Green Power Grid

Goals

- Understand how different renewable energy sources work
- Combine them to make a smart energy grid
- Make calculations based on data

Background

The wind and the Sun have been sources of energy for humans since ancient times. We've relied on the Sun to grow our crops and the wind to power our sailing ships for thousands of years. But ancient farmers and mariners alike knew that the Sun doesn't always shine and the wind doesn't always blow. To this day, farmers plant their crops at certain times of year so that they can receive the optimal amount of sunlight. And becalmed sailors, trapped in windless seas for days or sometimes months at a time, would run the risk of running out of food and fresh water.

Today we can use sunlight and wind to generate electricity with solar panels and wind turbines, but we're limited by the same reliability issues that troubled our ancestors. What do we do when the sun isn't shining or the wind isn't blowing? If there was a way to store excess energy at times when sunlight or wind were strong, that stored energy could be used when a solar panel or wind turbine wasn't generating as much electricity.

Modern science has developed a possible solution in the hydrogen fuel cell, a device that combines hydrogen and oxygen to generate an electric current and only produces water as a byproduct. Solar and wind energy can be used to split water into hydrogen and oxygen, and those gases can be recombined by the fuel cell. The hydrogen becomes a way to store the extra electrical energy.

The electrical grid that provides power to all the homes and businesses around the country depends on constant power being available, so a technology that can store excess power and make it available at times of high demand would be useful for any power source, but it's especially needed when the source is as intermittent as solar or wind.

Would this technique work well with both wind and solar power? Are there any advantages to one combination over the other, or is there a combination we're not considering that could work better?

In this activity, we will generate electricity with wind, solar, and fuel cell power to determine if a hydrogen energy storage system works better with a solar or wind power source.

Fuel Cell and Wind Procedure:

1. Look at the three different types of blades available (labeled A, B, and C). How are they similar? How are they different? Discuss with your group which type of blade you think would work best with your turbine and record your observations below.

2. Select the type and number of blades you want to test. Why do you want to test this type of blade first? Do you think it will be better or worse than the other types?

3. Check that the blades are in the same position using the three notches near the white bases of the blades. Rotate the individual blades if needed to get all the blades into the same position. Would your turbine still work if the blades were in different positions?

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4. Insert the blades into the Rotor Base and put the Blade Holder and the Blade Assembly Lock, then attach the Blade Unit to the metal shaft of the turbine. Can your blades be positioned backwards? How do you know if there's a "right way" for a blade to be positioned?

5. Now you're ready to use the electricity from the wind turbine to generate hydrogen gas using the electrolyzer. The electrolyzer is the blue square with "H2" and "O2" printed on either side. What do you think will happen if you connect it to a source of electricity like the wind turbine?

6. Your electrolyzer is also a hydrogen fuel cell that can generate electricity from hydrogen and oxygen. It has two small tubes attached to it. Is there anywhere else on the fuel cell that you could attach the longer tubes?

7. Look at the remaining pieces of your kit. If the fuel cell splits water into hydrogen and oxygen gases, what could you use to trap the gases so they don't float away?

8. Connect the tubes of your fuel cell so that you can trap the gases. To generate hydrogen, you'll need to supply an electric current from the wind turbine.

9. Turn on the fan and position it in front of the turbine. It will work best if you keep the fan close to the turbine and line up the center of the fan with the center of the turbine. Why would changing the position of the fan affect the wind hitting the turbine?

10. Connect the turbine to the fuel cell by using the red and black wires. Record your observations in the Data Table below: Did the fuel cell start producing hydrogen and oxygen gas? How do you know?

11. If H2 tank fills with hydrogen, disconnect the turbine and use the fuel cell to power the motor or LEDs. If the H2 tank doesn't have any gas, proceed to the next step. Record your observations below.

12. Discuss what you observed with your group and discuss what you want to change to try and get the turbine to produce more electricity: the number of blades, the angle of the blades, the type of blades, or some combination of those.

13. Disassemble your wind turbine and reassemble it with as many changes as you can think of, then reconnect it to the fuel cell. Record your observations in the Data Table below.

Observations

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Data Table:

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	H2 gas? (Y/N):	Other Observations:

Fuel Cell and Wind Experimentation:

1. Based on your data from the previous experiment, keep the angles of the blades the same and try different numbers of different types of blades to see which works best. Record your observations below:

Number of Each Type of Blade:	H2 gas? (Y/N):	Other Observations:

What combination worked best?

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2. If you used a combination of different types of blades, try changing the arrangement of the blades (A, B, A, B or A, A, B, B, for example) to try and get the rotor to turn faster. If your rotor spun fastest with only one type of blade, you can skip this experiment.

Blade Order:	H2 Gas? (Y/N):	Other Observations:

What arrangement worked best?

3. What's the farthest distance you can move your fan and still generate hydrogen gas? Use your ruler to measure how far your fan is from your turbine blades. Try different arrangements to see if you can get the turbine to work at even farther distances.

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	Distance (cm):	H2 Gas? (Y/N):	Other Observations:

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4. What's the fastest speed you can fill the H2 tank? Using your best configurations according to your previous data, see how long it takes to fill your tank. Record your observations below:

Blade Type (A, B, C):	Number of Blades:	Blade Angle (6°, 28°, 56°):	Time (sec):	Other Observations:

Fuel Cell and Solar Procedure:

1. Now you'll use your solar panel to power the electrolyzer in the same way that you used the wind turbine during the last experiment. Be sure you have a light source is bright enough to generate an electric current.
2. Connect the solar panel to the electrolyzer using red and black wires, just as you connected the wind turbine earlier. Record your observations below.

Observations

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Fuel Cell and Solar Experimentation:

1. Discuss with your group how you could get your solar panel to generate more electricity to run the electrolyzer faster. Try different approaches to see what works best. Time how long each configuration takes to fill up the H2 tank. Record your observations below:

Trial:	What You Changed:	Time (sec):	Other Observations:
1			
2			
3			
4			
5			
6			
7			
8			

2. Hook up your solar panel to both the LEDs and the electrolyzer using red and black wires and the circuit board. This will simulate a smart energy grid, using electricity while also capturing excess energy as hydrogen. Use your best configurations according to your data and see if you can get the LEDs to light up while also generating hydrogen. Record your observations below:

Configuration:	H2 Gas? (Y/N):	LEDs Lit? (Y/N):	Other Observations:

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Measurement

For this section, you will need a multimeter or the Horizon Renewable Energy Monitor. For an introduction to using a multimeter, click here.

1. Measure the current in amps and the voltage in volts while the wind turbine at its fastest configuration powers the LEDs and electrolyzer. Record your answers below:

Current: ______________ A

Voltage: ____________ V

2. Measure the current in Amps and the voltage in Volts while the solar panel in its best configuration powers the LEDs and electrolyzer. Record your answers below:

Current: ______________ A

Voltage: ____________ V

3. Power is the current times the voltage (P = IV). Based on your data, which energy source generated the most power while running the electrolyzer and LEDs?

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Analysis

1. Make a scientific claim about your electric generators.

2. What evidence do you have to back up your scientific claim?

3. What reasoning did you use to support your claim?

4. Design an experiment that would compare the output of one of the generators you tested with another form of renewable energy. Describe your experiment below.

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Conclusions

1. Based on your data, do you think that storing excess energy in hydrogen is a good way to deal with variable energy output from wind and solar power? Explain why.

2. Do you think that wind or solar power would be a better source of renewable energy for your community? Explain your reasoning.

3. Based on your previous answer and the data you collected, would you recommend that your community be powered by the energy source you chose with a hydrogen fuel cell system? Why or why not?