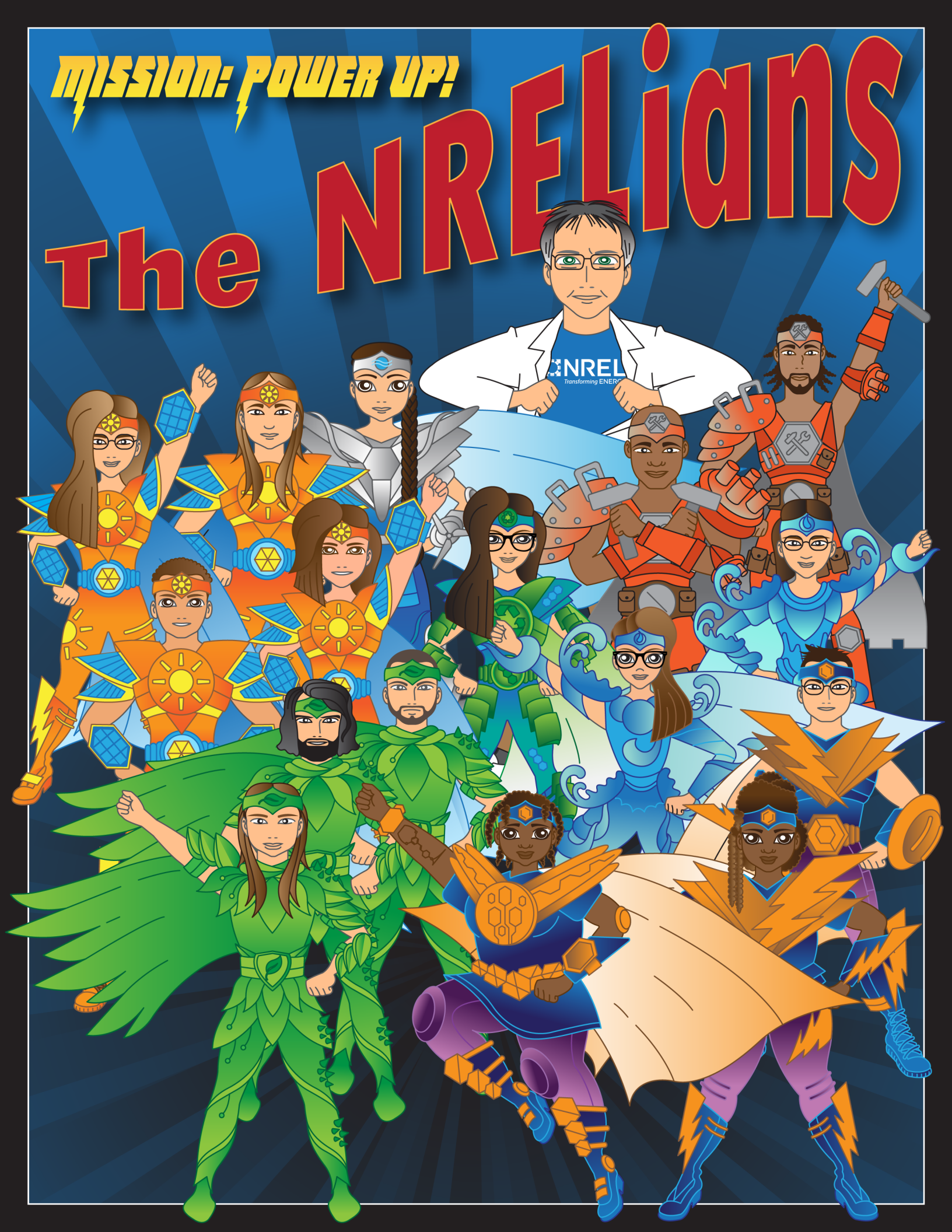
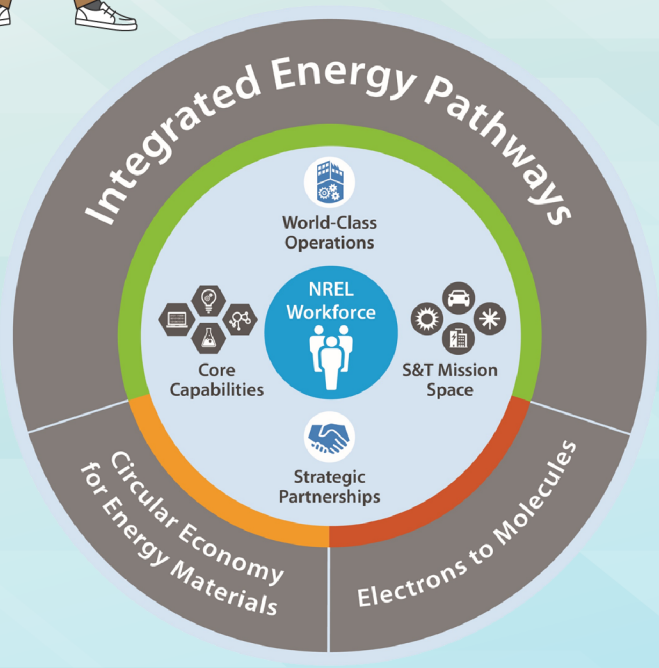

MISSION: POWER UP!
The NRELians
NREL

Hello, I am Dr. Martin Keller, and I am here today to tell you about an extraordinary group of superheroes. The National Renewable Energy Laboratory (NREL) is home to more than 2,500 superheroes, working in many different roles. I want to tell you a little more about all these NREL heroes and what they do.

Some NREL heroes do research. Their work can be broken down into three main categories:



In NREL's **Integrated Energy Pathways** research, our heroes work on modernizing the energy grid and helping to create a more energy-secure future for everyone.

In research related to a **Circular Economy for Energy Materials**, our heroes work on creating a sustainable future by designing and developing products that are easy to recycle and are made with renewable resources instead of fossil fuels.

In **Electrons to Molecules** research, our heroes work on using clean energy to convert low-value, high-availability chemicals, like water and carbon dioxide, into high-value end products like fuels for cars and plastics.

None of these groups could do their work without the help of our behind-the-scenes heroes. NREL has heroes who work with the researchers to communicate their discoveries to the public. NREL also has superheroes dedicated to the safety of the laboratory, superheroes who work on helping researchers get patents for their discoveries, and superheroes who keep the lab spaces clean. Really, NREL is like its own small city. It has heroes who perform almost every kind of job imaginable.

For this mission, you will work with a small group of NREL superheroes to help them defeat our nemesis, Dr. Fever. Dr. Fever likes it hot, and he is always working on evil schemes to increase the world's reliance on non-renewable energy and speed up the effects of climate change. Our heroes must work together to create a more sustainable future and defeat Dr. Fever. Will you help them?

NREL

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NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Solar NRELians,
It has come to my attention that Dr. Fever has been burning fossil fuels at an alarming rate. As humans use more and more electricity to power their lives, it will become increasingly important to make electrical energy from renewable resources. We must help the humans of planet Earth understand there is a better way! Can we show them the power of the sun?
Help me defeat Dr. Fever and his insatiable need to heat up our planet.
-M. Keller

Let's do it! I have an idea of how we can help people understand the power of the sun. We will need a sheet of sun paper and a few fun-shaped items from around the house! Sun paper is special paper with a chemical coating that reacts when it's hit by the sun's light waves, also called electromagnetic radiation.

Oh yes! I've seen this experiment before. We are going to arrange our fun-shaped items on the paper to create a picture. Then we will set it out in the sun for 15 minutes. This part is easier if you arrange your picture outside because then you don't have to balance it while carrying.

After they have been outside for 15 minutes, we will bring in our pictures and remove the items. You should be able to see your picture. We will rinse off our paper to stop the reaction.


Once the paper dries completely, the image you created will be permanent. It's like we took a picture using the sun!
That's really cool! We should also create some real power from the sun, too. Let's use a solar panel to help give our energy board game a little extra electricity. If you are following along at home, you can also watch this video to see a demonstration of the experiment.
It's exciting that we can help people see the sun's power. Once a technology becomes as visible as solar panels, people may think that the research is complete. However, we are always working on different ways to make solar panels more affordable and more efficient.
Wind and Water NRELians,
Dr. Fever would have you believe that water is only good for floating his boats and for dumping his waste, and that wind turbines only spin to cool off all his hot air. I know you all are part of the solution. Can we help humans understand more about turbines and the resources that spin them?
Help me defeat Dr. Fever and his misinformation mission.
-M. Keller


Let's do it! I read about a way to build a turbine. I bet we can use it to build both a water turbine and a wind turbine. We will need two paper plates, two gears, a generator, three jumbo straws, scissors, and a hot glue gun. That should let us build two different turbine heads: one for water and one for wind!
I think I see what you're getting at! Let's start with the water turbine head. We will need one of the paper plates, one of the gears, the three straws, scissors, and the hot glue. We will cut our straws in half. This will let us create a water turbine head with six scoops to catch the water.
I see! Once we have our six straw halves, we can create the scoops. We need to create a notch in the straws. This can be done by pinching the end of the straw together to make it lie flat, then cutting up at an angle. It will look like you cut a triangle out of the straw. This might be hard to picture. You can see a demonstration of this experiment in this video if you are confused.
I am going to set aside the scoops for a second and prepare my plate. My plate will be the backbone of my turbine head, but I need a way to attach it to the generator. I am going to glue the gear to the center of the front of the plate. I can use a ruler or gently fold the paper plate to find the center. I will use the hot glue gun to attach the gear, but you could also do this with tape.
Oh, wow! That's neat. You will be able to attach the plate to the generator and have it spin. Now that we have our gear attached, let's lay out the design of our turbine head. We will use the back of the plate. This gives a nice flat surface to glue the straws on. Lay out the straws so that all the scoops face the same direction. This will allow your turbine to spin easily. You will want your turbine to spin clockwise. Once you are happy with your design, you can glue on your straws.


Once the glue is dry, we will take this experiment outside to test it. We will be using water, so this does need to be done outside. We will need a large cup of water. Attach the plate to the generator by pushing the gear firmly onto the pin of the generator. Hold onto just the generator and hold the contraption away from your body. Pour the water onto the scoops of your turbine. It should spin! If you're using a voltmeter, the video will explain how to attach it.
That is really cool! We can use the remaining supplies to build a wind turbine head for our generator. We will need the other plate, scissors, our hot glue gun, and the second gear. For this experiment, we can be pretty creative. We will be making the wind blades out of the plate. This means we need to carefully design our blades before we cut them. How many blades can we make? How many can we attach to the gear? What shape should they be? Take some time to create your design before you cut. Once you have cut out one blade, you can use it to trace out the other blades if you want them to be identical.
Once we have the blades cut out, it will once again be important to practice laying out our blades on our gear. We will need to figure out how to glue all of them onto the tiny gear AND make sure they are all facing the same way. If you need a little help with this experiment, you can always check out this video.
Once you are happy with your layout, go ahead and glue! For this experiment, hot glue really is the best option, but other glues work, too. Do not use Elmer's glue. It will not stick to the gear. With some creativity, duct tape might work.

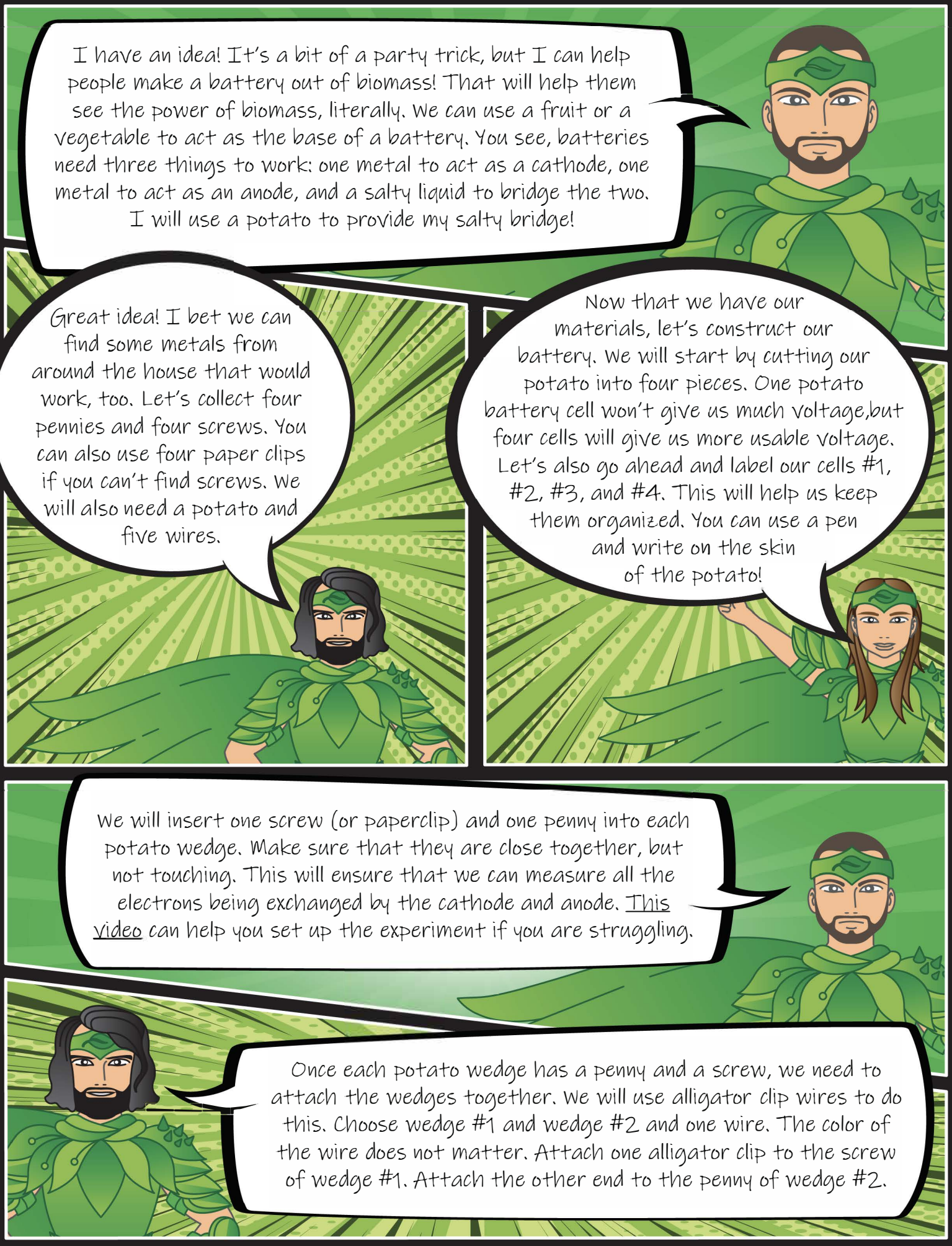
And finally, we get to test our wind turbine head! A fan is the easiest tool for testing the head, but if it is a very windy day, you might be able to test it outside. We need to attach our turbine head to the generator. If the water turbine is still on there, carefully remove it by pulling the gear away from the generator. Firmly push the wind turbine gear onto the pin of the generator.

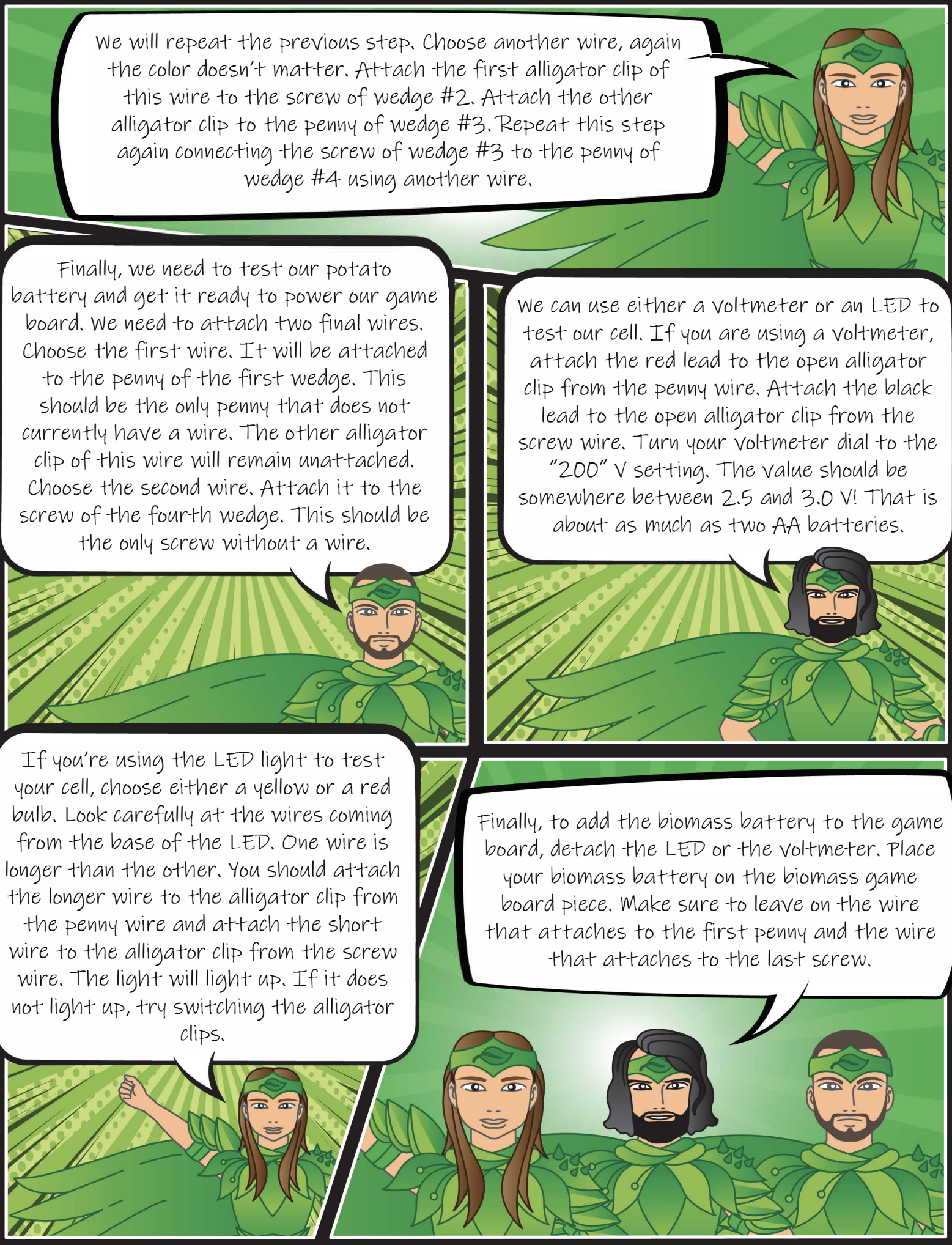
Finally, turn on the fan and see it spin! If using a voltmeter, the video will explain how to attach it. To add our turbine onto our game board, we will need to build a base. We will use the red cup and the popsicle stick. Use the hot glue gun to attach the generator to the top of the popsicle stick. Finally, tape the popsicle stick to the inside of the cup so the generator points out over the edge of the cup. The blades of your turbine heads should be able to easily spin. If they are hitting the cup, move your popsicle stick up and re-tape it. If your cup is falling over, you can add a small amount of weight to the bottom to hold it down.

Biomass NRELians,

One way Dr. Fever has been leading the charge on climate change is by clearing forests to build his evil lair. Every time he cuts down a tree, the planet loses an air purifier. As you know, trees help absorb carbon dioxide from the atmosphere. This harmful greenhouse gas is building up more and more, causing the Earth's temperature to rise. If only there was a way for us to help people see how important biomass is! Can you think of anything? We need to stop Dr. Fever before he cuts down every tree!

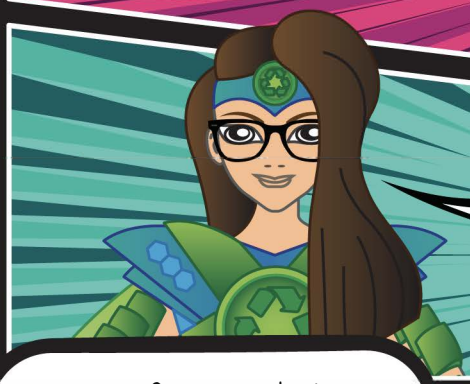
-M. Keller


I have an idea! It's a bit of a party trick, but I can help people make a battery out of biomass! That will help them see the power of biomass, literally. We can use a fruit or a vegetable to act as the base of a battery. You see, batteries need three things to work: one metal to act as a cathode, one metal to act as an anode, and a salty liquid to bridge the two. I will use a potato to provide my salty bridge!
Great idea! I bet we can find some metals from around the house that would work, too. Let's collect four pennies and four screws. You can also use four paper clips if you can't find screws. We will also need a potato and five wires.
Now that we have our materials, let's construct our battery. We will start by cutting our potato into four pieces. One potato battery cell won't give us much voltage,but four cells will give us more usable voltage. Let's also go ahead and label our cells #1, #2, #3, and #4. This will help us keep them organized. You can use a pen and write on the skin of the potato!
We will insert one screw (or paperclip) and one penny into each potato wedge. Make sure that they are close together, but not touching. This will ensure that we can measure all the electrons being exchanged by the cathode and anode. This video can help you set up the experiment if you are struggling.
Once each potato wedge has a penny and a screw, we need to attach the wedges together. We will use alligator clip wires to do this. Choose wedge #1 and wedge #2 and one wire. The color of the wire does not matter. Attach one alligator clip to the screw of wedge #1. Attach the other end to the penny of wedge #2.


We will repeat the previous step. Choose another wire, again the color doesn't matter. Attach the first alligator clip of this wire to the screw of wedge #2. Attach the other alligator clip to the penny of wedge #3. Repeat this step again connecting the screw of wedge #3 to the penny of wedge #4 using another wire.
Finally, we need to test our potato battery and get it ready to power our game board. We need to attach two final wires. Choose the first wire. It will be attached to the penny of the first wedge. This should be the only penny that does not currently have a wire. The other alligator clip of this wire will remain unattached. Choose the second wire. Attach it to the screw of the fourth wedge. This should be the only screw without a wire.
We can use either a voltmeter or an LED to test our cell. If you are using a voltmeter, attach the red lead to the open alligator clip from the penny wire. Attach the black lead to the open alligator clip from the screw wire. Turn your voltmeter dial to the "200" V setting. The value should be somewhere between 2.5 and 3.0 V! That is about as much as two AA batteries.
If you're using the LED light to test your cell, choose either a yellow or a red bulb. Look carefully at the wires coming from the base of the LED. One wire is longer than the other. You should attach the longer wire to the alligator clip from the penny wire and attach the short wire to the alligator clip from the screw wire. The light will light up. If it does not light up, try switching the alligator clips.
Finally, to add the biomass battery to the game board, detach the LED or the voltmeter. Place your biomass battery on the biomass game board piece. Make sure to leave on the wire that attaches to the first penny and the wire that attaches to the last screw.

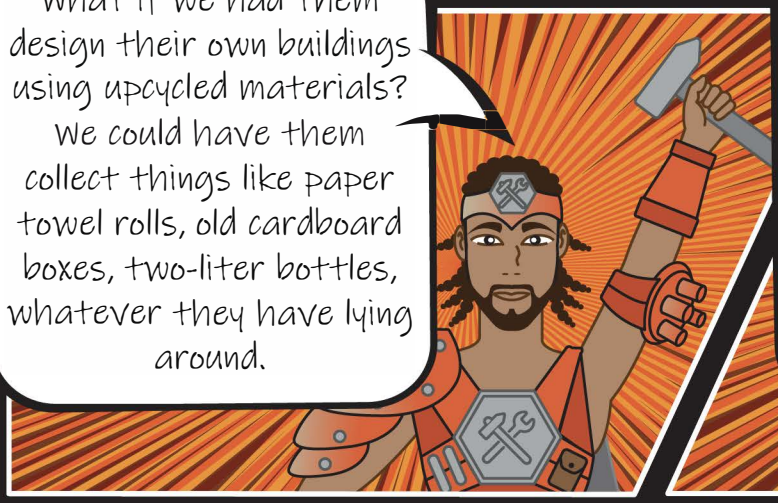
Sustainability NRELians,
We have new reports that Dr. Fever has been hard at work creating his new, patented Fever Achiever™. It will maximize his impact by producing excess waste. At NREL, we work hard to make construction a fever-free activity. I know we have also been working on reducing people's waste with new and improved plastics and upcycling techniques. I just wish there was a way for us to share our sustainable practices with everyone. Buildings, can you think of anything? What about you Plastics and Upcycling?
We need to hurry before Dr. Fever and his Fever Achiever™ destroy everything!
-M. Keller

Do you hear that team? They need us. How can we help people understand more about sustainability and creating energy efficient buildings?

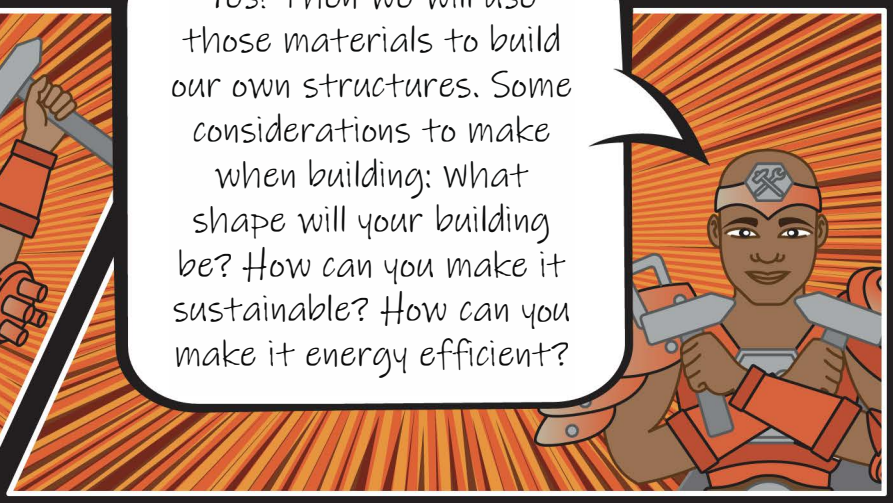


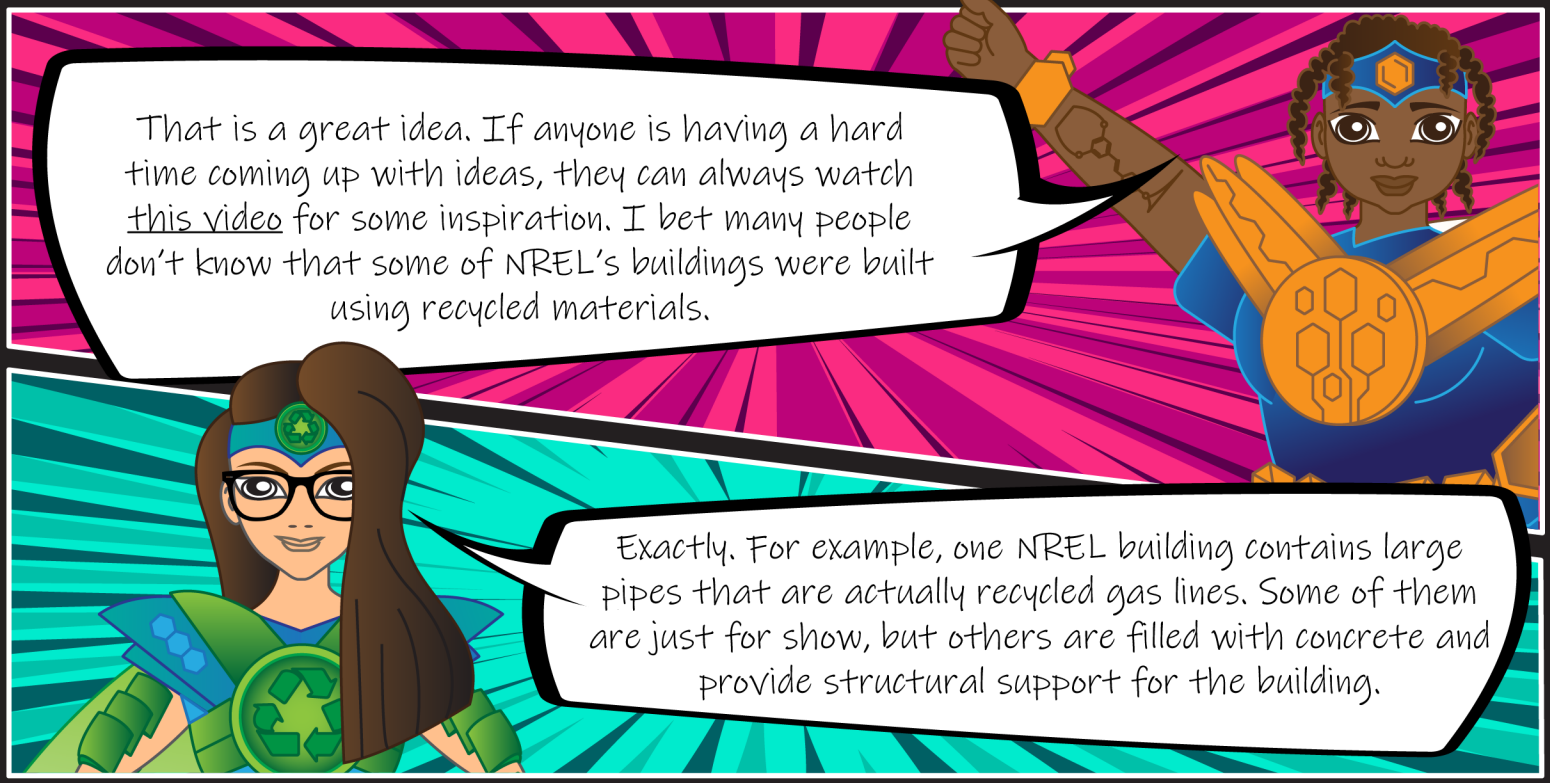
What if we had people design their own buildings?

What if we had them design their own buildings using upcycled materials? We could have them collect things like paper towel rolls, old cardboard boxes, two-liter bottles, whatever they have lying around.



Yes! Then we will use those materials to build our own structures. Some considerations to make when building: What shape will your building be? How can you make it sustainable? How can you make it energy efficient?



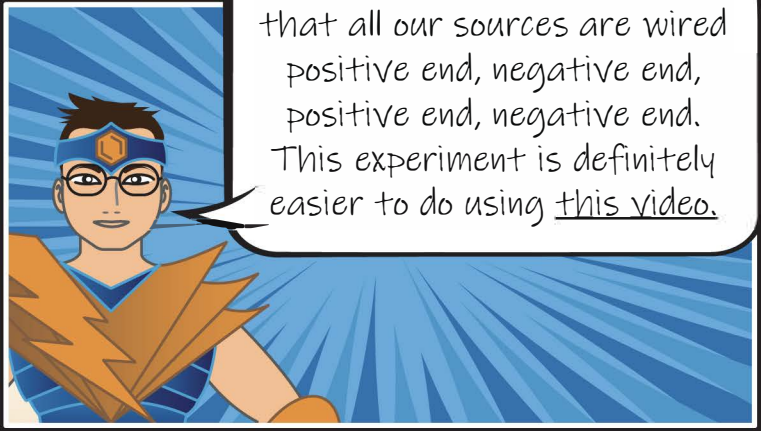

That is a great idea. If anyone is having a hard time coming up with ideas, they can always watch this video for some inspiration. I bet many people don't know that some of NREL's buildings were built using recycled materials.
Exactly. For example, one NREL building contains large pipes that are actually recycled gas lines. Some of them are just for show, but others are filled with concrete and provide structural support for the building.


And most of NREL's workspaces are designed with efficiency in mind. Almost all of our buildings use radiant heating and different forms of solar lighting. When we design buildings, we need to think about how the different materials will work to hold in (or keep out) heat and light.
We will construct our building structure and, when we are ready, we will place it in the center of the board. We also have a special wrap-around for the building. The X's show where to tape LED lights on the page. We will tape the lights in place using copper tape. Pay attention to the wires coming out of the LED lights. One is longer than the other. The lights need to be taped properly or they will not light up.

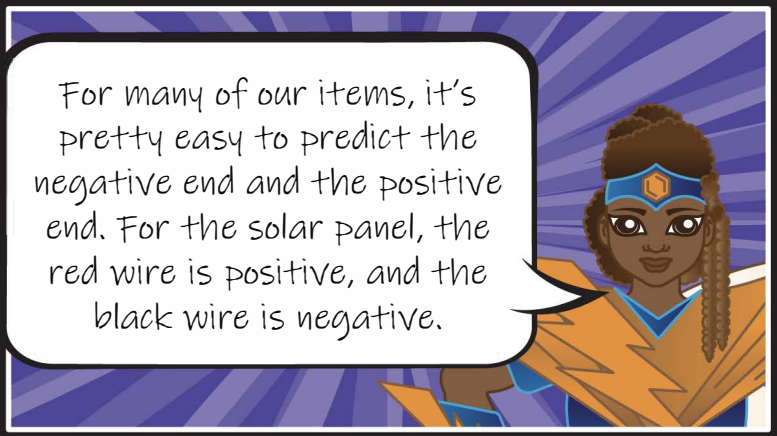
Grid Integration NRELians,
The other teams have all been working to create electricity and buildings through sustainable means, but I am worried that we are not helping them all work together! Dr. Fever has been busy working to destabilize the grid. The only way we can stop Dr. Fever is by working together to combine all these ideas! Can you help us put together our knowledge? Help me defeat Dr. Fever and his destabilizing destruction.
-M. Keller

I completely understand what he is saying. Right now, we have a biomass battery, a solar panel, and a pair of turbines, but none of them are powerful enough to power the building alone. We need to work to combine all these energy sources to create enough power to light up the lights on our building!

Good thinking! This part can be tricky. There is a lot to pay attention to when you are creating a power grid. For example, we need to make sure that we wire the sources together, so the electricity is always flowing in the same direction. Just like we wired our potato battery!

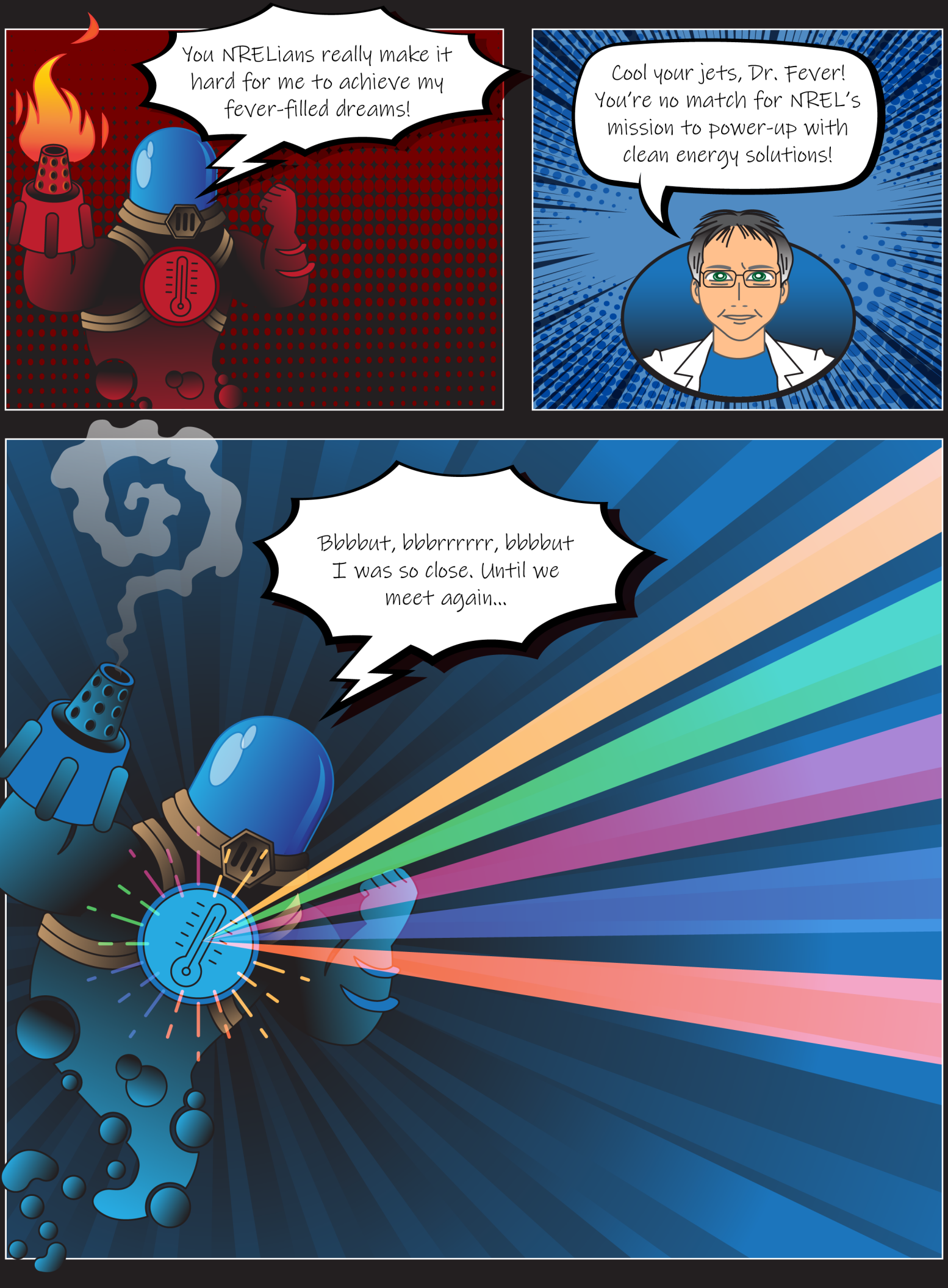


Exactly, we need to make sure that all our sources are wired positive end, negative end, positive end, negative end. This experiment is definitely easier to do using this video.



For many of our items, it's pretty easy to predict the negative end and the positive end. For the solar panel, the red wire is positive, and the black wire is negative.


True. And for the potato battery, the penny is positive, and the screw is negative. That just leaves the turbines. This one is definitely harder. If your turbine spins clockwise, the red wire is positive, and the black wire is negative. If it spins counterclockwise, your black wire is positive, and your red wire is negative.
Nice! That is good to know. Now, let's combine them! We are going to use our alligator clip wires to put it all together. Attach the wire coming off the penny of the biomass battery to the copper tape tab we created for the long end of the wire.
Next, connect the open alligator clip from the wire off the screw of your biomass battery to the positive wire of your turbine. Again, if your turbine spins clockwise, this will be the red wire. If your turbine spins counterclockwise, this will be the black wire.
Connect one end of an alligator clip wire to the black wire of the turbine. Connect the other end to the red alligator clip of the solar panel.
We are so close now! We are going to add one more energy source to our board: a battery pack! Batteries are really important for helping us integrate renewable energy onto the grid.
Right! We use batteries to store power when too much energy is being created, like on a really windy or a really sunny day. Then, on a cloudy day or at night, or when there is no wind, the battery pack can help make up some of the lost energy.
To connect the battery pack, attach the black alligator clip from the solar panel directly to the red wire of the battery pack. Finally, attach a new alligator clip wire to the black wire of the battery pack. Attach the other alligator clip of that wire to the tab we added for the short wire of our lights. Turn on your wind or water source and watch your building glow!


You NRELians really make it hard for me to achieve my fever-filled dreams!
Cool your jets, Dr. Fever! You're no match for NREL's mission to power-up with clean energy solutions!
Bbbbut, bbbrrrrrr, bbbbut I was so close. Until we meet again...

Supplies List

Here you will find a list of supplies required to complete each experiment, as well as links to products that are not as common (links are only suggestions and there are many options available for each product). These experiments can be completed using the supplies, along with the comic book and accompanying videos. Please email the NREL Education Center if any of the links listed here no longer work.

Solar Experiment:

- 2.0 V Solar panel
- Solar paper

Wind Experiment:*

- 20 oz plastic cup
- Craft stick
- Small motor
- Medium gear
- Hot glue gun
- 6" paper plate

Water Experiment:*

- 20 oz plastic cup
- Craft stick
- Small motor
- Medium gear
- 6" paper plate
- Hot glue gun
- Milkshake straws

Biomass Battery:

- Potato or other produce
- 4 pennies
- 4 galvanized screws
- 5 wires with alligator clips

Buildings and Plastic Upcycling:

- Maze wrap around
- 3 LED lights
- Copper tape

Grid Integration Experiment:

- 5 wires with alligator clips
- Battery pack
- 4 AA batteries

*For the wind and water experiments, the solo cup, craft stick, and motor set-up can all be reused for both experiments. Students DO NOT need two solo cups, two craft sticks, and two motors.

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