would be a disaster no matter what, but different energy systems can be better prepared to handle such storms. The electrical grid in Puerto Rico has needed improvements for a while. Officials had planned to put in a natural gas pipeline, but they did not seek any community input in making these plans. Putting in a pipeline would disrupt people’s homes, communities, and the environment. Community and environmental protests stopped the pipeline. Restoring the old electrical grid has many challenges, including transporting materials to the island and finding materials that will work in tropical weather.

Puerto Rico (and other communities) need options for alternative energy sources that can withstand storms and recover quickly after a natural disaster. The costs and benefits of these energy sources need to be communicated effectively to different community stakeholders. A successful design is one that uses renewable energy flexibly and efficiently, and that takes into account the needs and concerns of people in the community.

**Your task** is to use a renewable energy resource, namely wind power, to provide a solution for the Island’s energy problem. More specifically, you will design a wind turbine to generate electrical energy that will be used to provide electricity to the communities in need. To accomplish this task, you will work in teams as scientists and engineers. You will design, test, and refine your wind turbines to increase the efficiency, collectively decide which part of the island is the best location for your wind turbine, and present your proposal for solution to the key stakeholders in the community and the environmentalists.

**HANDOUT 1**

**Review of the Scenario**

* How did Hurricane Maria affect the life in PR?
* What seems to be biggest problem for the Puerto Ricans?
* What have been done to address the island’s electricity problem in the past? How did the community members and environmentalists react to the previous solution ideas?
* How can you as small groups of engineers and scientists work together to solve Puerto Ricans’ power outage problem? Provide suggestions.
* As the small groups of engineers and scientists, what do you need to know to be able to propose a solution to the islanders?
* Who are your audience? In other words, who do you need to convince to be able to enact on your solution?
* How should you go about presenting your proposals/solutions to receive support for your project?

**HANDOUT 2**

**PART 1. Wind Power and Wind Turbines**

Using an iPad or a computer, investigate how wind can be harvested to produce electricity, pros and cons of using wind as a source of energy, and the parts and functions of a power turbine. First watch the video provided at the link below. Then, visit the following websites to answer the questions below. For any additional websites you may want to use, please check with the teacher for approval.

Video: <http://www.pbs.org/video/nova-wind-power/>

Websites:

Wind Power:

<https://www.awea.org/wind-power-101>

Pros and Cons of Wind Power:

<http://www.pbs.org/now/science/wind.html>

How do wind turbines work?

<https://www.energy.gov/eere/wind/how-do-wind-turbines-work>

<https://www.youtube.com/watch?v=EYYHfMCw-FI&t=1s>

Environmental Impact:

<https://www.ucsusa.org/clean-energy/renewable-energy/environmental-impacts-wind-power#.WrQA7-jwY2w>

<http://windeis.anl.gov/guide/concern/index.cfm>

<https://sciencing.com/wind-turbines-impact-environment-positive-way-20177.html>

Cost comparison:

<http://www.pbs.org/now/science/wind2.html#costs>

**Questions:**

1. Why would global community need to come up with alternatives to fossil fuels?
2. What are the benefits of wind power as an alternative energy resource?
3. What are the drawbacks of using wind power as a source of energy?
4. In what ways can power production be compared to a crop?
5. In what ways can using wind power can help with economy?
6. What is a wind turbine? What does it do? How does it work?
7. What are the parts of a wind turbine? What is the function of each?

**HANDOUT 3**

**PART 2. Building, Testing, Evaluating and Refining a Wind Turbine**

We will use the KidWind resources to build our wind turbines except for the blades. You are also provided additional materials to complete your wind turbines. Instructions for the wind turbine can be found at this link (Only pages 3 to 6 will be used): <https://www1.eere.energy.gov/education/pdfs/wind_basicpvcwindturbine.pdf>

**Re-Design/Test/Refine:**

Question: *How do blades (size, shape, material, weight, number, curve/angle, etc.) impact the efficiency of your turbine?*

Work as a group to determine how you will investigate each variable. Share responsibilities. Show your work in the space below, including a drawing of the designs you constructed and tested, the variables you changed, your reasoning behind your designs, and the data you collected. At the end provide your most efficient design and explain how you determined its efficiency. Use the below template for each variable you investigate.

Design # :

Dependent Variable: Independent Variable:

Control Variables:

Explain:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Draw:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Trial 1 | | Trial 2 | | Trial 3 | | Average | |
|  | Voltage | Current | Voltage | Current | Voltage | Current | Voltage | Current |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |

**HANDOUT 4**

**PART 3. Determining the Best Location for the Wind Turbines**

Section 1. *Question: How do scientists and engineers decide where to place the wind turbines?*

1. To answer the above question, you will first investigate how the distance between your wind turbine and the wind source (fan) affects the amount of energy produced. For this, each group will use an identical fan. You will place your wind turbine 10cm, 20cm, and 30 cm away from the fan and record the value you read on the voltmeter. You should conduct at least 3 trials at each distance and take the average of your readings for more reliable data.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Distance | Trial 1 | | Trial 2 | | Trial 3 | | Average | |
|  | Voltage | Current | Voltage | Current | Voltage | Current | Voltage | Current |
| 10 cm |  |  |  |  |  |  |  |  |
| 20 cm |  |  |  |  |  |  |  |  |
| 30cm |  |  |  |  |  |  |  |  |

CLAIM (How does the distance between the fan and the wind turbine impact the energy produced?):

EVIDENCE (Explain what evidence/data supports your claim)

REASONING (How and Why does the data/evidence supports your claim?)

1. Second, you will investigate how the wind speed affects the amount of energy produced. For this, you will use fan with 3 settings. You will place your wind turbine 20cm away from the fan. You will check the value on the voltmeter by setting your fan speed to the slowest, medium, and the fastest setting. You should control the time of exposure (e.g., 30 seconds) each time. Also, you should conduct at least 3 trials at each fan setting and calculate the average of your readings for each setting for more reliable data.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wind/Fan Speed | Trial 1 | | Trial 2 | | Trial 3 | | Average | |
|  | Voltage | Current | Voltage | Current | Voltage | Current | Voltage | Current |
| Slowest (1) |  |  |  |  |  |  |  |  |
| Medium (2) |  |  |  |  |  |  |  |  |
| Fastest (3) |  |  |  |  |  |  |  |  |

CLAIM (How does the distance between the fan and the wind turbine impact the energy produced?):

EVIDENCE (Explain what evidence/data supports your claim)

REASONING (How and Why does the data/evidence supports your claim?)

*Question: How do scientists and engineers decide where to place the wind turbines?*

Conclusion:

Section 2. *Question: Where on Puerto Rico should you place your wind turbine?*

Below are the links to the wind maps (of average yearly and seasonal wind resource estimates for Puerto Rico) that will help you identify the location(s) on the island where you can construct your wind turbines. After reviewing the maps as a group, be prepared to propose specific location(s) and justify your proposal with evidence you gathered from the map.

<http://rredc.nrel.gov/wind/pubs/atlas/maps.html#2-6>

* [2-16 Annual average wind resource estimates in Alaska, Hawaii, Puerto Rico, and Virgin Islands](http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-16m.html)
* [2-17 Certainty rating of wind resource estimates in Alaska, Hawaii, Puerto Rico, and Virgin Islands](http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-17m.html)
* [2-18 Certainty rating of the wind resource estimates for areas with Class 3 or higher wind power in Alaska, Hawaii, Puerto Rico, and Virgin Islands](http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-18m.html)
* [2-19 Certainty rating of the wind resource estimates for areas with Class 4 or higher wind power in Alaska, Hawaii, Puerto Rico, and Virgin Islands](http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-19m.html)

CLAIM: What is your suggested location(s)?

EVIDENCE: What evidence/data from the maps did you gather to answer this question?

REASONING: How does your evidence support your claim?

**HANDOUT 5**

**PART 4. Presentation to the Community**

In this last part of the lesson, you will use all the information you learned since the beginning of the lesson to put together a proposal. This proposal will explain your solution as to how to use wind power to address the power outage in Puerto Rico. Your presentation of the proposal should;

* highlight the importance of alternative energy resources, more specifically wind,
* address how and why wind power can be a suitable alternative energy resource for Puerto Rico
* explain pros and cons of using wind power
* include the decision-making processes you went through to come up with your proposal -including how pros outweighs the cons in your proposal
* explain where you propose to locate the wind turbine on the island and why, and
* explains why they should hire you and fund your project.

You should use a visual media such as, PowerPoint or Prezi presentations or a Poster presentation, to communicate your ideas.

You should revisit the work you completed in previous parts (e.g., pros and cons of using wind power and wind turbines to produce energy) as you put together your proposal and presentation.

You will present your work, in class, to your peers who will be the key decision makers (e.g., community members and environmentalists).

Below is the rubric that explains how your work will be evaluated:

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Excellent**  **(3)** | **Satisfactory**  **(2)** | **Needs Improvement**  **(1)** |
| **Strength of the Proposal** | All arguments were supported by evidence gathered from the online and experimental investigations. | Arguments were mostly supported by the findings and the online investigations. | The arguments were not clearly supported by the online and/or experimental investigations. |
| **Clarity** | Information provided and the proposal was very clear for stakeholders to make a decision. | Information provided and/or the proposal was somewhat clear for stakeholders to make a decision. | Neither Information provided nor the proposal was clear enough for stakeholders to make a decision. |
| **Use of Visual Media** | The visual media was effectively used to present the ideas clearly and effectively. It was engaging and interactive. | The visual media used had interesting images, diagrams, charts, etc. but wasn’t engaging enough. | The visual media was not engaging nor was it interactive. |
| **Group Work** | Group members worked together effectively to present their proposal. | Group members worked well together but some had more responsibilities than others. | Group members weren’t well-prepared to present together or were distracted during the presentation. |
| **Enthusiasm** | Group members were very enthusiastic about their ideas and presented with great energy. | Group members were enthusiastic about the ideas but the presentation lacked energy. | Group members did not show any enthusiasm toward their presentation. |