KidWind Challenge

2013 GUIDEBOOK

Made in US

We source domestically whenever possible, and assemble and pack our kits in St. Paul, MN.

Our plastic components are made from recycled resins.

We Give Back

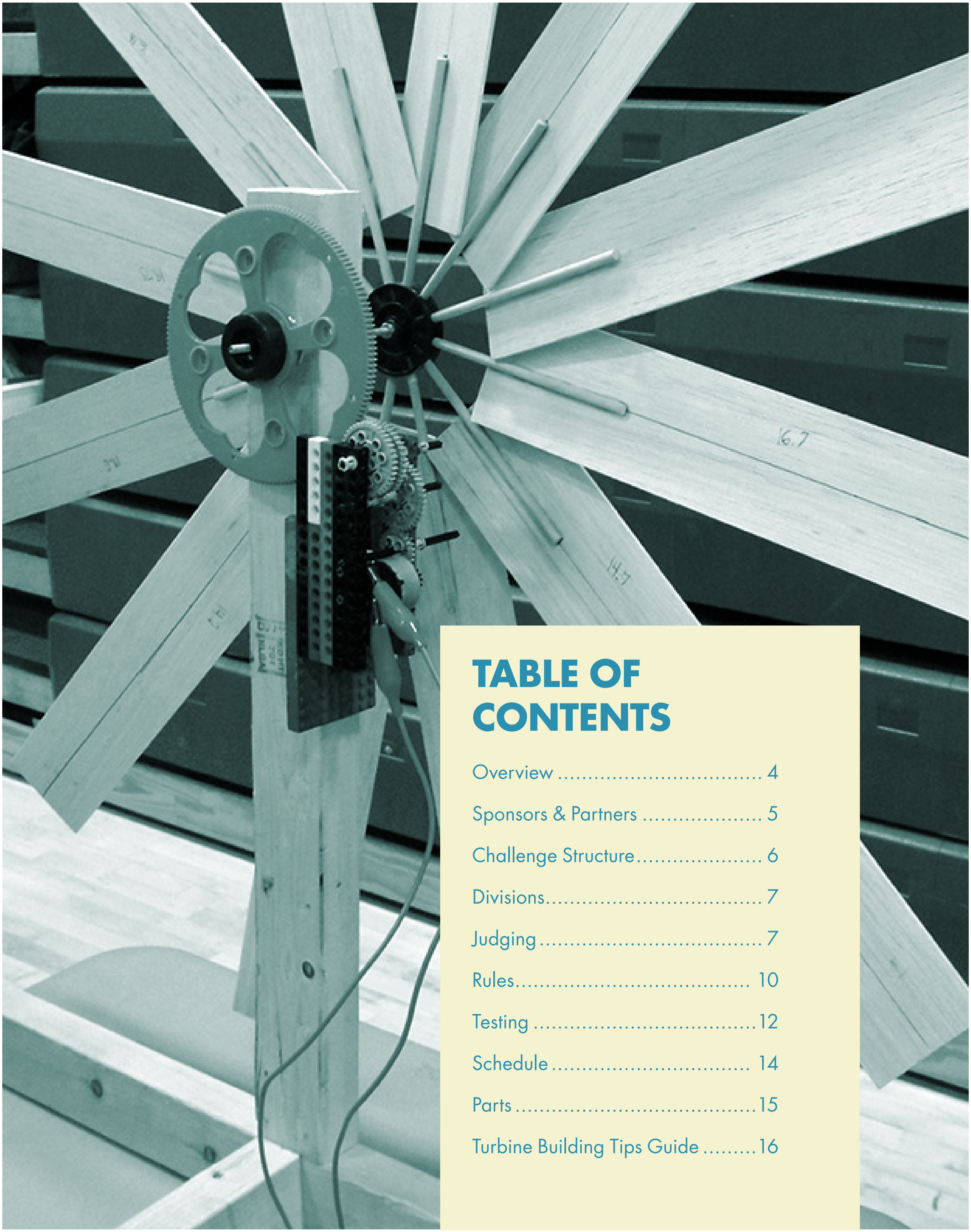
Proceeds from your purchase help us train and supply teachers.

KidWind Challenge Advisory Panel

We are currently building a formal Advisory Board for the KidWind Challenge. During the summer of 2012 we assembled an informal Advisory Panel that was greatly helpful in looking forward in 2013–2014. We thank this panel and hope to add some of these dedicated individuals to the Advisory Board in 2013:

- Charles Newcomb
- Kristen Graf
- Keith Etheridge
- Sarah Bonvallet
- Leah Bug
- Andy Lueth
- Trudy Forsyth
- Larry Flowers
- Cheryl Moeller
- Joe Rand
- Remy Pangle
- Darlene Snow

A Note on Reproduction



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Who is KidWind?

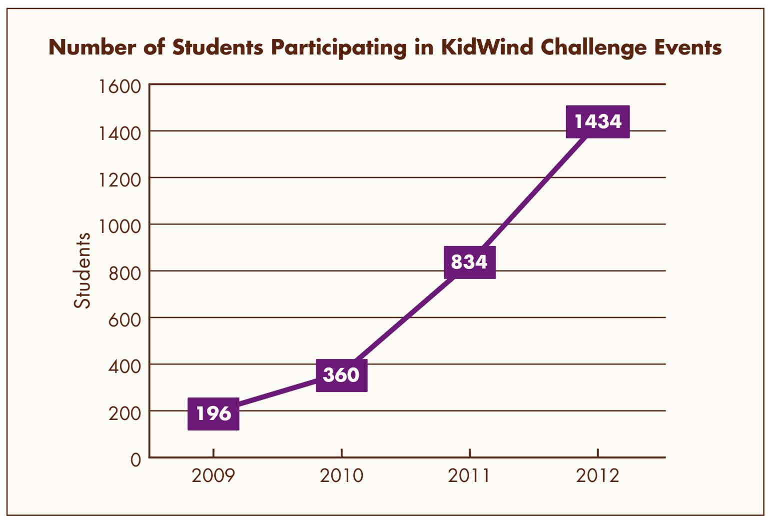
The KidWind Project is a team of teachers, students, engineers, and practitioners exploring the science behind wind and other renewable forms of energy. Our goal is to make renewable energy widely accessible through hands-on activities which are challenging, engaging, and teach basic science and engineering principles.

Founded in 2004, KidWind has established itself as a leader in renewable energy STEM curriculum and teacher training throughout North America. Over the past eight years, we have trained over 8,000 STEM educators through professional development workshops. These teachers impact over 600,000 students annually. We have also held teacher workshops in Costa Rica, Chile, Ireland, Taiwan, and the Caribbean. Our formal, standards-based curriculum provides an interdisciplinary platform for grades 6-12 teachers to engage students in wind energy science and technology.

History of the KidWind Challenge

Over the past four years, the KidWind Challenge has been successfully implemented in over fifteen states. Since the first KidWind Challenge was held in New York State in 2009, over 2,800 students have competed in over forty KidWind Challenge events across the country. During this same period, over 3,000 teachers have been trained to teach renewable energy science and technology in their classrooms through the design challenge. These teachers have impacted over 150,000 students in their classrooms, year after year.

KidWind Challenge Goals



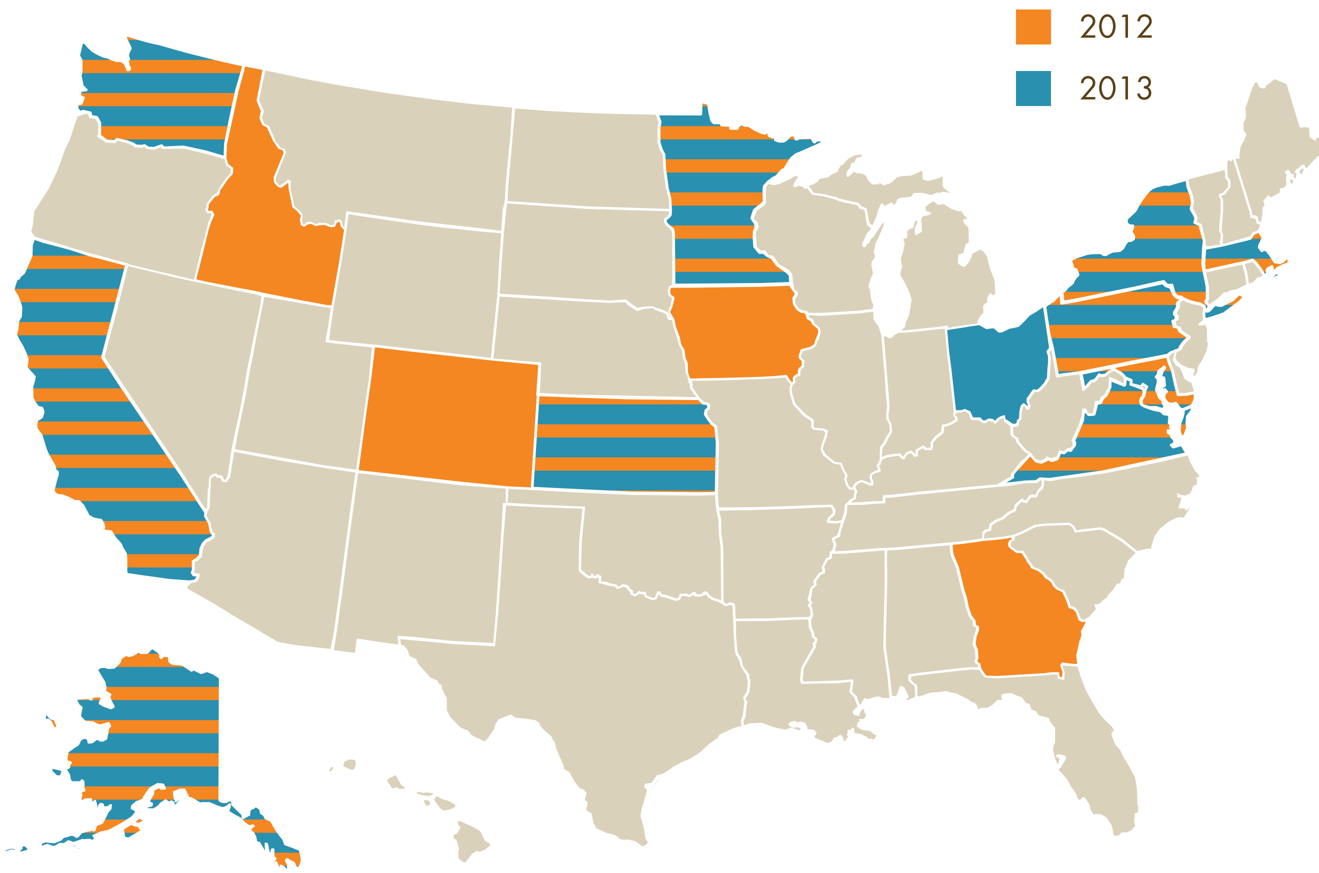
- Get students excited about the promise and opportunities of renewable energy—specifically wind power—and its relationship to global climate change.
- Foster opportunities for students to build, test, explore, and understand wind energy technology at a manageable scale.
- Get students—particularly girls and underrepresented populations—excited about careers in STEM fields related to renewable energy.
- Build capacity of teachers, coaches, and other educators to better understand wind energy technology and development, as well as its promise and limitations.
- Connect students to mentors and role models in the renewable energy industry.

Sponsors & Partners

Challenge Sponsors

While KidWind self-supports a number of Challenge events around the country, our impact would be limited without grants and sponsorships from renewable energy industry organizations and foundations. We are actively seeking additional sponsors to help us engage more students. Sponsoring a KidWind Challenge demonstrates an investment in the workforce of our clean energy future. We invite you to share in our passion to inspire these future leaders, engineers, scientists, innovators, and problem-solvers of our energy future.

KidWind Challenges 2012-2013



National Level Sponsors (Sponsorship in 2+ States)

- Constellation Energy

State Level Sponsors (Event Sponsorship in 1 State)

- Iowa STEM Scale UP Grant
- Puget Sound Energy (PSE)
- Wind Energy Foundation
- Dominion
- Wind Energy Foundation
- Mortenson Construction
- Siemens
- Gamesa
- Upwind Solutions
- Xcel Energy

Partners

We would like to acknowledge some of our 2013 partners:

- Women of Wind Energy (WoWE)
- Penn State Center for Science and the Schools (CSATS)
- High Tech Kids
- National Renewable Energy Laboratory – Wind for Schools Program
- California Regional Consortium for Engineering Advances in Technological Education (CREATE)
- Towson University
- Central Washington University
- James Madison University
- WindSenator Andy Lueth
- Vernier

Challenge Structure

Web Challenge

The KidWind Web Challenge allows students from anywhere in the world to participate using any kits or materials they can find. Teachers or students who are motivated and have some basic equipment can participate.

Learn more about the KidWind Web Challenge at www.KidWind.org.

Classroom/School/Regional Challenges

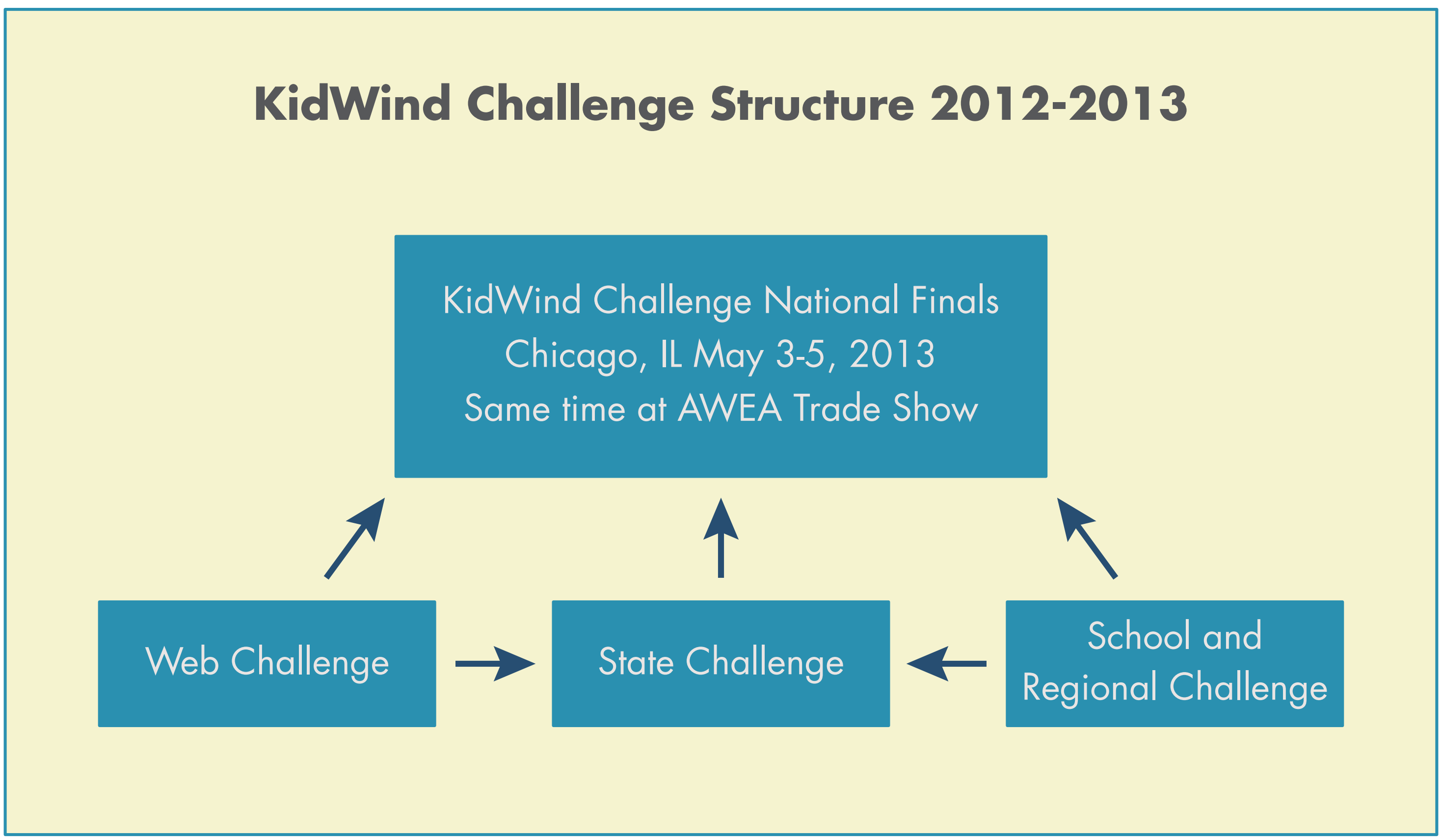
These are challenges ranging from a teacher in a classroom holding a challenge to an entire school having many classes compete to a challenge in a school district or regional area. While most of these events will be led by a WindSenator or KidWind Staff, any motivated individual (teacher, parent) can set this up if they have the skills and experience.

National Challenge

In 2013 the National Challenge Finals will happen digitally. KidWind will collect data via the web from local and regional challenges and in May 2013 we will select National Champions.

Planning for 2014

We are planning to develop more structure for the 2013–2014 KidWind Challenges—adding state level events, etc. We are planning to hold National KidWind Challenge Finals at the USA Science and Engineering Festival in Washington, DC. Stay tuned for more information as it becomes available.



Challenge Divisions

Age Divisions

- K–4 (Beta testing in Iowa)
- 4–8
- 9–12

Turbine Divisions

KidWind Stock Generator Division (4–12). Teams will be required to use the KidWind Wind Turbine Generator (H0002) as the main power generator on their turbine. This is the only part that is required. Teams may only use one generator per turbine.

Open Generator Division (Experimental 4–12). Teams will be able to use our wind tunnel to test anything they have built. Teams will be able to use any generators they want and may even build their own generators.

If their turbines produce alternating current (AC) the team MUST rectify output to direct current (DC) so we can properly collect energy output.

Awards and Prizes

1st–3rd Place. Trophies awarded.

Notebook Award. Best documentation of project process.

Judges Choice Award. Reserved for Judges to make special awards to an outstanding team.

Recycled/Reused Materials Award. Given to the team that uses the most recycled materials in their turbine.

Cash or other prizes may be awarded depending on levels of event sponsorship. Prizes will vary; consult the KidWind Challenge website to learn what may be offered at your local event.

Turbine Judging Rubric

- 40% Energy produced in wind tunnel
- 25% Turbine design
  - 10% Blades
  - 10% Drivetrain
  - 5% Tower
- 20% Report/engineer's notebook/documentation
- 15% Knowledge of wind energy subject matter

This rubric is used for almost all of the regional challenges.

At some KidWind Challenges at the classroom or local level you may only be evaluated on energy produced and turbine design as we may not have enough staff or time to do all the events. See website for details on exactly what will be evaluated at the KidWind Challenge you are attending.

For the KidWind Web Challenge students self–report output data. Each month we evaluate these turbines on energy produced, turbine design and a personal statement provided by the team.

Energy Produced (40% of score)

The total energy output of your turbine over the 60 second trial period will be collected using data logging software. Each team's energy output will be ranked relative to other competitors. Each team will receive points corresponding to their rank.

Scoring. The turbine with the highest energy output (milliwatt-seconds or joules) over the 60 second trial period will score 40 points. The next 10 turbines will lose 2 points off the turbine ahead of them–so 11th place will score 20 points. Each subsequent turbine will lose 1 point off the turbine in front of it (i.e. 12th place will score 19 points, 16th place will score 15 points, etc.).

Turbine Design (25%)

A panel of judges will examine your wind turbine design before testing it in the wind tunnel. You must be prepared to discuss/defend the choices you incorporated into the design. The design criteria you will be judged on include:

- The choices and mechanisms by which you maximized power output
- Craftsmanship of your design, creativity, and environmental decisions (eg. did you use recyclable materials? Can you take your turbine apart after the competition and reuse the parts?).

The judges will be very interested in how you developed and constructed specific parts of your turbine. Make sure you understand the decisions you made when constructed the following components.

- 10% Blades
- 10% Drivetrain
- 5% Tower

Written Documentation of Design (20%)

Students must produce some type of documentation that reflects their design process and their knowledge of wind energy science. It is up to each team to determine how they want to document this part of their project. In the past we have seen:

- Short reports
- Engineer's notebook
- Video or power point
- Science fair poster board

Students must provide the means to play a video or DVD, or run a slide show/power point, etc. We will not provide a computer or other device. Please keep videos to four minutes! See website for examples of past PowerPoints or videos.

Knowledge of Wind Energy and Energy Subject Matter (10%)

Building a wind turbine is only one aspect of the field of wind energy. At regional, state and national challenges you will be asked about your general knowledge of wind energy issues.

In the next section you will see some questions your team can explore as they prepare for this part of the Challenge.

10 Big Questions!

1. Devices that capture the energy in the wind come in many different forms. Think sailboats, kites, and pinwheels. There are windmills to pump water and grind grain, there are wind turbines for your home and for the electrical grid, and there are vertical and horizontal axis machines. What defines each of these kinds of turbines? What are some important ways that they are similar and different? What makes your wind turbine similar to these devices? What makes your wind turbine different?
2. Climate change is major challenge facing the world. What are the environmental benefits of generating electricity using the wind? What are some of the tradeoffs? Why would we want to harness the power of the wind? What challenges might we face in generating 20–30% of US electricity from wind?
3. From what sources do we generate most of our electricity in the US? What are the primary sources of electricity used in your region of the US? How much does it cost to power your house each month? How much of the electricity that is used in the US is generated by wind? How has this changed over the last ten years?
4. In some local communities wind power can be controversial. Below are concerns voiced by local communities. Evaluate the validity of these claims by doing your own research.
   - Sound. People that live near wind turbines sometimes complain that the sound from the wind turbines is causing health impacts from vibration and other acoustical affects. There is data that supports both sides of this argument. What do you think?
   - Aesthetics. Wind turbines can be an eyesore to some people. What can be done with wind turbines to minimize this problem?
   - Environmental Impact (Habitat). Wind turbines can change local habitats and have caused significant bird and bat kills in the past. What is the impact on wildlife from wind turbines? How are biologists and ecologists dealing with these impacts?

5. As wind and solar power are relatively new energy sources to the US pool they receive financial support to make them more economical. Fossil fuels and nuclear power receive subsidies as well. Do you feel that subsidies are appropriate in the energy industry? If you feel they are OK, what energy sources would you subsidize and why?
6. A great deal of research is going into making wind turbines more efficient. What components of wind turbines are undergoing rapid change and development? Which changes seem to be having the most impact in improving turbine performance?
7. What causes wind? What are the windiest parts of the US? Where are most of the wind turbines located in the US? Are there any offshore wind farms in the US? In the world? Why would we want to build wind farms in the ocean?
8. What is the equation that defines how much power is in the wind? What are the most important variables? How does this equation affect turbine design and placement on the landscape?
9. Developing and installing renewable energy, like wind and solar, requires professionals and experts from many different fields of study. What are some of the careers and jobs that make renewable energy possible?
10. Wind turbines can only generate power when the wind is blowing, just like solar panels only generate power when the sun is shining. As we all know, the wind does not always blow and the sun does not always shine. How can we deal with this "variability" of renewable energy resources? How can we ensure that we have power whenever we need it without relying on fossil fuels?

Questions Judges May Ask About Your Turbine

- Does your turbine have a gearbox, a pulley system, or is it direct drive?
- Did you make your own generator (Open Division)? What design did you use? How many versions did you test?
- Did you have any issues with friction? How did you reduce friction in your drive train?
- If you built a geared turbine, what kind of troubles did you have?
- How did you balance your blades? Do you notice any vibration when your turbine spins up to speed?
- Why are modern wind turbine blades shaped like airfoils? Are your blades shaped like airfoils? Did you try to make any airfoils?
- How did you determine the number of blades you would use? Did you perform any experiments?
- How did you determine the pitch (angle) of the blades?
- Why are your blades as long as they are?
- What materials did you use to make your blades? Why? What was important as you were building your blades?
- What techniques did you use to increase the power output of your wind turbine?
- What materials did you use to make your tower? What were some of the challenges you faced making a tower?
- What changes did you make to your turbine that lead to the most performance gains?

Rules for Building Competition Turbines

Beginning in 2013, there will be two main turbine divisions. These divisions are based primarily on the generator used in the turbine.

KidWind Generator Division (4-8) / (9-12)

- Your turbine must use the generator provided by KidWind as the sole power generator for your wind turbine. The judges must be able to verify that the correct generator is being used on your turbine. If the judges cannot verify that the generator is the correct one, your team may participate but will be unable to win prizes.
- Your turbine can have only one of these generators.
- Power must be generated solely by wind generated by the wind tunnel.
- Your turbine can either be vertical or horizontal axis.
- You may attach whatever you want to the generator to increase how fast or hard it spins (e.g. gears, bearings, supports, etc.).
- Your wind turbine must be free standing. A tower/stand will not be provided.
- You cannot use premade gearboxes, airfoils or blades.

Open Generator Division (Experimental) (4-8) / (9-12)

- The basic rule of this division is: If it fits in the tunnel, AND you built it, AND the judges think it is safe, we will run it!
- You can build your own generator based on plans you find from any source. You can use other generators that you purchase (e.g. the KidWind SimpleGen, the KidWind GenPack, Jameco, etc).
- Power must be generated solely by wind from the wind tunnel.
- Your turbine can either be vertical or horizontal axis.
- You may attach whatever you want to the generator (e.g. gears, bearings, supports, etc.).
- You can use a premade gearbox or a generator with a gearbox built in.
- You cannot use premade blades or airfoils.
- Your wind turbine must be free standing. A tower/stand will not be provided.

General Rules

Each team that registers must have their own turbine. You will not be allowed to modify another team's turbine and use it for testing. You cannot have one turbine shared between teams and simply change blades or other parts for each team.

Your team's turbine must be able to fit inside the wind tunnel and must be able to operate within the 48" × 48" internal dimensions of the wind tunnel. It is highly recommended that you design your turbine to fit with plenty of room within these dimensions. Sand bags or other weights will be available to hold the turbine in place in the tunnel if required.

There are no budgetary restrictions for your turbine design, but it is important to keep in mind that part of the judging process is the economical use of resources. Please use materials responsibly.

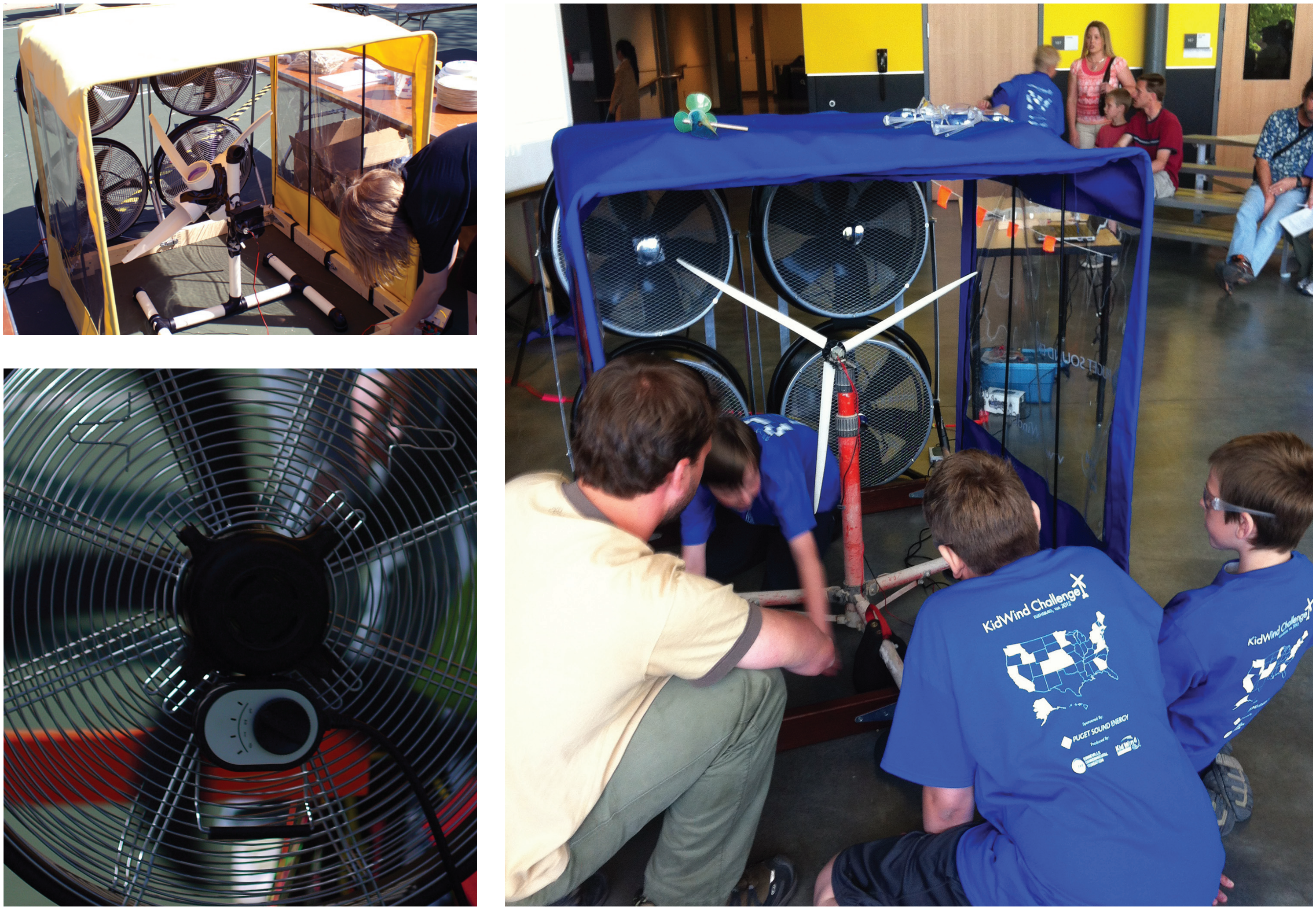
In both divisions you cannot use pre-manufactured wind turbine blades or airfoils/sheets that have been manufactured. You can, of course, attempt to make your own airfoils out of a variety of materials.

Metal, plexiglass and other dangerous blade materials are highly discouraged. On occasion, we have allowed these types of blades to be used, but only after local judges determined that there was an extremely low risk of failure due to assembly. Send us photos if you are unsure. Please be aware that turbines will be disqualified if they are deemed unsafe by the local judges.

Your turbine may use a gearbox or pulley system to increase power output. In the KidWind generator division it is legal to use gears and other drive components that are manufactured. You may not use a pre-packaged gearboxes. In the Open Generator division you are able to use premade gearboxes and generators that you feel are safe.

3D printed parts and components are allowed in all divisions as long as the components have been designed by the team. We will ask for all CAD files if we have any questions about the origin of the parts.

NOTE: Over the last few years students have used wheels from bicycles as part of their turbines. We have allowed these as the blades mounted to them are not made of metal and these wheels are designed to spin at high RPM. In 2013 we will still allow the use of these wheels, but please be aware that if the wheel assemblies appear unsafe local judges can disqualify these turbines.



The wind tunnel in use at KidWind Challenges in 2011 and 2012.

Turbine Testing

Wind turbines will be tested in a 48″ × 48″ wind tunnel at a wind speed of approximately 5 m/s. Please note: wind moving at 5 m/s within a space this large is surprisingly powerful, much faster than a single box fan. Test your device for high winds!

What this means is you need to watch for blade deflection and torque on your gearboxes. Prior to performance testing, student teams will be given a reasonable amount of time to test their devices in the wind tunnel. This will give you a chance to evaluate the conditions of the space.

All teams will be given time to tweak their turbine in the tunnel before actual testing begins. How much time will be determined by the type of event, number of entries, and free time available.

Testing Procedure

Once the testing session begins you will be given two minutes to set up your wind turbine inside the tunnel.

You must have two wires at the base of your turbine. You must label which wire is positive and which is negative. These wires will be attached to a circuit with a 30 ohm resistor in series and will simultaneously measure voltage and amperage.

In order to receive full marks for your turbine's functionality, your wind turbine must be able to start producing power once the wind tunnel is activated without external assistance.

During testing the wind tunnel will be running constantly.

We will collect power output data for 60 seconds. Your energy output score will be calculated using a Vernier data-logging system that collects voltage and amperage readings simultaneously. A sample is available at www.KidWind.org.

If your wind turbine slips, breaks apart, or falls over before the 60 second timer is started, you will either be given two minutes to set up your wind turbine again, or you will be allowed to remove the turbine to make repairs. In that case, you will be moved to the back of the line for retesting.

You will only be given one restart opportunity. It may be granted before the 60 second test begins, or once it has begun, but not both!

Local judges have final say on rulings and protests.

Who has to show up?

To be eligible for the competition, all members of your team must be present on the competition day. We require one adult for every ten students that attend a Challenge.

Exceptions include:

- Some, or all, of your team members are unable to attend because of a scheduling conflict with a school sanctioned trip (a signed note from the advisor is required).
- A team member cannot attend due to illness or family crisis (a signed note from the advisor is required).

Who can participate?

Any group of students in grades 4–12 are eligible to enter a team in any of the KidWind Challenges (web, local, regional). This includes students from public and private schools, home schoolers, after school clubs, Boy Scout and Girl Scout troops, etc. As long as you have an advisor you can attend!

There are no restrictions on the number of members in a team; however, big teams can be problematic as members may not have enough work to keep them occupied.

Each team must have an advisor. The advisor will be responsible for registering the team for the competition and managing the team's progress.

Neither KidWind, nor any local group will provide, or be responsible for, supervision of students. We require that there is one adult for every ten students that attend a challenge.

Registration page

Teams must register for an event to be eligible to attend.

You can register online at www.KidWind.org.

Upon registration—and depending on the state where your challenge is located—you may be eligible to receive a set of standard turbine materials at reduced cost. In some states these materials are distributed by KidWind and in other states they are distributed by a local agency.

Generic KidWind Challenge Schedule (Regional)

8:00am–10:00am Arrive at KidWind Challenge

Typically your team will arrive at a KidWind Challenge and be given a table or space to set up your turbine and other materials. As your team checks in we will usually distribute any t-shirts or other materials for your teams. At most challenges we will have the wind tunnel out for students to make some final tweaks and a tool area so that you can make any last minute repairs.

10:00am Announcements & Introductions

At this time we will convene the teams, introduce the judges ,and give you some idea as to how the day will progress.

10:00am–2:00pm Turbine & Team Evaluation

Although the exact time of the overlapping events depends on how many teams arrive at a Challenge, this generally takes two to four hours. Many different events take place during this time. Teams are typically assigned times for each event to make sure they accomplish each task.

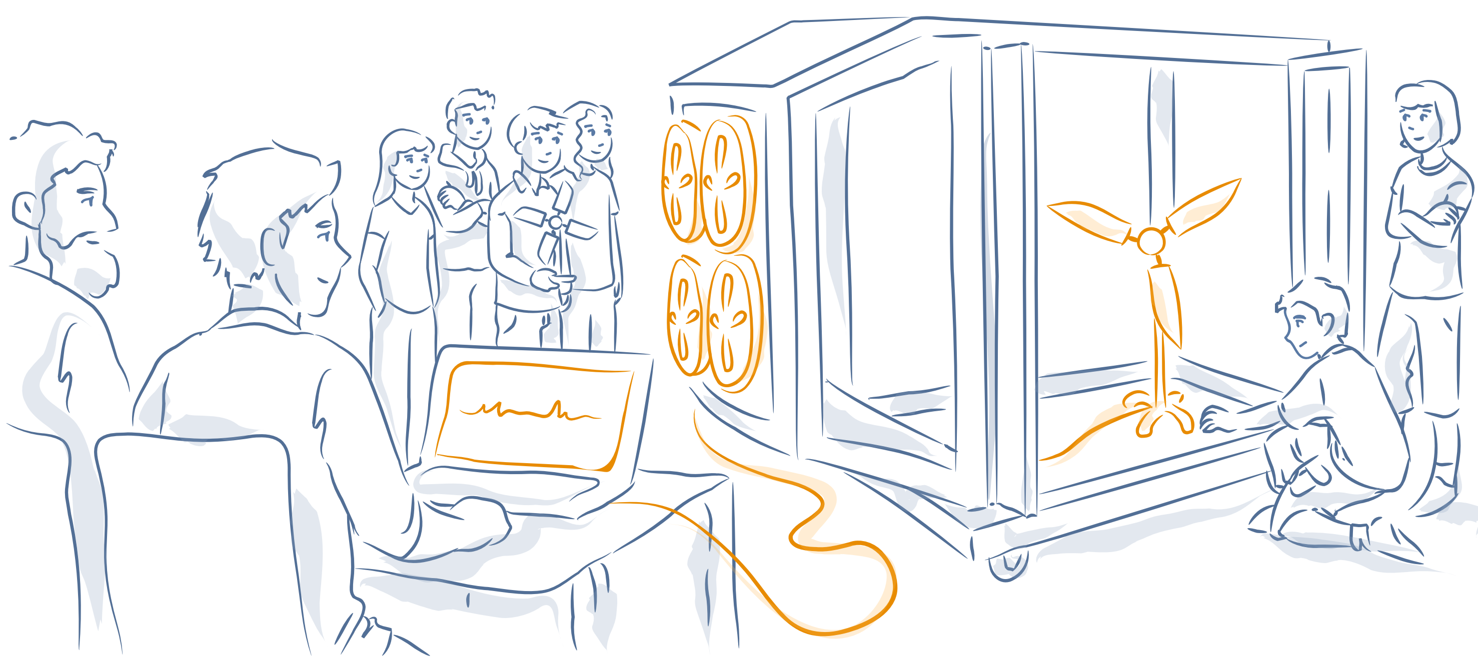
2:00pm Evaluation Events Completed & Judges Tabulate Scores

2:30pm Results & Prizes Announced

3:00pm End of Challenge

Food. Typically we do not provide food at events, although this depends on the budget we have for the event. Sometimes the Challenge is located in areas where food can be purchased and other times you may want to make sure that students have brought their own lunches.

Supervision. We ask that advisors bring their teams to the competition and that there is one adult supervisor for every ten participants.



Parts and Materials for the KidWind Challenge

KidWind offers a number of materials to help you get started on your turbine project. For some Challenges we have been able raise funds so that we can provide participants with free materials. Check your KidWind Challenge page to see what you are eligible to recieve

Parts

- Wind Turbine Generator (H0002). This is all you need to compete at a KidWind Challenge—the rest is just icing on the cake!
- Wind Turbine Hubs (H0005-1). The KidWind Hub makes it easy to attach blades to a generator. Though there are other ways, using this part makes it infinitely less difficult.
- Balsa Wood Blade Materials (H0017-10). Balsa wood is one option, but you can use anything to make blades. If you choose to use metal, be careful—judges may not allow you to run your device if they think it is unsafe. Premade airfoils are not allowed.
- Gears (H0046). You can use these gears to make your own gearboxes. Just don't bring a premade gearbox to a KidWind Challenge—unless you're in the Open Division, you won't be able to place.
- KidWind Challenge Individual Team Kit (M0001). This kit contains the basic components needed to start building a simple wind turbine, including the critical components to build two turbines. This kit includes generators (2), hubs (2), a basic multimeter, and electrical components to help you test performance. Tower and blade materials are not included.
- KidWind Challenge Teacher Package (M0002). This kit contains the basic components needed to start building a simple wind turbine, including the critical components to build 20 turbines. It includes generators (20), hubs (20), basic multimeters (4), and electrical components to help you test performance. Tower and blade materials are not included.

Full Kits

These are full turbine kits that include a comprehensive set of materials to make turbines and test blades. If you are just starting out these can be helpful as you explore how to make and test classroom wind turbines. These kits include a tower and some blade materials.

- Basic Wind Experiment Kit (A0018)
- Advanced Wind Experiment Kits (A0012). The Advanced Kit gearbox is not allowed in the KidWInd Generator division.

Exploring Homemade Generators

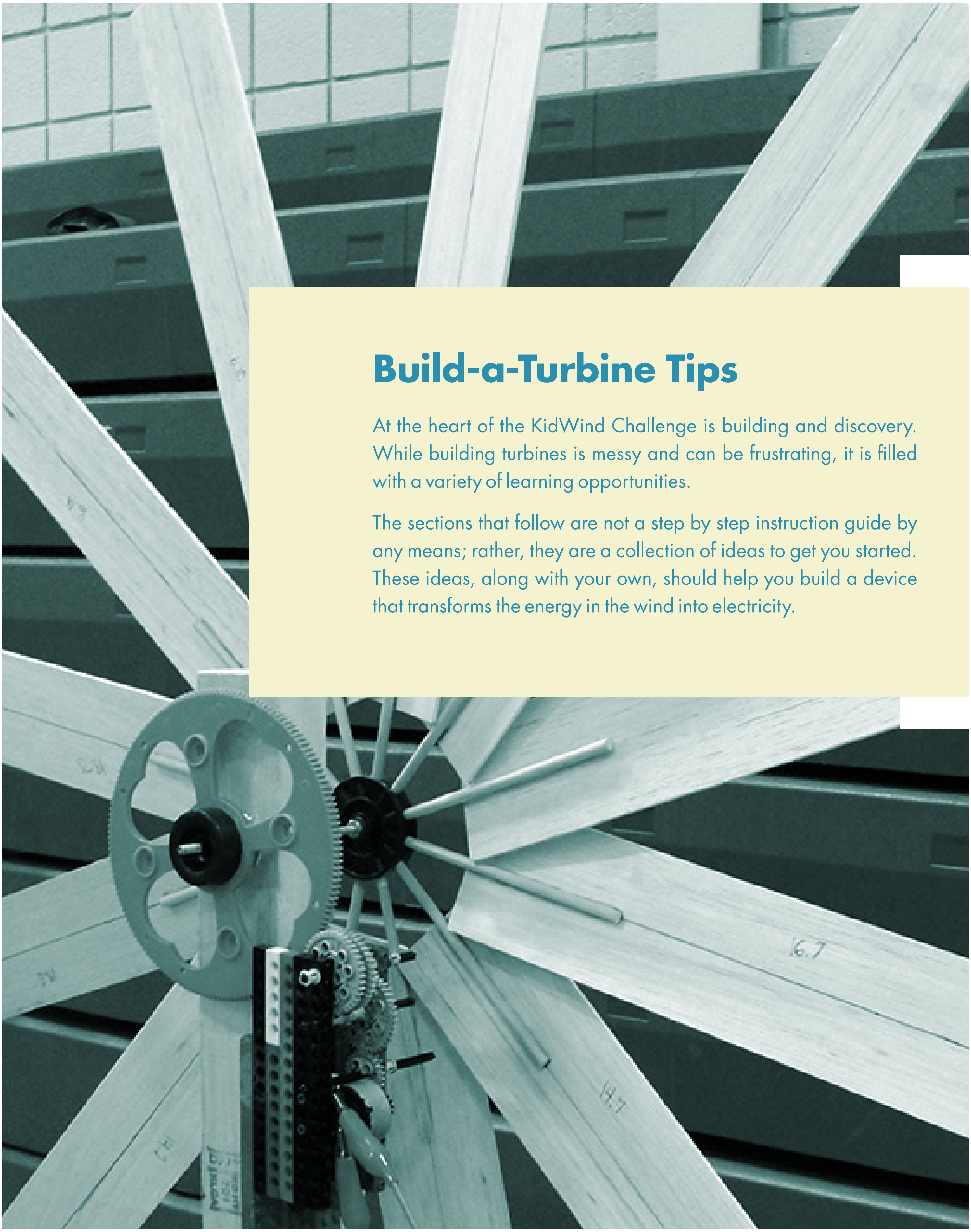
If you want to compete in the 2013 Open Division and build your own generators, check out these kits to get started:

- GENPack (A0016). This is an add-on for the Advanced Wind Experiment Kit.
- simpleGEN (A0051). There are many ways to make simple generators for a wind turbine. Do some research or check out the KidWind Challenge page for ideas.

Data Logging Equipment

- Digital Multimeter (H0022). Using a basic multimeter you can collect all the data you need to see how well your turbine is performing. Check out our online performance calculators at http://learn.kidwind.org/challenge/web/turbine_performance_calculator.
- Vernier Renewable Energy Logging System. KidWind uses Vernier equipment to test turbine performance. Vernier offers a wide variety of loggers and probes at www.Vernier.com. KidWind offers a basic package that will get you started testing your turbines—just like we do at regional KidWind Challenges.,

  You can read more about using your Vernier system at www.KidWind.org.



Build-a-Turbine Tips

At the heart of the KidWind Challenge is building and discovery. While building turbines is messy and can be frustrating, it is filled with a variety of learning opportunities.

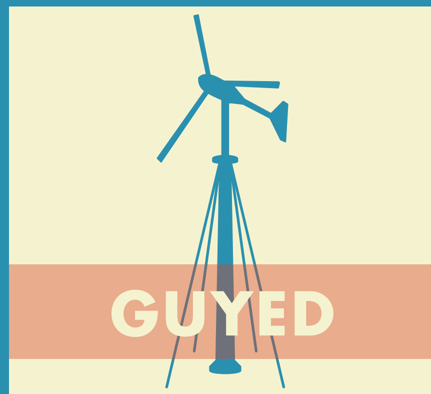
The sections that follow are not a step by step instruction guide by any means; rather, they are a collection of ideas to get you started. These ideas, along with your own, should help you build a device that transforms the energy in the wind into electricity.

Towers

Most real wind turbines use one of three types of towers:

Lattice Towers

This tower design uses a criss-crossing steel framework. These are very strong, self-supporting towers. They can be quite expensive due to the amount of steel they require.



Guyed Towers

These towers have a single pole or lattice structure supported by "guy wires" which anchor the tower to the ground. Another tower type commonly used for small wind turbines, Tilt-up Towers, also have guy wires and fall under this category.

Monopole Towers

A single, freestanding pole. Very strong, and very expensive. These require a crane to erect, and are used for large wind turbines. Monopole towers are also considered the most visually pleasing.

Creating Your Own Tower

You can make a tower for your wind turbine out of practically anything. Check out our plans on how to make a great tower using PVC pipe, but don't limit yourself! We have seen some great towers made from wood, cardboard tubes, Tinker-Toys, plastic, etc. Try experimenting with different designs! Which type of tower seems strongest? Why do you think certain wind turbines use the type of towers they use?

The only rules for making your tower is that it must have a firm base resting securely on the ground. It must also be tall enough so that your blades will not hit the ground.

If your turbine has a gear or pulley system, you will need to have some kind of platform or housing on top of your tower to hold the gear/pulley box.

Other things you'll want to think about: does your tower sway when the wind moves fast, or are your blades are out of balance? In really fast winds with large blades, you should have a weight on the base. Otherwise the turbine will tip over. This is why large turbines have huge foundations.

Generators

A generator is a device that converts mechanical energy into electrical energy. In 1831, Michael Faraday discovered that while a magnet is moving inside a coil of wire, an electrical "voltage" is produced between the ends of that wire. This discovery, known as Faraday's law, demonstrated that a relationship exists between electricity and magnetism.

A typical generator uses powerful magnets and many coils of copper wire. Faraday's law states that a magnet moving within a coil of wire has the potential to cause electrons to flow in a circuit. It is also possible to move the coil of wire within a magnetic field to generate electricity. Most generators consist of a rotating shaft, to which coils or magnets are attached. In the case of a wind turbine, rotating blades designed to catch wind are fixed to this shaft. Using generators, we are able to capture mechanical energy and convert it to electrical energy, powering the electrical devices we use every day.

As you start to build your turbine, you will need to decide if you want to build an AC generator or use a DC generator.

Inside DC motors.

DC Motors/Generators

The generator in many KidWind kits is actually a DC motor that spins using the energy in the wind. There are DC generators all over your house and school. We have spent a great deal of time looking for good small DC generators for a small turbine. You could compare our DC Generators to generators harvested from old household electronics, or to store-bought generators. Old VCRs, electrical toys and CD players are good places to start finding DC motors and gearboxes. LEGO motors are awesome! They crank out some great voltage, which can light lots of LED bulbs.

AC Generators

You could also use or build a simple AC generator in your turbine. KidWind has a kit called the GenPack that will allow you to explore AC generation by building your own generator. There are other companies that sell small AC generator kits as well. Build one, then try to use it as the main generator in your turbine.

Geared vs. Non Geared

When you start to build your turbine, you will have to make a decision on whether you want to make your turbine direct drive or use some kind of gear advantage to increase the RPM on the generator. Many residential scale turbines do not have gearboxes, and many utility scale turbines do have gearboxes, but that is starting to change.

While building a gearbox or a pulley drive can be challenging, it can greatly increase your power output. It is easier to build a pulley drive because you do not have to line things up as precisely. Gearboxes have less friction, but getting the teeth to line up and work well at high RPM can be difficult.

Pulleys or gears can give your wind turbine a mechanical advantage. This means that they multiply the mechanical force of the turning blades. This is done by using pulleys with different diameters or gears with different numbers of teeth. When the larger gear makes one full revolution, the smaller gear has to spin faster to keep up. Increasing the speed of rotation through the use of gears or pulleys is an example of a mechanical advantage.

Pulley/Gear Ratios

The gear ratio of your system will influence the power and torque you can produce with your turbine. "Gear ratio" is the relationship between the number of teeth on two gears that are meshed. When you are using a pulley system, this ratio is the relationship between the circumferences of the two pulleys you have connected.

Example: You have a geared system for your wind turbine. Your hub is connected to a driveshaft with a gear on it that has forty teeth. That gear is meshed with a gear that has twelve teeth. The 12–tooth gear is connected to your motor (generator). The gear ratio of this system would be 40 divided by 12, or 3 1/3. That means that every time your hub and blades do a full rotation, the motor driveshaft does 3 1/3 rotations.

A pulley system works much the same way. If the circumference of the large pulley is three times that of the small pulley, the small pulley (attached to your generator) will rotate three times for every one time the large pulley (attached to your hub) rotates.

One thing to note: we find that on small box fans it can be hard to drive gear ratios of more than 10:1. With more wind and better blades you can drive larger gearboxes. At the KidWind Challenge, when we use our large wind tunnel, we have seen students with 100:1 gearboxes. Your small fan at home cannot do this!

Problems Building Gears & Pulleys

Lining up the gears or pulleys is very important. If you are using a pulley system, the two pulleys will not have to be lined up precisely. This is because the drive belt (rubber band) connecting them can run at a slight diagonal. If the drive belt is not lined up well, it may have a tendency to slip off one of the pulleys. While a pulley system can increase your voltage a great deal, you may find it difficult to get enough amperage for high-torque demands, such as water pumping. This is due to the belt slipping on the pulleys.

With a geared system, lining up the gears is extremely important. The gears need to mesh together just right, so take time to find a setup that works. You'll need to make sure that the driveshaft and pulley system is secure and will not move too much when the wind blows. If it does, your drive train won't work.

Pulleys

- Advantages: High RPM of the generator, very high voltage, easy to assemble and line up
- Disadvantages: Bands will slip in high torque, low Amperage, rubber bands can slip off

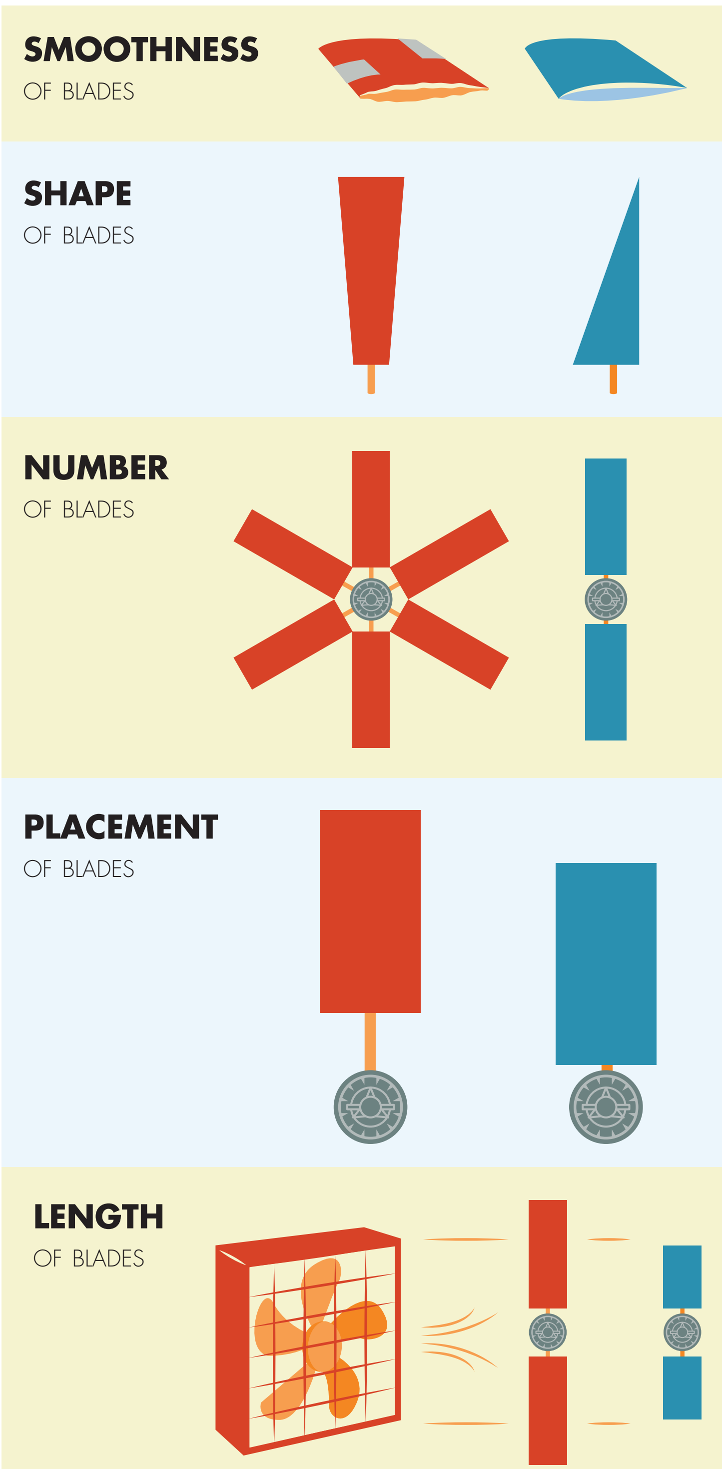
Gears

- Advantages: High RPM of the generator , High Voltage, More Torque, Generates High Amperage
- Disadvantages: Difficult to assemble and line up the gears, Less voltage than pulley

Turbine Blade Design

The blades on modern turbines "capture" the wind and use it to rotate the drive shaft of a generator. As we have mentioned, the spinning shaft of the generator spins wires near magnets to generate electricity. How well you design and orient your blades can greatly impact how fast these blades spin and how much power your turbine produces.

As you build your turbine you will need to perform experiments with blades to see which ones work best on your turbine. These experiments can be simple or very complicated, depending on how deeply you want to explore. Some blade variables you can test include:



Length, Shape, Number, Materials, Pitch, Weight

One thing we note at many challenges is that students do not spend enough time working to make very efficient blades. The teams that spend time and make very good blades often win the competitions.

To make blades, carve or cut different shapes and sizes out of a variety of materials (balsa wood, cardboard, felt, fabric). Tape or hot glue them to the dowels. Students have made blades out of styrofoam bowls, pie pans, and paper and plastic cups. Anything you find around the house or classroom can be made into blades as long as it is stiff and kind of light!

MAJOR Caution!! Never make blades out of metal or any sharp edged material because they could cause injury during testing. Blades on these small turbines tend to spin very fast (300-600 RPM) and can easily cut people if they have sharp edges.

Sloppy, poorly made blades will never make enough electricity. It takes time and thought to make good blades. One thing you must always think about when making turbine blades is: "How much drag are my blades encountering?" Sure, your blades are probably catching the wind and helping to spin the hub and motor driveshaft, but could they be spinning faster with more torque? If they are adding drag, your whole system will slow down. In most cases, low RPM means less power output. The faster the blades spin, the more power you make!

Quick tips on improving blades

- **Shorten blades.** Students often make very long blades, thinking bigger is better. While that is sometimes true, beginners have a hard time making long blades without adding drag. Try shortening them a few centimeters.

- **Change the pitch.** Often, students will set the angle of the blades to around 45° the first time they use the turbine. Try making the blades more perpendicular to the wind flow. Pitch dramatically affects power output. Play with it a bit and see what happens.
- **Not spinning.** If you have your blades attached, and they are not spinning, check the pitch of the blades. Are your blades oriented in the same direction? Are they flat? Are the blades hitting the tower?
- **Use fewer blades.** To reduce drag, try using two, three, or four blades.
- **Use lighter material.** To reduce the weight of the blades, use less material or lighter material.
- **Use stiffer material.** If your blades are bending in the wind or deflecting when the wind hits, you need to find a stiffer material.
- **Smooth surfaces.** Smoother blade surfaces experience less drag. A blade with lots of tape and rough edges will have more drag.
- **Get more wind.** Make sure you are using a decently sized box or room fan, one with a diameter of at least 14″–18″.
- **Blades vs. fan.** Are your blades bigger than your fan? This could be a problem, as the tips of your blades are not catching any wind and are just adding drag.
- **Blade shape.** Are the blade tips thin and narrow or wide and heavy? The tips travel much faster than the roots. Wide tips add drag.

Advanced blades

Two major forces act on wind turbine blades as they rotate: lift and drag. These forces are in constant competition. When you are optimizing wind turbine blades, try to maximize lift force but minimize drag force.

Wind turbine blades are airfoil shaped, much like airplane wings. This airfoil shape is designed to generate lift and minimize turbulence. Lift is primarily produced as a result of the angle-of-attack of the blade. This angle creates a deflection force on the upwind side and a vacuum force on the downwind side of a wind turbine blade. The deflected air causes a reaction force that pushes the blade.

Turbine blades are tapered more at their tips and are also twisted slightly. Because of this twisted pitch, they have a greater angle-of-attack near their root where rotational velocity is slowest. Velocity is higher at the tip of the blade, so the angle-of-attack there is smaller. Turbine blades are designed in this manner to optimize the balance between lift and drag at all points on the blade.

Most electrical generating wind turbines use two or three blades. This configuration allows them to capture the most power with the least wind resistance. Using the fewest number of blades possible also reduces cost. The actual angle and taper of the blades depends on the anticipated wind speeds at the turbine's location.

KidWind Blades

Flat blades create a great deal of torque, and therefore work well for weight-lifting experiments. Airfoil blades have less drag and can generate more power. You can make more sophisticated blades by giving them twisted pitch and an airfoil shape.

Ideas for constructing advanced blades:

- Bend card stock into an airfoil shape. Glue a dowel inside the blade. Tape bent card stock to a flat piece of corrugated plastic or balsa wood to produce an airfoil shape.
- Take a block of foam and form it into an airfoil shape. Try to incorporate both a taper and a twist into the design.
- Carve and sand a piece of soft wood into an airfoil.
- Cut blades out of some form of cylinder. Try a cardboard tube, a paper or plastic cup, etc.
- Soak card stock in water for a few minutes. Form it into the desired shape and clamp or tape it in place until it dries and holds that shape.

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