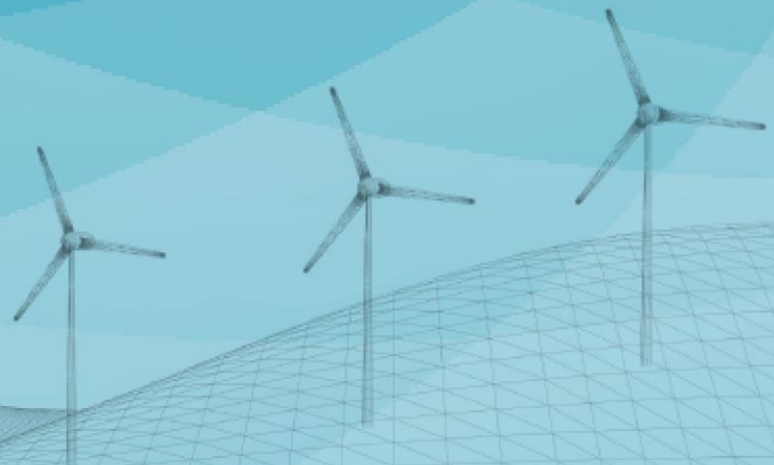




COLLEGIATE
WIND COMPETITION
U.S. DEPARTMENT OF ENERGY

U.S. DEPARTMENT
OF ENERGY
**COLLEGIATE WIND
COMPETITION 2020**



Preface

This is the first revision of the 2020 Rules and Requirements document in response to the impacts of COVID-19. The modifications are designed to accommodate the capabilities of student teams in the current situation, but if any team is unable to complete any of the deliverables, reach out to organizers. The goal is to maximize learning and organizers will work with each team to determine what is possible.

The U.S. Department of Energy Collegiate Wind Competition 2020 will be governed and adjudicated by this manual, which is intended to establish fair contest rules and requirements. In the case of a discrepancy with other competition materials or communication, this document takes precedence. The organizers reserve the right to change contest criteria, rules, and measurable outcomes as needed.

While teams work on their deliverables, principal investigators, co-principal investigators, graduate student advisors, and members of industry secured by each team for support can provide feedback about the team's design so the students can identify fatal flaws, prove technical rigor, or demonstrate feasibility of their concept. Teams are highly encouraged to pursue mentorships and sponsorships early in the course of the competition as it will provide immense benefit to the learning and overall competition experience. However, only undergraduate student team members may take an active role in any competition event. It is the role of the non-student team members to provide a supportive environment and the educational background necessary for the students to achieve success in the competition. **It is not appropriate for anyone other than an undergraduate student to be actively working on a turbine or making decisions.**

In addition, teams are encouraged to bring to our attention rules that are unclear, misguided, or in need of improvement. The organizers will seriously consider suggestions if they are feasible and are intended to improve the competition, its rules, measurable outcomes, fairness, or precision.

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Revision History

This is a revision to the original document modifying the competition to deal with COVID-19 impacts, issued on 04/09/2020.

1 Introduction

1.1 Background

According to the U.S. Department of Energy's (DOE's) *Wind Vision* report, wind energy could supply 20% of the nation's electricity by 2030 and 35% by 2035.¹ As more wind energy is incorporated into the U.S. power generation mix, qualified workers are needed to fill related jobs at all levels.

To help facilitate this process, DOE and the National Renewable Energy Laboratory (NREL) created the Collegiate Wind Competition in 2014 (hereafter referred to as the Collegiate Wind Competition or competition). The competition contributes to the creation and maintenance of American leadership in the transition to a global clean energy economy. Specifically, the competition's objective is to prepare students from multiple disciplines to enter the wind energy workforce by providing real-world technology experience. Positions in the workforce that require development include researchers, scientists, engineers, educators, project managers, and business and sales forces. Wind-energy-specific advanced degrees are not required for many of these jobs, but having wind-related experience is considered to be highly valuable.²

Each year the competition identifies a new challenge and set of activities that address real-world research questions, thus demonstrating skills that students will need to work in the wind or wider energy industry. The Collegiate Wind Competition 2020 challenge is to:

Research, design, and build a turbine for deployment in the high wind environment of eastern Colorado.

Specifically, competition participants will need to create:

- An effective mechanical, electrical, and aerodynamic wind turbine and load digital-only design that is safe and reliable for testing in an on-site wind tunnel (Note, the turbine need not actually be tested, but should be designed as if it were going to be.)
- A site plan and cost of energy analysis for a 100-MW wind farm in eastern Colorado.

The competition does not prescribe a power system market or wind regime.

2 Competition, Contests, Products, and Awards

The Collegiate Wind Competition 2020 consists of all the aspects and activities leading up to, during, and following the event. It includes the subcontract project agreement between the

¹ <http://www.energy.gov/eere/wind/maps/wind-vision>

² <https://www.nrel.gov/docs/fy19osti/73908.pdf>

competitively selected collegiate teams and NREL, as well as the contests, products, and virtual event.

During the event, teams compete in two contests: the turbine prototype contest, which includes a digital-only design, and the project development contest. Within each contest, teams' submissions (hereafter referred to as products) receive points toward winning the contest. An overview of which product contributes to the scoring of each of the contests is in Figure 1. How many points a product contributes to the overall score is covered in Appendix A.

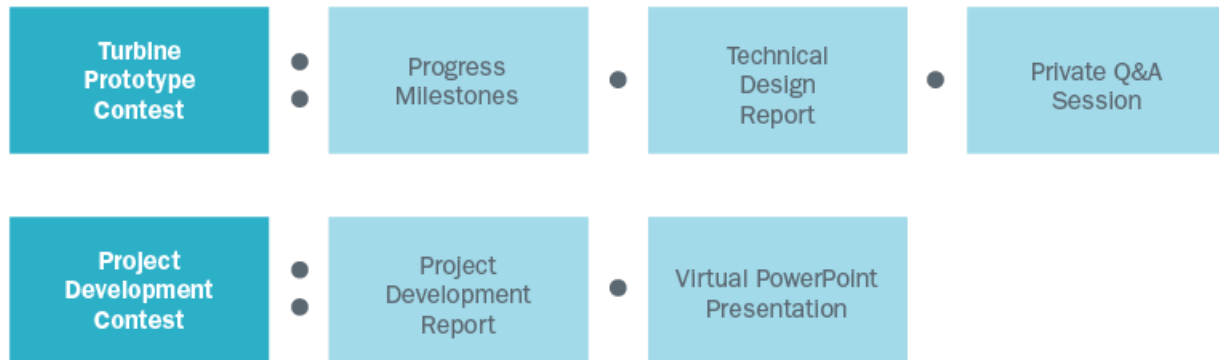


Figure 1. Contests and products overview. Further information available on the point breakdown available in Appendix A. Rubrics

2.1 Overview of Product Submission Deadlines

This section gives an overview of when products should be delivered. The virtual competition sessions will run over the course of three dates between May and June, to be selected based on team and judge availability. If any team is unable to make the available dates or complete the deliverables as outlined, reach out to the organizing team to work out an alternative. Refer to each product section and Appendix G for format requirements and submission instructions.

Table 1. Product Deadlines

Product	Submission Deadline
PRIOR TO COMPETITION:	
Dynamometer testing	Sunday 11/10/19, 11:59 p.m. MT
Rotor strength testing	Sunday 2/23/20, 11:59 p.m. MT
Power quality measurements	Removed from competition
Tech inspection prior to competition	Removed from competition
Project development report	Deadline will be five days prior to the virtual competition date agreed upon between team and organizers
Turbine design report	Deadline will be five days prior to the virtual competition date agreed upon between team and organizers
DURING COMPETITION:	
Project development PowerPoint presentation (digital)	Present on virtual meeting platform
Turbine design Q&A supporting materials (optional)	Present on virtual meeting platform

2.2 Awards

Since the turbine test will not be held this year, there will no longer be a winner for that contest, nor will there be any placements overall. Final scores and rankings for the modified project development and design contests will be shared with all participants. Awards for this year will include:

- Project development contest winner—the team that earns the highest combined score from all project development products
- Turbine digital design contest winner—the team that earns the highest combined score from the digital design and milestones completed prior to February 23

3 Turbine Digital Design Contest

The technical contest now consists of two components: a series of midyear milestones and a technical design report. The mid-year milestones due after February 23 and the turbine prototype are no longer required. Additionally, during the competition, the technical judges will conduct a brief turbine design question and answer (Q&A) session to clarify any questions they have after reading the reports before finalizing scores. The rest of this section will describe the

requirements for turbine design and the details of each of the contest elements. Detailed scoring algorithms and rubrics can be found in Appendix A.

3.1 Turbine and Load Design Requirements

Each team will design but are no longer required to build, a prototype wind turbine. The turbine design should follow the same process as if the final version would be tested at competition. Constraints are listed below for historical context and to guide the digital design in light of this requirement. The turbine must be designed to withstand continuous winds of up to 22 m/s during operation and up to 25 m/s when parked. Each turbine prototype must be designed for testing inside the Collegiate Wind Competition wind tunnels [further designated as “tunnel(s)” or “wind tunnel(s)”]. The basic wind tunnel configuration is shown at the end of this section.

3.1.1 Physical Design Constraints Within the Tunnel

The following tunnel requirements are included for historical context and to guide the digital design. Teams will no longer be required to test the turbine.

At zero yaw angle, the entire turbine must fit within the volume specified below and shown in Figure 2. The turbine may have the following maximum geometry:

- Rotor and nonrotor turbine parts must be contained in a 45 cm by 45 cm by 45 cm cube. This cube may be shifted as much as 10 cm aft of the yaw table centerline when the turbine is aligned with the flow.
- A 15-cm diameter cylinder centered on the mounting flange extending from the tunnel floor to the bottom of the cube can contain only nonrotor turbine parts. For this purpose, nonrotor turbine parts will be defined as anything that does not capture energy from the moving air, including the mounting flange.
- All turbines must fit through the turbine door (61 cm by 122 cm) in one assembly with no additional assembly occurring inside the tunnel other than attachment to the base flange and connection to external electrical components. Electrical connections should not be made in the nacelle during installation.

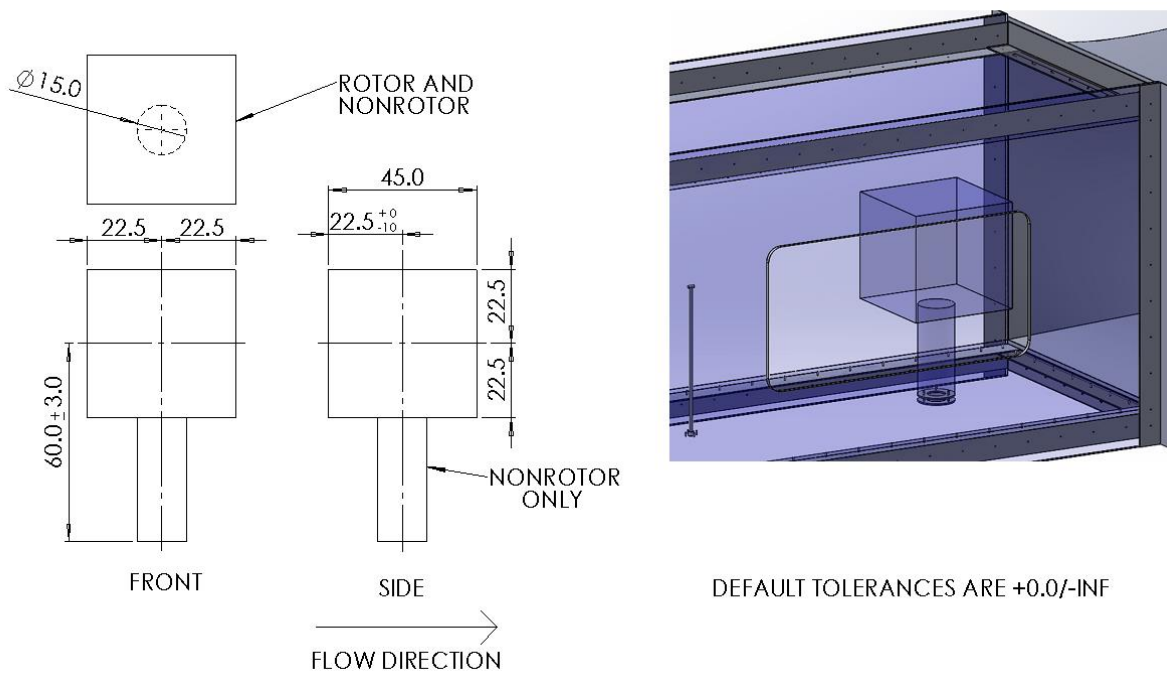


Figure 2. Allowable turbine volume

The wind turbine system must be mountable on the test stand within the wind tunnel as follows:

- The turbine base plate must be constructed of material no thicker than 16.1 mm. It should be designed and constructed with adequate tolerances to smoothly fit over three studs where it will be secured to the tunnel base flange with wingnuts. Figure 3 shows the bolt pattern and sizing of this flange and the dimension for the hole in this base flange to allow cables and connectors to pass through.
- Teams are free to apply their engineering judgment to their own base plate design, keeping in mind that the turbine base must be designed to withstand the tension of the mounting studs when torqued to approximately 50 Newton-meters.
- The tunnel base flange incorporates a turntable to generate yawed flow. The tunnel base flange, where the turbine is mounted, will be subjected to yaw rates of up to 180° per second with a maximum of two full rotations from the initially installed position.

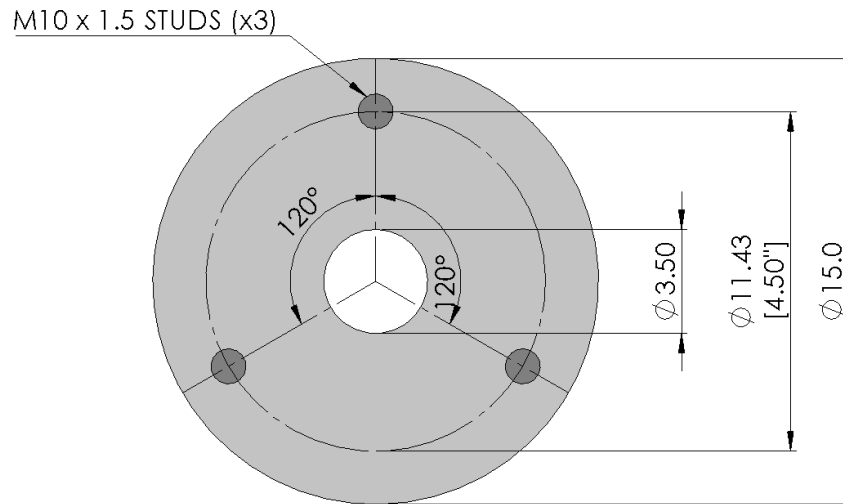


Figure 3. Base flange dimensions for turbine attachment to tunnel (dimensions in cm)

3.1.2 Physical Design Constraints Outside the Tunnel

The following tunnel requirements are included for historical context and to guide the digital design. Teams will no longer be required to test the turbine.

Within practical limits, there is no size restriction for components located outside the tunnel. These components must be incorporated into closed enclosures that are firesafe and meet or exceed a National Electrical Manufacturers Association (NEMA) Type 1 rating. All components must be electrically insulated from the enclosures. Teams should also pay careful attention to the standards for ventilation of these enclosures.

- NEMA 1 characteristics: Enclosures are constructed for indoor use to provide a degree of protection for personnel against access to hazardous parts and to provide a degree of protection for the equipment inside the enclosure against ingress of solid foreign objects (should not be able to insert fingers or tools through the enclosure when closed). It is important that the intent of the NEMA 1 rating be preserved even once all connectors and/or passthrough devices are installed.
- All cable passthroughs in enclosures must use cable glands or other similar devices that provide both strain and chafe protection.
- Tape is not considered adequate sealing of penetrations or passthroughs in the enclosure.
- All electrical cables leading from the turbine to the electronic components located outside the tunnel must be in cable form (no individual strands) and have connectors. Individual strands or bare wires will result in disqualification from testing until remedied. Twisting two or more strands together is permissible as long as the resulting multistrand cable has a connector on the end. Multistrand cables are encouraged when used in a logical way. For example, there could be one cable for all power wires and one cable for all control wires.

- Neither screw terminals nor spade- or fork-type lugs are considered acceptable connectors outside of enclosures. Each cable connection from turbine to enclosure should employ a quick-attach connector. Ideally, teams should be able to connect all their cables in a few seconds.
- All electrical components shall be mechanically secured to the enclosure.

3.1.3 Electrical Requirements

The following electrical requirements are included for historical context and to guide the digital design. Teams will no longer be required to test the turbine.

Figure 4 illustrates the electrical configuration of the prototype turbine, competition data acquisition system, and point of common coupling (PCC), which is the point of electrical measurement for the competition.

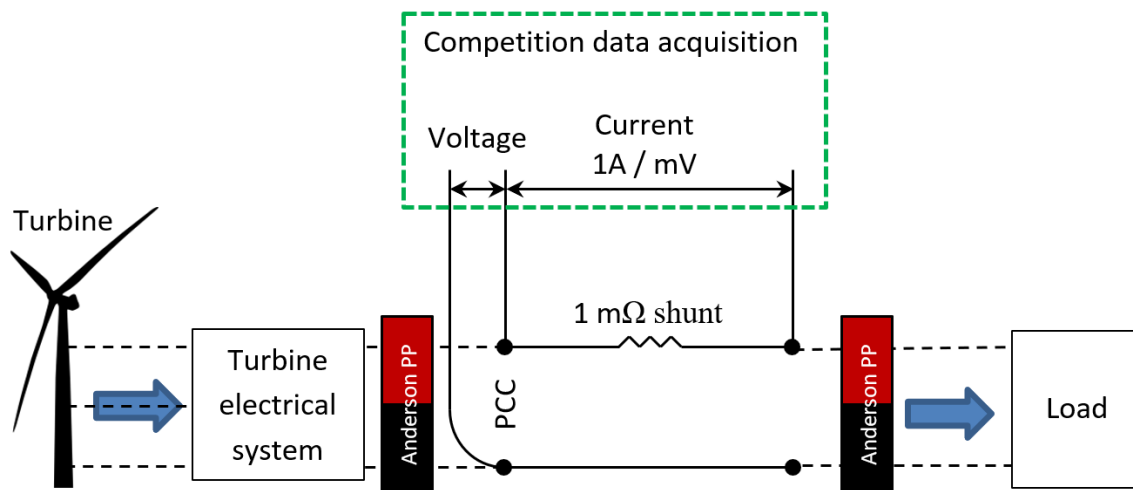


Figure 4. Load, turbine, storage element, and point of common coupling arrangement

- Voltage must be direct current (DC) at the PCC and is required to be at or below 48 volts at all times.
- The turbine base plate shall be tied to earth ground. To prevent overvoltage of the tunnel data acquisition system, turbine electrical system ground(s) must be electrically tied to this base plate with a 100 kΩ or lower resistance connection.
- Teams are expected to choose their own generator and design their own turbine and load system. Off-the-shelf components may be used, but the turbine and load system should be designed and built by the teams. Both components must meet safety requirements including, but not limited to, proper wiring practices, shielding of hazardous components, and proper heat rejection.
- **New for 2020, the turbine electronics must be in a separate enclosure(s) from the load to clearly differentiate load and control during inspection by judges, as shown in Figure 4. The turbine nacelle may also contain turbine electronics if desired.**

3.1.4 Specifications for the Turbine Side of the PCC

The following specifications are included for historical context and to guide the digital design. Teams will no longer be required to test the turbine.

- Energy storage elements, such as capacitors and/or inductors, may be used in both the turbine and the load but not for bulk energy storage on the turbine side of the PCC.
- No batteries of any type or capacitors or combinations of capacitors with nameplate voltage and capacitance ratings corresponding to over 10 J of energy storage ($E = \frac{1}{2}CV^2$) will be permitted.
- Turbine components may draw from the load but must register a zero state of charge at the beginning of the test.
- Wired connections between the turbine and load external of the PCC are allowed but must be optically isolated.

3.1.5 Specifications for the Load Side of the PCC

The following specifications are included for historical context and to guide the digital design. Teams will no longer be required to test the turbine.

- Bulk energy storage is allowed, provided it is utilized in a safe and reliable manner.
- To run the load, 120 VAC will be provided if desired.

3.1.6 Interfacing with the Competition Data Acquisition System

The following requirements are included for historical context and to guide the digital design. Teams will no longer be required to test the turbine.

- Wires should exit the tunnel at the turbine base through the center of the turntable. As shown in Figure 5, a table will be provided to display the load on the student side of the tunnel and hold any turbine electronics enclosures external of the tunnel. Rough distances are shown in the figure, but teams should provide adequate lengths of wire to run from the PCC to accommodate their desired enclosure arrangement on the table.

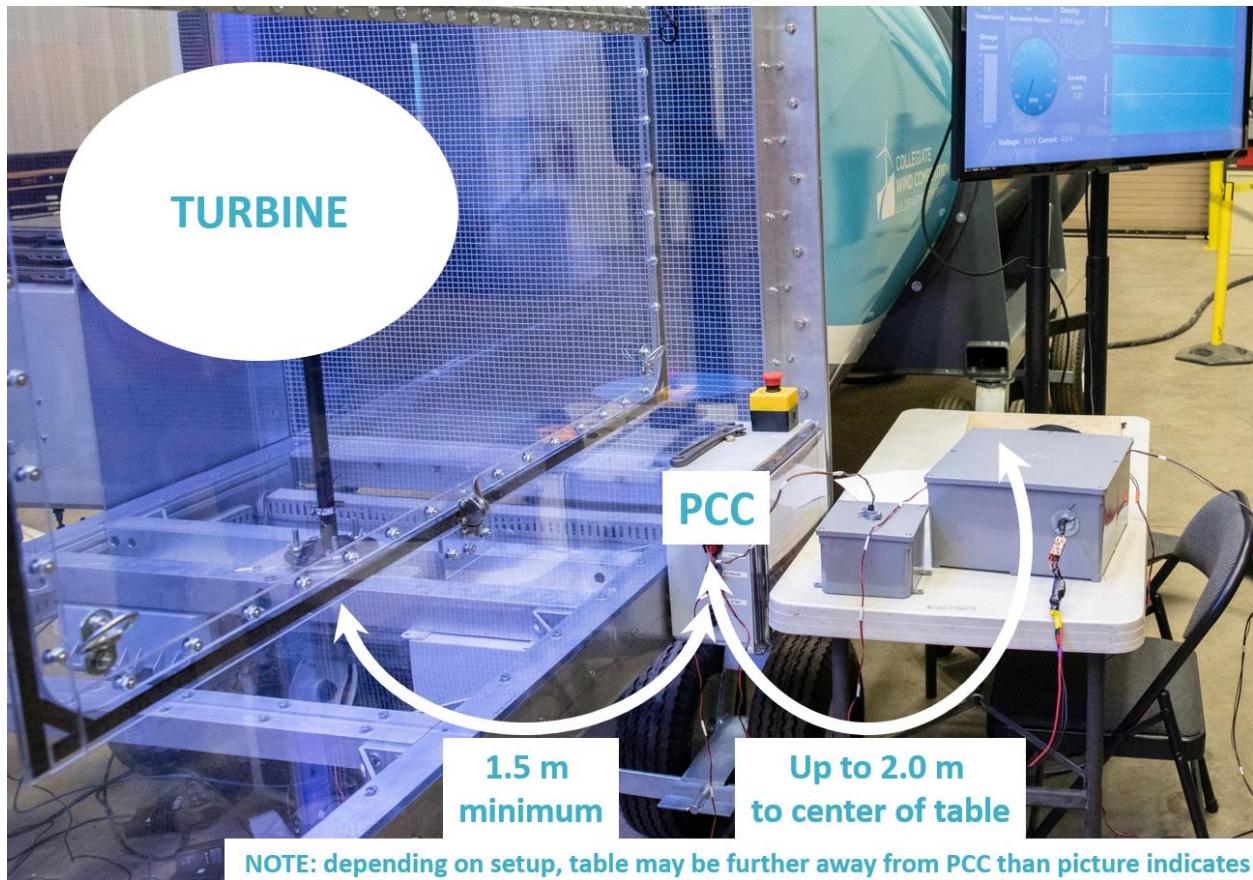


Figure 5. Wiring layout of PCC and student load display table

- To interface with the PCC, wires should be terminated with Anderson Powerpole connectors, PP15-45 (a red and a black, for positive and negative, respectively). See Figure 6 for correct polarity. Incorrect polarity must be corrected before testing.
- Teams are expected to provide their own Powerpole connectors of an appropriate size: 15 A, 30 A, or 45 A, which are specified to handle wire gauges from 10 American wire gauge (AWG) through 20 AWG. Each team can choose the wire size it wants to use in this range as long as the appropriate current-carrying capacities are taken into consideration. All three pin sizes fit into the same housing (PP15-45), as stated above.

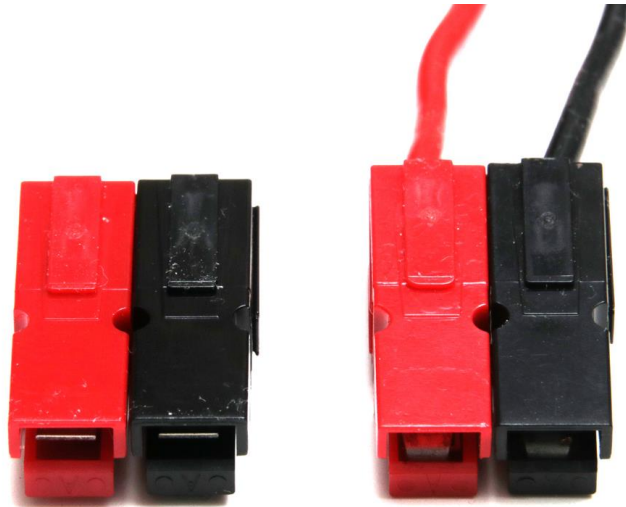


Figure 6. Proper Anderson Powerpole polarity to match tunnel wiring

- Turbines must be capable of shutting down on command through an emergency stop button as well as when electrically disconnected from the load.
 - The emergency stop switch will be located outside the tunnel. The emergency stop switch operates in the same manner as an industrial emergency stop chain. That is, it is closed during normal turbine operation and is opened during an emergency stop when the button is depressed.
 - In industry, emergency stop systems use this switch polarity so that multiple switches in and around a piece of hardware, such as a wind turbine, can be wired in series in a single wiring loop. In this configuration, opening any switch or a fault in the wiring will cause the whole circuit to open. Thus, an entire emergency stop system can be monitored by a single channel input. If the switches utilized the opposite polarity, the system would have to monitor each switch individually.
 - The emergency stop connector and wiring is rated for 3 A and thus is intended to carry a low current control signal—not high current power. Teams must describe their emergency stop system during tech inspection and explain how this design utilizes a signal that can never carry more than the rated 3 A.
 - Each team must provide a cable containing two wires (no smaller than 28 AWG) that reaches the PCC as labeled in Figure 5. This cable must be terminated, prior to the competition, with a standard JST RCY female receptacle housing connector [Manuf. P/N: SYR-02T housing using SYM-001T-P0.6(N) for the corresponding male pin contacts]. See Figure 7.³

³ Note: In the remote-control aircraft community, these connector pairs are commonly referred to as JST BEC connectors and are available from a variety of sources, including Digi-Key.



Figure 7. Team-provided connection to the manual shutdown interface

- The competition switch will be terminated with the corresponding polarity JST RCY male plug [Manuf. P/N: SYP-02T-1 plug housing using SYF-001T-P0.6(LF)(SN) socket contacts]. See Figure 8.³



Figure 8. Competition-provided connector for manual shutdown interface

3.1.7 Specifications for Competition Tunnel

The following tunnel specifications are included for historical context and to guide the digital design. Teams will no longer be required to test the turbine.

The competition tunnel is rendered in Figure 9. The dimensions of the test chamber are 122 cm x 122 cm x 244 cm. There are inlet and outlet components of the wind tunnel that extend beyond the test chamber. The tunnel has a drawdown configuration. That is, the air is sucked through the test section—entering at the left, exiting at the right—with the drawdown being induced by the fan on the right side of the tunnel. A honeycomb flow straightener at the inlet of the wind tunnel provides for near uniform mixing of the incoming air. There is a debris filter upstream of the fan section. The screen is composed of wire mesh to prevent turbine pieces from getting sucked into the fan unit.

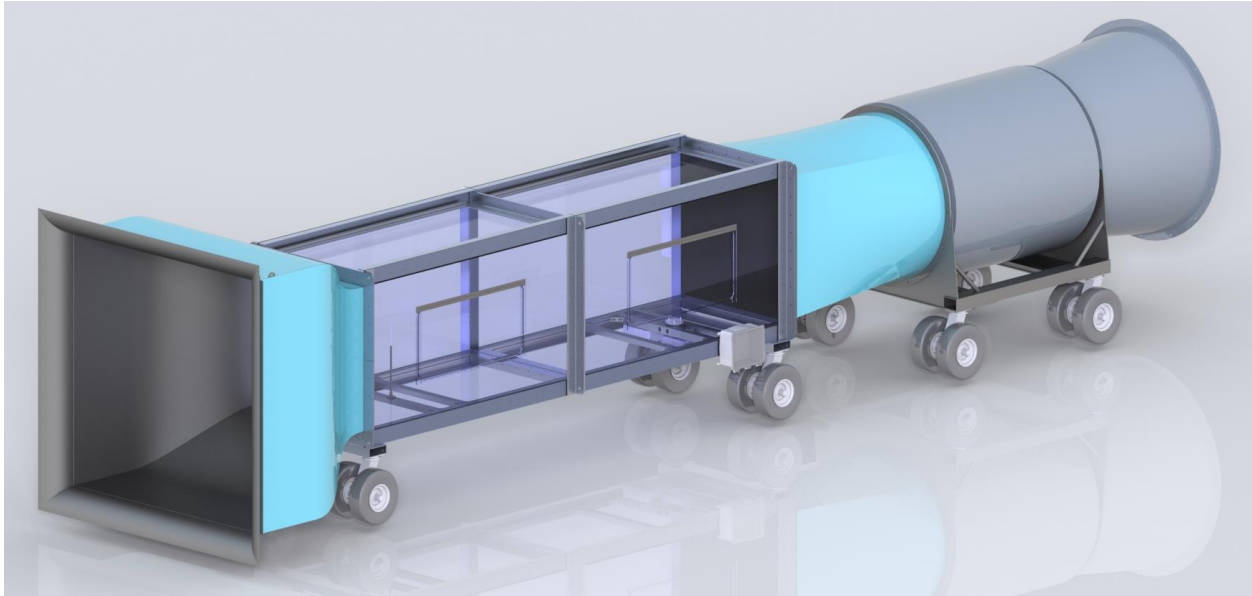


Figure 9. Collegiate Wind Competition wind tunnel basic configuration

3.1.8 Safety Specifications

During an in-person competition, staff would perform a safety inspection of the wind turbine and load system, which must be passed before the wind turbine and load system are installed in the wind tunnel. Appendix B contains a draft version of the safety and inspection sheet used to evaluate the turbines. The turbine safety officials make the final and official determination about whether a turbine may be tested in the wind tunnel. All turbine systems should be designed to pass this inspection.

3.2 Midyear Project Milestones

New to 2020, the competition will include a series of scored, midyear milestones to monitor the student teams' progress leading up to the final event and incentivize key aspects of the design. The power quality and tech inspection milestones have been eliminated in light of COVID-19. Teams will get credit for their work and scores on the other two milestones already completed.

Milestones are scored on a pass/fail basis; all elements of the deliverable must be included for the team to receive points in that area. Some milestones have multiple parts, in which case, each individual part of the milestone will be scored on a pass/fail basis. There are no set formatting requirements for any of the milestone deliverables.

3.2.1 Dynamometer Testing

A crucial part of designing and building a new wind turbine is being able to control the torque load applied to the wind turbine rotor by the wind turbine drivetrain. A useful way to test and optimize this control during development is by attaching the wind turbine drivetrain to a

dynamometer drive system, which can control the shaft speed applied to the wind turbine drivetrain.

For this milestone, students should construct a dynamometer suitable to drive their wind turbine drivetrain being designed for this competition. A simple dynamometer can be constructed by mounting a motor to a suitable bedplate made of a rigid material such as wood, plastic, aluminum, or steel, providing a place to mount the wind turbine drivetrain being designed for this competition onto that bedplate, and coupling the two together at the low-speed shaft of the wind turbine drivetrain.

To get credit for this task, the teams must show that such a dynamometer has been constructed, that the speed of the low-speed shaft can be measured and controlled by the dynamometer control system, and that a wind turbine style drivetrain can be and has been coupled to the dynamometer, both at the bedplate and at the shaft. It is not necessary for this wind turbine drivetrain to be the final system used in the test turbine at the competition as this dynamometer is intended to help the teams refine their designs. Further, the dynamometer must be a separate system, not a power tool such as a drill mounted to a board. A simple way to construct such a dynamometer system would be to purchase an R/C motor, suitable speed control with data monitoring, a way to control that speed control such as an R/C radio and receiver or a servo tester, a power supply to power the speed control, and a PC with suitable cables and software to monitor the speed control's telemetry. Coupled with a bedplate, a way to mount the components to the bedplate, and a suitable shaft coupling, such an assemblage of components will make an effective testing and development tool for the wind turbine drivetrain. It is strongly recommended that teams use this system for control system development.

Deliverables:

- Submit a single page write-up plus images on the design of your dynamometer, including a parts list; include pictures and/or video of the final product
- Submit a single page write-up plus images and video that shows your dynamometer drive system successfully controlling its own speed
- Show a prototype wind turbine drivetrain coupled to the dynamometer.

The write-ups must explain what is happening in the pictures and/or video and describe the methodology being employed to control the dynamometer. It is not necessary for the wind turbine drivetrain to successfully control its own torque—just that it can be spun by the dynamometer.

3.2.2 Rotor Strength Testing

Runaway is a serious condition that can lead to catastrophic failure for both collegiate turbines and utility turbines alike. Large turbine control systems are designed to be double fault tolerant in preventing runaway because making the system strong and stiff enough to survive runaway would be cost prohibitive when the wind speeds are not limited as they are in this competition. However, the size of collegiate turbines in combination with the availability of modern materials and limited wind speeds makes it possible to design a rotor system that can survive runaway. Due to the significant number of turbines experiencing rotor failure in past competitions, many related to loss of control, this year's competition includes a milestone to investigate rotor

strength directly. This is a two-part milestone. First, students should calculate their runaway speed from the C_p - λ curve and maximum competition wind speed. Second, the students, under principle investigator (PI) supervision and approval, should design a physical test to validate the team's rotor design at runaway conditions.

As the physical test could result in failure of the rotor, teams MUST take appropriate precautions to prevent injury of team members or spectators. The test procedure must be approved by a team PI in advance and that PI must be present during all tests. One method to conduct the runaway test would be to mount the rotor to an R/C electric motor, either the one used in the drive system of the dynamometer or a similar one and spin the rotor at the calculated speed from part one of the milestone. A remote speed control with telemetry should be used to allow all test members to be sufficiently far away from the test. Conducting this test outside will allow the student team to distance themselves from the spinning rotor. Experience from the R/C airplane community, with propellers spinning upwards of 20,000 rotations per minute (rpm), has shown pieces to fly upwards of 10 m away but rapidly slow down due to large surface area and low mass. When conducting the test, no persons should stand anywhere in the plane of the rotor or in front of it. Teams are responsible for determining their own safe operating distances. However, it is suggested to add some safety factor to the distance above. Teams should also consider the consequences of failure on surrounding equipment or facilities. Spotters should be stationed around the perimeter of the area where the test is being conducted in order to prevent someone unfamiliar with the hazards of the test from inadvertently entering a hazardous area. Barriers including cones and caution tape could also be utilized. All personnel present during the test should wear safety glasses with side shields. Impact shielding built out of plywood, polycarbonate, or metal or stationing test members inside vehicles could be used to further mitigate risk. The test should be conducted at a time in which the area under use is not busy with competing activities (i.e., nights or weekends when a parking lot is empty or a large athletic field is not in use). If teams are uncomfortable with how to safely conduct this test, they should work directly with their PI and school resources (e.g., Environmental Health and Safety department) to develop a plan that manages those concerns. Teams are also encouraged to reach out to the CWC testing judges for suggestions if they have concerns about safety. Additional details on hazards and controls can be found in Appendix E.

The team's rotor does not need to survive the test to get credit for this portion of the milestone.

Deliverables:

- Submit a single page write-up plus images that details how the runaway rotor speed was calculated. Optionally, any structural calculations investigating rotor strength and stiffness may also be included.
- Submit a single page test report plus images detailing the experimental setup for rotor testing including details on instrumentation. Also summarize safety measures used to manage risk and prevent injury. Provide a report on the results of the test, including a summary of the data collected. If the rotor failed, include a write-up on what was determined to be the root cause and how the team plans to remedy it.
- Optionally, teams are encouraged to include a short video of the test setup and the test being conducted with a short narrative of what is happening in the video.

3.2.3 Power Quality Measurements

The quality or variability in the power produced by a wind turbine is an important design factor. For real turbines, there are specific standards that a turbine must meet before being connected to the grid. In order to replicate this requirement for the competition, the turbine's average power will be measured during the power performance task. There is a prescribed maximum allowable variability in that value, which is provided in Section 3.5.2.

Teams are reminded that measuring power with a typical multimeter or similar device will return the average value because that device utilizes significant filtering and combines multiple measurements over time into a single value. For this milestone, teams should look at the higher frequency content of their power signal using an oscilloscope or data acquisition system with a sampling frequency of 200 Hz or higher. Teams are encouraged to test as wide an operating envelope of the generator and power electronics as possible to ensure they will meet the stability criterion in all cases. The power quality need not satisfy the prescribed allowable variability to pass this milestone.

Deliverables:

- Submit a single page write-up plus images that includes details on the instrumentation used to measure the power signal and the methodology used to characterize the amplitude of the noise on that signal.
- Include a time series of power measured at a frequency of at least 200 Hz and compare that signal to the stability criterion in Section 3.5.2. If present, discuss any filtering (either digital or physical) on that signal. If the time series does not meet the prescribed stability criterion, discuss plans to clean up the power output of the turbine.

3.2.4 Tech Inspection Prior to Competition

This milestone has been removed from the competition, but the information that follows should be used for reference in the digital turbine design.

To make the tech inspection process as smooth as possible, student teams should go through a tech inspection prior to the competition, working with a person that is as familiar with the competition and the rules as possible. Teams need not pass tech inspection in order to complete this milestone.

Deliverable: Submit a single page write-up plus images summarizing the qualifications of the inspector, certify that both the student team and inspector have read Section 3.1, and include a complete, signed tech inspection sheet from Appendix B. Detail any deficiencies and plans on how to remedy them before competition.

3.3 Technical Design Report

The technical design report explains the turbine concept development process from an engineering perspective. The design report should detail the complete design process as it relates to the turbine being tested in the competition wind tunnel. Teams should provide detail that is

adequate for an engineering review of the baseline and operating properties of the turbine and its subsystems, including mechanical loading requirements, operational limits, control algorithms, and software. At a minimum, the following topics should be included:

- A description of the design objective and how the design components support this objective
- A basic static performance analysis (e.g., C_p -Lambda report) of the turbine design that contains the annual energy production over a range of operational parameters
- An analysis of the expected mechanical loads and associated safety factors within the design
- A description and analysis of the turbine's yaw system (if included)
- An electrical analysis comprised of the generator model, power electronics (e.g., canonical model), electrical load model, and operating voltage including how the team plans to regulate voltage into the load during the durability task
- A control model analysis of the operational modes (i.e., the control states diagram and a description of primary operational modes)
- Documentation of associated software (e.g., control and/or logging) and its development. Due to COVID-19, teams should detail what was done prior to having to suspend work on their prototype turbine and detail what they would have done to complete this effort.
- The results of laboratory and/or field testing of turbine prototypes. Due to COVID-19, teams should detail what was done prior to having to suspend work on their prototype turbine and detail what they would have done to complete this effort.
- Engineering diagrams with at least a basic mechanical drawing of all components and an electrical one-line diagram.

At a minimum, the report must include the following sections:

- **Cover sheet:** Teams should begin the report with a one-page cover sheet that includes their affiliation and contact information. Indicate the team roles/hierarchy and approximately how many students, faculty, and others (e.g., sponsors, volunteers, and family members) are involved in the project.
- **Table of contents**
- **Executive summary:** The executive summary discusses components from all sections of the report and includes a short description of the team project. Teams should use their judgement when deciding how long to make the executive summary; however, one page is often sufficient.
- **Technical design.**

The technical design report should not exceed 20 pages in length including cover, table of contents, and appendices. Pages submitted beyond this limit will not be reviewed. References are not required to fit within the page limit.

Scoring criteria for the design report is provided in Appendix A. Report formatting requirements are provided in Appendix G. At the conclusion of the competition, team reports will be posted to the competition website for reference during future events.

3.4 Private Q&A Session

In addition to the written report, each team will spend 20 minutes with a virtual panel of judges to answer any remaining questions that the judges may have from their review of the written report. This question and answer period should begin with a brief overview that conveys the most important details of the technical design, clearly communicating the team's approach to design and development.

Presenters should showcase their turbine prototype as it exists, if possible, and have the option to use PowerPoint slides or other visual aids to engage with the judges. Please note visual aids will not be scored but can be used if necessary, to help clarify any questions the judges may have after reading the written report. Please see [Appendix H](#) for virtual presentation best practices and ensure this will all function as intended in advance of presentation time. Project overviews are limited to 5 minutes, which will be followed by 15 minutes of questioning from the competition judges. Additional attendees are allowed in the feedback session at the discretion of the students and their PI.

The judges will use the content from this project overview and Q&A period to make final adjustments to the technical design report score. Answers provided during the Q&A session will also be evaluated to gauge the depth of students' technical understanding of turbine design as indicated in the rubrics shown in Table A-2.

3.5 Testing Procedure

Due to the unfortunate circumstances surrounding COVID-19, the physical testing of turbines has been suspended and removed from the competition. The below sections are left in place for reference as students finalize their digital designs and reports.

The turbine testing portion of the turbine prototype contest consists of several individual turbine tasks. This section describes the requirements of the individual tasks in which the turbine is expected to perform and the parameters of the testing conditions. Details on scoring algorithms and point allocations between individual tasks can be found in Appendix A.

Testing provides teams with the opportunity to demonstrate their turbine's performance through objective tasks—and the testing outcomes help determine if they have succeeded in developing a durable, safe, high-performing machine (performance is a strong indicator of a turbine's ability to compete successfully in the marketplace).

Each turbine, along with its corresponding load system, will be tested in the competition wind tunnel. The contest will include the following tasks: turbine performance, turbine-rated rpm and power control, cut-in wind speed, turbine durability over a range of wind speeds and yaw positions, turbine safety, cut-out performance, and a parked high-wind event. Students will use their load for all tasks. While the prescribed order will be the same for each team, the exact amount of time at each setpoint could vary between schools. Thus, teams are expected to design their turbines to sense the local conditions within the tunnel and react accordingly for each task.

Exceeding the voltage limit set in Section 3.1.3 will result in an immediate abort of the testing sequence with all points gathered to that point retained but no more points earned after the abort. Teams may then attempt to fix the cause of the overvoltage and use their retest if available.^{4,5}

Verification of zero energy at the start of the test will be accomplished using the competition data acquisition system to measure zero current flow into the load at the PCC. Any questionable elements are subject to additional verification of zero energy by the testing team with a multimeter or similar device before the testing begins.

New for 2020, all wind tunnel testing tasks at competition will be optional. The teams will be able to choose if they want to design to accomplish all the tasks or a reduced set. Note that teams must attempt at least one task. Teams that are newer to the competition, teams with fewer returning members, and teams who are feeling behind schedule are encouraged to focus on fewer tasks. Teams may find it strategic to focus their efforts and maximize their points on a subset of tasks instead of spreading themselves too thin. Additionally, since each team will be tested in the same sequence in the wind tunnel, opting out of a task will allow a team to effectively skip over one that could have catastrophic effects on their system in order to score additional points on the later tasks. There is no penalty for opting out of a task beyond losing the points for that task. All teams will be ranked solely based on points and not on which teams attempted more tasks.

When installing their turbine in the tunnel, a team representative should be prepared to identify to the judges which tasks, if any, the team chooses to opt out of. If desired, teams may choose a different selection of tasks during their retest.

Only one team's turbine will be tested at a time. Teams are limited to 10 members (students and PIs) within the testing area. Other members can act as spectators. Each team will have 35 minutes of tunnel time to install their turbine, commission it, test it, and uninstall. Teams will be provided with a period of commissioning time prior to the scoring tasks, during which the teams may ask for any wind speed from 5 m/s to 11 m/s and do any work on their turbine or electronics they deem necessary to get their systems up and running. Teams may use as much of their tunnel time for commissioning as they would like, keeping in mind that the testing tasks will be stopped promptly 5 minutes prior to the end of the team's allotted period to allow time to remove the turbine. Students are encouraged to minimize install and commissioning time as much as possible because the complete series of testing tasks are expected to require upwards of 20 minutes to complete, depending on how fast the turbine stabilizes at certain testing conditions.

Additionally, teams may signal at any time during the test that they would like to turn the session into a practice session. In this case, the score for this attempt will be zeroed, and the team can use their remaining time to troubleshoot and learn about their turbine's performance in preparation for an additional session, if they have one available.

If there are unforeseen delays caused by the organizers (e.g., a wind tunnel issue or power outage), the time spent rectifying the problem will not be included as part of the team's allowable minutes. Team members will only be allowed to touch their turbines or controls during

⁴ https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=9880&p_table=STANDARDS

⁵ <https://www.mouser.com/pdfdocs/Why-are-Power-Designs-Moving-to-48V.pdf>

the following phases of testing: commissioning, to manually restart their turbine if they fail to restart after a safety shutdown task, and at the start of the durability task. Turbine failure is defined as anything out of the ordinary, such as cracking, breaking, pieces falling off, smoking, sparking, or failure to produce an electrical current, and will be cause for immediate stoppage of testing.

If a team wants to retest their turbine for any reason, team members may request a single retest during the provided makeup sessions later in the competition. The retest will be a full test, and all scores from the first test will be replaced, regardless of the turbine's performance in the retest.

Students are encouraged to bring spare components and/or assemblies and to design their turbines so that damaged parts or assemblies can be easily replaced. However, it is important to keep in mind that the turbine configuration throughout the entire competition should remain substantially the same as what is documented in the written report. For example, the number of blades, rotor axis, turbine configuration, and operating voltage must remain the same. Teams with questions about any changes or altered turbine components or assemblies are encouraged to discuss their particular situation with the organizers well ahead of the competition to ensure they are adhering to this requirement.

3.5.1 Cut-In Wind Speed Task

Cut-in wind speed—the lowest wind speed at which a turbine produces power—is one of the characteristics that can differentiate one turbine as being better suited to lower wind-speed regimes than others. Lower wind speed is generally deemed more desirable in the small turbine market.

In this task, each turbine will be subjected to slowly increasing wind speeds, from 2.5 m/s to 5 m/s, to determine the cut-in wind speed. For this task, “producing power” is defined as achieving a positive current average over a 5-second interval at a steady wind speed.

3.5.2 Power Curve Performance Task

The objective of this task is to test each turbine over a range of wind speeds to determine a power curve. It is meant to be a direct comparison of power performance between turbines, which is one factor by which real turbines are judged.

Each turbine will be tested at integer wind speeds between 5 m/s and 11 m/s inclusive for a duration of 60 seconds or less, with the stated intent of obtaining a “stable” power reading, which is defined as stable rpm and power per electronic testing device during the test period. As power output may fluctuate, for the purposes of this task, the allowable power outputs to be included in the maximum average power (per electronic testing device) during any 5-second interval will be defined as +/-10% of the maximum average power.

This stability criterion will also consider any noise that the data acquisition system measures. The system samples at 50 kHz with a filter with cutoff frequency of 22.5 kHz. These samples are then block-averaged down to 200 Hz. In order to meet the specified stability tolerance, teams should ensure that any noise in the power their turbine produces is adequately filtered and ensure that the combination of power variation and measured noise is within the specified tolerance when read by the competition data acquisition system. One way to reduce noise is to implement

an LC filter on the power output lines to filter noise coming from the switching of the power electronics.

3.5.3 Control of Rated Power and Rotor Speed Task

Wind turbines must withstand high winds without damage to their mechanical or electrical components. Because wind power is proportional to the cube of wind speed, the energy available in the wind quickly becomes very high as wind speed increases. To control rising mechanical and electrical loads, turbines must be able to limit their rotational speed and output power in these high-wind conditions.

In this task, each turbine will be subjected to two wind speed bins chosen by the organizers between 12 m/s and 16 m/s, and turbine performance in those two bins will be compared to the performance in the 11 m/s bin. The turbines are expected to keep the rpm at or below the rpm determined at 11 m/s and to keep the power at the same level as is determined at 11 m/s. The stability criterion defined in Section 3.5.2 will be applied to speed and power in this task.

3.5.4 Safety Task

Safety is of utmost importance to turbine designers and manufacturers. To be certified, turbines must be able to safely shut down rapidly and with a fail-safe shutdown capability. Turbines must shut down when disconnected from the grid as well as manually upon command, as described in Section 3.1. Each team may choose to address these shutdown scenarios with one or two systems or mechanisms.

In this task, the turbine will be required to safely shut down at two different times during the testing period at any wind speed—up to the maximum continuous operational wind speed specified in Section 3.1. For each turbine, the shutdown process will be initiated once “on command” and separately by disconnecting the load from the PCC. It is important that the load is disconnected from the PCC and not the turbine to ensure that the competition data acquisition system can continue to monitor the open circuit voltage of the wind turbine, which must not exceed the limit provided in Section 3.1. The turbine must also be capable of restarting at any wind speed above 5 m/s. For the purposes of this task, “shutdown” is defined as dropping below 10% of the maximum 5-second bin average rpm achieved during power performance testing. This reduction in rpm must occur within 10 seconds and remain below the limit indefinitely. If the turbine fails to successfully restart, the team may work on their electronics to manually restart their turbine, resulting in a zero score for the restart portion of the task.

3.5.5 Durability Task

Turbines are expected to perform over the long term and will be subjected to a wide variety of weather conditions. Producing power effectively and over the course of the turbine’s lifetime are desirable design qualities.

In this task, each turbine will be subjected to the same prescribed variable wind speed and direction function. Speeds will never be less than 6 m/s or greater than 18 m/s over a 5-minute test period. Yawed flow will be achieved using the tunnel’s turntable governed by the limits set in Section 3.1. This test helps verify that the turbine can function over a wide range of operating conditions.

The scoring for this task will be based on the turbine system’s ability to produce positive power using the student load. As noted in the following section, turbines should be designed to cut-out between 18 m/s and 22 m/s. Not producing power during durability due to cut-out engaging will result in no points attained during those times. Teams should design their turbines accordingly with enough margin.

3.5.6 Cut-out Regime and Parked High Wind Event Task

Wind turbines must be capable of surviving in extreme winds from a variety of wind directions. In order to do this, many modern turbines will transition from a power production mode to high wind cut-out as winds approach the maximum design operating speed.

This task will be run only if the turbine scores points during the durability task and is functional at the end of that task. It will be run in two parts. First, at the conclusion of durability, the tunnel will ramp up to 22 m/s over the course of a 45-second period. For the purposes of this task, “cut-out” is defined as dropping below 10% of the maximum 5-second bin average rpm achieved during the power performance testing. The reduction in rpm must occur sometime between when the ramp to 22 m/s starts and 15 seconds after the tunnel reaches 22 m/s, and it must remain below the limit indefinitely. Second, if the turbine successfully cuts out, the tunnel will ramp to 25 m/s, and the turntable will then go through a prescribed yaw motion. Turbine rpm must continue to remain below the limit during this time. No restart is required after high-wind cut-out.

4 Project Development Contest

The project development contest is a year-long effort to investigate key aspects of wind farm siting and project development activities.

It will be beneficial to develop a basic understanding of siting elements prior to beginning the preliminary wind farm design. This could include understanding wind resource data and performance estimation, factors that affect economics, setbacks, terrain effects, environmental issues, transportation constraints, transmission design, permitting requirements, turbine technology, and performance variables (i.e., wakes, inflow, availability, and site-specific losses).

The output of these efforts will include a written report delivered prior to competition and a PowerPoint presentation at competition. These deliverables are described in further detail below.

4.1 Research and Develop a Plan for a 100-MW Wind Farm in Eastern Colorado

Teams must assess wind farm development opportunities within the defined region and create a rough development plan. Team members must be prepared to explain their process to judges at the competition.

4.1.1 Develop a Site Plan and Conduct Financial Analysis

1. Select a site within the area highlighted on the map in Figure 10.
 - a. This site cannot be on an existing wind farm or one that is under development.

- b. Be prepared to explain how this site was chosen. Some considerations may include wind resource, terrain, landowners, vegetation, access to transmission, transportation access, and environmental and community factors.
2. Develop a preliminary wind farm design.
 - a. Draft preliminary design:
 - i. Choose turbine type, hub height, rotor diameter, and number of turbines. The total project size should be less than or equal to 100-MW.
 - ii. Define project boundary.
 - b. Research site characteristics:
 - i. This investigation may include: terrain, vegetation, general wind resource, wildlife, land ownership.
 - c. Collect information for permitting:
 - i. Research local ordinances
 - ii. Research sensitive species in the area, sensitive ecosystems, impacts to wildlife, and mitigation processes that have been successfully implemented in the past.
3. Conduct a cost of energy and cash flow analysis for the 20-year expected life of the project. It should, at a minimum, consider each of the following elements in the cost of energy analysis:
 - a. Initial capital cost: This covers costs associated with development, turbine procurement/installation and balance of station costs. Costs include site preparation, turbines, foundations, electrical hardware, electric collection system and transmission lines, substation, windfarm control and monitoring equipment, O&M facilities and equipment, shipping, resource assessment, surveying, legal counsel, project management, permits, construction insurance, title insurance, lease payments during construction, engineering services, sales and use tax, etc. Costs should be expressed in dollars and in \$/kW.
 - b. Annual operating expenses: Key cost categories here include O&M costs (including preventative maintenance, corrective maintenance, and spare parts), land lease costs, annual property tax, asset management, operational insurance, and scheduling fees. Teams should consider the potential of increased costs year-over-year. Costs should be expressed in dollars and in \$/kW-year.
 - c. Net annual energy production.
 - d. Market conditions: The team should research what the market is willing to pay for the MWh's produced and compare this with the cost of energy.
 - e. Financing plan: Some elements the team should consider include are: construction financing, tax equity, sponsor equity, permanent (long-term) debt, financing fees, debt and equity return requirements, depreciation, and income tax.
 - f. Incentives: This includes national incentives, like the production tax credit and any regional incentives. The team should research potential abatements for property tax and sales and use tax.

Other items the team may wish to balance include triple bottom-line opportunities (social, environmental, financial), restoring the site at the end of the project life, and asset disposal/recycling.

If an economically viable project is not feasible at this time, discuss economic developments (e.g., incentives, novel financing mechanisms, market changes, power purchase agreement pricing) and/or technology developments that would be required to make the project viable.

Note: Steps 2 and 3 may require several iterations to balance financial and technical elements.

4. Finalize detailed design of the site plan.
 - a. Collect wind resource information, contour data, roughness, etc.
 - b. Pick turbine locations
 - c. Plan site access roads
 - d. Plan transmission to nearest substation
 - e. Plan land leases.

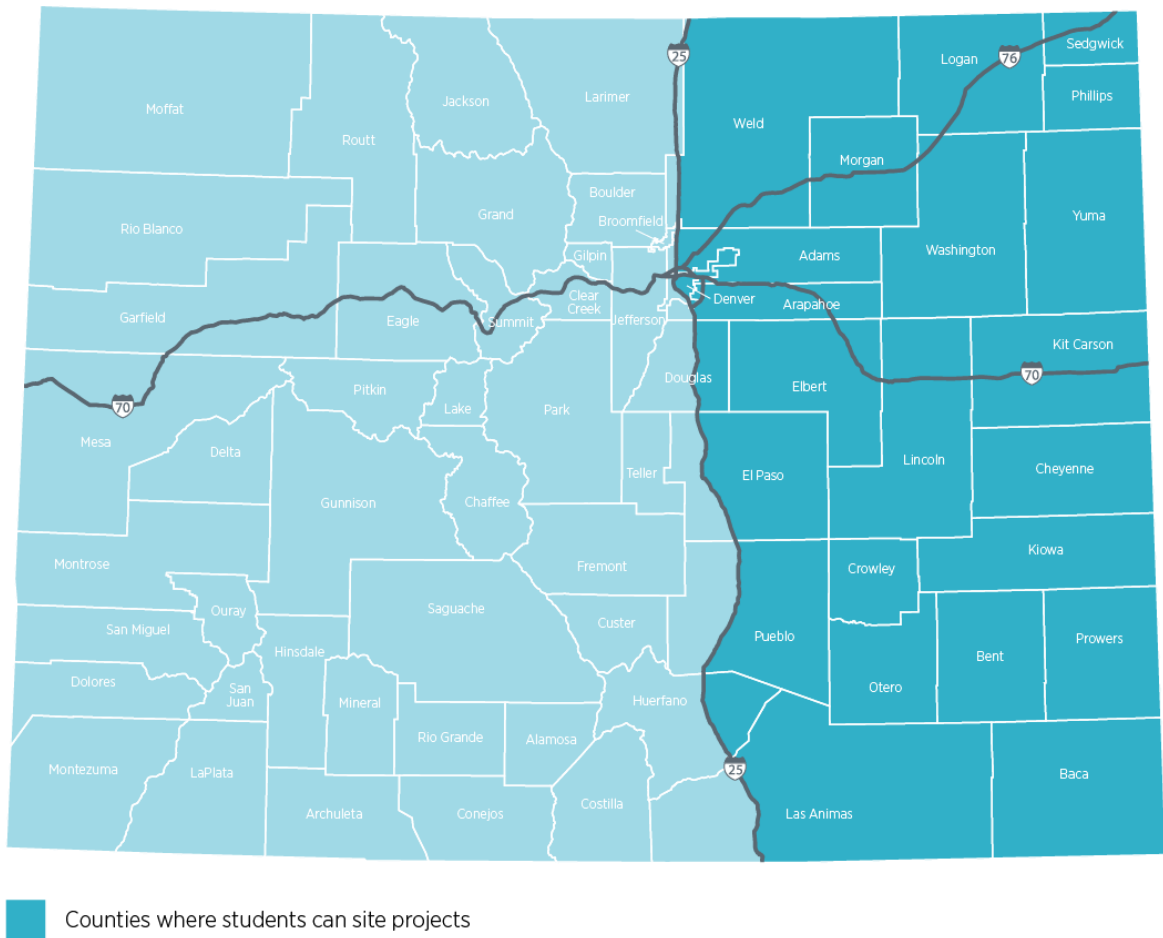


Figure 10. Map of Colorado

4.1.2 Deliverables

4.1.2.1 Written Report

The project development written report is the primary means for a team to provide detailed information about the project to the judges, given that the judges have a limited opportunity at the competition event to evaluate the year-long project development activities. At a minimum, the report must include the following sections:

- **Cover sheet:** Teams should begin the report with a one-page cover sheet that includes school affiliation, contact information, project name, team roles/hierarchy, and approximately how many students, faculty, and others (e.g., sponsors, volunteers, and family members) were involved in the project.
- **Site description and energy estimation:** This could include information about the wind resource, site layout, sensitive environmental or community regions, why this site was selected, and risks and fatal flaws.

- **Financial analysis:** This section should outline the financial potential of the project noting required capital, financing, and key assumptions (e.g., project marginal costs). The team should demonstrate the path to solvency and outline the project’s potential through cash flow analysis. Full pro formas are not required; however, it is recommended that higher-level, more long-term summaries be included to communicate the attractiveness of the project for investment.
- **Discussion of optimization process:** This section should describe the iterative process of optimization that occurred between the preliminary site design and the financial analysis.

The report should be no more than 15 pages in length including cover, table of contents, and appendices. Pages submitted beyond this limit will not be reviewed. References are not required to fit within the page limit.

Scoring criteria for the written report is provided in Appendix A. Report formatting requirements are provided in Appendix G. At the conclusion of the competition, team reports will be posted to the competition website for reference during future events.

4.1.2.2 Virtual PowerPoint Presentation

Each team must submit their written report and PowerPoint presentation digitally by the deadline determined by the presentation timeslot selected.

During the virtual presentation, teams will present their proposed wind farm site plan during an assigned presentation session with the judges who will represent potential project owners or investors. This presentation should convey the most important details of the project, which may include items from the written report. The report and PowerPoint presentation, however, would ideally be complementary rather than redundant.

The teams will have 15 minutes to present their project with another 10 minutes for questions from the judges. PowerPoint slide deck can be any length.

The scoring criteria is provided in Appendix A. At the conclusion of the all virtual presentations, team’s PowerPoint presentations will be posted to the competition website.

Glossary

Competition	The competition is all aspects and activities leading up to, during, and following the event. It is the subcontract project agreement between the competitively selected collegiate teams and DOE's National Renewable Energy Laboratory, the contests, products, and event, collectively referred to for a given year as the U.S. Department of Energy Collegiate Wind Competition.
Contests	The competition consists of several contests with multiple products.
Event	The event is when and where the teams compete in the contests.
Products	Products are what the team builds, writes, submits, and brings to compete in the competition.
Test	The overall time period in the wind tunnel during which each team's turbine is subject to various wind speeds and scored on the testing tasks.
Task	Each individual achievement goal of the test turbine that will be scored during the wind tunnel testing period.

Appendix A. Rubrics

Turbine Prototype Contest

Table A-1. Scoring Rubric for the Midyear Progress Milestones (100 Points Total)*

Description	Possible Points	Score
Midyear Progress Milestones (65 points)		
Dynamometer testing (constructed =10, controlled = 15, coupled = 15)	40	
Rotor strength testing (runaway tipspeed = 10, runaway test = 15)	25	
	Total	

* No points will be awarded if a milestone is late. The power quality measurements and tech inspection prior to the competition have been eliminated.

Table A-2. Scoring Rubric for the Technical Design Report and Q&A (250 Points Total)*, **

Description	Possible Points	Score
Technical Design Report (200 points)		
Concise, readable, and descriptive with logical flow	15	
Presents and communicates technical information clearly and intelligently	15	
Design objective description for test turbine	20	
Static performance analysis	20	
Mechanical loads analysis and associated safety factors (including yaw system if present)	20	
Electrical analysis (including both loads and storage element)	20	
Controls analysis (including storage element)	20	
Software documentation and description (including storage element if applicable)	20	
Engineering diagrams including mechanical and electrical drawings	25	
Results from laboratory and/or field testing	25	
	Subtotal	
Private Q&A Session (50 points)		
Demonstrated understanding of technical design during Q&A	50	
	Subtotal	
	Total	

* 20 points will be deducted for each day the report is late.

** Formatting requirements are in place to ensure an equal amount of space for all teams to tell their stories to the judges. Reports not formatted to the requirements in Appendix C that are deemed to be utilizing more than the allotted space will be penalized at the discretion of the judges proportional to the infraction. Furthermore, extra pages will be ignored.

The following table and task scoring for turbine performance testing is left in for reference only as students finalize their turbine digital design reports. No points will be awarded for this section as physical testing has unfortunately been eliminated this year.

Table A-3. Scoring Rubric for Turbine Performance Testing (No points awarded)

Description	Possible Points	Score
Turbine Performance Testing (250 points)		
Cut-in wind speed task	25	
Power curve performance task	50	
Control of rated power	25	
Control of rated speed	25	
Safety task	50	
Durability task	50	
Cut-out and parked high wind	25	
	Total	

Scoring algorithms for each testing task are described in the next sections.

Cut-In Wind Speed Task

A team will earn 5 points for each half m/s bin below 5 m/s, inclusive of the lower bound and exclusive of the upper bound in which they can produce power, as defined in the cut-in wind speed task description (Section 3.5.1), up to the maximum score of 25 points for this task.

Power Curve Performance Task

A total score for this task will be calculated according to Table A-4 by multiplying each power measurement in watts in 1-m/s wind speed intervals from 5 m/s to 11 m/s by the factor given. If power is not stable within the specified tolerance in Section 3.5.1, the score for the bin will be zero.

Table A-4. Weighting for the Power Curve Performance Task

Wind Speed (m/s)	Factor
5	0.7
6	0.8
7	0.8
8	0.7
9	0.4
10	0.3
11	0.1

Control of Rated Power and Rotor Speed Task

Scores for power will be calculated according to the following:

$$r_p \equiv \frac{\text{measured power in bin of interest}}{\text{measured power at 11 m/s}}$$

$$\text{Bin Score} = 12.5 \frac{[\tanh(-20 * |r_p - 1| + \pi) + 1]}{[\tanh(\pi) + 1]}$$

In Figure A-1, a ratio, r_p , of 1.000 represents perfect power control at the same value as was measured in the 11-m/s bin. The weighting shown will be multiplied by 12.5 for the two selected bins to obtain scores for each bin.

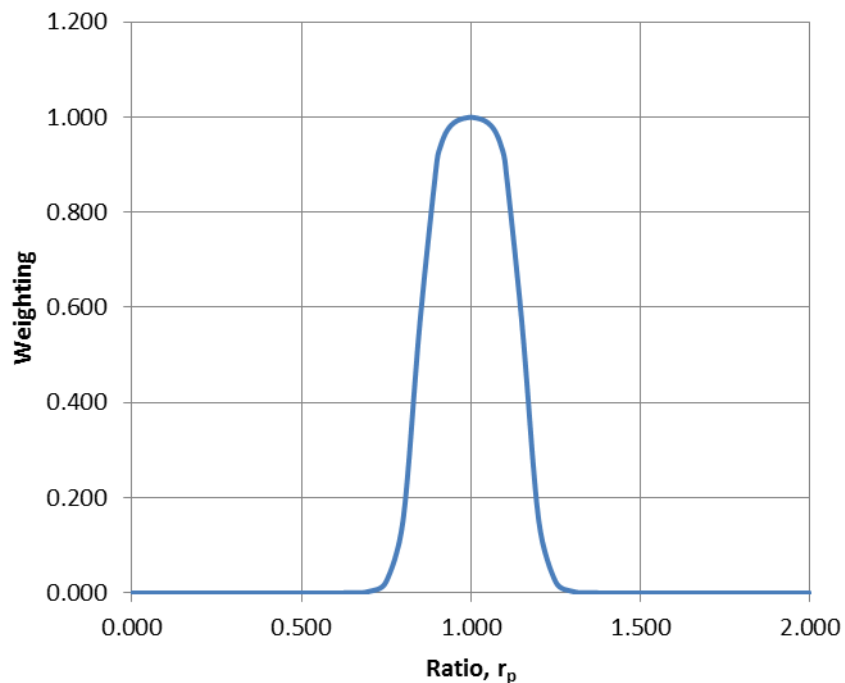


Figure A-1. Score weighting based on power ratio for control of rated power task

Scores for rotor speed control will be calculated according to the following:

$$r_s \equiv \frac{\text{measured speed in bin of interest}}{\text{measured speed at 11 m/s}}$$

$$0 < r_s < 1.03 \rightarrow \text{Bin Score} = 12.5$$

$$r_s \geq 1.03 \rightarrow \text{Bin Score} = 12.5 \frac{[\tanh(-20 * |r_s - 1.03| + \pi) + 1]}{[\tanh(\pi) + 1]}$$

In Figure A-2, a ratio, r_s , of 1.000 represents the perfect rotor speed control at the same value as was measured in the 11-m/s bin. The weighting shown includes a 3% buffer above and infinite buffer below that speed to obtain full points. The weighting shown will be multiplied by 12.5 for the two selected bins to obtain scores for each bin.

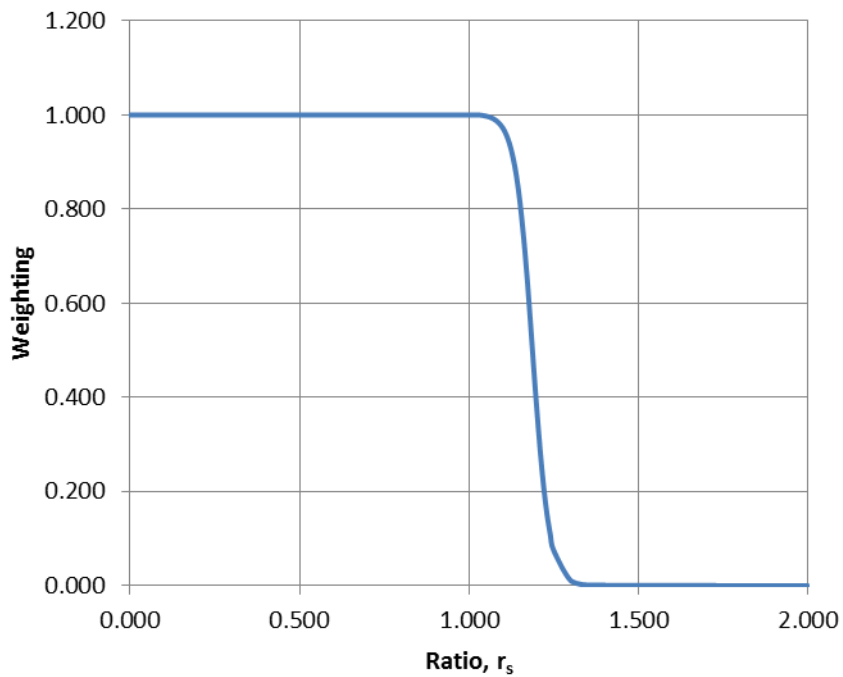


Figure A-2. Score weighting based on rpm ratio for control of rated rotor speed task

Safety Task

The safety task is scored on a pass/fail basis in two parts, governed by the limits set forth in the safety task description (see Section 3.5.4). If the turbine achieves a successful shutdown upon manual initiation, the team will receive 15 points. If the turbine automatically restarts, the team will receive an additional 10 points. If the team has to manually restart the turbine, the team will receive zero points for the restart. If the turbine achieves a successful shutdown when disconnected from the load system, the team will receive an additional 15 points. If the turbine automatically restarts when reconnected, the team will receive an additional 10 points. If the team has to manually restart the turbine, the team will receive zero points for the restart.

Durability Task

This portion of the competition will be scored on a second-by-second basis for 5 minutes. Each 6-second period during which the turbine system produces positive power for the entire period will result in 1 point being awarded.

Cut-out Task

During the first portion of the task, 15 points will be awarded for a successful cut-out. For the second portion of the task, 10 points will be awarded if the turbine rpm remains below the cut-out threshold as the windspeed is increased and the turbine yaws.

Project Development Contest

Table A-5. Project Development Contest: Develop Plan for 100-MW Wind Farm (300 Points Total)*,

** , ***

Description	Possible Points	Score
Quality of Deliverables (75 points)		
Written report: concise, readable, and descriptive with logical flow; communicates technical information clearly	25	
Presentation: professional, clear project pitch	25	
PowerPoint: well designed, illustrative, appropriate use of text and graphics	25	
	Subtotal	
Analysis (225 points)		
Site selection and identification of potential siting challenges	20	
Wind farm layout and resource assessment (e.g., constructability)	35	
Articulation of community and environmental impact and mitigation approaches (understanding local ordinances, such as setbacks, assessments, and permitting)	30	
Cost/kWh	40	
Depth and thoroughness of balance-of-station elements considered in the financial analysis (CapEx)	25	
Evaluation of annual operational costs (OpEx)	25	
Bankability of financial plan and evaluation of risks and alternatives	30	
Understanding of market opportunities and constraints (e.g., power markets, ownership, taxes, incentives)	20	
	Subtotal	
	Total	

* 25 points will be deducted for each day the report is late.

** Formatting requirements are in place to ensure an equal amount of space for all teams to tell their stories to the judges. Reports not formatted to the requirements in Appendix C that are deemed to be utilizing more than the allotted space will be penalized at the discretion of the judges proportional to the infraction. Pages in excess of page limit will be ignored.

*** Part B from the original Rules and Requirements document has been eliminated.

Appendix B. Sample Safety and Technical Inspection

A sample of the sheet used to evaluate test turbines prior to competition is provided on the following page. Teams are normally required to work through this process in advance of the competition with a qualified research technician, advisor, or similar university personnel as the final midyear project milestone. Due to the circumstances surrounding COVID-19, teams are encouraged to incorporate the requirements of this inspection into their digital design explicitly.

CWC 2020 Safety and Tech Inspection Sheet

Team Name: _____

SAFETY - cannot practice or test if noncompliant

- Wiring is deemed safe and uses adequate gauges—no electrocution or overheating hazard
- Electrical systems are tied to earth ground w/ 100 kohm or lower resistor
- Energized electrical components are adequately shielded—both electrically and mechanically (NEMA 1 is preserved)
- Proper heat rejection
- Voltage is ≤ 48 VDC at PCC at all times
- Turbine mounting flange fits over studs without having to be forced (test fit to tunnel flange)
- Team load runs on 120 VAC maximum
- For the team load: all charging or bulk energy storage follows industry-accepted best practices (i.e., safe circuitry overvoltage/undervoltage protection, flame/spill containment)

NONSAFETY - can practice but must fix prior to official testing

General

- All electrical components outside the tunnel are contained in enclosures meeting NEMA type 1 or greater (no tape)
- Cable passthroughs in enclosures provide strain and chafe protection (e.g., cable glands)
- Turbine electronics and load electronics in separate enclosures
- All external wiring is in cable form and utilizes commercial connectors (no screw terminals or spade/fork type lugs)
- All electrical components are mechanically secured to the enclosure

Turbine

- Turbine for testing is substantively the same as in the report
- Turbine side of PCC: no batteries, excessively large capacitors (indiv. or combo ≤ 10 J)
- Turbine is capable of fitting through the door in one assembly

Volume

Rotor and nonrotor components are:

- Within a 45-cm cube centered horizontally on flange axis, shifted at most 10 cm aft
 - Vertically the rotor midplane is $60 \text{ cm} \pm 3 \text{ cm}$ above the flange top plane to center it in the test section
- Nonrotor parts only:
- Base plate is ≤ 16.1 mm thick and tower is less than 15-cm DIA cylinder from base of cube to tunnel floor

Wiring

- Wiring will reach PCC (test fit)
- E-stop terminated with standard JST *female* receptacle with *male* pins (test fit to DAS system)
- E-stop signal (JST connector wiring) never draws more than 3 A and uses normally closed polarity during turbine operation (students to describe)
- Anderson Powerpole polarity is correct (test fit to PCC)

Load

- Team-supplied load

INSTALL

- Reflective tape for rpm

Inspecting Judge Signature: _____

Date and time: _____

*noncompliance checkboxes should be circled above

Reinspecting judge - Initial compliancy above with date and time of reinspection

Reinspecting judge signature when complete: _____

Date and time: _____

Appendix C. Roles and Responsibilities

Table C-1 shows the competition roles, who are performing in each role, and what the role entails.

Table C-1. Roles and Responsibilities

Role	Individual(s) Assigned	Definition
Collegiate Team	Multiple	Collegiate teams execute the will of their team members, principal investigator (PI), and co-principal investigators within the rules and requirements of the competition. Teams consist of undergraduate students only, but graduate students may be involved as mentors or advisors. There is no limit to team size. However, the number of students that teams may bring to the competition will be limited based on space requirements. Interdisciplinary teams are encouraged in the following areas of study: engineering, business, marketing, environmental science, communications, policy, and social sciences.
Collegiate Team Lead Principal Investigator	One per team	Serves as the lead faculty member and primary representative of a participating school in the project. This person provides guidance to the team throughout the project and ensures that the student team leader disseminates information received from the competition organizers. The PI teaches, advises, and coaches the students on the skills necessary to compete in the various aspects of the competition. Some teams may specify multiple PIs who are contacts for the team, but in this case, one person should be identified as the lead.
Collegiate Team Student Leader	One per team	Attends informational sessions with the PI, represents the team when communicating with competition organizers, and disseminates information received from the competition organizers over the course of the entire project, including monitoring communications (i.e., the Slack channel that is discussed later in this manual) during the event.
Student Mentors	Multiple	Due to their unique perspective, students having completed their undergraduate degree or graduate students are encouraged to act as mentors to the collegiate team. Similar to team PIs, mentors should provide a supportive environment and the educational background necessary throughout the contest without making active decisions themselves.

Collegiate Team Co-Principal Investigator(s) or Supporting Faculty	Multiple	Supports the PI in the above duties but typically does not directly engage with DOE/NREL Collegiate Wind Competition staff.
Competition Manager	Amber Frumkin, DOE	Represents the U.S. Department of Energy (DOE) and has the final decision-making authority in all aspects of the competition.
Competition Operations Manager	Elise DeGeorge, NREL	Leads correspondence with the collegiate teams regarding contracts and team expectations. During the competition, the operations manager is the primary point of contact for dispute resolution. Tasks include collating scores and supporting the testing team, collegiate teams, judges, competition manager, and head rules official. Reports to the competition manager.
Competition Operations Coordinators	Christa Nixon and Jenny Wiegele, NREL	Coordinate competition logistics including registration, lodging, overall event schedule, and individual team schedules. Lead correspondence with teams and event feedback. Support collegiate teams, judges, head rules official, and operations manager.
Contest Lead	Heidi Tinnesand, NREL	Coordinates all activities related to the contests. Key point of contact for questions related to engagement with the judges, individual competition contests, and protocol.
Head Rules Official and Turbine Safety Official	Jason Roadman, NREL	The head rules official and chair of the rules panel. The only official authorized to write and modify the rules. This individual reports to the competition manager. The turbine safety official makes the final decision about whether a turbine can be tested or not in the tunnel due to safety concerns.
Rules Panel	See definition	Rules panel members, a subset of the competition organizers and/or contest judges, are solely authorized to interpret the rules. If there is any doubt or ambiguity about the wording or intent of these rules, the decision of the rules panel shall prevail.
Communications and Outreach Point of Contact	Jenny Wiegele, NREL	Coordinates all aspects of media representation, website management, publications, signage, and outreach.
Competition Safety Point of Contact	Ian Baring-Gould, NREL	Point of contact for questions or issues related to safety.

Core Competition Staff	NREL KidWind	Performs all duties to ensure a safe, effectively communicated, and fair competition. The competition organizers, including the competition manager and operations manager, will work to ensure a seamless event.
Contest Judges	To be announced	Conduct and evaluate each individual contest at the competition.

Appendix D. Logistics

Due to the ever-changing nature of COVID-19, the most up-to-date logistics information will be provided to the teams directly from competition organizers. The following details provide an outline of the expected competition structure and are subject to change.

Teams are responsible for familiarizing themselves with the details provided, both in this document and via internal communications channels, and proceeding accordingly. Some of these topics are detailed in the following subsections.

Event Schedule

The event schedule will be provided to participating teams once it has been finalized. Slots will be determined based on preferences provided by each team in the doodle poll and organizers will do their best to accommodate based on judge availability, but note that these slots are not guaranteed. Assigned slots will include:

- Project development presentation
- Turbine digital design Q&A
- Final awards ceremony.

Virtual Event Login

All individuals participating in the virtual presentations should review [Appendix H](#) for teleconferencing best practices. Any members of each team and PIs, Co-PIs, advisors, and mentors, are, however, welcome to attend both their team's presentation sessions and the final awards ceremony.

Virtual login information for both private presentation sessions, access to the event app, and awards ceremony will be provided closer to assigned competition date.

Virtual Networking & Career Development

In lieu of attending AWEA CLEANPOWER, upon request, organizers will set up virtual meet-and-greet activities and informational interviews with industry representatives for any interested students. If any team members are interested in this opportunity, connect with the organizing team prior to your assigned virtual presentation slot to schedule.

Organizers will also develop a video montage to feature each team's successes this year. We encourage everyone's involvement so we can highlight the wind energy experience gained, the breadth of students involved, and the continued dedication to learning in an unprecedented situation. This will be shared on available channels to wind energy professionals as possible to highlight the skills each team developed over the course of this academic year despite the challenges, and students will be able to share it as well. More information on scheduling, best recording practices, and specific questions will be provided directly from organizers.

Feedback

Throughout the organization and execution of the event, organizers will request feedback from participating teams, judges, volunteers, and others. This feedback is taken very seriously both

during the year and for future competitions as we work to improve the organization and execution of the event. To support that continued improvement, it is crucial that participating teams seriously consider and convey both positive and critical feedback. All participants should expect and plan to provide feedback at the conclusion of the event. Consider opportunities to capture and provide individual and/or team feedback to organizers throughout the year as well.

Appendix E. Safety and Conduct

This section is left in for reference, despite any changes due to COVID-19, and applies for any work still being conducted.

The competition is a forum for students with an interest in wind energy to showcase their innovative ideas and demonstrate their knowledge. The event is designed to be safe, fair, and competitive, as well as be a fun learning experience and a professional growth opportunity. Each team is responsible for the safety of its operations in accordance with the subcontract agreement. Each team member shall always work in a safe manner during the competition. Participants are expected to conduct themselves in the spirit of the competition by being team players both within their own teams and amongst competitor teams.

Teams must follow Occupational Safety and Health Administration rules for safety equipment based on expected activities (see NREL/university subcontract, Appendix B Clause 8: Worker Safety and Health Requirements, for more information). Organizers may issue a stop work order at any time during the project if a hazardous condition is identified.

All team members must wear appropriate personal protective equipment when working on, testing, and operating wind turbines. Teams are expected to use the following appropriate protective equipment for use during wind tunnel testing and other potentially hazardous activities at the competition:

- Safety glasses (student provided)
- Hard hats (competition provided)
- Steel-toe boots if expecting to handle heavy loads⁶ (student provided)
- Electrical personal protective equipment if electrical voltage demands it (student provided)
- Hearing protection for use in areas that are near the wind tunnel during operation (student provided).

Table C-2. Suggested Hazards and Controls for Testing Prototype Wind Turbines

Hazard	Control
<p>Inexperience with potentially destructive testing</p> <p>Testing a rotor to failure can be hazardous to people nearby</p>	<ul style="list-style-type: none"> • Work with your PI to determine appropriate safety measures for reducing the potential for injury • Consult your local safety department to determine appropriate hazards and safety control strategies specific to your campus and testing area that meets the school's requirements

⁶ Teams should use their judgment for steel/composite safety-toed shoes. If there is any danger of foot injuries due to a falling or rolling object or objects piercing the sole, safety shoes should be worn. Steel toes are usually rated for 50 pounds dropped from 18 inches.

<p>Electrical shock</p> <p>Shock from coming into contact with energized conductors</p>	<ul style="list-style-type: none"> • Follow your campus's electrical safety requirements • Only work on de-energized systems • Lock the system so that it cannot be turned on or start moving inadvertently while someone is in contact with the rotor and test equipment
<p>Noise</p> <p>A rotor assembly coming apart can create a loud, sudden burst of sound</p>	<ul style="list-style-type: none"> • Wear appropriate hearing protection such as approved ear plugs or earmuffs in the test area • Follow manufacturers' recommendations for proper usage
<p>Hazards to the eyes, face, and head</p> <p>Projectiles could be thrown with great force from a rotor or component undergoing testing, injuring a person's eyes, face, or head (if debris takes a parabolic trajectory)</p>	<ul style="list-style-type: none"> • Wear eye protection marked with a Z87+ symbol around the rotor and test area • Information regarding eye protection can be found here: https://www.grainger.com/content/qt-personal-protective-equipment-requirements-125 • Wear hard hats if you have determined that there is a potential for injury to the head from falling objects; more information: https://www.grainger.com/content/qt-241-hard-hat-requirements
<p>Thrown debris</p> <p>A rotor assembly will come apart with great force, sending projectiles into the surrounding test area</p>	<ul style="list-style-type: none"> • Check the area to ensure its clear before moving into the test phase; notify everyone involved that testing is about to begin • Keep people away from the rotor during testing at what you have determined to be a safe distance with appropriate barriers to keep others out; the barriers should have signage describing the hazard • Station spotters around the perimeter of the area where the test is being conducted in order to prevent someone unfamiliar with the hazards of the test to inadvertently enter into a hazardous area • Develop controls that allow testing to be done remotely at a safe location and to safely shutdown the test • Determine if equipment in the area could be damaged and protect it accordingly • Determine if there are pressurized gas cylinders, hydraulic systems, or chemical storage containers that could be damaged during the test and if they need to be moved or protected • Create housing surrounding the plane of rotation that is able to withstand the forces of the rotor coming apart <ul style="list-style-type: none"> ○ NREL uses 0.5" thick polycarbonate • Keep the area downwind and upwind clear of people where debris could be thrown with the direction of airflow or from sudden ricochets

Each team is responsible for the transport of its wind turbine and all necessary tools and equipment as well as for any damage to or loss of such items. Shipping information will be provided before the competition event.

As part of DOE's and NREL's culture, renewable energy and sustainability go hand in hand. It is a common public perception as well. As a result, the competition is about renewable wind energy, and we expect that participants will embrace and showcase sustainability where possible during all aspects of the event (e.g., reducing waste in packaging for shipping, reusing packaging materials that were used in transporting items to the competition, and eliminating the use of non-recyclable materials such as foam packing peanuts). In addition, we encourage team members to engage in common sustainable activities such as recycling paper and beverage containers. Team creativity to support this mission is encouraged.

Appendix F. Dispute Resolution

Disputes are a serious matter and will be treated as such. Disputes must:

- Be submitted to the competition operations manager by the collegiate team PI
- Be submitted via email. Due to COVID-19 and the virtual nature of the competition, in-person notification is no longer required.
- Include a clear description of the action being protested, referencing the appropriate section of this rules document.

Once submitted, the competition operations manager will meet with the head rules judge and initiate an internal review of the dispute. Disputes will be discussed amongst at least three judges and/or competition organizers who will gather appropriate information through interviews or other means, and a final ruling will be issued. If it is concluded that the issue has a broader impact on the entire competition, the head rules official will consult with all necessary members of the DOE/NREL organizing team to determine next steps.

If the head rules official makes a decision that may directly or indirectly affect the strategies of some or all of the teams, the decision will be recorded in the “Decisions on the Rules” section of the Slack channel (discussed further in Appendix G) within 24 hours. If the dispute is being handled during the competition event, an announcement at the next major address to teams (e.g., opening or closing remarks for the day, lunch) may be substituted for the Slack channel post.

In all cases, the head rules official has the final say in all disputes.

Appendix G. Communications and Contest Details

External Communications

Organizers will use the website, energy.gov/cwc, to showcase the various elements of the competition, ongoing collegiate team engagement, and information about how to participate in future competitions. The website will feature important documents, such as this manual and [identity guidelines](#), that provide information about the competition itself and how the competition name, logo, and visual identity can be used.

Teams are expected to manage external communications.

Internal Communications

It is each team's responsibility to stay abreast of the latest competition communications from the organizers. Communication between the teams and the organizers occurs via one or more of the following:

- **Slack channel:** Official communications suitable for viewing by all team members and organizers will be posted on the Slack message board. Instructions for joining the Slack channel will be provided by NREL to the teams following each team's commitment to participate. Students should reference specific sections when posting questions and search past threads to find out if their topic has already been addressed. When creating a new question, structure the question as a new thread within the appropriate channel.
- **Box.com repository:** This tool is used by the organizers and teams to transfer large files such as competition products. Notification of, or requests for, file transfers are made via the Slack channel or email.
- **Conference calls:** Teams are strongly encouraged to participate in scheduled conference calls with the organizers. Invitations and instructions for participation in conference calls are provided by the competition operations manager via email until the Slack channel has been established but provided via the Slack channel thereafter.
- **Email:** For expediency, and to protect confidentiality, organizers may choose to communicate with teams via team members' email addresses as listed in the Slack database; however, most official communications occur via the Slack channel.

Branding

Teams are encouraged to develop an online presence and branding platform for their team to showcase their work throughout the year. This platform may include web pages, social media, outreach material, and team T-shirts. Regular updates and engagement with school and external media are recommended, and efforts will be shared by NREL and DOE channels as allowed. The use of the competition logo or name as part of individual school/team branding and platform is covered by the [identity guidelines](#).

To get teams started, examples of good team branding and an engagement toolkit will be provided prior to the competition. All branding and social outreach should conform to the safety and conduct provisions described and be of high quality for a national-scale industry event.

Teams will have the opportunity to set up meet-and-greet meetings and informational interviews with industry experts virtually through coordination with competition organizers. Requests for these meetings must be submitted via the Slack channel or via email at least 5 days prior to the virtual competition date selected.

Given the shift to a virtual competition, teams can sign up for individual virtual interviews with organizers so they will have the opportunity to share their story in how they continued working on the competition and what they learned during the competition year. These will be recorded and disseminated after the conclusion of the competition to share those accomplishments with the industry.

Confidentiality and Intellectual Property

There are portions of the competition that are decidedly open to the public for purposes of generating interest and providing general information. Team members should keep in mind that various media outlets may be present during the competition. Any information made known and/or discussed should be expected to receive widespread and uncontrolled dissemination. Teams should consider in advance what level of information regarding all aspects of their turbine and turbine design they desire to have publicly available versus information that provides a competitive advantage, is critical to their performance in the competition, or is of a proprietary nature and essential to potential future business endeavors.

Team members agree to the use of their names, likenesses, content, graphics, and photos in any communication materials issued by the organizers, event sponsors, and attending media.

Content and images (graphics and photos), and any publications in which the content and images appear, may be viewed and made available to the general public via the websites of the U.S. Department of Energy, National Renewable Energy Laboratory, and event sponsors with unrestricted use.

The organizers and event sponsors will make all reasonable efforts to credit the sources of content and images, although they may be published without. To ensure proper usage of and credit for images, teams should submit photos and graphics through the competition Box.com repository.

Judging and Scoring

Panels of judges are responsible for scoring team performance in each contest (e.g., technical design, turbine testing). The judges will have detailed expertise related to the content they are responsible for evaluating. Each panel will also include diverse backgrounds that allow the judges to evaluate performance from a variety of angles.

Competition organizers will ensure that, to the extent possible, judges will not:

- Have personal or financial interests in or be an employee, officer, director, or agent of any entity that is a registered participant in the competition

- Have a familial or financial relationship with an individual who is a registered participant
- Provide advice to teams, although they can provide clarification on the judging process
- Discuss team performance with other teams or their advisors.

Names of the selected judges will be announced prior to the 2020 Collegiate Wind Competition.

Judging Rubrics

Judges will use detailed scoring rubrics to evaluate team performance in each of the categories. These rubrics give all participants a clear idea of what they will be evaluated on in each contest.

Products submitted prior to the event will be thoroughly reviewed and evaluated by the judges. Each judge will complete a rubric independently as the team is competing or based on the review of submitted products. At the completion of each event segment, judges will discuss each team's performance before finalizing the rubrics. The team of judges will submit one unified rubric to the competition manager for scoring purposes.

Team Feedback

In an effort to provide as much feedback as possible, teams will receive copies of the scored rubrics, which will be provided following completion of the competition. Teams will receive a short narrative that is derived from the judges' deliberations after each team's presentation. Teams will also receive copies of notes that judges have written on the individual rubric forms.

Submittals and Submission Locations

Submittals are considered on time if they are received by the competition manager by the respective due date stated in this document.

All products must be saved in the formats indicated.

Products due ahead of competition must be delivered to the competition Box.com repository (a link will be provided in the Slack channel). A folder for each team will be created, and it will be the team's responsibility to provide email addresses for each student that needs upload access to the account.

Teams can submit early copies and updated revisions until the deadline. Each folder will be closed, or "unshared," after the submission deadline. Revised products will not be accepted after the deadline.

Written Report Formatting Requirements

The following format requirements apply to the written reports:

- Reports should adhere to the page limits detailed in respective sections.
- Pages should be 8.5 x 11 inches, paginated, and have 1-inch margins at a minimum.
- References should begin on a new page with distinct page number format from that utilized for the body of the report.

- Content should be single-spaced.
- The body of the report must use an 11-point font at a minimum.
- Captions for figures and tables must be numbered for easy navigation.
- The final documents must be submitted as a PDF file, adhering to the following criteria:
 - Bookmarked report sections
 - Embedded fonts
 - Minimum resolution of 300 dpi on all images
 - *Do not* create a PDF from scans or by outputting the content into a raster image format (e.g., .jpg, .tiff, .png, or .gif) and then creating a PDF from the images
 - *Avoid* all-raster PDFs. While they are large files at 300 dpi, they are of unacceptable quality at lower resolutions and are not scalable without degradation.

Audio Visual Presentation Requirements

Audio visual presentations are not required but if utilized should follow the following format requirements:

- Videos should be of a .MOV or H.264 compressed.MP4 (MPEG-4) file type with a resolution of 720 x 480.
- Presentations should be of 16:9 aspect ratio.
- No background music that violates U.S. copyright laws is allowed; all incorporated music must be an original or royalty-free composition, and proof of licensing must be submitted with the final file and transcript.

Electronic File-Naming Instructions

The required file-naming convention for all electronic files is:

[TEAM ABBREVIATION]_[PRODUCT ABBREVIATION]_[SUBMISSION DATE (YYYY-MM-DD)].[EXTENSION]

Table G-1 presents a list of team names and abbreviations; Table G-2 lists product names and abbreviations.

Example: A report submitted by California Maritime Academy on April 23, 2020, would have the following file name: MARITIME_Report_2020-04-23.PDF.

Table G-1. Team Names and Abbreviations

Team Name	Team Abbreviation
California State University, Chico	CHICO
California State University Maritime Academy	MARITIME
James Madison University	JMU
Northern Arizona University	NAU
Pennsylvania State University	PSU
Texas Tech University	TTU
Tuskegee University	TUSKEGEE
University of Maryland	UMD
University of New Haven	UNH
University of Wisconsin-Madison	UWM
Virginia Polytechnic Institute and State University	VT
Washington State University-Everett with Everett Community College	EVERETT

Table G-2. Product Names and Abbreviations

Product Name	Product Abbreviation
Written report	Design Report or Project Development Report
Presentation	Pres
Poster	Poster
Product zip before competition	Portfolio
Audio visual presentation (if applicable)	AV

Appendix H. Virtual Conference Participation Etiquette

The following best practices are highly recommended for remote participation:

- Teams are responsible for knowing their meeting point of contact and ensuring that connections and technology all work prior to their start time. Test your internet connection, audio and video capabilities, and ability to use the virtual meeting program before your presentation time. The organizers have built in transition time, but it is limited to five minutes for each team.
- Use a hard-wired internet connection (i.e., ethernet cord). Wi-fi connections can be used but are not ideal.
- Mute your audio connection (phone and/or computer) when you are not intended to be speaking. The organizers will mute participants with excessive background noise.
 - Ensure you are only using one audio connection. Connect to audio via your phone OR your computer, but not both.
- Teams are encouraged, but not required, to use their webcam for presenting. Audio narration of slides is also acceptable.
 - Ensure you have a clean background while streaming video (e.g., no inappropriate or offensive images in the background, or people walking around).
 - Avoid window backdrops for lighting.
 - Be sure you look professional in your dress and speak professionally during your presentation.
 - Refrain from distracting behavior while sharing your video and/or audio, such as drinking or eating.